WORK ALLOCATION IN COMPLEX PRODUCTION PROCESSES: A METHODOLOGY FOR DECISION SUPPORT

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Abstract
The purpose of this paper is to develop a Method for Decision Support of Work Allocation in Complex Production Processes, not based on Time and Motion studies, but considering other factors that might impact this decision. From a project developed on demand of a large Brazilian petrochemical company, researchers from the Production Engineering Department, University of São Paulo, developed a method based on the generation of alternative scenarios offering different possibilities for Work Allocation, using Action Research methodology.

Keywords: Work allocation, Complex Operations, Scenarios

Introduction

This article presents the development of a Methodology of Decision Support for Work Allocation in complex production processes. It is known that this decision is frequently taken empirically and that the methodologies available to support it are few and restricted in terms of its conceptual basis. The study of Time and Motion is one of these methodologies, but its applicability is restricted in cases of more complex production processes, as is the case, for example, of continuous flow operations intensively supported by automation technologies.

The method presented here was developed as a result of a project coordinated by the authors, on demand by a large Brazilian petrochemical company, in one of its plants operating in Brazil. The work consisted in providing technical-conceptual support to help in the analysis of the process and modification of work allocation in the operational area of one target plant.

Since the late 1980s, the company in question has been under a restructuring process, in order to improve its financial and operational performance. Within this context, aiming to reduce labor costs, measures such as the increase in industrial automation, outsourcing of activities and reduction in operational staff were taken, using as parameter the comparison with similar plants in Brazil and abroad. The decision process was conducted empirically, based on the managers' experience and on several historical and conjuncture variables that certainly influenced the decision.

The company in question is a continuous processes industry, in which the technological (indivisibility of the process, high level of integration of equipments, centralization of operations control) organizational (non-dependence between work pace and productivity) and economical (fixed labor costs) characteristics and their complexity (interdependence of the operation variables, symbolic character of process variables, randomicity and unpredictability of operation) have implications for the organization and the type of work required, specially for the operational area (Khurana, 1999), which makes the classical methodology for work allocation – the studies of Times and Motion – not applicable to this case (Zarifian, 1994).

This work therefore attempts to propose a method not based on Times and Motion (though it can be used cautiously as one more input) to support the work allocation decision in Complex Operations (such as the continuous processes operations), and that could be also used as a planning tool for the organization. To develop it, the following premises were used as starting points:

- The decision over work allocation is generally a decision of political nature, since different conflicting interests – both within and outside the company – are affected by it.
- There is not a method universally accepted to deal with the work allocation issue. The method to be employed depends on analysis of the productive process and on the identification of the factors that interfere in the relation among technology, productive system and the role played by operators in the process.
- Also, there is no "optimal" decision over the work allocation issue. It cannot be ignored that this decision is not just technically feasible and that it interferes in the interests articulated within (workers, managerial staff) and outside (unions, service and product suppliers, governmental institutions, shareholders etc) the organization, interests that gain or loose as the personnel contingent increases or decreases.

Based on these premises, an original methodology was generated, specially developed for the case in question, but which, as the work will attempt to demonstrate, may be replicated to other companies, with or without complex processes, in the industrial or services sector.

The method proposed is based on the generation of different alternative scenarios that show distinct possibilities for manpower allocation. Each scenario is oriented by certain premises and assessed by a set of significant efficiency indicators for the company.

Therefore, this article is organized as follows: in section 2, a discussion of the theme is made as from a bibliographical review; in section 3, the methodology used is presented; in section 4, an explanation is provided for the scenarios concept and its application for work allocation and, finally, in section 5, the conclusions, merits and restrictions of the methodology proposed are presented.

Bibliographical Review

Characteristics of Continuous Processes and their Implications for Organizing Work

The continuous processes industry is characterized by the continuity of its production. This type of process is found in different industrial sectors, as for example petrochemical, steel, paper and pulp and electric power generation. Technological and economic characteristics and complexity of this type of process have important implications for the work organisation in these industries, especially in the operational area.

From the technological point of view, continuous process is characterized by:

Raw material indivisibility: since the productive process is composed of a sequence of chemical reactions and unit operations, most of the times it is not possible to distinguish inputs from final products.

- High level of integration among equipments: instead of isolated machinery performing different operations, a continuous process is characterized by a sequence of equipments interlinked and interdependent, resulting in low flexibility and interchangeability of equipments. The process is not, therefore, formed by discrete operations, but by process phases.

- Greater possibility of centralizing the operations control: since the interaction among the operators and the product is reduced and nearly all of it is subject to intermediation of equipments.

Besides these characteristics, a continuous process is usually characterized by a high level of automation and the use of computerized integrated control systems, which implies specific interactions among the workers and the task to be conducted: the main task of the operators thus becomes monitoring and controlling the process variables, aiming to maintain operational continuity, correcting occasional deviations and dealing with unpredictable flaws and variability in equipment performance (Buchanan & Bessant, 1985).

The economic characteristics that have implications for the work organization are:

No direct dependence between the work pace and productivity: productivity is dependent on the operational output of the equipments, and not on the pace of human work.

- Capital-intensive industrial plants and fixed labor costs: the continuous process industry tends to require high investments in equipments, and the labor cost does not vary according to the volume produced, and may be considered fixed.

Given its technological characteristics – interdependence of its variables, process indivisibilidty, randomicity and unpredictability, symbolic character of the operation (codificaction and abstraction) – the work operation and organization in continuous processes may be considered as complex. The operation of a complex process requires a work organization and an operator profile different from other types of operation. The type of task performed by workers in a continuous and complex process significantly differs from the work developed in a manufacturing process: the operators work is basically monitoring, controlling process and equipment parameters, analyzing and taking action about deviations identified in relation to a specified condition known by the operator. One may argue that automated systems are also designed for this function, but they are not always able to perform it without some human interaction. In some situations, the operator is required to take full control of part of the operations and to conduct one or more maneuvers independently of technology.

The perception to distinguish abnormal situations ("events") from trivial situations and the course of action to be taken in each case is an essential task for operators of this type of process. He/She must be able to make decisions about each task conducted, which requires relatively wide knowledge and an understanding of the whole process, attributes that are occasionally required, at a smaller scale, in operations characterized by discrete production processes.

Moreover, since the process and, therefore, the activities associated to it are indivisible and interdependent, the work is eminently collective, conducted by teams and not by an individual.

The work allocation method using the study of Times and Motion emerged in the works conducted by Taylor (1947). This method does not take into consideration important factors that might affect work allocation, although it is still used nowadays to support this decision in different environments - for example, Yeh, Lan & Lai (2005) for discrete manufacturing processes and Brennan and Orwig (2000) for engineering consulting companies.

The indivisibility and the interdependence of tasks and the dissociation between human work pace and the process productivity make Times and Motion method (from now on T&M) not suitable to complex and automated operations. The application of T&M presupposes the decomposition of the work into simple standardized tasks and with standardized execution time. The work in the operation of a continuous process cannot be divided and it cannot have its time standardized, either, due to its much more intellectualized character (monitoring, control and adjustment of parameters) and its imprevisibility (for example, it is very difficult to know when there will be one and how long a failure in a piece of equipment will last). Also, the T&M method fails to consider the collective character of the work in a continuous process, as it only analyzes the technical issue of the work and does not consider the capacity – and the necessity – for cooperation among workers.

It is also relevant to point out that, for T&M application, there is a fundamental differentiation between the productive and non-productive times. This distinction lies basically between the time in which the worker executes an operational task and the time in which he/she does not. In the case of continuous and intensely automated processes, this distinction makes little sense. How to identify between productive and non-productive time in process monitoring activities?

Nevertheless, in the absence of alternative methods that support work allocation and that take into consideration the continuous process complexity and characteristics, many companies have attempted to use eminently quantitative methods (based on T&M) of work allocation, with less than encouraging results. Most of these decisions, therefore, have still been made based on empirical criteria and on an *ad-hoc* basis. The next section attempts to develop the contribution of the present work, attempting to fulfill this conceptual and practical gap.

Work allocation– Factors to be considered

It is understood that different factors affect work allocation (see figure 1, as follows). These are:

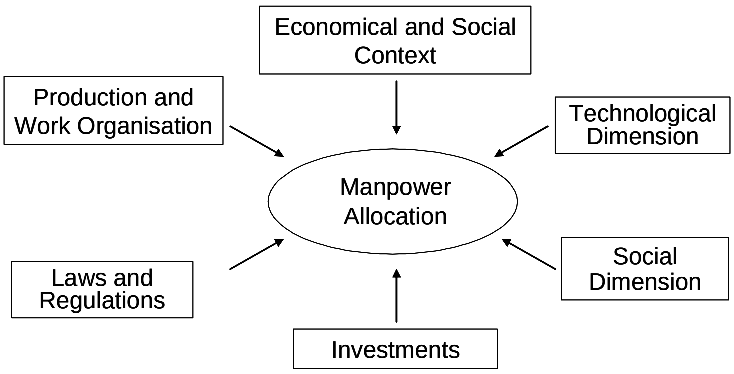

Figure 1 – Factors affecting Manpower Allocation

- The economic and commercial context in which the company is inserted and its development strategy.
- Social and demographic dimension – operators' characteristics: formation, individual and collective competencies, experience/ professional trajectory, time at the company and health situation.
- The production and its organization, including work organization (criteria for dividing and coordinating the activities).
- Technical dimension – involves both the production processes themselves and the products (quality and diversity criteria).

- Investments in the existing installations or foreseen for new installations.
- Laws and regulations that may be related to the work and its organization.

Besides, the decision on work allocation must be made under consideration of the different perspectives that usually influence it at a larger or at a smaller scale:

- The company point of view, including the different managerial views
- Workers' point of view, including their union representatives.
- Technical point of view, that is, deriving from the application of principles and methodologies conceptually adequate, validated and available to help decision-making on work allocation.
- Other points of view: analysis of competitors, *benchmarking* related to installations and similar operations, tradition and cultural aspects, characteristics of the industry.

Work allocation necessarily undergoes a discussion which has to consider and make explicit these different points of view. And why is it important to make it? Without this discussion and the explanation of different points of view, there is a great risk of choosing a solution with results inferior to the ones desired or even of choosing an unfeasible solution, since possibly aspects relative to the work, to workers' demands, intermediate level personnel in the hierarchy, union, organization interests or of part of it failed to be considered.

Use of Scenarios as a Planning Tool

A *Scenario* can be defined as a mental model accepted and shared with the world outside, involving descriptions of a possible future with internal consistency, that is, the outcome of a plausible trajectory (Heijden, 1996).

The use of scenarios comes from the Strategic Planning field, which have started with efforts conducted at Shell, that developed a method for planning future actions based on experts opinions from different knowledge areas. These scenarios expressed future possibilities, with a certain degree of uncertainty, but based on a coherent logic.

In this work, the use of scenarios does not intend a specific representation of the future, but to simulate the impact of work allocation in relation to critical indicators for the company management. Thus, the choice of impact indicators becomes a critical point of this method and the criteria for choosing them must necessarily contemplate the previously discussed factors (such as investment, social dimension, etc).

Methodology

In this work, the option was for the Research-Action methodology, which is, the use of an academic and scientific view to study the resolution of problems of an organization together with those directly involved in the subject (Coughlan & Coughlan, 2002).

This article derives from a project developed by the team of researchers of the WTO (Work, Technology and Organization) area – from the Department of Production Engineering - University of São Paulo, on demand of a large Brazilian company in the petrochemical sector, which needed support to work allocation decision for the operational area of one of its plants.

As expected results, the following were defined:

- The establishment of key indicators associated to relevant aspects for work allocation, allowing the assessment of scenarios;
- The building of coherent and consistent alternative scenarios assessed by these indicators;

- The development of a method, which might be replicated at any moment, at any plant in the company or in other organizations.

The building of scenarios was the main methodological element utilized. The scenarios were defined as situations in which different elements interfere in the work process, including technological, organizational, social, political and strategic factors. These factors are interlinked, building a certain logic that structures the organization of work. From the understanding of this logic and the analysis of the different factors, based on indicators developed to express the performance of the scenario in relation to factors of the organization interest, it was possible to build different new scenarios from the initial one, which represents the current situation of the plant studied.

The research-action process lasted approximately five months, along which part of the researchers team followed the work routine of the company full time, and it was developed in five phases, as follows:

Phase I – Delineation of the Current Scenario
Phase II – Building of Alternative Scenarios
Phase III – Analysis of Scenarios
Phase IV – Revision of Scenarios
Phase V – Presentation of Results

Phases II, III and IV were developed in three different sequential cycles, as will be showed further on, so that the development of consistent and coherent scenarios could be reached.

Phase I - Delineation of the Current scenario

In this phase, the aim was to get familiar with the work routine of the company and to collect the largest possible volume of information concerning the production and work process, in order to have a good understanding of the current scenario.

Then, in order to deepen the understanding of work in the operational area of the plant, *workshops* with operators were done. These *workshops* had the important role of making visible the strategies and courses of action developed by operators to conduct their activities.

After this, the establishment of the *indicators* for assessing scenarios was started. These indicators should express the criteria by means of which the scenarios would be developed and assessed.

Next, the premises defining the *contour conditions* – of technological and organizational nature - of the current scenario were identified. Also, the different levels of premises and the possibility of alterating each of them were identified.

So, an initial scenario of the current situation was developed. This scenario was exhaustively assessed with a group of different managers of the company, in order to improve it, specially regarding to the indicators used to assess it.

Phase II – Building of Alternative Scenarios

After finishing phase I, the building of new different scenarios was started. Each scenario has a driver or conductor for its development, that is, an opportunity for improvement identified in the previous phase.

A recursive test process of the scenarios was established in relation to the indicators chosen in phase I, collection of new information to clear doubts or obscure points, possible change and refinement of indicators besides the identificaction of premises not previously perceived. A first impact assessment exercise was conducted on the changes caused on indicators by the scenarios.

Phase III – Analysis of Scenarios

The current scenario, as well as a first version of the scenarios developed, was presented to the managers of the company, for identification of inconsistencies and possible assessment errors. As a result, there was a general assessment of the managers' reaction to the scenarios and to the indicators used, which allowed for some of the scenarios and for refining the set of indicators.

Phase IV – Revision of Scenarios

As a result of the previous phase, the project team started to revise the scenarios developed, implementing the agenda for collecting new relevant information. Fundamentally, attention was turned to observing operators', managers' and technicians' work, coupled to the new consultation to the documented data.

After collecting and analyzing the new data, phase II was resumed for developing new scenarios, necessarily more consistent in relation to the ones previously produced, configuring a recurrent.

Phase V – Presentation of Results

Finally, phase V was that of presenting the final set of premises, indicators and scenarios, with the corresponding justifications and analyses, in terms of impacts caused and the benefit/ cost relationship of the alterations in relation to the current scenario.

The Scenario Concept and its application for work allocation decision

The building of scenarios is the main axis of the method to support the work allocation decision developed here. As already discussed, a scenario could be defined as a representation of situations where different elements interfering in the work process are interlinked building a certain logic which structures the organization of the work processes.

From the understanding of this logic and the analysis of the different factors, based on indicators developed to express the performance of the scenario in relation to factors of the interest of the organization, it is possible to build several new scenarios from the initial scenario, which represents the current situation of the company. These scenarios can then be analyzed in terms of the changes in the indicators chosen in relation to the current situation.

Thus, the decision makers concerned with work allocation could conduct sensitivity analyses of the current scenario as related to the changes likely to be introduced, verifying their impacts and converging in relation to more advantageous scenarios according to the goals of the company.

Example of the scenario concept applied to a fictitious company

Due to the secrecy commitment of the project team concerning the company that was the object of the research-action process, the next section will present an example of the application of the method , a plant from a fictitious company named "X", with continuous process in the petrochemical sector.

Indicators	Analysis	Developments
Hability to conduct	The operator of area I cannot	There may be malfunctioning of

inspections and (area) readings and/or panel procedures	accomplish all his tasks within the shift. Normally, inspections and product sampling are delayed.	equipments for lack of adequate inspection. Lack of laboratory analysis may undercover severe process problems.
Volume of overtime work	On average, each operator works **y** hour overtime/month (number considered excessive by the company), to cover vacations, training and absences.	The operation excessively depends on overtime work.
Availability for developing individual/ collective competencies	Operation focused on routine activities– time for updating, reading and training is reduced. Training is usually conducted during free time. Time of training procedures, technical courses and capacitation in the console is of, approximately, **w** hh/year.	Need to make operational training viable to allow for the flexibility of OP and for continuous capacitaction of more inexperient supervisors and operators to compensate turnover. Current need for training – corporative, procedure updating, technical courses and capacitation in console takes approximately **y** hh/year.
Availability for proposing innovations (improvement in process, procedures and others)	Operation focused on operational continuity. Innovations and process improvements are the BHT personnel's role.	Process engineers have little availability of time for proposing innovations and improvements in processes, as they are involved in other projects in the company and do not devote attention to operational problems.
Organizational atmosphere	Excess of work and overtime causes dissatisfaction among the operational staff.	Dissatisfaction has been increasing "turnover" year after year. About **n** people a year resign or get transferred, increasing the need for new operators training time and capacitation.
Operational safety and occupational health	The occurrence of doubling, overtime and training during free time has decreased resting time.	Increased probability of human fault during operation.

Table 1 – Analysis of Current Scenario

Indicators	Potential Impacts of Manpower Allocation
Hability for making inspections and (area) readings and/or panel procedures	With flexibility of functions among area operators, there is availability of time to comply with the whole of the inspections and samplings routine.
Volume of overtime	With an extra operator to cover for workers on vacation and absentees, there is a reduction in overtime per operator.
Availability for developing individual/ collective competencies	With an extra operator to cover for workers on vacation and absentees, there is time availability for training in AT, without the need to generate Overtime to make training viable.
Availability for proposing innovations (improvement of process, procedures and others)	Involvement of operators and supervisors in projects for improving processes provides greater development of individual competencies.
Organizational atmosphere	With more training, greater involvement of operators in innovation, in improvement projects and reduction of overtime, there may be an increase in satisfaction and potential reduction in resignations.
Operational safety and occupational health	Respect to resting time and reduction of Overtime reduces operators' fatigue and accident risks.
Impact on the Benefit/ Cost Relation in the scenario	There is an increase of 5 operators, representing an increase by 15% in the labor cost, but there is significant reduction in the cost of overtime (which is paid with an additional value). Greater availability of time for training allows accelerating the qualification process of inexperient operators and reduces negative impacts of turnover on the team.

Table2 – Analysis of Alternative Scenario 1

Conclusions

This article sought to contribute to the lack of literature and of structured methods on the theme, starting from a presupposition that it is necessary to develop a method that organizes information, as much as possible explicits the premises and the consequences that the decisions on work allocation might cause. One of the main possible merits of this method is to show the critical decisions concerning work allocation, as it takes into consideration the different factors and the different points of view (lower staff, managing staff) that interfere and are affected by this decision. Another possible merit is the use of alternative scenarios, which allows for discussing the planning of the operation as a whole, by means of using a tool that induces the collective discussion of the variables and alternative ways for organizing the operation.

The application of the method in the company in question showed the importance that has to be given to the speed at which the adequate competencies can be mobilized to deal with the so-called "events", typical of any operation, but that are critical in environments marked by continuous and complex processes. The opportunity cost of not being able to count on the number of operators and the respective adequate qualification for dealing with "events" is a fundamental aspect that has to be considered in the analysis of the efficiency of modern operation systems. Moreover, the case under analysis showed how a decision of increasing personnel may be hindered by the lead time necessary for complete training operators to be able to do all the work, specially those considered more complex: in typical continuous processes environments, there is an "inertia" inherent to the process of increasing personnel, a characteristic that cannot be left aside in a decision of this nature. The decision taken today will have strong implications on future changes.

Nevertheless, the methodology here proposed also presents some restrictions: its application depends on mobilization of different actors and of an internal disposition of the organization to simultaneously decide on different variables. Furthermore, as it demands discussion and search for a consensus among the different parts involved, its application could take time and be tiresome, mainly in complex environments in the different acceptions of the word.

As a pioneer work on an alternative method for decision support of work allocation in complex production processes, a new front emerges for further researches in the area, for discussing and improving the method, its applicability to other types of activities and processes, specially those requiring predominantly intellectual and intensive work in terms of knowledge.

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