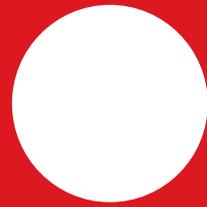


# **organisation of working time, competitiveness and quality of life**

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Ajuntament de Barcelona  
Usos del Temps

This new document, which forms part of the “Time Dossiers” collection, shows quite clearly how fundamental the organisation of working time is within the social organisation of time, influencing both the productivity of activities that generate goods and services and people’s quality of life.

*Organisation of working time, competitiveness and quality of life* takes an in-depth look at the most important modalities of flexible organisation of working time and production systems that have to function without interruption, while focusing attention on the meso level of working time organisation, which is made up of three phases: planning, programming and task allocation for each person in the workforce.

An essential point when organising working time is finding a balance between adapting production capacity to demand and the quality of life of workers. In other words, it is necessary to find a balance between *passive flexibility*, decided by the company, and *active flexibility*, in which workers have a greater margin for manoeuvre to organise their working time and, in consequence, their personal and social time.

The ultimate objective of this publication is to contribute reflections and knowledge, with the aim of making companies’ organisation of time more efficient without overlooking their staff’s quality of life .

**Jordi Hereu**  
Alcalde de Barcelona



The “Time Dossiers” collection was created with the intention of enabling different experts, from very diverse backgrounds, to show us how the social organisation of time can be modified.

Working time continues to be the mainstay of this social organisation: an organisation currently based on the somewhat unequal sharing of tasks. Analysing it, studying it and proposing new forms of organising it will, together with other factors, allow us to construct a city in which Information and Communication Technologies (ICTs) and a targets-based work culture become pillars for achieving greater competitiveness in companies and harmonising uses of time according to people’s needs throughout their life cycle.

This new study makes it clear that changing the values of working culture is possible, and that concepts such as efficiency, building loyalty to retain talent and promotion with equal opportunities, etc. may be the best bases for constructing the future of our citizens and of our business fabric.

**Imma Moraleda**

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# 1. INTRODUCTION

## 1.1. What is the organisation of working time?

The organisation of time in a society is one of the most important elements relating to people's quality of life and to productivity in activities that generate goods and services (Corominas and Crespán, 1993). The influence on these of the timetables of schools, hospitals and primary healthcare centres, leisure events, television, restaurants and in general, those of companies and institutions, is evident. All of these, the results of regulations or of sets of individual or collective decisions, very significantly condition people's work as well as their personal and social activities (taking the children to school, shopping, going to the cinema, sleeping, etc.).

A very important component of the social organisation of time is the organisation of working time (which we will refer to using the initials OWT). Organising working time consists of determining the quantity and temporal distribution of working time and the tasks that each person working has to carry out at each moment, in such a way that a set of conditions are respected and the solution optimises or is satisfactory in relation to one or more quality indicators.

In other words, given a time horizon, such as the year, and a working group, organising working time consists of determining, for each person in the group, how many hours they have to work each day and with what timetable and what tasks they have to carry out at each point. The quality of the solution adopted has to be evaluated from the viewpoint of the company or institution<sup>1</sup> (adaptation of the capacity time profile to the demand time profile, cost, strength against absenteeism, use of overtime, etc.) and from the viewpoint of its workers (regularity of working timetables, number of consecutive days with a high number of hours of work, distribution of days off and holidays, etc.).

Since the environments in which it is applied are so very varied, the OWT may be a very simple or a very complex task. In an organisation where the timetable is fixed and common to all personnel and each member of the workforce is specialised in a determined task and does not know how to do any other, there is not much margin for taking decisions. In contrast, for example, in a system with annualised hours working (hours of work can be distributed irregularly throughout the year, as long as the total is equal to a previously established quantity) and multi-skilled personnel, numerous solutions of very diverse quality are available, and determining one of them that is optimum, or at least satisfactory or acceptable for the organisation and for its staff is a com-

plex task that may require a lot of work if there are no appropriate tools available for resolving it.

In this chapter we see that the OWT has gradually become more complex as flexibility has become more necessary for companies, while people, as workers, who also desire flexibility for the organisation of their time, want to avoid any introduction of flexible OWT modalities meaning a deterioration in their working and living conditions.

## **1.2. From the Industrial Revolution to the present day**

The replacement of the craft-based production system by industry meant a radical change in the organisation of working time. The change was from timetables governed by the sun and organised individually or in small groups to those governed by the factory siren, which, when it sounded, determined and uniformised the working timetable.

From the Industrial Revolution onwards and for many years, the OWT presented few difficulties, because it was very rigid and uniform over time: a certain number of working hours each day, each day with the same timetable. In any event, the debate, and sometimes combat, focused on quantity: the struggle for the eight-hour working day, for example.

Furthermore, the family structure and the fact that married women did not normally work outside the home allowed development of work and social activities through a strict division of functions based essentially on gender and, therefore, undesirable.

For a long time, the only time organisation problems that presented any difficulty were determining the ideal number of extra hours to do each day and the organisation of shifts to cover the functioning of an industry or a service (in a hospital, for example) during a time greater than that of a person's working day, such as 24 hours a day, 7 days a week. This is a problem that is generally difficult to resolve satisfactorily and that has been and is a challenge for the OWT; even so, there are traditional solutions for many typical situations.

<sup>1</sup> If, like some dictionaries, we understand a company to mean an economic unit for the production of goods or services, the breadth of the acceptance allows the inclusion of units of the administrations and all kinds of non-profit organisations (foundations, associations, non-governmental organisations, etc.). In contrast, the more current acceptance associates it with the pursuit of profit as an essential characteristic. In this text, the word "company" may have either of the two aforementioned accepted meanings and the context will allow in each case to which it is referring. Occasionally we also use the term "employer" to refer to any element of the set of organisations that carry out productive activities through staff and a combination of diverse resources.

Companies or employers obtain products, which may be goods or services. Goods can be warehoused (noodles, chairs, printers, etc.). Services (teaching, cutting hair, inspecting facilities, etc.) can not, but they are still products. In other words, when the text talks about products, it is referring to both goods and services.

It is clear, however, that things have evolved and, eventually, the pace of changes increased substantially over the course of the second half of the last century. Currently, the problem of the OWT is focused on finding a balance between adapting capacity to demand (which is a form of improving productivity) and the quality of life of working people.

### **1.3. Social changes and changes in the production system**

The changes that have had a more direct influence on the OWT can be classified into two types.

Firstly, changes in family structure (for example single-parent families or families in which all the adults work) and in personal habits and family behaviours (as regards, for example, shopping for food or household goods or the lessened respect for Sunday as a day of rest. These changes make coordination of working and personal activities difficult and have led to demand, from working people, for flexible timetables, which present no direct benefits for employer organisations but that, within certain limits and for some types of activities, present no drawbacks either. It is for that reason that companies can consider them acceptable or even implement them by their own initiative if they consider that they might attract better qualified personnel or increase the workforce's job satisfaction.

Secondly, changes in the manufacturing system. Here we are interested in highlighting those more related to matching capacity and demand, one of the more general problems most difficult to resolve satisfactorily in company management.

Demand for products, whether goods or services, is never completely uniform over time. To the contrary, often it varies very significantly according to the time of year (soft drinks, ice-creams, motorbikes and cars) according to the days of the month or week (restaurants, cinemas, supermarkets) or according to the time of day (supermarkets, bars, banks and building societies). The ideal solution is to have a production capacity that at any time matches demand, but this has a cost, and furthermore, it is not always possible.

In the case of products that cannot be stored (services, but also electrical energy), once everything possible has been done to favourably modify the demand profile (prior appointment, marketing actions, differentiated rates according to the time or day), the only possibility for satisfying demand, if one does not accept the impossibility of satisfying only a part or alternatively an almost constant excess of capacity, is to use tools to modify capacity in a way that means it can be adapted to demand at all times, as long as it is possible and profitable.

The manufacturing industry (which has the advantage that timetable fluctuations do not affect it – i.e. the hours of the day in which purchases or orders for an industrial product are made do not have repercussions on production planning) has traditionally resorted to overtime to be able to achieve greater capacity at times of high demand (and sometimes to hiring temporary workers, but that is not always possible, for legal reasons or because the work requires an expertise that can only be obtained through long experience) and

to stockpiling at times of slack demand to be able to satisfy demand at times when it is strong. Both modifying capacity (via overtime or temporary work) and stockpiling have associated costs and finding the optimum combination of these tools to satisfy demand is no trivial matter. As for stocks, there is a general tendency to reduce them, for very diverse reasons, such as increased space costs or the possibility that any units warehoused may become obsolete and lose the greater part of their market value.

This tendency towards reducing stocks, plus the increase in the importance of services among business activity as a whole and the globalisation of the competition that reduces margins, show the convenience of adapting production capacity to meet demand as far as possible. Flexibility in working time, in line in this case with company needs and not, initially, with those of the people working there, is one of the most important tools for achieving this adaptation.

Also affecting the OWT is the increase in staff multiskilling, as against the more traditional single-skill specialisation. This makes allocating tasks more complex, whereas when there is no multiskilling it is a much simpler matter.

## **1.4. Classes of flexibility**

Flexibility can be defined as the facility of adapting to changes swiftly in a way that is not too costly.

In contrast with rigidity, which is normally considered as a highly undesirable defect in a person or an organisation, flexibility is habitually charged with positive connotations. This, however, depends on the viewpoint adopted.

If flexibility is the facility to adapt to change, clearly we will have a different type of flexibility according to the changes to which we are referring. While one production system may adapt well to changes in total demand volume, but not to changes in its composition, in other words, the distribution of the total demand among the diverse types of company products; another may behave itself in the totally opposite way. The *Diccionari de la llengua catalana* from the Catalan Studies Institute (2nd edition, 2007), defines work flexibility (a concept it presents as belonging to the sphere of economic theory) as the adaptation of work volume to production needs, with the possibility of hiring and firing workers with a minimum of legal regulations. However, we do not use this definition. Flexibility relating to changes in the volume of demand can be obtained with flexible modalities of working time organisation, such as annual hours working or others that are described later.

There are systems in which the element that best determines production capacity is not personnel but equipment. However in the case of most services, production capacity depends very directly on the hours of work available and therefore the flexibility to tackle fluctuations in total demand volume requires flexibility in the availability of working hours (in contrast, flexibility in relation to changes in the composition of demand is more closely linked to the staff multiskilling). Flexibility in OWT allows production capacity to be adapted to demand, without variations in the workforce, within an interval whose width depends on the characteristics of the system of flexible organisation of working time.

From the viewpoint of people, the only flexibility desirable is that which is called active flexibility of work time, in which the person has to work a given number of hours per period (for example, 37 hours per week) but with a timetable not completely determined by the company, which conditions it via rules such as the establishment of a more or less broad interval for entering work and another one for leaving. Currently, teleworking makes flexibility possible as regards the place where work is done and offers new possibilities for active flexibility of working time. This type of flexibility has no repercussions on the company's production capacity, but it has positive consequences for those people working there, who can better organise their activities and combine (or reconcile, as is usually said now) the personal and social aspects of their lives with working aspects. Indirectly, it can also have positive consequences for other people, for example the fact that it means avoiding rush-hour travel or even, in the case of teleworking, because of the reduction in the amount of travelling.

In contrast, passive flexibility, in other words that in which distribution of working time is decided by the company, implies more or less significant drawbacks for people and, therefore, they consider it undesirable or may even consider it worthy of rejection.

It is necessary, therefore, to find solutions that are acceptable for all parties involved, which means that flexibility has to be regulated, and that it has to be negotiated and agreed. Staff may understand that the company requires flexibility, but it is logical that they demand fulfilment of certain conditions and also compensation, which may consist of reductions in working time or increased remuneration.

The modalities for introducing passive flexibility are very varied. For example, overtime hours, more or less limited in number, annualised hours working, or working time or hours accounts, where hours worked over or under a daily reference value, for example, are credited or charged to the hours account of each working person, with maximum values for positive and negative account values. Evidently, there are mixed systems, e.g., annual hours working with the possibility of overtime hours).

It is clear that it is not easy to evaluate the repercussions of introducing or modifying a condition or one of the parameters that define the system (e.g. maximum number of hours at the end of the year, maximum number of daily hours, maximum balance of hours account, etc.). It is for this reason that the company and its staff have to have access to instruments that allow them to evaluate the consequences of adopting one solution or another. These instruments are indispensable for negotiating on rational and quantified bases.

## **1.5. Macro, meso and micro levels of organisation of working time**

What has been said so far clearly shows the scope and importance of OWT, as well as its tendency to be increasingly important and, at the same time, more complex.

It is useful, therefore, to distinguish what we could call levels of OWT. For our part, we consider three of these, which we have called *macro*, *meso* and *micro* levels.

The *macro* level is the one that corresponds to the laws<sup>2</sup>, stipulations and customs that establish maximum values for working hours and the conditions these have to respect such as the opening hours of schools, shops, health centres, transport timetables, television and show times. People who work (in a factory, a hospital, a school, a shop, a fire station, etc.) have to be able to go shopping, take the children to school, enjoy their leisure time, etc. Obviously, this level of OWT presents problems that it is not possible to resolve to everyone's satisfaction, as made clear by the debates over shop opening hours, modes of transport, etc., that so often appear in the media. In fact, this *macro* level corresponds to the social organisation of time, of which the OWT is a very important element, but not the only one.

The issues that are the subject of this publication correspond fundamentally to the *meso* level, which is dealt with in the following section.

The level that we call *micro* is that of decisions on breaks for personal needs and recovery of fatigue and on the time necessary, in some workplaces, to prepare to start work or leave it (put on or take off a uniform or work clothes, put away or put out instruments, etc.): They are classical issues in work organisation. The solutions are adopted, often in a negotiated way, on the basis of more or less empirical laws.

## **1.6. The meso level: planning and programming of working time and allocating of tasks**

On the *meso* level, conditioned by the higher (*macro*) level, the issue is to determine, for each person in the workforce, how many hours each has to work in each period (each day, each week) with what timetable and, finally, what tasks each has to carry out at each moment in time. We will refer to these three types of decisions, respectively, with the terms *planning*<sup>\*</sup>, *programming* and allocation of tasks. Since they are nearly always determined by this order, it can be said that they constitute the three stages or phases of the *meso* level.

Traditionally, the only variable considered by *planning* was the number of overtime hours. Normal working hours, outside holiday periods, were fixed. With time, different flexibility modalities have been introduced: annual hours working, working time (or hours) accounts and others. In the more general case, based on a forecast of demand, it has to be determined, for each member of the workforce, how many hours each has to work every day (or every week) of those included in the *planning* horizon; the solution has to respect conditions, established by laws or by agreements, which have to guarantee that dedication to work is compatible with health and personal life. It is a complex problem that requires advanced instruments.

<sup>2</sup>As regards Spain, see Bodas (2002), Fita (1999), Martínez and Garicano (1996), Millán and Díez (1999), Monreal (2005).

**Programming**, in other words, the determining of working timetables (work starting and leaving times) has for some time been presenting significant difficulties in services that cannot control the temporal distribution of demand (via, for example, a prior appointment system). Traditionally, attempts have been made to achieve adaptation of capacity to demand with the use of different timetables that were very often fixed for each person. It was a case of determining how many or which people had to be allocated to each type of timetable. From the moment the possibility is accepted that the number of hours per day or week may be variable (as happens with annual hours working or working hours accounts), the possibility also opens up that the timetable of each person may be variable. Management becomes more complex and the system becomes less comfortable for people. Therefore, in determining solutions, it is necessary to take into account preferences for one type of timetable or another. In many cases, the determination of timetables is very directly linked with the last phase of this process, the allocating of tasks.

The allocating of tasks has to take into account the distribution of demand over time, the **efficiency** of each person in each kind of task, the effects of learning and unlearning and any grievances that may be caused by non-equitable distribution of tasks.

**Planning** and **programming** and sometimes the allocating of tasks are based on forecasts relating to a determined temporal horizon. The passing of time, however, shows up discrepancies between reality and forecasts. These discrepancies and the new forecasts produced taking them into account may make it advisable to review decisions made previously. It is then said that the tasks are replanned, reprogrammed or reallocated. Since these reviews may imply modifications to the organisation of working time and, in consequence, to the lives of workforce members, when carrying them out, attempts must be made to ensure that changes related to what was planned previously be as small as possible.

In general, solutions to working time organisation cannot be evaluated according to a single criterion, because, in addition to those corresponding to the company's viewpoint (such as cost or quality of service), the people working there must also be taken into account (regularity of working day or availability of completely free weekends, for example). The problems that are presented in the OWT are, therefore, of a markedly **multicriteria** nature.

For all these problems, tools have been developed (many due to the team that has written this publication). Specifically, **mathematical models** have been generally of **mixed integer linear programming**, and it has been shown that they can be resolved in an effective way making use of commercial programming. These tools can help administrations, companies and staff representative bodies to configure solutions that improve the **efficiency** of production processes for goods and services without jeopardising, and, if possible, even improving, quality of life for people who work there.

All of these issues are dealt with in greater depth in the following chapters. Chapter 2 describes the most important modalities of flexible organisation of working time, Chapter 3 refers to OWT in production systems that have to

function without interruptions. Chapters 4, 5 and 6 talk respectively about [planning](#), [programming](#) and task allocation. Chapter 7 contains the conclusions. Finally, bibliographical references and a glossary are included.

## **2. MODALITIES OF FLEXIBLE WORK TIME ORGANISATION**

In this chapter we describe those more common working time organisation modalities that offer flexibility to the employing organisation and the people who work there. Specifically, we present the modalities of rigid timetable with overtime, teleworking, annual hours working and working time accounts.

### **2.1. Rigid timetable with overtime**

When the system of organisation of working time is based on a rigid timetable (e.g., the number of working hours is the same every day), the only way of modifying capacity is through the use of overtime (i.e. working more hours than the normal amount).

According to the Workers' Statute (hereinafter WS)<sup>3</sup>, overtime is considered to be those extra hours worked above the maximum duration of the ordinary working day (any excess of hours worked to prevent or repair accidents and other extraordinary and urgent damage are not accounted for as extra hours, notwithstanding their compensation as overtime). The number of extra hours cannot be greater than 80 hours per year and working extra hours is voluntary (except where this has been agreed in the sectorial agreement or individual job contract).

As regards the compensation of overtime, the WS establishes that through the sector agreement or, if none applies, the individual job contract, payment for extra hours must be established at the amount set, which in no case can be inferior to the value of an ordinary hour, or to compensate them with equivalent time of remunerated rest. In the absence of this kind of agreement, it is understood that they must be compensated via rest within 4 months following them taking place. In any case, it is necessary to comment that nearly all extra

<sup>3</sup> Workers' Statute, Chapter II, Fifth section (Working Time), Articles 34 (Working hours) and 35 (Overtime).

hours worked are compensated monetarily (INE, 2000). Thus, from the personnel viewpoint, the advantage of this modality is, undoubtedly, the extra remuneration that it involves and upon which numerous families depend to make ends meet.

For a long time, overtime has been the main source of flexibility in order to adapt production capacity during periods of high demand. However, the high cost involved and the fact that it does not solve the need for flexibility in periods in which the necessary capacity is lower than normal, makes it a suitable instrument only for those companies that enjoy a relatively stable level of activity, with occasional increases. In these cases, the OWT consists of deciding the number of hours of overtime that each person has to work in each period (day, week, etc.).

## **2.2. Active flexibility and teleworking**

As commented in the previous chapter, active flexibility is the name given to that in which the person has to work a given number of hours per period, but with a timetable not completely determined by the company. Currently, for example, teleworking makes it possible to be flexible regarding the place of work and offers new possibilities for the active flexibility of working time. This kind of flexibility does not have major repercussions on the company's production capacity, but it has positive consequences for its workers and, indirectly, for other people too.

Specifically, we understand teleworking to mean a flexible form of work organisation that consists of carrying out professional work without the physical presence of the person in the company, at least during an important part of their working day. It encompasses a broad range of activities and can be carried out on a full-time or part-time basis. The use of teleworking implies the frequent use of electronic information processing methods and the permanent use of some telecommunications means to maintain contact between the teleworker and the company (Gray et al., 1995).

A European Framework agreement has existed on teleworking since 2002, establishing some general guidelines for collective negotiation. It specifies that this form of working is voluntary, it also talks about data protection, about the responsibility of the worker to take care of the computer equipment, about social security, about training and about their inclusion in sector agreements. In Spain there is no specific regulation of teleworking; currently it is regulated by the WS under one of the variants of so-called "home-based working"<sup>4</sup>. Furthermore, collective agreements in Spain do not normally regulate teleworking, for example in 2006 only 10 collective agreements made reference to it (Arasanz, 2008). The majority of companies carry out individual negotiations with their teleworking staff and this does not emerge in official statistics. Spain is still a country where the percentage of people teleworking is low, in 2000 it was in tenth position with just 2.8% of the working population, whereas Finland, which led the group, had 16.8% of its working population teleworking (*El País*, 27/8/2000).

Even though teleworking does not have to take place in the home, as has

<sup>4</sup> Workers' Statute, Chapter I, Fourth section (Job contract modalities), Article 13 (Home working contract)

been commented, its differentiating characteristic is that it requires the knowledge and use of information and communication technologies (hereinafter ICT). In fact the most usual form of teleworking is at “telecentres” which can be promoted by private or public initiatives. The sectors that have experienced most growth in people teleworking are Banking and Insurance, together with the ICT sector itself. Teleworking is most frequent in companies that have a greater percentage of “knowledge-based” personnel, i.e. people dedicated to design, research, management, finances or IT. Teleworking is also frequent in the commercial sector, especially in sales. Evidently teleworking is also increasing in results-managed activities, of the project type, where it is easier to measure the activity carried out during teleworking (Pérez, 2001).

In summary, teleworking is a form of flexibility in working time and work location. For the company, among the prominent benefits are: the possibility of keeping on staff of high value for the company who need these characteristics of flexibility, the reduction of general expenses and of work absenteeism with the consequent increase in staff productivity. For the teleworker, it is precisely the flexibility of the working day that stands out, the reduction in travel, the personal choice of working environment and the autonomous management of one’s own time. Evidently this way of working has its drawbacks for the teleworker: lack of personal contact, lack of immediate support when a problem needs to be solved by the company, the complexity of social and labour protection and the need for more training in ITCs, among others.

## **2.3. Annual hours working**

Annual (or annualised) hours working consists of hiring workers for a certain number of annual hours with the possibility of distributing them in an irregular way over time, according to production needs. Thus shorter or longer working days are worked according to whether capacity needs are low or high, respectively, while the weekly or monthly wage remains constant. This modality presents a set of advantages – mainly for the company – and drawbacks – mainly for the workers – which will be commented on later. Normally some kind of compensation is offered to workers in exchange for accepting this system and, to avoid overloading them excessively, a series of limits and conditions is established that must be taken into account when organising working time.

Although some first forerunner can be found of annual hours working to tackle variations in necessary capacity (for example, in 1956, three hundred workers at Sevalco, in Avonmouth, United Kingdom, had an annual hours working contract), the first significant cases date from the end of the 1960s, when some French, German and Scandinavian companies started to make use of this modality. Yet it wasn’t extended until the end of the 1980s, when its use began to grow, mainly in the services sector (Stredwick and Ellis, 1998). However, the number of contracts with annual hours working did not grow as much as expected; the difficulties (long negotiations, commitment) that are involved in introducing such a system are one of the main causes. In this sense, IRS (1991) highlights the need for good cooperation between employer and workers in order to make introducing annual hours working effective.

In France, annual hours working experienced quite a notable increase following the implementation of the Aubry II Law or 35-hours Law which established, basically, a reduction of working time to 35 hours per week on average, without any reduction in salary, in exchange for permitting annual hours working, subject to different rules.

In a recent study on annual hours working in Great Britain, Gall and Allsop (2007) conclude that even though in the last decade there has been growth in its scope, the growth rate has fallen. In their opinion, that is due to the reduction in the number of organisations that could consider introducing annual hours working, together with the drawbacks that this type of system can present and which we will discuss later.

Currently, in the majority of countries the law contemplates the possibility of introducing a system like this, through collective or individual negotiation. Specifically, in Spain, the WS<sup>5</sup> establishes that the ordinary working day (which has to be agreed in collective sector agreements or job contracts) will in no case exceed 40 hours per week of effective work on average in the annual calculation and that, through sectorial agreements or if there is none, agreement between company and workers' representatives, the irregular distribution of the working day over the year can be established.

In fact, there are numerous collective wage agreements that contemplate the possibility of irregular distribution of the working day, through different versions or modalities of the annual hours working system. According to a report by the EIRO (European Industrial Relations Observatory) dated 2003, in Spain (and other countries) the most usual is that the sectorial wage agreement establishes the basic parameters of the annual hours working system (for example, the annual number of hours of work) and that, the details of the system are negotiated within the context of the company itself or, even, the place of work, between the management and workers' representatives. According to the same report, in 2002 some 45.5% of workers were covered by collective agreements that contemplated the possibility of distributing working time in a flexible or irregular way. However, it must be taken into account that there may be companies where, despite the sectorial agreement allowing the flexible distribution of working time, this has not been implemented. Moreover, it is worth mentioning that this percentage includes not only annual hours working, but other systems of flexible organisation of working time such as, for example, the working time accounts system, which is the subject of the following section of this chapter.

Diverse articles, studies and reports make clear the benefits and drawbacks that introducing annual hours working presents for company and workers alike. In fact, certain contradictions are even found in the literature, as is the case with aspects such as reconciling working, family and personal life or planning individual free time: it is evident that in many cases this will be jeopardised but, in other cases, it may even be improved. These contradictions are not the only ones that appear in the literature; defenders and detractors of annual

<sup>5</sup> Workers' Statute, Chapter II, Fifth section (Working Time), Article 34 (Working Hours)

hours working sketch a confusing scenario, and, often, do not argue their contributions (Lusa, 2005). The main reason is that some benefits and drawbacks are not the result of annual hours working in itself but the specific conditions which are negotiated.

In Table 1, a summary is presented with the general benefits and drawbacks of annual hours working.

	Benefits	Drawbacks
FOR THE EMPLOYER	<ul style="list-style-type: none"> <li>■ Adapt capacity to demand.</li> <li>■ Better use of human and material resources. This involves reduction of costs: overtime, temporary staff, lost sales, hiring and firing.</li> <li>■ Better planning of budgets, with more foreseeable costs.</li> <li>■ Improvement in the level of service (orders served on time or with less delays).</li> <li>■ Improvement of quality (for example due to the reduction of temporary staff).</li> <li>■ Reduction of work absenteeism.</li> <li>■ Reduction of rotation.</li> <li>■ Catalyst for other changes and innovations.</li> </ul>	<ul style="list-style-type: none"> <li>■ Long and tough negotiations.</li> <li>■ Complication of the system of organisation and control of working time.</li> <li>■ Possible loss of human capital (reduction in number of hours of overtime worked).</li> </ul>
FOR THE WORKERS	<ul style="list-style-type: none"> <li>■ Job stability (no redundancies in periods of low demand).</li> <li>■ Stability of salary over time.</li> <li>■ Possibility of increase in base salary (as compensation for accepting increased flexibility).</li> <li>■ Possibility of reduction in the total number of hours worked or increase in holidays (again, as compensation).</li> <li>■ Increase in advance notice of time-tables to be worked.</li> <li>■ Reduction of precarious contracts.</li> </ul>	<ul style="list-style-type: none"> <li>■ Reduction of income for overtime.</li> <li>■ Possible increase in number of hours worked at inconvenient times (weekends, end of the day, etc.) without additional remuneration.</li> <li>■ Intensification of work (many hours of work) especially in periods of high demand.</li> <li>■ Difficulties in reconciling work, family and personal life.</li> <li>■ Possible differentiation in the rules of working time and in remuneration structures within the company (makes negotiations difficult).</li> </ul>

**Table 1.** Benefits and drawbacks of annual hours working

The key aspects that determine finally the existence and magnitude of benefits and drawbacks are, on the one hand, the specific characteristics of the annual hours working system and the possible compensations in exchange for flexibility, and on the other, the way in which this is introduced into the company or specific job post.

Good negotiation and a good system for organising working time are two key aspects, strongly related, that have to permit that employer and workers alike enjoy the benefits that these kinds of systems can offer to both parties, as well as minimising the drawbacks.

The most common types of compensation (in exchange for flexibility) are reduction in the total (annual) number of working hours, the increase in the number of days holiday and salary rises. However, sometimes these kinds of flexible systems are introduced in exchange for keeping one's job (for example, because transferring production elsewhere is avoided).

As has been mentioned previously, any annual hours working system is characterised by considering a certain number of hours that are distributed in a not necessarily regular way throughout the year. Over time, the exercising of collective bargaining has given rise to diverse variants or modalities; below some of these that have been found in different collective and company agreements are described.

- **Fixed number of hours:** the number of work hours (for example per week) has to be between a minimum and a maximum value (for example between 30 and 45 hours per week). This modality, the simplest of all, avoids working days that are too short (e.g., having to travel to the workplace or having to operate a production system for just a few hours) or too long (fatigue that may bring with it health problems and a reduction in performance). Obviously, the wider the margin, the more flexibility the company will have to tackle the necessary capacity. For that reason, these limits, together with the annual number of hours, are key parameters during negotiations. The drawback of this variant is that, as the number of hours of work, in each period, could be of any number, the management of the specific timetables of different people can become quite complicated.

- **Predetermined types of working hours:** with this other modality, the number of hours of work in each period (for example, week) has to match a predetermined list; for example weeks of 28, 35 or 46 hours that correspond to a short, medium and long working day respectively. If, furthermore, the number of working hours in one year is established (or limited), a system is achieved with which workers can end up quite satisfied. Firstly, the number of strong weeks (e.g. with a long working day) is limited and it is guaranteed that there will be quite a few weak ones, and, secondly, with so few possible working hours combinations, good organisation of free time seems more viable. Naturally, the OWT (for example the programming of specific timetables) by the company is notably simplified. It is worth saying that, despite the fact that this modality may not seem very flexible, it achieves very good adaptation of capacity to needs (providing that the number of workers is not very small as, in this case, the combination of different working hours gives little room for manoeuvre). A variant of this modality, which conserves the majority of its advantages and may offer even more flexibility, consists in defining intervals, instead of working hours: for example, working weeks of between 25 and 28 hours, wor-

king weeks of between 32 and 37 hours, and working weeks of between 44 and 46 hours.

- **Flexible weeks bank:** finally, this modality consists of limiting the number of weeks of the year in which the working week can be different to the reference week. The flexibility of this system is directly proportional to the number of flexible weeks.

Whichever the modality, the specific details of the system have to be negotiated and agreed. To avoid significantly jeopardising the possibilities for reconciliation of the working, family and personal lives of workers, usually two types of conditions are negotiated and established:

**a)** In this group we have, firstly, the minimum term of notice of the days and/or timetables to be worked and, secondly, what is called the rigid or fixed term or period, which is that during which the decisions communicated cannot be modified. For example, if the term of notice is two weeks and rigidity four weeks, this means that, once the timetable that will be worked during a certain number of weeks is communicated (with a minimum notice of two weeks), the first four weeks can no longer be modified.

**b)** This other group includes those conditions that affect the distribution of working time over time. Some examples found in collective bargaining agreements or employer agreements of known cases are:

- Limit the annual number of weeks in which the working time is considered heavy or long (i.e., greater than a high value such as, for example, 46 hours). Establish a minimum number of weeks per year in which the working time is considered light or short (i.e., no greater than a low value such as, for example, 28 hours).

Ensure that the average working hours in any group of a certain number of consecutive weeks is no greater than a certain number of hours/week (this condition, with groups of 12 consecutive weeks and a maximum of 44 hours/week) appears in the French Aubry II law).

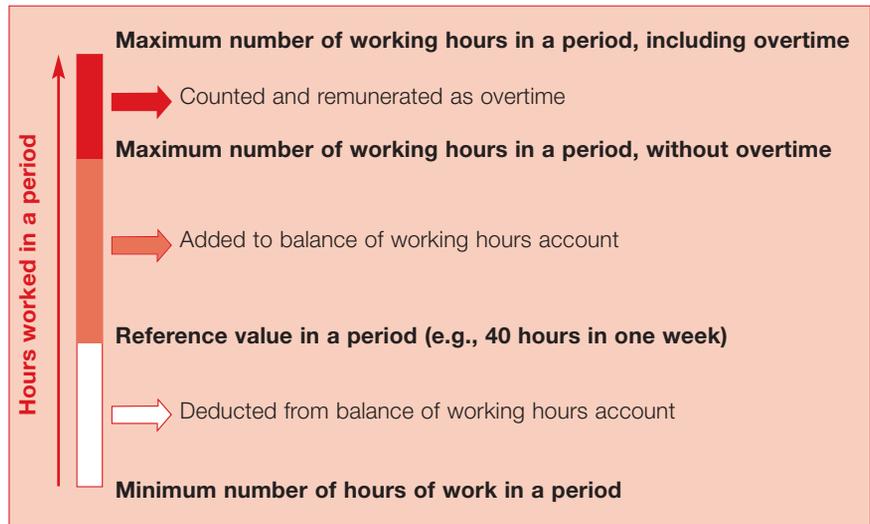
Impose periods of rest after heavy work periods. For example, if the average of hours in a group of 8 weeks is greater than 46 hours/week, then the number of hours worked in each of the following two weeks cannot be greater than 28 hours.

## 2.4. Working time or hours accounts

The systems of working time accounts, also called working hours accounts, can be considered as a generalisation of annualised working hours, considering a horizon that is not necessarily annual. For this reason, many of the aspects commented upon in the previous section are applicable also in the case of working time accounts.

Via individual working time accounts each person has their own account so that, if in a period (for example a day or week) that person works a number of hours greater than the reference value (for example 8 hours per day or 40 hours per week) the different is credited to their account, and if they work less, then the difference has to be deducted from their hours account balance. Thus, more or fewer hours of work can be assigned to each person, as suits. As in the case of annual hours working, the number of hours of work in a

period also has to be between a minimum value and a maximum value. In some cases, they are combined with extra hours in such a way that upwards of a certain number of hours per day or week are considered and remunerated as overtime (the maximum number of overtime hours in a period is also usually limited). Figure 1 shows how this functions .



**Figure 1.** Functioning of a working hours account

Working time or working hours accounts emerged at the end of the 1960s in Europe and later reached the United States; at first, they appeared to give flexibility to workers (Owen, 1977), providing that it did not enter into conflict with the company's activity. Working time accounts, as a source of passive flexibility (i.e. for company needs) were used for the first time in Germany in the automotive sector, and later developed in other sectors (also services such as banking or information technologies) and countries (see Lehndorff, 1999, for more details).

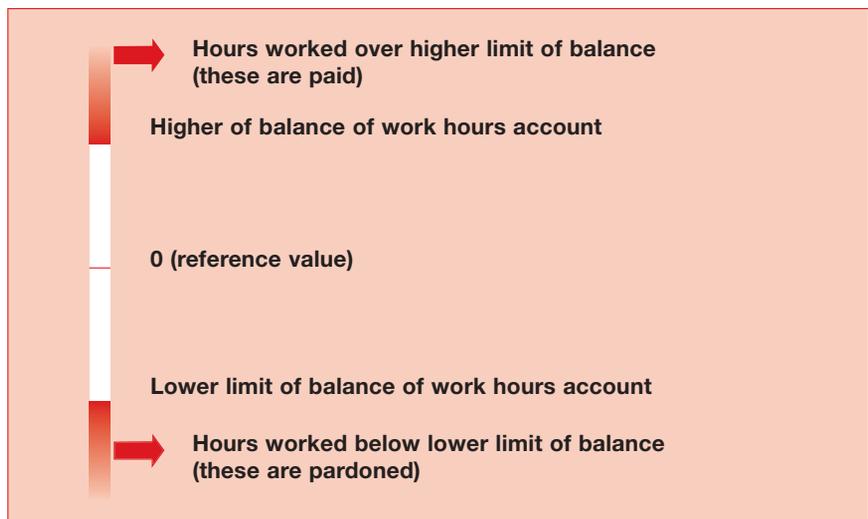
It has been reported that, in Spain, different companies such as Renault, Opel, Seat and Sony have adopted different flexible working time organisation schemes since the end of the 1990s. It is also important to take into account that cases where the overtime hours are compensated with rest may be considered as a case of working time accounts, even though this scheme has not been explicitly defined.

The benefits and drawbacks of working time accounts for the company and its workers are essentially the same as in the case of the annualised working hours. The differentiating benefit of the working time accounts is that the number of hours in one year is not pre-established (there may be years in which more or less hours are worked than others, according to production needs), so they are especially appropriate for those companies or organisations that need to adapt their capacity to a demand that varies during a period that may be longer than one year, maintaining a relatively stable workforce. In other words, working time accounts are an instrument for flexibility in the long term.

Obviously working time accounts also have to be negotiated and the conditions that have been mentioned for the annualised working hours case remain valid.

In each period, the balance may be positive (the company owes hours to the worker), negative (the worker owes hours to the company) or even, and, to maintain the system under control, it is usually arranged that the balance of each person should remain within limits that can be more or less broad, as agreed (for example, between -100 hours and +200 hours).

Sometimes, the company may write off hours that are under the lower limit and/or pay those that exceed the upper limit. This allows the avoidance of undesirable situations such as the following: imagine an industrial process in which all the people working have to necessarily work the same timetables. Since the initial situation of each person may be different (differences in length of service, time off, etc.) it is very probable that each has a different balance. Let us suppose that there is one that has reached the upper limit of her balance; the only way of ensuring that this person remains within the established limits is working a number of hours no greater than the value of reference, in order not to add more hours to their balance. Now, it is evident that this may enter into contradiction with the company's production needs and for that reason, one solution is to work the hours necessary and leave the balance of that person as it was, crediting their account with the extra hours they can do (in no case can this person be asked to pardon the hours to the company, as the situation is not their responsibility). Should the worker have reached the lower limit of their balance and it be convenient for the team to work a lower number of hours, what would happen is to pardon the hours not worked to that person in order to maintain their balance at the established limits. Figure 2 aims to illustrate what has been explained above.



**Figure 2.** Non-strict limits of a work hours account

In addition, in some cases it is established that if the hours worked over or under the limit in a period have not been compensated at the end of a certain period of time (for example four months), then they run out, and according to the value of the balance, they are pardoned (when the balance is negative) or

paid to the worker (when the balance is positive). This is done to avoid reaching situations of strong imbalance where many people have a positive balance (the company owes many hours) or a negative one.

# 3. CONTINUOUS FLOW PRODUCTION SYSTEMS

## 3.1. Introduction

In accordance with what was said in chapter 1, the expression “production systems” covers all those with which products are obtained, whether these are goods or services.

Firstly, we consider as continuous flow production systems, with a certain abuse of the language, those in which the activity is uninterrupted (as in a hospital) or in which it stops in a programmed way after functioning continuously for quite a long time (e.g. systems in which cycles are repeated of eleven months of work and one of shutdown – for staff holidays and equipment maintenance, for example).

There are other production systems that cannot strictly be considered as continuous flow systems, such as establishments (shops, bars, restaurants, etc.) that open to the public every day of the week (but close at night) or organisations (such as banks and building societies) that, with a limited daily timetable, do not close for holidays (except for bank holidays). In these systems more than one person for each position is necessary, since the time that the work position has to be active is much greater than the working day of one person (the working week, in the case of a restaurant that opens every day; the working year, in the case of a bank office that opens on all working days of the year). This means that these systems present problems with many points of contact with those of strictly continuous functioning. Therefore, in this chapter we will refer to one type (for example hospitals) and the other (for example, to systems that have to operate 7 days per week, even if not during 24 hours per day).

In some of these production systems, the organisation of working time does not refer to people individually, but to teams. For example, to maintain functioning at a chemical plant or an assembly line it may be necessary, at all times, to have a team of people with a determined composition, as regards its members’ knowledge; thus, if the plant or line has to function 24 hours per day, 7 days per week, a certain number of teams are necessary to relieve each other.

There are cases, such as that mentioned in the previous paragraph, in which the permanent presence of one and only one team is required, as the capacity necessary, with regards the staff present, is uniform over time. In others, the temporal profile of the capacity necessary has different values over time. We will assume, therefore, that it does this in a cyclical way, in other words the profile varies within a determined time interval but it is repeated indefinitely (for example, a variable profile within the week, but that is the same for all weeks).

The organisation of the remainder of this chapter is as follows. Section 3.2 describes the reasons for which there are production systems that require continuous functioning; the next section (3.3) will indicate the drawbacks presented in these systems by the organisation of working time, the modalities and variants of which are the subject of section 3.4; finally, section 3.5 contains the basic concepts for obtaining solutions.

## **3.2. The reasons for continuous flow operations**

There are two main reasons for a system to have to function without interruption.

The first is that the nature of some activities is inseparable from continuous functioning because they consist of uninterruptedly watching over people or things (hospital care, police surveillance) or because they have to give a response to events that may arise at any time and that if they are not treated swiftly and appropriately may have very severe consequences (emergency medical services, ambulances, fire extinctions, telephone attention services for emergencies, response to incidents at nuclear facilities).

The second, the fact that an interruption in the system's functioning has such a high cost or implies a period of inactivity so long that it cannot be assumed, as happens, for example, with blast furnaces, in which an uninterrupted functioning is maintained until the refractory is spoiled, as a stoppage would mean the deterioration and substitution of this element and long, costly operations. We can say that, in these cases, technical reasons force continuous functioning, even though, in the final instance, it can be considered that economic reasons are behind them.

There are also systems that function continuously for directly economic reasons. There are cases in which the investment in equipment is very high and it can only be profitable if made to function without interruption. In others, the reason is the forecast of fast obsolescence of equipments or the product.

If we understand continuous functioning in the broadest sense as indicated in the previous section, we can add reasons of a commercial type (in the final instance, obviously, economic). A bakery or a bar that opens every day of the week will have higher income than if it closes on Sundays, because the demand will be addressed to competing establishments that are open, with the possibility of losing clientele, even on the days it is open, because clients get used to other providers. Similarly, the banks and building societies open every day of the year except bank holidays, without shutting for holidays.

For these reasons, continuous functioning systems have been, for a long time

and increasingly, very numerous and the proportion of the employed population working there, very high.

### **3.3. Drawbacks relating to the organisation of working time in continuous flow systems**

In a continuous flow system, working timetables have to be allocated to the people or teams in such a way that the conditions established by the legislation or collective agreement are respected and at all times the necessary capacity is available. According to how conditions are defined it may be there is no solution, but it may also be that there are many. Once conditions and criteria for evaluation of solutions are established, the aim is to determine that the problem has no solution, if this is the case, or, if there is, to find one that is optimum (or if no more, satisfactory) in accordance with the criterion or criteria adopted.

As the system has to function every hour of the day and every day of the week (or only every hour of the day or only every day of the week), a rostering system has to be established, in which shifts can be fixed or rotating. Shift work is quite widely used and for that reason the expression forms part of everyday language (it is said, for example, that a company works three shifts).

In the fixed shifts system (taking the case of three shifts per day) there is a group of people who always work in the morning, another group who always work in the afternoon, and another that always work at night. People can change shift, but only when there are vacancies and in certain conditions, because in these systems often the step from one shift to another is considered as promotion.

In the rotating shifts system (which in fact is the system that corresponds to the concept of shift working in Spanish labour legislation), people change, cyclically, from working in the morning to working, for example, in the afternoon, and afterwards, at night. This can also be described as alternating work timetables .

On the one hand, drawbacks for the company and for people as workers:

But whether the system adopted is fixed shifts or rotating shifts, there are people (all of them, in the case of rotating shifts) that have to do night or weekend work and that originates a set of drawbacks.

- Increase in the costs per hour worked. The quantity of this increase depends on the country and business sector, but it is quite generalised that nighttime work or rotating shifts are associated with a salary supplement.
- Greater complexity in personnel management, especially in OWT.
- Reduction in productivity and quality of service during nocturnal hours.
- Greater gravity of accidents that take place at night (although they are less in number).
- Increase in propensity for accidents when people work alternating timetables.

Moreover, there are drawbacks for people, in relation to their individual, family and social activities. The nature and importance of these drawbacks depend a great deal on the individual; there are people who prefer working at night or having days off mid week, because that way they can better enjoy their pastimes (for example because they avoid the typical weekend crushes typical of some routes and places). Furthermore, it is difficult to evaluate the impact of night-time working or alternating timetables, because it can only be studied in people who work effectively under these conditions, which excludes those who refuse to do it in the first place or have done it and were unable to stand it.

Even so, different studies have made it clear that, for the majority of people, night-time working and alternating timetables have the negative – and not at all unexpected – consequences that are indicated below (Santibáñez and Sánchez, 2007). These include physical or health problems, related with sleep (difficulty in sleeping outside night-time hours, due to light or sound; difficulty in adapting to the changes when alternating timetables; falling asleep at work) or with eating (due to a lack of adaptation to timetables and changes in the type of food, linked with timetables). And also family and social problems, with partners, children, friends and social activities in general, due to the disparity of timetables with those of other people.

Overall it can cause tiredness, agitation and irritability.

## **3.4. Modalities and variants**

The complete definition of a shift-working system involves the adopting of numerous decisions.

### **3.4.1. Fixed occupation or shift rotation**

One of the most important, as can be deduced from what has been said in the previous section, is the choice between fixed occupation or shift rotation. Generally, the rotating shifts system is very poorly accepted by staff, therefore its introduction causes many problems, except in the case of a new company. In the fixed occupation system, working conditions are not the same for everyone. In rotating shifts, they are; there are no inequalities, but it could be said that everyone has equally poor job conditions.

Fixed occupation shift systems are easier to design and to interpret than rotating shift systems. However, finding a good solution is not usually trivial.

Let's suppose that it is necessary to cover, 7 days per week, a set of 2 identical work positions, which have to function during 8 hours per day with 3 people (A, B and C) of which A and B have a timetable with an average of 40 hours per week (equivalent to having a proportion of working days over the total equal to 5/7), with 1 complete weekend free in every 2 and the condition that every day one, at least, of the 2 people A or B has to be present. The third person, C, will have a working week of 32 hours, with a proportion of working days of 4/7 and will have to work all days of every weekend.

The following table defines one of the solutions that respects these conditions, with a cycle every 2 weeks (each column corresponds to a day of the week)<sup>6</sup>

Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	A	A	A	A	-	-	A	A	A	-	-	A	A
B	B	B	-	-	B	B	B	B	B	B	B	-	-
-	-	-	C	C	C	C	-	-	-	C	C	C	C

If it is considered inconvenient for A and B to have stretches of 7 successive working days, the solution can be modified as reflected in the following table:

Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	A	A	A	-	-	-	A	A	A	A	-	A	A
-	B	B	B	B	B	B	-	B	B	B	B	-	-
C	-	-	C	C	C	C	C	-	-	-	C	C	C

In which A and B work a maximum of 6 consecutive days and have a stretch of 3 consecutive days off, but corresponding to different days over the length of the cycle (A, from Friday to Sunday; B, from Saturday to Monday). Now, if we consider a 4-week cycle we can re-establish the equivalence between the timetables of A and those of B:

Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	A	A	A	-	-	-	A	A	A	A	-	A	A
-	B	B	B	B	B	B	-	B	B	B	B	-	-
C	-	-	-	C	C	C	C	-	-	-	C	C	C

Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
-	A	A	A	A	A	A	-	A	A	A	A	-	-
B	B	B	B	-	-	-	B	B	B	B	-	B	B
C	-	-	-	C	C	C	C	-	-	-	C	C	C

In this solution both A and B have, in each cycle of 4 weeks, 2 complete weekends (one of which is three days long). The conditions of C cannot be considered better or worse than in the preceding solutions.

A rotating shifts system involves a certain number of teams (for example, four: A, B, C, D), each of which has, every week, a different working timetable, in

<sup>6</sup> We use the abbreviations Mo, Tu, We, Th, Fr, Sa, Su to refer to the 7 days of the week, from Monday to Sunday.

<sup>7</sup> We will use the abbreviations M, A, N and H to refer to morning, afternoon, night and holiday, respectively.

such a way that the timetable of team A, in a given week, is the same that team B had the previous week. If we take any week as a reference, when a number of weeks equal to the number of teams has passed (four in our example), one cycle will have been completed and a new one started again.

Having defined the timetables of each shift (for example: from 0600 to 1400 hours, from 1400 to 2200 hours and from 2200 to 0600 hours in the morning of the following day, which we can designate as morning, afternoon and night, respectively), the rotating system can be described, in a very compact way, through a table with a number of rows equal to the teams involved in the rotation (also equal to the number of weeks that form the cycle) and seven columns (corresponding to each one of the days of the week). The following table corresponds to a case with 4 teams (and, therefore, with a cycle of 4 weeks) in which there must be a team present throughout the week, with the exception of Sunday morning, in which an external team carries out maintenance of the installations:

	Mo	Tu	We	Th	Fr	Sa	Su
1	M	M	M	M	M	M	F
2	F	T	T	T	T	T	T
3	T	F	F	F	F	N	N
4	N	N	N	N	N	F	F

Team A will have, in weeks 1, 2, 3 and 4 of the cycle, the working timetable described in rows 1, 2, 3 and 4 of the table, respectively. Team B, the same weeks, the timetables corresponding to rows 2, 3, 4 and 1. The same goes for C and D. Each column in the table corresponds to a day of the week and shows how many teams there will be that day in each of the parts into which any given day is considered to be divided (morning, afternoon and night, in this example). In the example, from Monday to Saturday, both inclusive, there will be a team in the morning, one in the afternoon and one at night (and one that will be having the day off) and, therefore, there will be activity 24 hours per day; on Sunday, there will be one team in the afternoon and one at night (and two having the day off) and, therefore, there will be no production activity in the morning. Every 4 weeks all the teams will have had a total of 8 days off, which includes a complete weekend (Saturday and Sunday), a block of two consecutive days (Sunday and Monday) and one of 4 (from Tuesday to Friday, both inclusive).

### 3.4.2. Number, duration and start and finish of shifts

As seen in the previous example, the number of shifts has to be defined (2, 3 or more shifts per day?), and also the duration (equal or different durations?) and the starting and finishing times of each shift.

Let's compare, for example, a three-shift system (morning, afternoon, night: M, A, N) with a two-shift one (day, night: D, N), to cover 24 hours per day, 7 days per week:

Mo	Tu	We	Th	Fr	Sa	Su
F	M	M	M	M	M	M
M	F	F	T	T	T	T
T	T	T	F	F	N	N
N	N	N	N	N	F	F

2 shifts per day

Mo	Tu	We	Th	Fr	Sa	Su
D	D	D	D	F	F	F
F	F	F	F	N	N	N
N	F	F	F	D	D	D
F	N	N	N	F	F	F

3 shifts per day

In the two daily shifts system, there are, at most, 4 consecutive working days, 2 complete weekends out of every 4, and 7 consecutive days holiday every 4 weeks. In relation with the 3-shift system, the conditions for sleeping and family and social life are better; the management is simplified because there is only one change of shift per day and the number of commutes from home to work and vice-versa are reduced by a third (from 21 to 14 every 28 days).

The 2-shift system increases staff fatigue at the end of the working day and, therefore, the possibility of errors and accidents. In some types of activity, therefore, it may be unfeasible. Furthermore, the fact that every 4 weeks there are 7 consecutive days holiday, in other words, quite a long period of absence from work, means that a certain amount of readjustment is required by staff which may lead to important losses in productivity.

As for the duration of the shifts, it can be the same for everyone or not. For example, the night shift can be shorter than the others.

The definition of the starting and finishing times for shifts is very important because eating and sleeping timetables depend upon them, as do the possibility of having a social life and making use of collective transport.

Moreover, it must be taken into account that in many cases there must be an overlapping, in other words, that the start of one shift must be more or less prior to the end of the previous shift. This may be due to the fact that staff cannot be doing the production activity at the very moment that they enter the factory or office (for example, because they have to get changed, or because, as happens in mines, covering the distance between the company entrance and the place where work takes place requires an appreciable amount of time) or that they have to interrupt production activity a certain time before leaving

the workplace. Or also the fact that the staff of one shift has to pass information on to the incoming shift, even though, in this case, the time that the shifts need to overlap can be reduced and even eliminated with electronic information storage systems or with forms.

### 3.4.3. Juxtaposing of shift systems

There are systems in which all the staff are allocated to equivalent shifts, in other words, to shifts with the same working hours and corresponding to the same days of the week. There are others in which a part of the staff work shifts and the other part does not (in a factory, it is normal for the factory floor to work shifts and the commercial and administration staff not to; the case can also arise where there are sections of a workshop that work shifts and others that do not, due to the different productivity of the different groups – one section may produce in one shift the components that the others need to do the production of three shifts).

There are also systems with two (or, more rarely, more than two) juxtaposed shift systems. One of the possible causes is the aforementioned difference of productivity between sections (one section may work two 8-hours shifts and the other section work three). Another, is the extension of the time that the system functions. For example, when changing from 24 hours per day Monday to Friday operation, with staff in 3 rotating shifts, to a 24 hours per day 7 days a week operation. In a case like this, the difficulty of getting veteran company staff to change from a system with all the weekends off to another in which they will only have a weekend off every so often. A solution that has been adopted often in practice is that of maintaining the previous system for the veteran staff and hiring new staff to cover the weekends in two shifts:

	Mo	Tu	We	Th	Fr	Sa	Su
Veteran staff	M	M	M	M	M	F	F
	T	T	T	T	T	F	F
	N	N	N	N	N	F	F
New staff	F	F	F	F	F	D	D
	F	F	F	F	F	N	N

### 3.5. Obtaining solutions

The problem to be resolved is defined once it is known how the day has been divided into parts (such as morning, afternoon, night: M, A, N), how many teams are necessary each of the parts of each day of the week, the conditions that solutions have to respect and criteria for evaluating them.

The conditions can be fixed by the laws, which are different according to the different countries and times (maximum number of consecutive working days, right to enjoy two consecutive days of holiday with a certain frequency, etc.),

for collective bargaining or company decision. Some conditions are considered rigid, in other words, their fulfilment is compulsory: if a person works one day on the night shift, they cannot work the day shift the following day. Others, are considered to be more or less flexible. For example, it is desirable that if a series of days with work in the mornings are programmed, for example, another series of working days (in the afternoon or at night) cannot be started without intercalating between the two a certain number of days off. However, it may be admissible that, once in the cycle, after one day of work in the morning, there is another of work at night.

A solution can be represented, if we put the rows of the table one after another, with a sequence formed by a number of symbols equal to 7 times the number of weeks that form a cycle. But, in accordance with what was indicated in the preceding paragraph, not all combinations of symbols are valid. Let's suppose that after a day of work in the morning (or afternoon or at night) it can only be followed by another day of work in the morning (or afternoon or night, respectively) or by a day off, that there is a maximum number of consecutive working days and that the number of days off, after a series of days of work, depends on the number of days that comprise this series. Thus, a reasonable way of constructing a rotating system is to try to form the total sequence based on elements (we could call them parts) corresponding to a certain number of consecutive days and that comprise some first working days (in the morning, evening or at night, in the case of 3 shifts per day) followed by a sufficient number of holidays (such as: MMMMMHH, AAAAHHH, NNNNNHHH,...). In this way, due to the way the solution is obtained, it is ensured that the complete sequence fulfils some of the most important conditions and it is evident that it is much easier to construct it thus than to do it symbol by symbol.

Staff normally value the proportion of complete weekends off within the cycle, the maximum number of consecutive days off or the fact that there is, within the cycle, some series of days off that is quite long.

From the company viewpoint, in the first instance, all the solutions in which the number of teams present in each one of the parts of each day of the week is exactly the desired number, are equivalent. However, for the staff they can be more or less satisfactory and the company logically has to prefer those that are more pleasing for their workers.

But, in many cases, the conditions that the solutions have to respect are numerous and it is already quite difficult to find solution that fulfils them (what is technically known as a [feasible solution](#)). Thus, the problem is very similar to that of the popular *sudoku*: putting symbols into boxes, in accordance with certain specified conditions. In any event, for many typical situations solutions have been worked out and published (Carcelén, 2000) which are not necessarily always the only feasible ones. For example, to cover with a team 7 days per week and 24 hours per day:

Mo	Tu	We	Th	Fr	Sa	Su
M	M	M	M	M	M	M
F	F	T	T	T	T	T
T	T	F	N	N	N	N
N	N	N	F	F	F	F

The problem can be formulated mathematically and an attempt to resolve it made using a commercial programming application. However, these tasks are not trivial; they require specialist staff and suitable computer instruments.

When the issue is solely to find a **feasible solution** rather than an optimum one, manual resolution can be attempted. It is even possible to try and generate different solutions and evaluate them. For example, let's suppose that the aim is to establish a system of rotating shifts, with 5 teams, so that there is a team working 24 hours per day, 7 days per week. The average of weekly working hours for each team will be equal, therefore, at  $24 \cdot 7/5 = 33.6$ . We can find solutions like the two indicated below (Laporte, 1999):

Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
F	F	F	M	M	M	M	T	T	F	F	F	M	M
F	F	T	T	T	F	F	M	M	M	M	F	F	F
M	M	M	F	F	T	T	F	F	N	N	N	N	N
T	T	F	F	N	N	N	F	F	T	T	T	F	F
N	N	N	N	F	F	F	N	N	F	F	M	T	T

In both solutions each team works, in one cycle, 7 days in the morning, 7 days in the afternoon and 7 days at night and has 14 days holiday. The two include two complete weekends off, one of which forms part of a run of 6 days off in the first solution and 5 in the second. The main drawback in the first solution is that it includes 7 consecutive days of working nights, but the working days working in one part of the day are separate from the working days in another part of the day by two or three days holiday; in contrast, in the second solution there are only 5 consecutive days of night-time working, but there are 6 consecutive days of morning shift working and the 7th day of morning shift working immediately precedes, without any day off in between, followed by 4 days of afternoon shifts. The type of rotation is different in the two solutions: M-A-M-A-N (the more traditional one) in the first and A-M-N-A-N-M in the second.

Let's finish with a more difficult case (Laporte, 1999), which illustrates how a relaxing of conditions allows, sometimes, a solution to be found to problems that otherwise would not have one. The issue is to cover a service 24 hours per day, 7 days a week, with 5 teams, so that there is one team present all 168 hours per week, except on Saturdays when there has to be 2, as indicated in the following table:

	Mo	Tu	We	Th	Fr	Sa	Su
M	1	1	1	1	1	2	1
T	1	1	1	1	1	1	1
N	1	1	1	1	1	1	1
F	2	2	2	2	2	1	2

In fact this table is almost the same as the one that would correspond to the previous example (in which we would have only ones in the first three rows and twos in the fourth). From this observation can be deduced the idea of obtaining a solution based on one of those in the previous example.

If we start off with the first of those shown previously, we can obtain, by relaxing the conditions, the following:

	Mo	Tu	We	Th	Fr	Sa	Su
F	F	F	F	M	M	M	M
F	F	F	T	T	T	F	F
M	M	M	M	F	F	T <sup>+</sup>	T
T	T	T	F	F	N <sup>+</sup>	N	N
N	N	N	N	N	F	F	F

Where N<sup>+</sup> and A<sup>+</sup> indicate, respectively, that the timetable of the night shift on Friday is lengthened 4 hours corresponding to Saturday morning and that the Saturday afternoon shift begins 4 hours earlier. We have relaxed, therefore, the condition that the working day must always have the same number of hours (at least for all the days that have the same letter).

In the cited article (Laporte, 1999), which has a very significant title (“The art and science of designing rotating shifts”), it is revealed that frequently the conditions that companies consider indispensable for the solution to meet are incompatible (in other words, that there is not solution that satisfies all of them) and that, in contrast, it is not difficult to realise that the relaxation of one of them may lead to the existence of [feasible solutions](#). Therefore, even now, finding solutions for a shifts problem requires a combination, in variable proportions, of science, and let’s put it this way, of art.

Very often, however, the solutions are numerous and at the same time the issue is to discover the criteria to evaluate them in order to find one that is optimum of quality close to that of optimum solutions. In this situation it will be necessary to make use of [mathematical programming](#) or of [artificial intelligence](#) techniques.

# 4. PLANNING OF WORKING TIME

This chapter deals with the first of the problems that we have called the *meso* level of OWT: **planning**. In the first section it presents the problem of **planning** working time; in the second, the conditions that the solution (the plan) has to satisfy are discussed; in the third, the need for and advantages in carrying out the **planning** are argued; in the fourth, evaluation criteria for the solutions (the plans) are discussed; next the tools are introduced for **planning** working time with overtime, with annual hours working and with working time accounts; and, finally, the elements that must be taken into account in the introduction and management of an OWT system with passive flexibility are described.

## 4.1. General description

**Planning** working time consists of determining the number of hours that each person has to work in each period (day, week, etc.) of a given temporal horizon (for example, usually one year). Normally the plan has to satisfy a series of more or less complex conditions and it is desired that it is optimum (or at least satisfactory in relation with a certain criterion or set of criteria).

This problem can be more or less complicated according to the particular characteristics that are given: type of OWT system (it is not the same planning when there is only the possibility of doing overtime as when there is an annual hours working system already running); conditions that the plan has to satisfy in relation with the distribution of working time over the course of time; type of production process (process that requires the simultaneous intervention of a set of workers – all have to do the same working day – or each person can carry out the complete process - each person can do working days different to those of the others, etc.); type of product (whether it can be warehoused – indefinitely or for a certain time – or not); multiskilling<sup>8</sup> of staff (where there is no multiskilling, the time of each category of workers can be planned separately, whereas when there is multiskilling, all staff have to be considered globally and the complexity of the problem is greater); type of relationship with the demand (if it can be served with a delay or not); type of capacity necessary (profile and whether it is considered that it is known or subject to random-

<sup>8</sup> See section 6.2.1 for more details on the concept of multiskilling

ness); consideration of holidays (whether these have to be determined too or are already pre-set); other decisions that have to be considered (production levels, hiring and firing, hiring of temporary staff, etc.); evaluation criterion or criteria for the plan; etc. Thus, even though a single type of technique can be recommended to resolve this problem, it is evident that the specific procedure of **planning** has to be adapted to each particular case.

Evidently, in any case the demand or needs of production or capacity constitutes an indispensable piece of data for carrying out **planning**. For this reason, it is best if a forecast that is as reliable as possible can be determined. As regards **planning** needs greater than those necessary to cover demand will have to be considered because, firstly, the capacity really available will be lower than that planned (due to people leaving and absenteeism) and, secondly, in the case of services, long queues can form due to the irregularities that occur both in the arrival of clients (because this is random, many people may arrive in a very short space of time) and in the service time (also random, and it can be very short or very long according who serves and who is being served).

The plan produced is updated every certain number of periods (for example, each month) to take into account changes in the forecast of the capacity necessary, as well as the differences between planned working times and those really worked. For updates it must be taken into account that, generally, there will be a term for notifying the plan and a term of rigidity, as has already been explained in section 2.3.

## **4.2. Conditions that the plan must satisfy**

**Planning** of working time has to basically satisfy two sets of conditions. The first is that which establishes the relationship between planned capacity (which depends on the number of hours of work done by each person) and necessary capacity; in the case of goods, it also includes the relationship between production, stocks and demand. In the second group there are the conditions that affect working time, both the work hours done in each period and their distribution along the temporal planning horizon.

The second group is subject to the type of OWT system that is implemented at the employing organisation. In the case of a rigid timetable with overtime hours, it will include only the limits per period and along the horizon of the overtime hours, as well as possible compensation with rest. In the case of annual hours working, or working time accounts, the number of conditions that affect the distribution of working time, as well as their complexity, increase considerably.

## **4.3. Need and advantages of carrying out working time planning**

When a system of flexible organisation of working time is implemented, **planning** becomes a necessity, but at the same time it is desirable because of the benefits that it offers for both the company and its employees.

The fulfilment of conditions such as those explained in chapter 2 (limits of overtime hours, that the number of heavy weeks is no greater than a certain number, that the average of hours worked in each group of 12 consecutive weeks is not greater than 44 hours/week, that the balance of the hours account remains within the pre-established limits, etc.) are very difficult to guarantee without prior [planning](#), at least without causing severe damage on the level of company activity. The case could arise where the more hours needed, few need to be planned in order to meet the conditions, or that a point is reached in which there are some people who have already done their annual work hours before the year finishes and temporary staff have to be hired to substitute them. Planning working time with a sufficient temporal horizon not only guarantees fulfilment of the conditions, but furthermore it guarantees that the resources (in this case, capacity linked to human resources) are used in the best way possible, making efficient use of them.

But planning working time is not only good for the company, but for the people working for it too. Firstly, because they can have a reliable calendar a certain amount of time beforehand and, secondly, the [planning](#) procedure can incorporate, as far as possible, their preferences for certain working hours. Both aspects contribute to better reconciliation of work, family and private life.

## 4.4. Evaluation criteria for solutions

The solution adopted will depend to a great extent on the evaluation or optimisation criteria considered and which guide the [planning](#). When an optimisation procedure is used, the plan obtained is that which fulfils the conditions and, at the same time, is optimum in relation with the criterion or criteria considered.

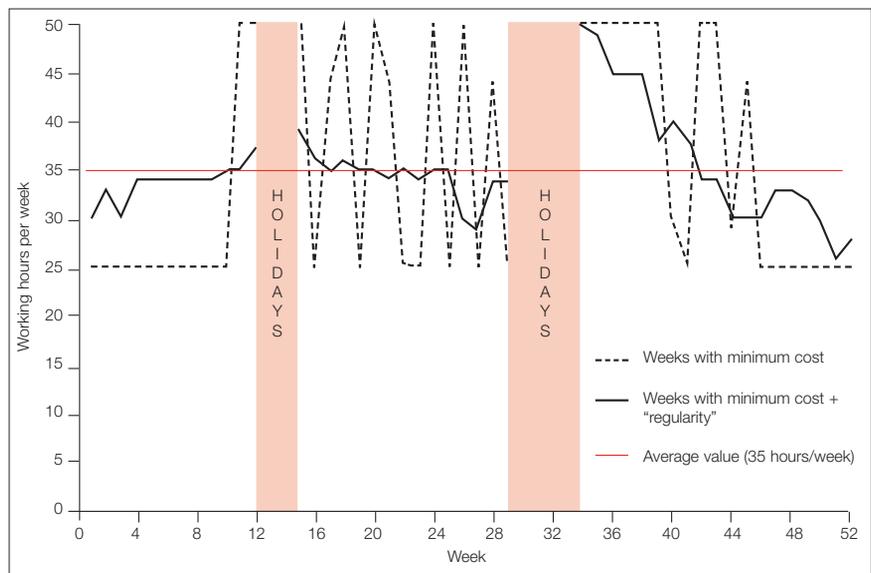
Among the diverse criteria that can be considered, there are some that are important for the company and some that are important for the company's workers. For the company, it is evident that the main criteria are, on the one hand, economic (that means maximising the financial margin or difference between income and the costs of overtime, temporary staff, lost sales, stocks, etc.) and on the other, the level of service (satisfy the demand in every period or minimise the delays and queues, avoid the use of temporary staff when that may compromise quality or allocate tasks to those categories that best carry them out). Evidently the company also has to be concerned with the satisfaction of the people working for it, as that will lead to increases in productivity and quality as well as in a reduction in absenteeism and the rotation of staff.

The criteria for evaluating the plan that are important for the workers are basically related with the allocating of working hours and the distribution of working time. On the one hand, there may be people that, in certain periods, have a preference for certain types of working day (short or long), in order to make their work compatible with some other activity. On the other, for the majority of people it is preferable that the distribution of working hours over the course of time be as regular as possible, in order to minimise the drawbacks that the flexible systems present. Finally, when there is the possibility of working overtime, it is best if distribution is as fair as possible, in order to avoid resentment because of inequality.

Obviously obtaining a plan that is optimum for all the criteria may turn out to be impossible, for the simple fact that there are some that are incompatible

with each other (for example, the more regular the distribution of working hours, the more difficult it is to adapt to a necessary variable capacity, and therefore, the higher the costs). For this reason, criteria must be prioritised in order to consider them in a hierarchical form or alternatively award a weight to each and optimise a function that includes them all, but taking into account the relative importance (weight) of each of them; these aspects form part of what is known as [multicriteria optimisation](#).

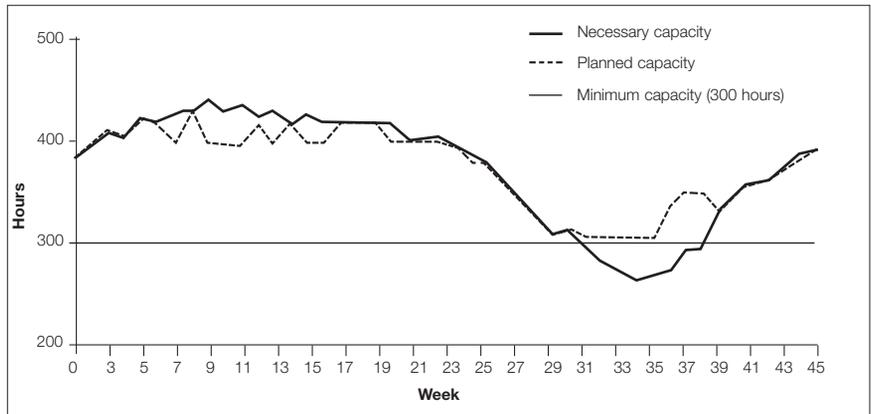
To illustrate this concept a graphic is included (Figure 1) which shows the number of hours work, for a given person, in each of the weeks of the year. The dotted line corresponds to the solution obtained considering only the minimisation of costs criterion, and it can be seen how the distribution of this person's working weeks is quite irregular. The continuous line corresponds to the solution obtained when the criterion is to obtain the most regular distribution possible of working time, but without detriment to the minimum cost (this is achieved adding a condition that the cost of the second solution is the same as obtained when cost is the only optimisation criterion). As can be appreciated, the distribution of working weeks in this second solution is notably more regular than in the previous case. This happens because in minimising the cost, there could be many (thousands even) of equivalent solutions in relation with this criterion, but very unequal as regards other criteria (such as that of regularity). What happens in determining the second plan is to choose, among all the solutions of minimum cost, that which optimises the criterion of regularity.



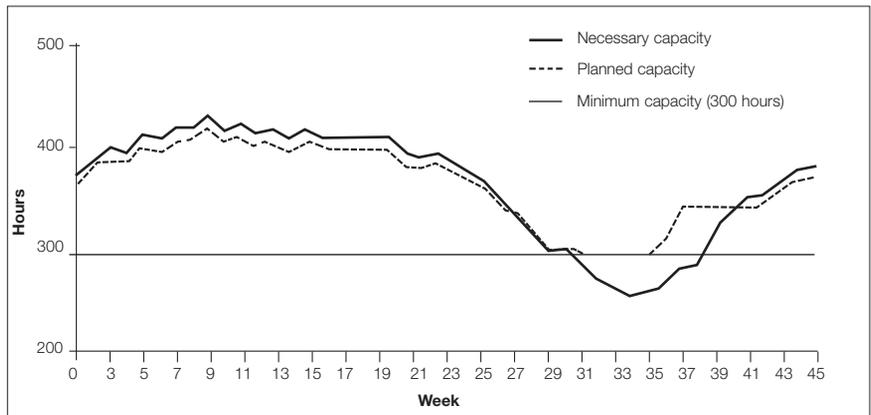
**Figure 2.** Obtained vs necessary capacity with the objective “minimum cost” (Corominas et al., 2004)

Another example of hierarchical consideration of diverse criteria, in planning working time with annual hours working, can be seen in the following figures.

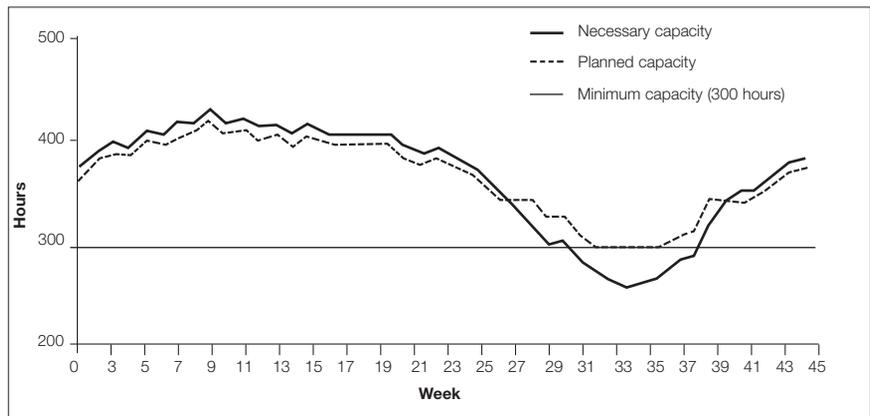
The first solution (Figure 2) is that obtained when the objective consists of minimizing the cost of temporary personal to cover needs (the shortfall in capacity). In the second (Figure 3), the shortfall in capacity is distributed in a regular way; it is preferable to have a small deficit in several weeks than to have them concentrated into very few weeks since, in this way, the service level is better and demand can be catered for either with a small extra effort by the workforce or alternatively by hiring one more person. Finally the third solution (Figure 4) shows the capacity obtained when adding the criterion of distributing the capacity surplus in a regular way. In all cases the optimum value of the preceding criterion or criteria is maintained (minimum cost in the second case and minimum cost and regularity of capacity shortfalls in the third).



**Figure 2.** Obtained vs necessary capacity with the objective “minimum cost” (Corominas et al., 2004)



**Figure 3.** Obtained vs necessary capacity with the objective “minimum cost” + regularity of capacity shortfall” (Corominas et al., 2004)



**Figure 4.** Obtained vs necessary capacity with the objective “minimum cost + regularity of shortfall and surplus capacity” (Corominas et al., 2004)

Tot i que pugui semblar evident, cal remarcar que és molt difícil (o impossible) obtenir aquestes solucions en un temps raonable, sense instruments de [planificació](#) dissenyats *ad hoc*, com els que es presenten a la secció següent.

## 4.5. Tools for planning working time with overtime, with annual hours working and with working time accounts.

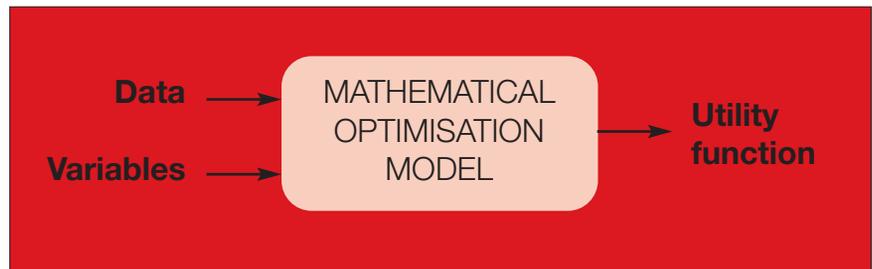
The use of tools based on [mathematical models](#) is, according to the experience of the authors of this publication, one of the most appropriate ways of resolving the problem of [planning](#) working time. [Mathematical models](#) allow the fulfilment of conditions to be taken into account while optimising the evaluation function of the solution under consideration.

[Mixed-integer linear programming](#) or MILP (a kind of [mathematical programming](#)) is a technique that has allowed us to make models of and resolve working time [planning](#) problems with overtime hours, annual hours working and working time accounts in a very effective and efficient way, reaching an optimum (or nearly optimum) solution in reasonable time.

It must be said that, until a few years ago, the machinery (computers) and programmes available allowed only MILP or very simple models with small dimension to be resolved and, therefore, it would have been unthinkable to tackle the types of problems of working time [planning](#) that are described in this chapter. However, technological advances in recent years mean that nowadays, using programmes of commercial use, we can resolve problems of real dimension and complexity in very satisfactory times.

A MILP is a [mathematical model](#) for optimisation that can be considered like a box with inputs and outputs (see Figure 5). The inputs correspond to: (1) the data of the problem (known information that cannot be modified) and (2) with the variables or information that can be controlled or decided (within certain

limits). The output of the model is the utility function that it is aimed to optimise (minimise or maximise) and the depends on the value that the variables take. The objective of a **mathematical model** for optimisation is that of determining what value each variable has to take in such a way that the utility function is optimum.



**Figura 5.** Mathematical model

A **mathematical programme** makes a model of the real programme using mathematical functions. The programme consists of three differentiated parts:

- Variables: all those unknowns to which one wants to give a value.
- Restrictions: equations which make a model of the conditions that must be met by every **feasible solution**.
- Target function: this is the function that one wants to optimise (for example, minimise costs, maximise regularity of working hours, etc.).

Below follows a simple example for a a problem of **planning** working time with overtime hours only compensable monetarily.

The idea is to determine the number of extra hours to be worked by the people in a team that works on an assembly line, in each of the working weeks of one year. The information available is as follows:

- There is a forecast for the demand of the product to be manufactured (which is unique) in each of the 48 working weeks of the year (we will note it with  $d_t$ ,  $t=1, \dots, 48$ ), which is relatively stable with moderate peaks at certain times. It is supposed that only with the help of overtime hours can the forecast demand be tackled.
- All people work the same timetable.
- The normal working week is 38.5 hours/week.
- The maximum number of overtime hours is 10 weekly and 80 annually.
- To produce one unit on the line requires 0.02 hours (equivalent to 50 units/hour).
- The cost of an extra hour is 400 €
- The cost of warehousing a unit of product during a week is 0.5 €. The initial stock is zero.
- It is wished to satisfy demand by minimising total cost (extra hours + maintenance of the units in stock).

The [mathematical programme](#) that it is necessary to consider is the following:

- Variables:
  - Quantity to be produced in each one of the weeks: we note it with  $p_t$  ( $t=1, \dots, 48$ )
  - Number of units in stock at the end of each of the weeks; we note it with  $s_t$  ( $t=1, \dots, 48$ )
  - Number of extra hours to worked by the team in each of the weeks: we note it with  $he_t$  ( $t=1, \dots, 48$ )
- Restrictions (conditions to be satisfied):
  - Maximum number of extra hours per year:  $he_1+he_2+he_3+\dots+he_{48} \leq 80$   
 $he_1+he_2+he_3+\dots+he_{48} \leq 80$
  - Maximum number of extra hours per week:  $he_t \leq 10 \quad t=1, \dots, 48$
  - Number of hours necessary to produce cannot be greater than those available:  $0,02 \cdot p_t \leq 38,5+he_t \quad t=1, \dots, 48$
  - The stock at the end of the previous week plus the production of the current week is equal to the demand plus stock at the end of the current week:  $s_{t-1}+p_t = d_t+s_t \quad t=1, \dots, 48$  (remember that  $s_0=0$ )
- Target function:  
[MIN]  $\{400 \cdot (he_1+he_2+he_3+\dots+he_{48})+0,5 \cdot (s_1+s_2+s_3+\dots+s_{48})\}$

Once the [mathematical programme](#) has been formulated, it can be resolved (e.g., determine the value of the variables and of the target function) through programmes of commercial use. The solution tells us how much needs to be produced and how many extra hours have to be worked, in each week.

For the [planning](#) of working time with annual hours working, with and without extra hours, numerous models can be found (which correspond with various specific cases) in Lusa (2005); for the case of working time accounts, one could consult, for example, Corominas et al. (2006 and 2008).

## 4.6. Introduction and management of an OWT system with passive flexibility.

The introduction of an OWT system with passive flexibility has two aspects: firstly, the part of dialogue, negotiation and representation of staff and, secondly, the technical part, which has to include the design and introduction of computer systems for the management and control of working time.

The negotiation has to give rise to the parameters of the flexible system of working time organisation: annual number of hours, limits of daily and/or weekly hours, type of working days that can be used, conditions that the distribution of working time has to satisfy, limits for the balance of the working hours account, compensation of overtime hours, etc. Furthermore, in these negotiations it is necessary to establish the compensation that the workers will receive in exchange for the flexibility that they provide through the non-homogeneous distribution of their working time which may create an added difficulty for them with regards to reconciling working life, family life and personal life

(even though, as we have said, the use of suitable procedures allows these drawbacks to be minimised as far as possible): usually, less hours of work, more holidays or more pay.

In this sense, the same **mathematical models** that serve to carry out the **planning** of working time can be used to generate objective and rational information on which to base the negotiations. For example, **planning** instruments can be used to generate different plans that correspond with different system configurations (scenarios) always with the objective of maximizing the financial margin. The value of the target function obtained by the different scenarios allows agreement with the staff representation both regarding compensation and the system's characteristics, so that the result turns out to be satisfactory for both parties.

By way of example, the value has been included in Table 1 of the financial margin resulting from applying a model of working time **planning** with annual hours working for different scenarios; each of them is characterised by the number of hours per annum (1,840, 1,748 or 1,610 hours/year) and by the limits of the working week, which can be more or less flexible ([40,40] – rigid timetable, [40,50] – rigid timetable with overtime hours, [30,45] or [25,50]). In all cases, conditions have been added in order to avoid overloading workers at times of heavy demand. In the table,  $K$  indicates the financial margin obtained in a scenario without flexibility: 1,840 h/year of work and a fixed working week of 40 hours.

There exist, at least, two ways of achieving an increase in the financial margin through the introduction of annual hours working: (1) increasing flexibility and reducing total working time as compensation (for example, reducing to 1,748 h/year in exchange for being able to plan working weeks of between 35 and 45 h/week, the profit increases to  $1.45 \cdot K$ ) and (2) increasing flexibility, without reducing working time, and offering monetary compensation to staff (for example, establishing lower and upper limits for the working week of 25 and 50 hours, respectively, and, in exchange, offering a part of the 46% increase in the financial margin that the company can expect to obtain thanks to staff flexibility). Evidently, the possibility also exists of reaching a mixed solution between both (for example reducing the annual number of hours to 1,748, with working weeks of between 25 and 50 hours, and offering a part of the increase of the 53% that would be obtained in the financial margin thanks to this flexibility).

The aspect that it is important to highlight is that, thanks to **planning** tools, it can be based on rational and objective data, and not on simple intuition.

		working week limits (hours/week)			
		[40, 40]*	[40, 50]**	[30, 45]	[25, 50]
hours/year	1.840	K	1,016·K	1,46·K	1,55·K
	1.748			1,45·K	1,53·K
	1.610			1,021·K	1,083·K

**Table 1.** Example of table for negotiation of annual hours working (Lusa, 2005)

\* Rigid timetable

\*\* Rigid timetable with overtime

The other aspect of the introduction of a flexible OWT system is the design and development of instruments for management and control of working time. Fortunately the MILP models discussed in the previous section can be resolved with commercial programmes that, at the same time, can be integrated into the company's computer system, in such a way that the necessary data exchange takes place. Evidently the computer applications developed can be more simple or more complex, according to the type of company (type and size of workforce, type of production process, collective bargaining conditions, etc.).

Finally, it will be necessary to foresee a system for the control of working time, suitably integrated with the application just mentioned.

# 5. PROGRAMMING OF WORKING TIME

**Programming** of working time consists of allocating work timetables to staff. It is a traditional problem in OWT that has evolved in recent years by admitting that timetables cannot coincide with each other, both those of staff in general and those of each individual in particular, during a more or less long temporal horizon. This fact has caused the increase in the complexity of the process of allocation. Furthermore, the number of employer organisations that provide services outside of normal working hours has increased significantly, which makes the diversity of timetables possible increase.

In employer organisations with variable necessary capacity throughout the day, the week and/or the month, it is especially appropriate to carry out **programming** of timetables that allows the system's capacity to be adapted to needs. In this context, the challenge of OWT is to programme staff timetables to adapt as well as possible to the necessary capacity, maintaining the salary cost under control, respecting all the regulations applicable and (for example the length of timetables and break periods) and considering staff satisfaction.

In the rest of the chapter a classification is presented of the cases of **programming** working time, the description in details of one of the cases considered, that of the problems of individualised allocation of pre-established patterns, of which evaluation criteria of solutions will be indicated and, finally, the tools used in **programming** working time.

## 5.1. Cases of programming working time

Corominas and Crespán (1993) propose a classification of the problem of **programming** working time. They use the concept of *pattern*, defined in the following way: in a time interval called *cycle*, divided into *periods*, the name *pattern* or *work pattern* is given to a vector of binary components (as many as periods making up the cycle) that indicate, for each period making up the cycle, the absence or presence of staff.

The **programming** of working time consists of defining the admissible patterns and determining who or how many people from each category have to be allocated to each pattern. The patterns are not the same for all staff and, for a single person, can change on a more or less long temporal horizon. Finally, the

work timetable allocated will be a specific pattern (in fact, in this chapter the expressions “list of patterns” and “list of timetables” will be used indistinctly).

The classification of problems with **programming** working time proposed by Corominas and Crespán (1993) is as follows:

- **Problems of workforce size with pre-set patterns.** In a generic way, the necessary capacity is available, in general variable over time, and a pre-set list of work patterns is established; each pattern has an associated cost and the aim is to determine how many people need to be allocated to each work pattern in order to satisfy the necessary capacity at minimum cost.

- **Problems of individualised allocation of pre-set patterns.** The number of people to whom a timetable must be allocated is known, and the aim is to determine which specific people (or to which categories) each pattern is assigned from between those of a list of pre-established patterns. The complexity increases if staff preferences for certain patterns is taken into account.

- **Problems of assigning patterns with implicitly defined patterns.** These arise when the list of admissible patterns is too long to make it explicit and, thus, conditions are defined that the patterns must meet to be able to assign them to a person or a certain category. It is especially suitable in environments related with transport, where the duration of travel conditions the timetable of the staff involved.

- **Problems of determining patterns that meet certain conditions.** These correspond to the case of organising working time in a continuously functioning production system with rotating shifts, which is dealt with specifically in chapter 3.

Below the case of problems in individualised assigning of pre-set patterns is detailed, describing the starting data, the evaluation criteria for the solution and the calculation tools.

## 5.2. Problems of individualised allocation of pre-set patterns

In the problems of individualised allocation of pre-set patterns the aim is to determine which specific timetable, from among those in a list of pre-set timetables, is allocated to each person, with advance knowledge of the necessary capacity in each period. The timetables allowed can be numerous and has to consider, among others, restrictions in the length of timetables, the placing of breaks or the minimum time between consecutive working periods.

To suitably dimension the workforce and provide them with their timetables, in Buffa *et al.* (1976) a scheme is proposed that contains the following steps:

- **Step 1: Forecast demand period by period** (usually periods of thirty minutes or an hour are used, recognising the difficulty of developing timetables with periods of shorter duration). One way of calculating is based on representative samples of observations. For example, the demand for a shopping centre can be estimated based on the billing carried out in each period of a standard week, which allows invoicing to be associated with a certain number of

clients, applying a correction factor taking into account the visits of clients that do not make any purchase, among other questions.

■ **Step 2: Convert demand forecasts into necessary staff capacity period by period.** If the rate of customer arrival and the rate of service is uniform through the operating day, the same number of people will always be desirable. If, in contrast, one of both are not uniform, the necessary capacity for running the service will vary throughout the day and the capacity necessary will be established based on the size of the demand and the idiosyncrasy of the tasks to be carried out.

■ **Step 3: Determine the set of permitted timetables.** In a generic way, a list of admissible timetables must be established for each of the values adopted by the total number of hours of work resulting from the [planning](#) or the type of job contract (for example, 12, 24, 30, 35 or 40 hours per week). The conditions for a timetable to be considered admissible are difficult to define and, once this obstacle has been overcome, difficult to [make into a mathematical model](#) without using a large number of variables and restrictions. For this, the usual base is a list of timetables established by agreement between the company and its staff, whose elements have to respect the legally established conditions. Additionally, it is possible to assign an indicator to the timetables that reflects the preferences of each individual for one timetable or another, rather like a traffic light: red for prohibited timetables, green for permitted timetables and amber for those acceptable only in necessary cases.

■ **Step 4: Select a set of timetables that minimises the cost,** providing, at least, the minimum number of staff required in each period of time. The distinction between the necessary level of staff and the minimum level acceptable is recent in the [programming](#) of staff timetables (Thompson, 1997). In a generic way, in companies it is fundamental to ensure a minimum value of staff that allows tasks to be carried out correctly or, simply, be able to maintain the employing organisation or the service, although it is better to approach the level of service desired (necessary capacity) as closely as possible.

The objective of step 4 (which coincides with the problem presented in this section) consists in efficiently resolving the allocating of staff timetables in each period of time (weeks, fortnight, etc.) of the [programming](#) horizon. For this, the following information which characterises the specific problem to be solved must be available:

- The relationship of staff with the category to which they belong.
- The types of tasks that the staff of each category can perform and the suitability and efficiency corresponding to each *category-task* pair. Multiskilling of staff leads to an increase in the complexity of the decision-making process as it significantly increases the number of solutions possible.
- The list of timetables admissible for each person, with the possibility of introducing preferences or limitations in the list.
- The minimum value of capacity for each time period of the [programming](#) (hour, half-hour, etc.). as has been commented, this detail ensures a sufficient presence to maintain the work centre open, and can be especially suitable for security issues.
- The capacity necessary for each type of task (which has to be equal to or greater than the minimum capacity value), in each period of time of the [programming](#) horizon.

The function to be optimised is complex, as habitually different objectives are considered (in the next section these will be listed in greater detail). The main objective is usually that of minimising deviations of the resulting capacity with respect to the capacity necessary, respecting the minimum capacity value, for each one of the periods. Moreover, it is also important to consider as far as possible the preferences of staff when allocating timetables and suitabilities when allocating the types of tasks to categories.

### 5.3. Evaluation criteria of solutions

According to the discussion so far, the issue is to get the presence of staff that provide the solution to the necessary capacity, considering the satisfaction of said staff with regard to preference for timetables and the suitability of the task to its category.

The ideal solution would be that in which, in each period of the [planning](#) horizon, the capacity obtained is equal to the capacity necessary. But in reality, the capacity necessary may not be reached in all periods; the case may arise that to cover the capacity necessary in some periods, staff must be surplus or lacking in others. The positive difference between obtained capacity and necessary capacity in a period is known as the *surplus*; similarly, the negative difference (the necessary capacity is not totally satisfied) is called capacity shortfall or *deficit*.

The usual thing to do is consider the shortfall and the surplus according to the evaluation function in a linear form (in other words, considering only the number of units of shortfall and/or surplus). Unfortunately, unsatisfactory solutions can be obtained due to the fact that two solutions with the same shortfall or surplus may be considered indifferent to each other independently of the distribution of this total value between all the periods (ten units of deficit of the necessary capacity distributed across ten periods does not have the same impact as if distributed across only two periods, for example, although the deficit value is the same); so, it seems logical to prefer a solution in which the shortfall or excess is distributed regularly across periods to another in which it accumulates exclusively in one or a few periods. Consequently, the shortfall and surplus have to have a non-linear repercussion in the evaluation function, penalising rather than linearly the accumulation in a few periods.

Furthermore, for minimising the impact that the deficit has to have over the level of service, this must be considered relative to the value of the necessary capacity. For example, For example, with a deficit of 10 people, the repercussion on the service level is much lower if the necessary capacity is 50 people (10 out of 50 corresponds to a deficit of 20%) than if it is 12 (10 out of 12 corresponds to a deficit of 83.3%, considerably higher in this second case). Consequently, the final objective is to evenly distribute the deficit and relative surplus between the different periods.

In summary, the criteria that must be considered in defining and searching for the optimum solution are as follows:

- Ascertain the minimum capacity value, without which it is not possible to keep the employing organisation or service open.

- Minimise the capacity deficit with respect to the necessary capacity, and distribute it evenly between the different periods and types of tasks.
- Minimise the capacity surplus with respect to the necessary capacity, and distribute it evenly between the different periods and types of tasks.
- Maximise staff preferences when allocating timetables.
- Maximise the suitability of the *category-task* allocation.

The ideal solution will be that which implies neither a capacity deficit nor surplus in any period, in which the allocated timetables had no penalisation for the staff and the suitabilities of the task types assigned to staff were as high as possible. In general, the said ideal solution will not exist and a target function must be defined that allows taking into account the relative importance that the decision-maker grants to the capacity deficit for each type of task, to the capacity surplus for each task, to the penalisation of the timetables allocated and the suitability of the allocation made. It is a common situation of a [multi.criteria](#) decision. Within the different possibilities of [multi-criteria](#) optimisation, the strategy is recommended of weighting the components of the target function, using the coefficients to hierarchise (Ojeda et al., 2004).

## 5.4. Instruments for programming working time

Ojeda (2004) describes the research carried out taking into account the evaluation criteria cited in section 5.3 and the data presented in section 5.2. The research work developed by the team of actors has obtained satisfactory results using [mathematical models](#), specifically [mixed linear programming](#) (MLP).

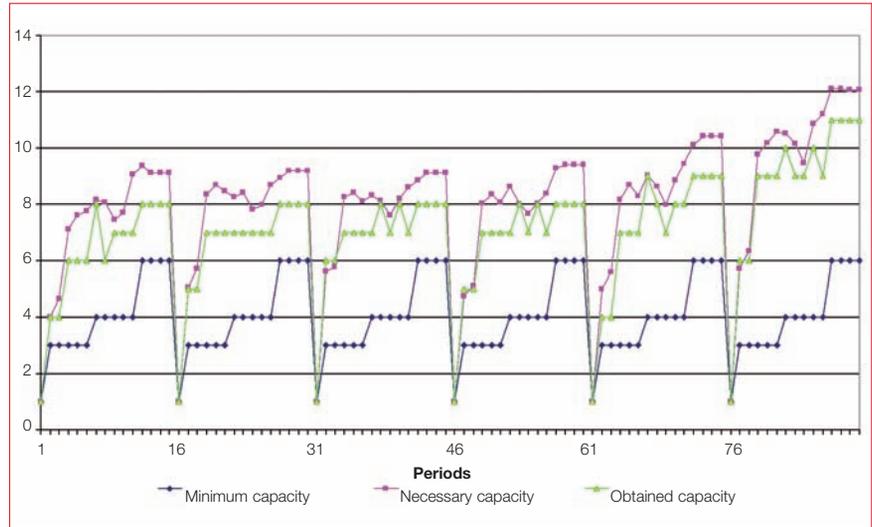
However, [mathematical programming](#) does not allow assurance that optimum solutions or even [feasible](#) solutions are always obtained or that the [mathematical programmes](#) can be resolved within an acceptable calculation time; in consequence, in some cases it could be necessary to design and programme a resolution algorithm made to measure for the particular case to be resolved.

Next (figure 5.1) the result of a real case of a services centre with an operating week from Monday to Saturday from 7 a.m. to 10 p.m is presented. A programming period of one hour has been considered, which is equivalent to 90 periods per week. There is a workforce of 30 people with four different types of contract (40, 30, 24 and 12 hours per week), and a list of 226 possible timetables in total. The minimum value and the necessary value of the capacity in each period is known. In figure 5.1 one can appreciate the evolution of the capacity curves (minimum, necessary and obtained) according to the time of day and the day of the week.

The programmed week corresponds to a situation of workforce dimension very much below the necessary capacity, but it allows appreciation of the even distribution of the deficit across all the periods of six days under study and how the capacity curve obtained guarantees the minimum capacity, firstly, and secondly, how it continues, more or less faithfully, the necessary capacity curve.

**Figure 5.1.** Minimum capacity, necessary capacity and obtained capacity.

It is worth commenting that in the studies carried out, tests have been performed with problems of up to 500 people with thousands of possible timetables, obtaining satisfactory results in approximately 100 seconds of calculation time.



# 6. TASK ALLOCATION

## 6.1. Introduction

Rodríguez (2006) describes Tasks Allocation (hereinafter, TA) as “the *decision that within the context of Organisation of Working Time, takes as its starting point the knowledge of the staff available to do the tasks demanded as well as their capacities and performances in doing them and that while incorporating the organisation’s priorities and respecting the behaviour guidelines as previously established, gives as its result the task that each person has to do at every moment of the period in question. The behaviour guidelines mentioned are the result of economic, ergonomic and quality reasons as well as organisational priorities, staff preferences, social aspects, legal provision, working systems used, etc.*”).

There are many cases in which TA has an important role. We present below some examples and we take the opportunity to introduce some of the most important factors that make TA a complex decision that requires specific help tools.

A first example could be a shop where one can distinguish, among other activities, three well-differentiated types of task: checkout operation, serving customers and refilling/placing items correctly on shelves. According to the customers present in the shop, the staff allocated to each type of task varies over time. When there are few customers, the time is used to refill shelves, whereas when there are a lot of customers, this task is virtually abandoned with more staff working on serving and checkout operation. The fact that one type of task is practically abandoned arises often and is due to the fact that there are not enough staff to cover all the tasks; in this way the organisation establishes priorities in executing tasks. Also in this example it can be observed, often, that not all staff can always taken on the three types of task, this is due to the fact that not all staff are multiskilled. Later on we will refer to multiskilling factors and organisational priorities in more detail. Evidently these factors do not only affect this case, but it has served us to introduce some of the factors more directly involved in TA.

The second example corresponds to a manufacturing factory, specifically we are situated on a series production line, as is common in different sectors such as the automotive sector, electronics, food processing, etc. Some tasks are very repetitive, for example at a single workstation car doors are continually fitted, or a specific element is incorporated into a television set, or some ingre-

dients are added to a pre-cooked dish; this means that, once a certain time has passed performing this type of task, fatigue occurs in executing it, but this fatigue can be overcome simply with a change in task type. We refer to this situation, among others, when talking about the rotation factor. In this example, a need for rotation due to physical fatigue has been presented, but as will be seen in the following case, the reasons for a rotation of task type can be varied.

The third example corresponds to the anaesthetist's service of a hospital. It is not easy for the anaesthetists' collective to maintain their expertise before any kind of surgical intervention, if when allocating the type of intervention to each one certain factors are not taken into account. One of these factors is rotation between the different types of surgical intervention in which they take part. This factor is applicable to other collectives, inside and outside the healthcare sector.

The last example is that of any ordinary office and its customer care service; a person assigned to this service, with solid experience in the office, will be knowledgeable about the administration procedures carried out there and will act with more **efficiency** before the customer than another who has little experience. However, it is also necessary for new people to join this service and for them to be involved in the administrative processes of the office, for that it will be necessary that new staff dedicate a certain amount of time to training in each of these processes. It is necessary to programme the time dedicated by new staff members to each process in order to facilitate their learning. We will talk later about the learning factor in relation to TA.

In TA there are many factors that intervene. Rodríguez (2006) presents an extensive classification of the characteristics and variants of over twenty factors. We will highlight some of the most important factors present in the majority of decisions made within the context of TA. First of all we will present, within the general description, the conceptual framework of TA and tackle such factors as *multiskilling*, *rotation*, *learning*, and *forgetting*. We will also discuss *suitabilities* in the performance of the types of tasks and the *preferences* of both organisation and staff.

## 6.2. General description

The basic TA premise is: given  $n$  types of tasks and  $m$  resources, the aim is to determine an allocation of each type of task to a resource, optimising an evaluation function and satisfying the additional conditions to be considered. In our case, resources are those of staff available in each of the periods of the horizon (Lusa, 2003).

The *horizon*, the term in which the allocated assignment is performed, may be of years, months, weeks, days, working days, etc. And the *intervals* (periods in which the horizon is divided) could be: years, months, weeks, days, hours, minutes, etc.

The evaluation function at times can be very complex, as typically, as will be seen in section 6.3 on evaluation criteria, there are numerous criteria to be evaluated: economic, organisation preferences and staff preferences. In the

same way, the conditions that it is necessary to satisfy are not habitually simple, as it is necessary to incorporate legal, ergonomic and social aspects, work systems, etc.

Different factors can be added to the basic TA premise that make the TA more complex. One of the most important factors is the capacity necessary for each type of task in each period, which can fluctuate more or less, besides the complication represented by having access to the corresponding information. Another factor to be highlighted is the number and type of tasks to be carried out, the specific knowledge of the staff and their type of multiskilling, the presence of other factors such as rotation or learning, the fact that there is not sufficient staff available to cover the capacity necessary of all types of tasks (then establishing priorities between them) or alternatively wanted to introduce preferences of the organisation and its staff alike, all this means that real applications of TA increasingly require more specific support tools in the organisations (Pastor and Corominas, 2007).

TA, as it has been approached until now, corresponds to a *static* decision, in other words given all the information, the desired allocation is obtained. In many cases the information gradually changes during the execution of the allocated assignment and it is necessary to go back and do a new allocation for the rest of the horizon with the new information; we refer then to the fact that the TA is *dynamic* and it will be necessary to do reallocations within the same horizon.

Another factor that it will be necessary to consider is how two allocations corresponding to two consecutive horizons interact. In other words, once the allocation is made for one horizon, the allocation for the next horizon is not usually independent of the allocation made in the previous horizon or at least, is not independent of that carried out in the last periods of the previous horizon; for example it is necessary to incorporate, in the [planning](#) of the new horizon, the last tasks carried out by each person in past [planning](#). Again it will be necessary to foresee what we will call TA *concatenation*.

There are many forms of allocating types of tasks to people and this allocation has important effects on the costs of personnel and on the achieving of targets by the organisation. TA has to permit achieving the optimum use of staff capacities.

Organisations have, as one of the challenges, to establish a method to allocate types of tasks to personnel; the method has to contemplate the specificities of each environment. For example: whether the types of tasks are mobile in time, whether a shift will include breaks, whether extra personnel will be available, whether there is a type of task that require specific abilities, whether the personnel have different capacities and performances, whether it is necessary to respect certain guidelines established in advance, etc.

Carrying out TA manually requires the investment of a great deal of time and effort; often, TA is based on trial and error, which consumes time and is not too viable when the allocation has to be carried out in a brief period of time or when it is necessary to establish a reallocation because unforeseen circumstances have arisen.

## 6.2.1 Multiskilling

We use the term multiskilling to refer to the range of capacities that a person has that allows him or her to carry out different processes or functions, which we will generically call types of tasks.

Having multiskilled staff represents an advantage in achieving working flexibility, as it gives the organisation the capacity to plan and work according to the variable demands of the market. Furthermore, the benefits that having this type of staff can be seen in the reduction of costs, in the improvement of quality, in the best use of resources, in a better service for the client, while at the same time resulting in a high level of staff satisfaction, etc. Organisations with multiskilled staff can resolve the changes in the demand for products in the most effective way. Staff believe that multiskilling will allow them greater job satisfaction, to remain longer in the organisation, to have a job that offers more mental challenges, a greater sense of responsibility, and better remuneration for their work. Multiskilling achieves a reduction in job monotony.

The use of multiskilled staff has been beneficial in different organisation, let's look at some cases. For example in flexible cellular manufacturing systems, where the number of people is smaller than the number of machines in the cell (as a multiskilled person uses different types of machines); in this case the objective is to balance the load and avoid bottlenecks. In the construction sector, working by projects and having a somewhat unstable image makes it difficult to attract new staff; a potential strategy has been for staff to be multiskilled, to increase productivity and quality and maintain work continuity. In the hospital sector, as commented at the start of this chapter, for the anaesthetists' collective, multiskilling is very important; it allows for reductions in costs, means better attention is given and consequently greater patient satisfaction achieved. In the hospital sector, with the use of multiskilled staff, less specialists will be needed and more staff with general knowledge, with a special focus upon patients. According to recent studies, 80% of medical institutions wish to have access to multiskilled personnel in their workforce and 75% of people working in this sector show themselves to be receptive and kindly predisposed to carrying out multiskills training. Staff multiskilling has also been incorporated into mechanics' workshops; in addition to other benefits, a reduction of the equipment necessary and the space used is obtained, along with staff that cooperate and carry out a job for a common purpose. Another sector where use of multiskilling has been beneficial is in self-service shops: it is very necessary to have multiskilled staff as the capacity necessary for different types of tasks often changes greatly according to the time and the day.

The level of multiskilling may be equal for all personnel or perhaps some people will have more skills than others or alternatively the level of [efficiency](#) will be different according to the type of task they carry out. The success of the use of multiskilling depends on the capacity for achieving the appropriate allocation of staff to the types of tasks, which allows the organisation's targets to be reached.

As has been commented, there are different types of multiskilling; if we look to the number of types of tasks that each person can do, we will talk about the organisation being *totally multiskilled* if all the staff can do all types of tasks. The organisation will be *semi-multiskilled* if although there are multiskilled people, not all can do all types of tasks or alternatively they can do them but do

not all achieve the same performance. The organisation will be *non-multiskilled* if it does not have this type of staff.

In many organisations the staff structure is established by categories. The staff of a category may or may not be skilled enough to carry out all the tasks in their category or only some of them. It is also common, at least in several organisations, that the people in a category have hierarchical multi-functionality (we could also call it *hierarchical multiskilling*), in other words that the staff of a certain category have the skills to do the tasks of the immediately inferior category or of all the inferior categories.

### **6.2.2 Rotation**

We refer in this section to the importance of staff changing (or *rotating* through) types of task all along the TA horizon. Evidently rotation between tasks will be possible among multiskilled staff. The reasons for this rotation can be diverse, at the start of the chapter three were mentioned: due to physical fatigue, to maintain expertise levels and to facilitate learning. In fact, fatigue can be as much physical (in the broadest sense: visual, fixed position, acoustic, etc.) as mental and emotional. Other reasons for which it is necessary to rotate between tasks that staff do are to avoid monotony and to balance workloads between staff.

Prior to TA, it must be established which will be the rotation patterns for each type of task, in other words it is necessary to determine the minimum and maximum work periods in each type of task (usually there is a preparation time before doing each type of task which means that a minimum assignment time has been established), rest periods between two consecutive assignments to the same type of task, the time for changing from one type of task to another (including the time for leaving one type of task, the break if there is one and the time for preparing the new type of task), etc. In fact it will be necessary to determine the patterns of rotation that will be used. Two types of patterns will be used, one of rotation by block and the other of rotation by rank. The *rotation by block* pattern establishes an exact number of continuous periods that people have to dedicate to a type of task when allocated to them; if, for example, there is a change of type of task every two hours, then the block is of two hours. The *rotation by rank* contemplates a minimum number and a maximum number of periods dedicated to the type of task allocated; for example it is necessary to do the same type of task for a minimum of one hour and it cannot last for more than three hours. An organisation can make use of the two types of patterns according to the nature of the type of task to be allocated.

### **6.2.3. Learning and forgetting**

*Learning* is the process of acquisition of knowledge, skills or values through study or experimentation. Every day people are subjected to the learning process. When some task or activity is repeated frequently, it can be observed that the skill in doing it improves, it is performed better and in less time than the first time it was done.

Linked with learning there is *forgetting*, which is related with the intensity of the memory. Due to forgetting, when a period of time passes without doing a certain activity, the difficulty in doing it once more increases.

It is easy to realise the importance that the rotating of types of tasks will have in facilitating training and to hinder forgetting. It is a case of doing the tasks in a repeated manner in order to accumulate experience and increase skill in doing them. If the time that has passed between the allocation of two tasks of the same type is too high, then it is possible to fall into forgetfulness regarding this type of task.

Different authors have been researching the theory of learning and specifically there are different works on learning curves. From the 1939 model used at the Wright Corporation to today, models for learning curves have been developed and adapted. These curves are based on the fact that on many occasions, the learning of one type of task is slow during the initial phase of doing it and is forgotten more quickly if the type of task is no longer done. The person who is expert in one type of task also presents a brief learning period in each change of type of task, but quickly reaches the expertise rate to carry out the type of task allocated, which also involves minimising the number of errors (Ibáñez and Sánchez-Martínez, 2007).

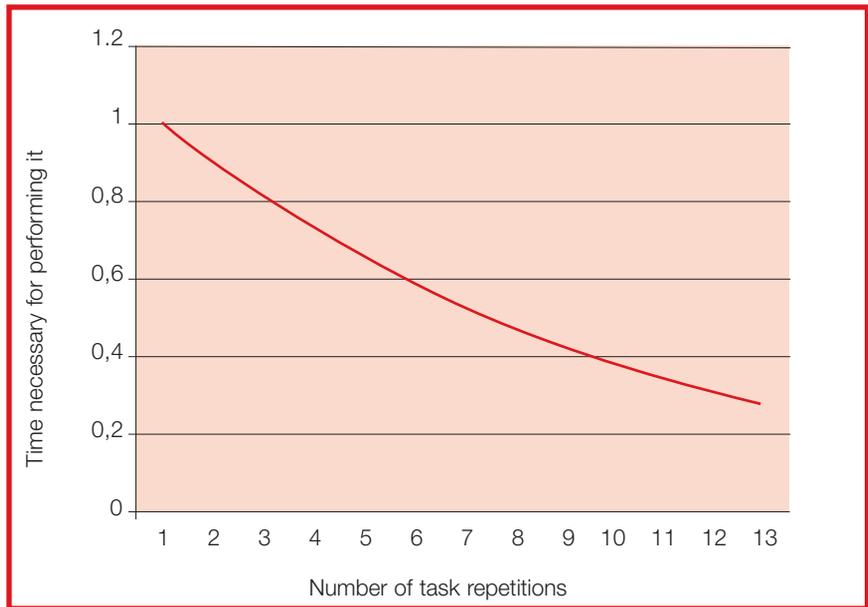
Learning curves are based on three hypotheses. The first is that the time necessary to do a task diminishes every time it is repeated. The second hypothesis says that this reduction of time continues until a standard time is achieved. The latter indicates that the unitary rate of reduction of time is ever smaller (Hottenstein and Bowman, 1998). For example, let's suppose that the first time a person does a task they take 1 minute, the second time 0.9 minutes, the third 0.81 minutes and so on successively until they reach a standard time, which is the time necessary for an experienced person. This case corresponds to what can be seen in table 1 and figure 1.

Number of times that task has been done	Time needed to do it
1	1
2	0,9
3	0,81
4	0,73
5	0,66
6	0,60
.....	.....

**Table 1** Example of learning curve

**Figure 1. Learning curve**

As has been explained, a learning curve shows the relationship between the duration in doing one type of task and the number of times it has been repeated. There are different models for calculating learning, from the most simple such as arithmetic and logarithmic models, to more complex mathematical functions with more parameters, such as the Nembhard and Osothsilp (2005) model. The most recent models also incorporate forgetting and/or continuous



improvement. Through the use of models of learning curves, the programming and allocation of tasks approaches reality more closely.

### 6.3. Criteria for evaluating solutions

A great diversity of criteria for evaluating solutions exists, according to the characteristics of each organisation. One classification considers: economic criteria, regularity in work criteria and criteria relating to the organisation and the staff's preferences.

It is proposed to measure *economic criteria* under two aspects; staff costs on the one hand and on the other, the degree of satisfaction of the necessary capacity. As has been commented previously, it is not always possible to satisfy the necessary capacity of each type of task in each period; sometimes a type of task being advanced or delayed causes certain costs while not satisfying the necessary capacity causes a lack of income.

The term *regularity in work* highlights two aspects: the time devoted to each type of task and equity between tasks. With respect to the *time devoted to each type of task*, sometimes it will be useful for it to be maintained at certain ideal proportions; one of the causes may be to maintain a certain level of training in each of them. In a clothes shop, for example, it may be desirable for each person to be assigned to working on the till for approximately 20% of time, displaying new stock for another 20% and 60% attending to customers. As for *equity between tasks*, this refers to the interests, on the organisation's behalf, when the availability of staff does not coincide with that necessary in each type of task, then some organisations prefer that all types of tasks satisfy their needs on a similar level. This would be the case where the organisation does not permit, for example, the abandoning of certain types of tasks to be able to satisfy the needs of others.

Considering the *preferences* of both organisation and staff is one of the challenges of OWT. The organisation's preferences are mainly linked to two concepts: that of preferences for carrying out types of tasks, establishing priorities for execution in the case that there are not sufficient staff to satisfy all the necessary capacity; and, to incorporate the preferences in the use of personnel, whether by cost, by capacity, by need for training, etc. Staff preferences can be both for performing certain types of tasks or wanting to devote a determined ideal proportion of their working time to each type of task. Table 2 summarises these criteria.

Criteria in TA	
Economic	Staff costs  Satisfaction of necessary capacity
Regularity in work	Proportion of time devoted to each type of task  Equity between types of tasks
Preferences	Of the organisation: in carrying out certain types of tasks and the allocating of staff to types of tasks  Of staff: to perform certain types of tasks and to want to dedicate a determined ideal proportion of their time to each type of task

**Table 2.** Criteria in TA

## 6.4. TA support tool

As can be deduced in light of what has been explained above, there is a major diversity of characteristics in TA, defined by factors such as labour laws, type of staff, nature of tasks, etc. Therefore production of a model for general use, valid for any environment, is not possible; however, it is possible to produce TA support tools valid for a set of previously established factors.

Next the case is presented of a company that has a chain of shops (Ojeda, 2004), where the following characteristics are considered: there are from two to four types of tasks, according to the shop in question; the staff are capable to doing all types of tasks, but with different performance levels according to category and type of task. The necessary capacity is deterministic and known in advance (already translated into staff needs in each period for each type of task), the staff available in each period is known before TA is classified by categories (which could be 2, 3 or 4 according to the shop). The [mathematical model](#) seeks the optimum allocation of staff to the tasks for a horizon of a week, so that the necessary capacity for each type of task is satisfied. The

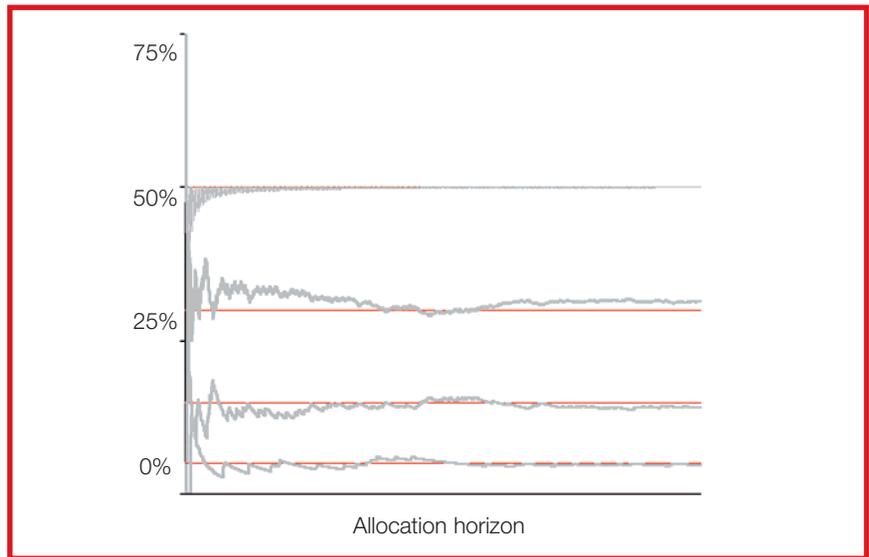
optimum allocation is evaluated considering different criteria based on the priorities of the organisation and the staff: for the organisation, ideal allocations of staff to types of tasks are incorporated and for staff, their preferences in doing certain types of tasks. These characteristics are summarised in table 3.

<b>Characteristics of the case of a chain of shops</b>
Fixed and known available capacity
From 2 to 4 types of tasks according to the shop
From 2 to 4 types of staff categories according to the shop
Staff multiskilling: different performances according to category and type of task
Staff of 25, 50 100 and 150 people
Organisation priorities for allocating staff categories to tasks
Staff preferences for performing certain types of tasks
Horizon one week, open daily from 7 a.m. to 10 p.m., periods of one hour

**Table 3.** Characteristics of the case of a chain of shops

Additionally there are types of tasks where it is considered that the rotation has to be done by entire block of periods and others, in contrast, are considered to be done by rank, between a minimum time and a maximum time of continuous dedication to a type of task. The model also considers the fact that it is desired that, at the end of the TA horizon, a determined proportion of time has been allocated to each type of task for a specific person.

Figure 2 shows the percentage of time that a certain person will devote, after application of the TA tool, during the allocation horizon, to each of the four types of tasks, knowing that the ideal percentage of time that the person had established was of 50%, 30%, 15% and 5% , respectively. Stabilisation is achieved around ideal values after overcoming initial transitory periods.



**Figure 2.** Percentage of time that a certain person will devote to each of the four types of tasks, during the allocation horizon, knowing that the ideal time percentages are 50%, 30%, 15% and 5%, respectively

The use of the tool that has been proposed is not limited to any specific sector and has been designed to allow its adaptation to the priorities and needs of organisations. In any case it is necessary to continue working in order to incorporate a larger diversity of characteristics that appropriately reflect the peculiarities of different organisations.

## 7. CONCLUSIONS

The organisation of working time is a very important component of the social organisation of time, due to the repercussions it has on the productivity of activities that generate goods and services and on people's quality of life.

Social changes and changes in the production system have made the coordination of work activities and personal activities increasingly difficult, which has led to the demand, by people working, of flexible timetables. This flexibility is called active flexibility and today, teleworking has opened up new perspectives.

Moreover, the growing importance of products that cannot be warehoused (fundamentally, services) and of the costs associated to holding stocks reinforce the need, by companies, of having a production capacity that is flexible. And a certain element, often fundamental, for having a flexible capacity is the flexible organisation of working time (passive flexibility).

Passive flexibility is advantageous for the company, but from the viewpoint of its workers it has some drawbacks, as it involves a loss of control over their free time. Therefore, for passive flexibility to be acceptable to them, it needs to be subjected to well-specified conditions, established by law or by formal agreement.

There are diverse modalities of flexible organisation of working time such as the traditional overtime, annual hours working and working time or hours accounts. These modalities can be combined and give rise to mixed systems.

This gives rise to an infinity of variants, because each basic modality includes parameters that can take on different values (the maximum balance of the working hours account, the maximum number of extra hours in one year...).

As it is not easy to evaluate the repercussions (economic and labour-related) of introducing or modifying the conditions or parameters that characterise the system, it is necessary for the company and its personnel to have instruments that allow them to estimate the consequences of adopting some solutions or others and negotiating on rational and quantified bases.

Of the three levels that can be distinguished in the organisation of working time (which we have called *macro*, *meso* and *micro*), this work focuses on the *meso* level, which contains the decisions relating to [planning](#) and the [programming](#) of working time and to the allocation of tasks.

To give support to the taking of these decisions, there are currently efficient instruments available, the main characteristics of which have been exhibited in preceding chapters.

These tools can contribute to the establishment of satisfactory organisation of working time, in other words, that combine the **efficiency** of organisations with the quality of life of the people working for them.

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# GLOSSARY

## Efficiency

The efficiency of a resource that intervenes in a process is the quotient between the result obtained and the number of units of the resource applied to it. If a person does a type of task, efficiency can be expressed in number of units per hour (for example, in a machining factory, number of pieces per hour).

Sometimes, efficiency is expressed in terms relating to a value adopted as a reference. For example, it can be considered that 200 pieces/hour is an optimum efficiency and this is adopted as a reference (1 or 100%); if a person does 160 pieces/hour, we will say that that person has an efficiency of  $160/200=0.80$  or 80%.

Efficiency must not be mistaken for **effectiveness**, in other words, the capacity for doing what is to be done. A person or a machine can be effective yet not be very efficient. In contrast, it is not possible to be efficient without being effective.

## Artificial intelligence

Generically, this is the capacity of a machine to do tasks considered typical of human intelligence, such as playing a game of chess or recognising handwriting.

More specifically, it is a heterogeneous set of techniques, including some oriented towards finding optimum or approximately optimum [feasible solutions](#) to complex problems.

## Mathematical model

Very often, to find out the answers that we ask ourselves regarding the properties or behaviour of a real object, we do not resort to consulting the object directly, but to a model of this object. For example, to find out the distance by road between two cities, we do not examine the territory, we look at a road map, which is a model of the territory. Or alternatively, to find out the intensity of the current passing through a resistance, if we apply a given potential difference we do not need to do the experiment, because we have the model for

this system: Ohm's law.

In general, it is said that an object  $M$  is a model of another object  $R$  for a person  $P$  if and only if  $M$  answers the questions that  $P$  asks himself or herself with regard to  $R$ .

There are many classes of models (graphic, maps, maquettes, etc.) Mathematical models are equations or sets of equations that relate variables representative of characteristics of the object  $R$  (mathematical expressions corresponding to Ohm's Law or the law of universal gravitation are examples of simple mathematical models.

### **Multi-criteria (analysis)**

Multi-criteria analysis is a branch of decision theory that studies the taking of decisions when the solutions have to be evaluated according to diverse and incommensurable criteria, in other words, criteria that do not have a common measure (for example, a repairs service can be evaluated by cost and the proportion of breakdowns resolved in a time no greater than 3 hours).

### **Planning**

This refers to the action and the effect of planning, in other words, of forecasting actions that have to be carried out in an interval of future time, which is known as the **planning horizon** and is divided into **periods**.

### **Mathematical programme**

This is a **mathematical model** that includes a function that it is desired to optimise (which is called the **target function**) and equations or inequations (called **restrictions**) that the values of the **variables** have to satisfy.

### **Linear programming**

This is a **mathematical programme** in which the **target function** is linear, the **restrictions** are linear equations or inequations and the **variables** are real and cannot take on negative values.

### **Mixed-integer linear programming**

This is a **mathematical programme** in which the **target function** is linear, the **restrictions** are linear equations or inequations and some **variables** are integers (in other words, they are only allowed to adopt integer values). If all of them are, it is said that it is an **integer linear programme**.

Section 4.5 includes an example of this.

### **Programming**

This refers to the action and the effect of programming, in other words, of planning actions that have to be carried out in a future time interval, which is called the programming horizon, and which is divided into periods.

This definition is similar to that of **planning**. Planning and programming are related concepts and distinguished by the degree of detail (planning is more aggregated and programming, more detailed). The typical planning horizon is one year, divided into periods that may be months, blocks or a certain number of weeks (4, for example) or weeks. In programming, the horizon is very short (perhaps a week or a day) as are the periods (hours or fractions of an hour).

### **Feasible solution**

In a problem in which conditions are imposed upon solutions, the name feasible solutions is given to those that fulfil the conditions.

For example, if we seek values for  $x$  that make maximum the value of the function  $f(x)$ , with the condition that  $x$  cannot be less than 5,  $x = 5$  is a feasible solution (in contrast,  $x = 4$  is not a feasible solution it is also said that it is a **non-feasible solution**).

# ABOUT THE AUTHORS

**Albert Corominas** holds a PhD in Industrial Engineering, a degree in Information Technology and is university chair professor of the Department of Companies Organisation and of the Institute of Organisation and Control of Industrial Systems at the UPC Barcelona Tech. His professional and academic experience has focused on the sphere of industrial organisation and especially on development and the application of quantitative techniques for the problems of designing production and logistics and operations management systems. He is a member of different professional and scientific societies and author or co-author of books and articles in Spanish and international magazines. He has directed and participated in numerous agreements with companies and organisations in research projects. For over twenty years he has paid special attention to problems of working time organisation; in recent years, as the main researcher for two projects of the National Research Plan (2001-2004 and 2004-2007), which have led to various articles in international magazines.

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**Amaia Lusa** is an Industrial Organisation Engineer, who earned her PhD at the UPC Barcelona Tech and lecturer at the Companies Organisation Department of the UPC. Her research, at the UPC's Institute of Organisation and Control of Industrial Systems (IOC), focuses on the development and application of quantitative techniques for the resolution of problems of design

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