EXPLORING THE MODERNIZATION PROCESSES OF RAILWAY WORKSHOPS

JOSÉ LUIS LALANA SOTO | INSTITUTO UNIVERSITARIO DE URBANÍSTICA DE VALLODOLID (ESPAÑA)
LUIS SANTOS Y GANGES | INSTITUTO UNIVERSITARIO DE URBANÍSTICA DE VALLODOLID (ESPAÑA)

insur3@uva.es

INTRODUCTION

This paper is an approach to the modernizing processes of the great railway workshops during more than one hundred and fifty year's life time. The subject is, obviously, too extensive and complex. What does exactly "modernizing" mean? The need of modernization can be due to several reasons, and it can cause different effects, from growth to reorganization or closure. At the same time the phrase "railway workshop" can refer to a wide range of facilities.

We will explore the most important modernizing processes of the great workshops built by railway companies for their own use, although there are a variety of situations among workshops, depending on the date of their construction, the character or quantity of the work to be done, finances, size and strategies of the promoting railway company or prevalent ideas of economy. Moreover, the company does not usually build what it wants but what it can.

> «It may be said that the general layout of a shop is not always representative of an arrangement considered the most satisfactory for the work to be accomplished, but rather the most practical under the circumstances governing at the time the shop was built». *in: Railway Shop Up to Date* (1907)

However, there were many points in common for the majority of railway workshops, so we can broadly approach to their modernizing processes because most of them were affected, although some were more or before than the others. Nevertheless, it is convenient to bear in mind that the analysis of every particular case requires going into a lot of details.

Nearly all the railway companies had a little number of large facilities to undertake the heavy repairs of their own locomotives and rolling stock.

Daily maintenance and light repairs were undertaken at small service workshops near the engine houses, but because of use steam locomotive gradually became less efficient, and every few years it needed to be almost totally dismantled. This operation is known as 'heavy repair', and it is, in fact, the engine rebuilding. In addition to required maintenance, at workshops the engines were upgraded and improved, being their equipment replaced and new accessories added.

Large railway workshops, known as main, general or central workshops, were facilities equipped to undertake heavy repairs and improvement, even with experimental equipment, of locomotives and rolling stock. Those

facilities were also the suppliers of replacement parts for the whole railway company, especially for smaller workshops.

Besides, «constructing a new locomotive came within the capability of a railway company, who had the advantage over external suppliers in knowing the operational characteristics of particular designs.» (David Boughey, 1999). In fact, a few companies built some locomotives and cars in their workshops, although as a general rule, most of this work was performed by external firms. There were a number of exceptions to this rule however, and the most remarkable one was the Britain's experience:

> «By the early 1870s the majority of Britain's larger railway companies were building locomotives in their own workshops, only occasionally turning to external suppliers. Such a policy stands in stark contrast to that followed by foreign lines, with the exception of the Pennsylvania Railroad which met much of its own locomotive requeriments internally from 1875». *in:* David Boughey (1999), *Business and Economic History*

Railway own workshops are aimed to a specific work: repair of railway material, especially locomotives and rolling stock. Their facilities and equipment are similar to those of an external manufacturer, but there is an essential difference: railway workshops are industrial establishments managed by companies whose main business is the transport of passengers and goods, rather than construction. The companies are both producers and consumers of their wares, and so they can afford to choose their own way of manufacturing them. In short, like manufacturers, railway own workshops are industrial even larger establishments to work over locomotives and rolling stock, but with no identical objectives.

Christian Chevandier (1993) wrote in *Cheminots en usine* that railway workshop workers are a «Classe ouvrière étrange, hybride, s'affirmant cheminots, paraissant métallos». The same assertion is applicable to facilities as they are industrial as well as railway establishments. In this paper, we want to explore main modernizing processes at railway workshops, bearing in mind their "hybrid" character.

TECHNICAL AND ORGANIZATIONAL INDUSTRIAL MODERNIZATION IN THE EARLY YEARS OF THE TWENTIETH CENTURY

Even though during the XIXth and the first half of the XXth century the product, that is the steam locomotive, had no significant variation, railway workshops were affected by the great industrial changes in the early years of the XXth century. Two of those changes should have to be underlined: one of technical nature, occurred when electricity stopped being a scientific experiment to become an industry, and the other of organizational nature, when the new scientific management principles were formulated by Taylor and his disciples.

However, as a general rule railway workshops adopted novelties very slowly. A 1907 publication by Railway Master Mechanics observed that railroad shops were «extremely conservative in the matter or taking up new ideas, and probably working to less advantage than any other manufacturing establishment, for the reason that railroad repair is practically devoid of competition.» (Seely, 1977; *The Construction of the Eire Railway System*). On the other side of Atlantic Ocean, Alfred Williams, in his *Life in a Railway Factory* (1915), asserted: «many of the methods employed, both in manufacture and administration, are extremely old-fashioned and antiquated; an idea has to be old and hoary before it stands a chance of being admitted and adopted here».

Modernization would reach railway workshops, as in many other cases, at the moment and the manner it became possible. That is, only when the workshop system became inefficient and too expensive, the company would undertake modernization. Maybe this was due to business growth, since workshops needed to grow with railways, or to any other reasons such as fire, renewal or reconstruction of the buildings. And modernization would just go as far as finances, available land or circumstances allowed it. Moreover, given the reduced number of workshops and their essential role within railway exploitation, modernization had to be undertaken without stopping the industrial activity and so workshops were updated mainly by additions, rather than new construction, and generally later than other industrial groups.

The example of Piermont Shops (Eire Railway), described by Seely is valid for almost every railway workshop in almost every country and time:

> «The [workshops] building represented a potpourri mixture of types, materials and sizes, added on an ad hoc basis whenever the railroad found some new problem to meet... The Erie was not the only railroad to facilitate maintenance in such an unplanned fashion. The railroads were learning as they went ands making changes and additions as needed. But the impact of poor finances obviously limited how the Erie could make those additions. » *in:* Seely (1977), *The Construction of the Eire Railway System*

Great changes normally will happen at completely new facilities, designed according to modern concepts to take advantage of available technical resources, but in practise old facilities were mostly used, where modern and old-fashioned elements coexisted. As a result, modernization will not be the best as possible, as previously pointed out, but the most suitable according to means and requirements of the company. One example is given by Carolyn Dougherty:

> «With plenty of room to expand, the shops built new facilities... rather than demolishing older ones; new processes were also accommodated in newer shops in other locations. Buildings were built for particular purposes, and then either torn down or reused instead of rebuilt or redesigned.» *in:* Dougherty (2002), *Southern Pacific Company, Sacramento Shops*

In essence, it is not the kind of work itself what changed, but the resources and methods to do the work. Nevertheless, there were some technical changes that compelled railway companies to modernize their facilities; as an example, the increasing size of steam locomotives, that rendered progressively inefficient some railway facilities, although this circumstance had much more effect on engine houses or turn-tables than on workshops.

TECHNICAL MODERNIZATION: THE APPEARANCE OF ELECTRICITY, A NEW SOURCE OF POWER

The first technical problem to be solved was to organize a maintenance system, with two main options: either many small facilities involving shorter movements of locomotives and rolling stock, or few large establishments with greater operational capability. Most publications about railway engineering, both American and European, consider the centralized maintenance system, with a large well equipped workshop as the most viable option:

> «Il n'existe généralement, même dans les lignes les plus importantes, qu'un seul atelier de grande réparation. Cet atelier est une véritable fabrique pour construire les machines aussi bien que pour les réparer; car réparer une machine locomotive usée par un long travail, c'est souvent la reconstruire.» *in:* Perdonnet (1860), *Traité élémentaire des chemins de fer*

> «Puede, pues, haber sobre una línea muchos talleres secundarios para el entretenimiento conveniente; pero las grandes reparaciones se hacen en uno solo, que constituye un verdadero establecimiento industrial.» *in:* Vallespín (1875), *Lecciones provisionales sobre ferro-carriles*

> «It is much more economical for any road to have one grand machine shop, at which all the principal work of construction and of heavy repairs shall be done, than several small ones. The best and cheapest work is done by costly special machinery, which ought to be provided for any great establishment, but can not be afforded for several shops; such machines are generally capable of doing all the work that could be required of them for the largest road, an need no be duplicated if the important repairs are concentrated at one place.» *in:* Paine (1884), *Elements of Railroading*

> «No matter how large and complete the main shop may be, the outlying points can advantageously and profitably use a moderate tool equipment for taking care of running and light accidental repairs, leaving heavy repairs and manufacturing to be done at the main shops. With such an equipment and organization, we believe that relatively small shops are undesirable, expensive and unprofitable, and that the larger, completely equipped main shops will handle the repairs in the most satisfactory manner.» *in: Convention of the American Railway Master Mechanics' Association* (1905)

The first modernization process, in some railways, was the concentration of resources in a small number of facilities. Some American and most of European companies early had specialized establishments for heavy repairs, whereas for other companies it was a serious problem which would never be completely solved.

In the end of the XIXth and early years of the XXth century, several technical advances having an enormous importance for industrial processes appeared, such as welding, the use of air driven small tools or the heavier machine tools with high speed steel. But the most important technical advance was, undoubtedly, the introduction of electricity as a source of power. Thanks to electrical transmission of energy, industrial plants could become safer, and more efficient, reliable rational.

Concerning railway workshops, electric power meant a great step forward mainly in three aspects: artificial lighting, overhead travelling cranes for lifting entire locomotives or their heaviest parts, and machine tools with electric independent motors.

However, the adoption of those advances did not take the same time in every case. While electric artificial lighting rapidly spread out, overhead travelling cranes, that required high and strong buildings with solid foundations, would take longer, and the introduction of electric independent motors for machine tools was very slow. In fact, the machine shop with hundred of mechanical transmissions and belts often survived in railway workshops until the 1970's. In the meantime, there were intermediate phases: the installation of electric generators associated to steam engines, the use of old machine tools which had their steam boilers replaced by electric motors but their mechanical transmissions preserved. Actually, few railway workshops took readily the advantages of the new source of power.

Electric power had an effect not only on processes, but also on workshop layouts, since the new possibilities offered by technical advances required a different space arrangement.

We can use as an example to approach this subject- still too extensive and complex- the main buildings of locomotive works, that is, the erecting, boiler and machine shops.

Typical arrangement of the XIXth century locomotive works, whenever the size and the shape of available land made it possible, was a main building for both erecting and boiler shops, and great courtyards that guaranteed light enough and allowed to make outdoor jobs. The main building contained a transfer table, which permitted the central bay to be divided into rows of erecting pits perpendicular to the building long axis. We can

see a typical example of this kind of building for erecting and boiler shop at Batignolles Works (near Paris), designed by Eugène Flachat for the *Compagnie des chemins de fer de l'Ouest* in 1856.

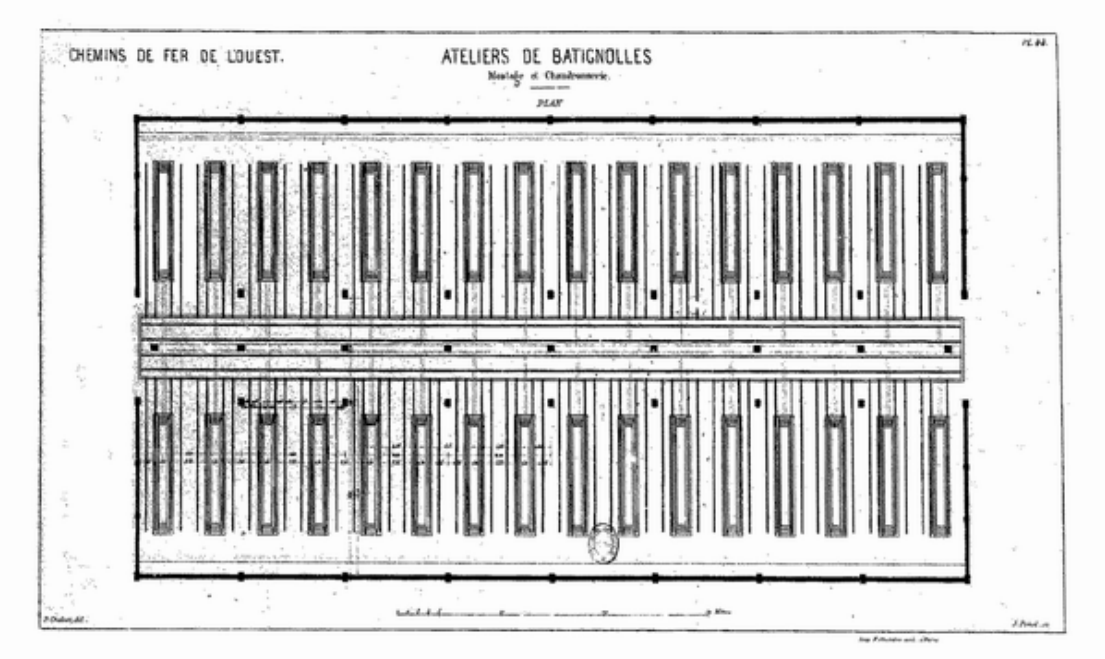

Image 1: Batignolles Works (France): Erecting and boiler shop in 1862

The building, usually wooden, was cheap and simple, with light foundations. The lifting of locomotives was made by mechanical means, and the heaviest parts, like the boiler, were moved by the transfer table.

The machine shop was near, but normally in an independent building. This layout was imposed by the necessity of a long and complicated system of mechanical transmissions operated by a steam engine. Movements were transmitted to machine tools through belts. Alfred Williams described one of those characteristic shops at Swindon Works as it follows:

> «The fitting sheds are large buildings and are packed with machinery of every conceivable shape and kind. Within them are lathes large and small, machines for slotting, shaping and drilling, drills for boring round and square holes, punches and shears, hydraulic tackle, and various other curious appliances almost incapable of description. There are hundreds of yards of steel shafting, pulleys ands wheels innumerable, and miles of beltage [...] To view the interior is like peering into a dense forest where all is tangled and confused and everything is in a state of perpetual motion. » *in:* Williams (1915), *Life in a Railway Factory*

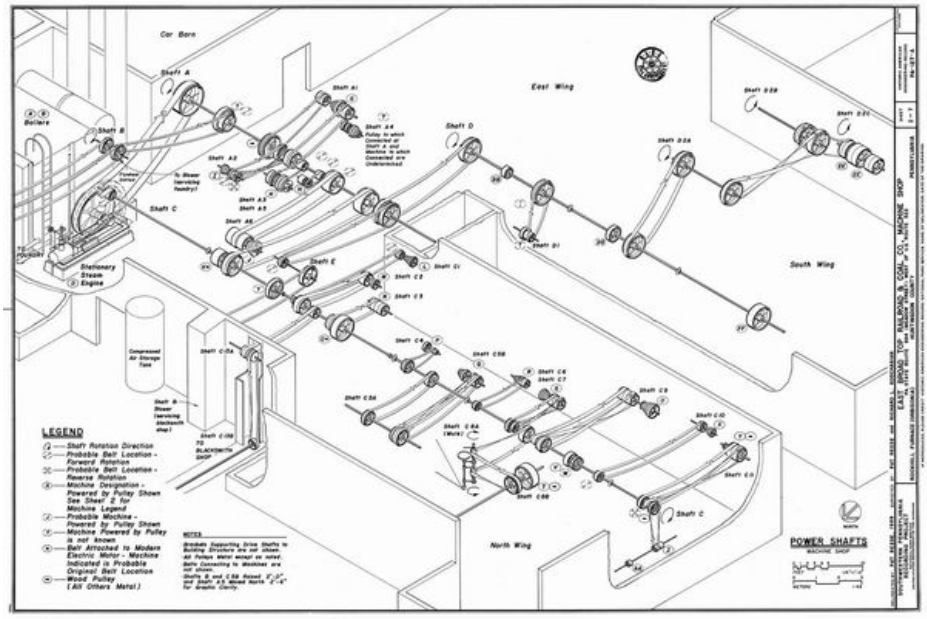

Image 2: Transmissions and belts diagram in a small machine shop.
East Broad Top Railroad & Coal Company. HAER PA-127-A

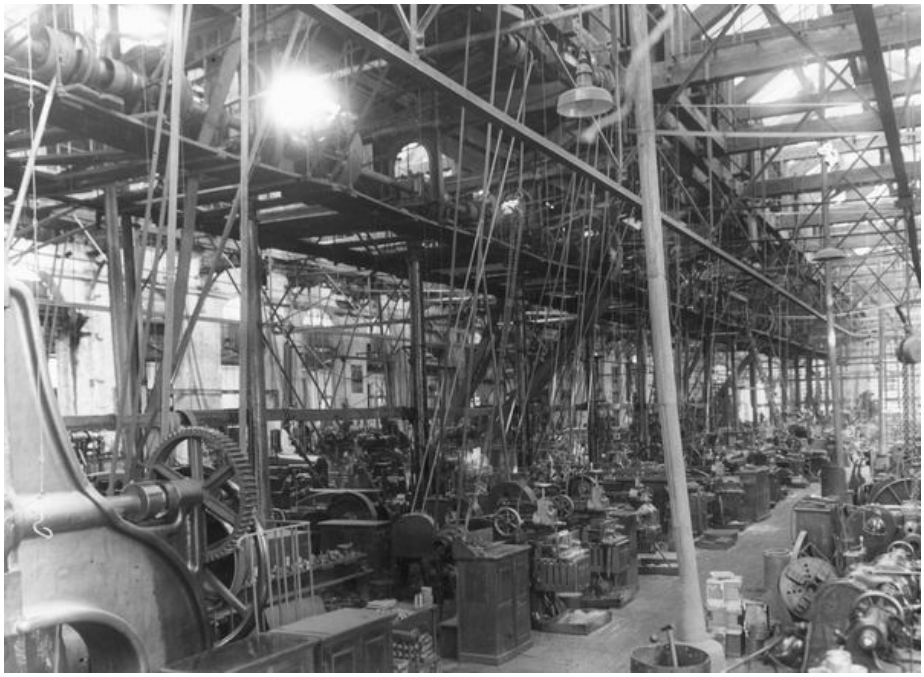

Image 3: Old machine shop in Valladolid Works (Spain). 1950's

In the layout of locomotive workshops the importance of the transfer table remained undiminished until 1900, despite difficulty and long time needed for operating inside and frequent breakdowns as a result. The arrival of electricity gradually imposed a new more compact layout (natural light is no longer essential). The main building, now including erecting, boiler and machine shops tends to a longitudinal layout, with long erecting tracks parallel to the building long axis. Transfer of elements is made by overhead electric travelling cranes working into groups or isolated, at several levels. In this way, the erecting, the boiler and the machine tool shops are now arranged following the productive process phases.

Although there are a lot of examples to illustrate this layout, German Braunschweig Works, built for the reparation of *Reichbahn* standardized locomotives is a particularly interesting one. These workshops were

described in a 1929 journey report of a group of Spanish engineers. The layout allowed the introduction of streamlined work, with the suitable arrangement of specialized machines and workers to undertake heavy repairs in eleven one working day phases.

> «In earlier shops the use of the transfer table was the principal factor in determining the most practical lay out in providing communication among the buildings. The introduction of the powerful overhead travelling crane, capable of lifting the heaviest locomotive, is shown to have modified the arrangement of buildings. » *in: Railway Shop Up to Date* (1907)

But this little example is useful as well to understand that analysis of every particular facility is very complex. There were longitudinal erecting buildings equipped with overhead travelling cranes before electricity arrival, but only in the greatest world workshops like Altoona (*Pennsylvania Railroad*) or Crewe Works (*London & North Western Railway*). Those travelling cranes, however, were inefficient, because they were not powerful enough and they frequently broke down. In addition, in many cases, old transversal buildings coexisted with new longitudinal ones.

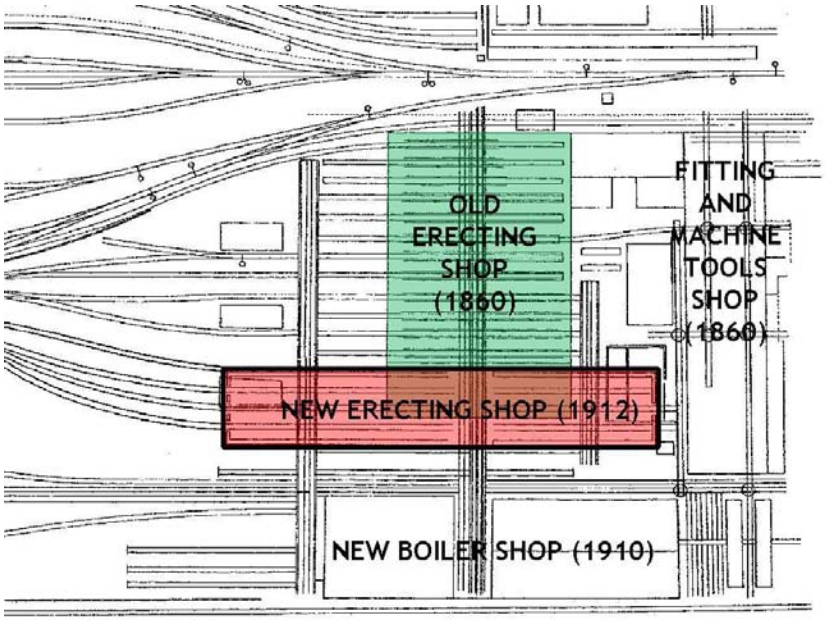

Image 4: Emplacement of new erecting shop in Valladolid Works, 1912.

It is also remarkable the different viewpoints sometimes found depending on whether the information source is American or European. Regarding the longitudinal design of erecting shops, J. Davis Barnett wrote by the end of the XIXth century:

> «The European practice of making the erecting shop narrow compared with its length, using three (or at most four) longitudinal tracks, and spanning them for their whole length with overhead power traveling cranes, has not often been adopted in America, although we have specimens at the Canadian Pacific Ry., Montreal, Altoona, West Burlington, Indianapolis, Roanoke, and at Hamilton, Ont. » *in:* Barnett (1889), «The Design and Construction of Railway Shops»

Nevertheless, this layout was called the "American type" by Galine (*Exploitation technique des chemins de fer,* 1901) and other contemporary European engineers, despite American practice, even after electricity, was plenty of transversal buildings for the erecting shop, although equipped with electric overhead travelling cranes.

As a matter of fact, it was electric power that made longitudinal layout buildings to be preferred and so widely adopted.

In short, railway workshop engineers were conscious of the main problems of their old facilities and the modernization of technical elements was generally undertaken by railway companies, if not quickly, at least as soon as particular circumstances made it possible.

It did not happen the same way with the other great industrial change of the XXth century: the scientific management.

ORGANIZATIONAL MODERNIZATION: THE SCIENTIFIC MANAGEMENT AND RAILWAY WORKSHOPS

Like technical advances, the new organizational methods were widely known but, contrarily, railway companies did not adopt them equally, because they rarely believed in scientific management as the best way to do the work with the available resources.

Spreading ways of knowledge about new methods would be basically the same as for technical advances: visits to foreign facilities and technical journals and magazines, some of them worldwide known (*Revue Générale des chemins de fer*, *Railway Gazette* and others). Far-reaching articles like «Note sur l'organisation du travail dans les grands ateliers de locomotives de la Compagnie du chemin de fer d'Orléans», by Marcel Bloch, published in 1925 in the *Revue Générale des Chemins de Fer*, caused a great stir originating quite a lot of comments and new articles. So did engineer's travel reports, usual in any railway company and sometimes having a great repercussion.

We will not analyze in this paper such a deeply and largely debated subject, and we will only point out some particular aspects concerning scientific management.

First of all, "scientific management" involves a wide range of processes and actions which should be individually studied, although they are often greatly related, such as scientific accounts, the space arrangement, the bonus system of pay, time and task analysis or supervising.

On the other hand, to study the application of scientific management principles in railway workshops it is necessary to consider at least:

- The financial situation and labour relations at the railway company at that time.
- Technical characteristics of tracks and lines, the type of exploitation and business strategies of the company.
- Technical knowledge of working process in every shop (in which parts of the process and to what extent could it be applied taking into account the great variety of tasks involved). Sometimes work is similar to mass production, but some tasks are almost handicraft.
- Real data that allow to analyze the impact of new methods on the final results, beyond official sources. At this point we find a general problem of historic studies: partiality of the information. In this regard, we cannot forget that publications or visits show just what they want to. They relate us all about success, but nothing about problems without solution; they would never say

for instance that a long, complex, expensive reorganization did not produce the expected results. Unfortunately, in most of the railway workshops this kind of historical data were missing.

We want to emphasize that the application of scientific management met a lot of trouble in both American and European railway workshops. Still in 1975, Leslie Waters wrote:

> «Much progress has been made in rationalizing labour utilization. Unfortunately, there are still countless ways in which resources are wasted. The odd rules in turn force management to adapt their decisions to the incongruities which, in turn, may make both operating practices and technological changes less than optimal. »
> Waters (1975): "Railroads from World War II to Date and Beyond".

In this paper we want to approach the main problems of work rationalisation in railway workshops: the kind of work to be done, the necessity of a great investment whose results were uncertain, the necessity of reorganizing the whole exploitation system of railway company, the necessity of solving ancient problems, the interest in work quality considered as a main principle, rather than quantity.

The first element to take into consideration is the kind of work entrusted by the company. Almost every railway company in the steam age had an enormous variety of locomotives, from several manufacturers, strongly differing one from each other in parts, maintenance and repairing methods. This problem becomes even worse due to the fact that most of the large railway companies grew by mergers or absorption of small railways, including locomotives and rolling stock. Finally, features of steam locomotives were also very different according to characteristics of railway lines or the way of exploitation of every company. As a result,

> «… sometimes the work resembled mass production... but most shop work was repairing existing rolling stock. There were many types of locomotives, freight and passenger cars. Although they had many common parts, there were countless variations in their structure, which mean that the work was more varied and required more skill than repetitive assembly-line mass production.» *in:* Graves (1981), «Applying Scientific Management Principles to Railroad Repair Shops-The Santa Fe Experience»

> «By 1883 the Sacramento Shops was maintaining 480 locomotives of 48 different types and from 15 different manufacturers. To maintain such a collection it would have been easier for shop staff to fabricate new parts than to stock and catalog spare parts for every type of engine...» *in:* Dougherty (2002), *Southern Pacific Company, Sacramento Shops*

Secondly, the application of scientific management required long time, large investment, the results were uncertain, and made much more complicated the organization of work. In addition to introduction cost, betterment in results should be enough to assume increased general operating expenses. Regarding this subject, French engineers Asselin and Collin, in a series of articles published in 1906 in the *Revue Générale des Chemins de Fer*, after a business trip in United States of America, wondered if application of modern methods of rationalization would not mean greater expenses than needed to acquire new material, enough to slow down the work in the workshops.

In third place, streamlining work in workshops involved the reorganization of the whole exploitation system of railway companies. To the ancient work quality objective there is now a new one to be added: the reduction of time devoted to heavy repairs.

In the United States, railway companies tried to make an intensive use of locomotives by increasing their services at much as possible which involved relatively frequent replacements of expensive material, and so reduction of the number of immobilized locomotives at workshops became a very important question.

But in most European railways during steam era the objective was to prolong useful life of locomotives as much as possible, and so, every locomotive had its own staff (engine driver and stoker) always servicing with it, as it is explained in almost every treatise on railways. Consequently, railway companies had a great number of vehicles, different in age or characteristics, which complicated the work, but allowed them to easily render train services. In this way, as the main objective of work rationalization in workshops, that is, reduction of locomotive immobilization time for heavy repairs, it was not so important, thus it was considered as more rational no to adopt all the principles of scientific management in workshops.

In 1933, a group of Spanish railway engineers visited several French and Belgian workshops. In the report of this journey, they described in detail the system of work at Tours Works (where Marcel Bloch had undertaken his changes), and they concluded that the success in application of that system in Spanish workshops were, at least, doubtful.

> «La disposición general de nuestros Talleres no permite la adopción de este sistema o por lo menos sería de dudoso éxito, y por ello tenemos que apelar para mantener nuestra producción a trabajar simultáneamente sobre mayor número de locomotoras, aumentando su estancia media, para el mejor aprovechamiento de la mano de obra.» *in:* Compañía de los Caminos de Hierro del Norte de España (1933)

The following data are an extract from the same report. Probably, this information is a somehow distorted view of the situation, but it shows that the reduction of average stay required larger facilities and more workers.

	Capacity (locomotives)	Workers	Monthly production (locomotives)	Average stay (days)
Épernay (France)	15-16	1.600	6-7	**28**
Hellemmes (France)	12-13	1.600	5-7	**27**
Tours (France)	13	1.300	8-10	**20**
Valladolid (Spain)	10	1.280	12-13	**60**

There is still another essential matter: to be successful in adopting scientific management, it was indispensable to solve ancient difficult problems, especially those concerning interchangeability of replacing parts and material, by means of a reliable supply and delivery system or a new space arrangement. In general terms, these are basic principles of Taylor's system, but in railway workshops they were present before Taylor and were not easy to solve.

Regarding space arrangement, as already seen in the technical section, it was always an essential problem, present from early activity in railway workshops. From the Auguste Perdonnet's *Traité élémentaire des chemins de fer* (1860) to any technical railway magazine , this problem was examined with great detail, as shown by the two following examples:

> «The relative positions of the several shops toward each other should be studied, with a view to make the journeys of the things which go from one to the other shop as short as possible; and also to work through any shop from one end toward the other, where successive operations are required on the same material. » *in:* Paine (1884), *Elements of Railroading*

> «Le varie sezioni dell'officina [...] debbono pure essere disposte con nesso logico al fine di rendere minimo il trasporto dei materiali che da una lavorazione debbono passare ad un'altra.» *in:* Opizzi (1913), *Ferrovie e Tramvie*

However, better arrangement inside railway workshops changed as time went by and always depending on available technical resources or work organization.

Other important question related to all the above mentioned is standardizing locomotives, rolling stock, spare parts, machine tools or supplies. Any official documents of railway companies, early referred to the importance of the standardization. Paine (1884) wrote: «nothing is more important upon a railroad than interchangeablity of parts in every thing which is subject to wear», but even in engines from the same builder interchangeability was rare. In the twentieth century it still remained as a heavy problem in most railway workshops, although some companies, as *Pennsylvania Railroad*, got it solved soon. The Altoona Works «introduced standard car designs in 1859, standard locomotive classes in 1868 and, with the establishment of the first railroad test department in 1874, standard product specifications.» (Peter Stott, 1990; *Pennsylvania Railroad, Altoona Works*, Historic American Engineering Record PA-108)

For those railway companies that solved the problem of standardization, and normally in new facilities, as the above mentioned case of Braunschweig (specially built to undertake the heavy repairs of only six types of locomotives), the introduction of the scientific management resulted in great success. But in many other cases starting from old facilities and a great variety of material, railway companies considered that the solution itself of these old problems would be enough to get a spectacular improvement of workshop efficiency, without going into more controversial or complicated subjects such as bonus system of pay or analysis of times and tasks.

On the other hand, the objectives of railway companies are different from manufacturers' Above quantity or rapidity, quality of work, and very specially the reliability of the vehicles put in service, was the main objective Asselin and Collin (1906, op. cit.), as they examined American railway workshops, wondered if quality would not feel the effects of the new methods. The following three examples, American, French and Spanish ones respectively, show how important this aspect was for railway companies:

> «When engines are bought from the manufacturers there are sometimes more frequent failures or small parts than upon the engines which are built in the shops of the railroad company, probably because such work is done by the piece in the manufactories and by the day in most company's shops.» *in:* Paine (1884), *Elements of Railroading*

> «Le système qui consiste à confier les réparations du matériel à l'industrie privée a été longtemps controversé. Les services de traction, qui trouvent le travail moins bien fait que par leurs propres ateliers, y son en général hostiles.» *in:* Bricka (1894), *Cours de chemin de fer*

> «Los obreros de los ferrocarriles producen, por lo general, menos que los de la industria particular, debido, por una parte, á la organización existente en las Compañías, que impide favorecer de un modo rápido á los agentes que tienen gran estímulo para el trabajo, y, por otra, á la constante atención del personal para fabricar todas las piezas del modo más perfecto y acabado, sin tratar de encubrir los defectos que presenta el material. Si los trabajos efectuados son más caros, tiene en cambio la garantía de construcción, y el que, con buenas

> herramientas, se puedan ejecutar las reparaciones en la forma y tiempo que más convenga á las necesidades del servicio.» *in:* Rahola (1913), *Tratado de ferrocarriles*

Application of scientific management involves much more complexity, with a lot of aspects to be taken into account such as systems of pay: either individual or collective, by day, by piecework, or bonus systems as proposed by Hasley, Gantt or Rowan (used in French railway workshops). Even in a lot of American workshops, railway companies never tried to introduce those systems of pay, as shown in the following examples:

> «The SP apparently never tried to institute piecework at the Sacramento Shops. At various times some shops [...] had quotas for individual employees. Other shops [...] worked on an assembly line and had a daily quota. [...] But this was not typical; generally jobs took as long as they took the workers were not generally pressured to work quickly». *in:* Dougherty (2002), *Southern Pacific Company, Sacramento Shops*

> «Emerson's work on the Santa Fe was not widely copied. To my knowledge, he introduced his form of scientific management to no other railroad. [...] The only other railroad whose shops were Taylorized was the Canadian Pacific, but this was engineered by H. L. Gantt. » *in:* Graves (1981), «Applying Scientific Management Principles to Railroad Repair Shops-The Santa Fe Experience»

Another aspect contributing to complexity was labour relations. As Carl Graves explained, the labour movement normally objected to the application of scientific management that, in its turn, was the answer of companies to the increasing importance of trade unions:

> «My research suggests that scientific management faced two obstacles in railroad shops, one from the workers and one from the managements. Were it not for stiff worker resistance, the system might have spread farther. Perhaps equally as important, railroad managements were often sceptical of major reorganization of their shop operations, for understandable and not-so-understandable reasons. The bonus system ended on the Santa Fe in 1918, not because the company decided that it was no longer useful but because it was under intense pressure from shopmen.» *in:* Graves (1981), "Applying Scientific Management Principles to Railroad Repair Shops-The Santa Fe Experience"

Scientific management was, in addition, a business answer against increase of trade unions. Again in Carl Graves' words (1981): «By introducing scientific management, the Santa Fe hoped to check rising repair costs, increasing union influence over shop work, and general deterioration in worker-management relations. »

Finally, the achievement evaluation of introducing scientific management in railway workshops can not be possible without taking into account technical characteristics of both railway material and the facilities built to repair it. In some works, where repetitive tasks resembled mass production, it was quite easy to apply new methods (manufacture of spare parts or rebuilding of freight cars), while in any others it turned to be really difficult, because they were more varied and required highly skilled workers. For example, the final assembly of the locomotive, on which reliability and high quality of repair works depended essentially.

> «The conventional steam locomotive was a robust machine comprising several closely interrelated major components, such as the boiler, the cylinders and engine motion, and the smokebox front end and steam passages. Their relationship needed to be well balanced to achieve optimum performance and efficiency which were also significantly dependent on the skill and effective teamwork of the footplate crew.» *in:* Larkin (1992), *An Illustrated History of British Railways' Workshops*

Even if scientific management had been put into practice to a large extent of the workshop, and affected, for example, 60% of workers, can we assert that it was a streamlining organization when the most important works depended on "the skill and effective teamwork" of workers?

One more time, it is curious to verify up to such an extent railway engineers were conscious of their own problems, and looked for possible solutions at the other side of the Ocean. Whereas European engineers when visiting American companies had great admiration for their good operation Charles Paine wrote:

> «The breaking down of the engine while upon the road occurs oftener than is creditable to our constructors or to our master mechanics. It is proper for the superintendent to expect, when a machine is sent out to take a train, that it will run through, without hindrance from defects in the machinery. It is said to be a rare occurrence in England or France to have an engine disabled upon the road, and this is affirmed upon the best authority... It seems, from the continual break-downs, as if no such lesson was taken to heart upon many American railways.» *in:* Paine (1884), *Elements of Railroading*

In short, the knowledge of organization new methods was quickly spread, but most of railway companies were reluctant to apply the methods in their own workshops because of financial difficulties or because their exploitation general strategies would get complicated, even though some elements of scientific management already existed at workshops longer before being formulated by Taylor.

> «L'effort de rationalisation du travail des dépôts et des ateliers a débuté bien avant que ne se manifeste l'influence des méthodes tayloriennes. Cet effort concerne tout autant la mécanisation des opérations, que l'organisation de l'espace ou la spécialisation des tâches. Son essor s'est trouvé limité par les contraintes financières et par une vision de la technologie qui associait le travail bien fait et la qualité du produit au savoir-faire ouvrier. » *in:* Caron (2003), «À propos de la rationalisation du travail dans les ateliers des compagnies de chemins de fer en France, 1880-1936»

THE EFFECTS OF RAILWAY MODERNIZATION SINCE WORLD WAR II

The Second Industrial Revolution, especially replacement of steam with electricity or petroleum products as source of power, reaches to rail. In the early years of the XXth century railway industry tried out new electric and diesel locomotives. After World War II, old steam railway traction gradually moved into diesel and electric type. Hegemony of steam would go down in History. North America adopted diesel locomotives quickly. The process in Europe was slow, and often electrifying the lines would be chosen instead. Anyway, the number of steam locomotives decreased year after year. By the 1970's most railway companies gave up steam for ever.

> «Steam locomotives were scrapped, given to museums, or turned over to park were children showed a great capacity to dismantle them.» *in:* Waters (1975), «Railroads from World War II to Date and Beyond»

New engines had many technical advantages. They were much more reliable and had greater autonomy. Their maintenance was not so frequent and the facilities needed to do it were simpler than those for steam ones. As an example, thanks to double driving cab, changing the running direction was very quick and easy, and there was no need of special facilities (turn-tables or tracks arranged in triangle) to do it.

At the same time, new traction systems required fewer workers and railway business became less important for society and consequently less profitable; railways declined before road or airlines. Nowadays, railway has recovered certain importance thanks to urban transport and high speed trains, but new trains, normally self-propelled cars, need a new kind of maintenance, with the replacement of parts at set intervals to eliminate downtime. Facilities are better equipped than they were in the past, but they are smaller and simpler.

The end of steam age and the new circumstances reduced drastically the importance of great workshops. Nowadays, railways do not need huge highly specialized facilities, with complex layouts and several thousands of workers.

In addition, great manufacture firms, affected by those problems as well, have suffered a wide process of concentration in recent years. Great new transnational firms have extended their business from construction of new material (not only for railways, but also airplanes, ships and others) to repairing and maintenance of rolling stock.

As a result of those processes railway maintenance systems need to be reorganised. Concerning great own workshops some has been limited or relocated, but most old workshops have been closed or sold to external firms, and their workload transferred to depots or private contractors. When *British Rail* was born in 1948, the company had 49 "Main Works" coming from old railway companies: 18 for locomotives, 14 for carriages and 17 for wagons, although in some of the railway towns all three activities were undertaken. By 1992 only Eastleigh and parts of the Main Works in Glasgow, Doncaster and Wolverton, now under the title *British Rail Maintenance Limited* remained as BR ownership. Works in Crewe, Derby and York were sold in 1989, and now they belong to *Bombardier Transportation*.

In some cases, great industrial spaces remained in the heart of urban areas. Towns will provide those places with different uses, from parkings to apartment buildings or shopping arcades and occasionally railway museums.

THE END OF STEAM AGE

After World War II, the largest railway workshops were gradually reorganized to be adapted to the new traction material, mainly reusing existing buildings.

> «Diesels represented a radical technological discontinuity, since they did not share any significant technology or components with steam locomotives and since their manufacture demanded vastly different organizational routines and managerial competences. » *in:* Churella (1998), «Market Imperatives and Innovation Cycles: The Effects of Technological Discontinuities on the Twentieth-Century Locomotive Industry»

But electrical and diesel locomotives represented, as Albert Churella said, a «radical technological discontinuity», that required a new system of maintenance and repair, often new facilities, especially with regard to depots and daily service workshops, and a new staff. There was no need any more of many old jobs such as blacksmiths or tinkers, and new locomotives needed new skilled workers, like electricians and motor engineers.

Skill of workers is now less essential. Repair of modern locomotives is made mainly by replacement of standardized elements, manufactured in external specialized firms, which in some cases also designed and constructed the locomotives as well. Repairs can be made quickly, and final results depend on the technical resources available rather than workers' skill.

Steam locomotives were robust engines that could complete the journey, unless a really major failure occurred. But they were very susceptible to the temperaments both of their own machinery and the crew. Diesel and electrical locomotives are much more reliable. However, these engines can become completely immobilised by the malfunction of some components. To find the element which causes this malfunction can take longer time.

> «The story goes that if a steam locomotive failed, it required fifteen minutes to find the problem and eight hours to repair, while with a diesel, a failure led to eight hours of work finding the difficulty an fifteen minutes of repairs» *in:* Seely (1977), *The Construction of the Eire Railway System*

In addition, final quality of the works is always almost the same, and modern locomotives do not need so many heavy repairs. Locomotive maintenance can be scheduled, and it is not necessary to send it often to great workshops. Between two heavy repairs of a steam engine, it could run about 200.000 kilometres, but modern self-propelled cars run about 1.500.000 km.

Concerning maintenance system, the new locomotives made decentralized workshop organization economically desirable. Largest workshops tend to specialize in a few types of works (certain types of locomotives, rebuilding or remodelling freight or passenger cars) and gradually the size of these great workshops declined. Self-sufficiency, typical way or production in railway workshops, is given up. At the same time, small service workshops grow and improve their equipment. The result is that differences between minor and major workshops are not the great gulf any more. When steam locomotive disappeared, railway workshops looked for less spectacular and more commonplaces.

In recent years, new maintenance models have spread. These new models follow the same tendency to increase equipment and decrease staff. The traditional corrective maintenance pursued to solve breakdowns, when there was a failure. Now, new methods look for avoiding appearance of the breakdowns (preventive maintenance), and try to determine, by a detailed analysis of incidents, the weak points of engines (predictive maintenance). Now, railway maintenance is moving into systems which include all these types.

Image 5: Development objectives in maintenance activity, from presentation document of *Matenimiento Integral de Trenes* (Spanish railways Business Unit for maintenance and repair locomotives and rolling stock), 1997.

Anyway, even though diesel and electrical locomotives made railway workshops lose their dominant role, they will remain as an important element of rail business for the rest of the twentieth century.

Railway workshops have increased their workload by updating old-fashioned cars or self-propelled cars, and, in some cases, expanding their works to foreign clients.

At the same time of technical changes, there are other aspects to be taken into account, especially the decline of the railway as a way of transport and the entry of largest manufacturers firms into repair work.

RAILWAYS: A DECLINING BUSINESS

As the twentieth century went by, rail lost its role as almost universal way of transport in competition with roads or airlines. This subject may not be new to anyone. After World War II railways went trough a lot of problems, profitability of business strongly decreased and became, in the case of private companies, to bankrupt, compelling governments to get involved into revitalization programs, the same as for government. In most rails, the abandonment of loss-making lines has been a usual fact.

The decrease of financial capacity still made worse the situation of railways own workshops.

The last decades of the twentieth century rail business has known, however, a small resurgence, thanks to urban intermodal transports and the high speed trains. But this resurgence has had limited effect on workshops.

Particularly important is the recent irruption of large manufacture firms in the area of maintenance. During last third of the twentieth century, a lot of workshops were closed, while others were privatized or sold; in the workshops still owned by railway companies the activity became more and more at outside arms.

First, the most important manufacturer firms have known a spectacular and fast process of concentration. Concentration is not unknown for industry nor for rail business. All great railway companies have grown by mergers or absorptions of smaller lines. Obviously, the manufacturers of rail material have suffered these processes as well. But in recent years, this aspect has reached so far. A good example is the trajectory of the largest rail equipment manufacturer in the world: *Bombardier Transportation*.

Rail Division of Bombardier was created in 1974, and was gradually grown. In 1984, Bombardier acquired Alco Power Inc, in 1989 it was the turn for ANF, the second French manufacturer or rail equipment, including its facilities in Crespin, and so did Bombardier with British, Canadian, Austrian, Mexican (Constructora Nacional de Carros de Ferrocarril), German (Waggonfabrik Talbot) and other companies. Since 1997 Bombardier has been investing in China. Finally, in 2001 Bombardier acquired *ADTranz*, and became the first worldwide firm of rail industry. *ADTranz* (*ABB Daimler Benz Transportation*) had been creating in 1996 as a result of the merger of *ABB Henschel* and *AEG Transportation*. In 1999, shareholder DaimlerChrysler bought ABB shares and renamed the company as *Adtranz DaimlerChrysler Rail Systems*. At the moment it was the second great manufacturer of rail equipment, but the first one, *Bombardier*, finally acquired the firm, as we have related previously, in 2001. Now, *Bombardier* has 41 productive establishments in 21 countries all over the world.

In the last third of the twentieth century, railway companies have closed plenty of old workshops, and the repair has been more and more entrusted to private contractors, that have widened their business from construction to maintenance and repair of traction and rolling stock.

We will briefly review the British case. In 1923 all British railway companies were merged in four Main Line Companies: *Great Western Railway*; *London, Midland & Scottish Railway*; *London & North Eastern Railway* and *Southern Railway*. Previously, two old workshops had been closed (Nine Elms Works and Longhedge Works, both in London area). After this reorganization of entire rail system, several old workshops were closed too

(Gateshead, Stoke Works, West Yard Works), but most of them went on with their activity until 1948, when the nationalization of British railways took place. The new railway company, *British Rail*, had a total amount of 49 Main Works: 18 locomotive works and 31 rolling stock works (14 for passenger vehicles and 17 for wagons), and a lot of subsidiary works. In 1962, BR transferred control of all main workshops to a new body, called *British Railways Workshops Division*, and 11 over their 17 locomotive main works were closed in the 1960's (in addition to Kilmarnock, already closed in 1959).

The *Transport Act* of 1968 allowed the railway to seek external contracts and in 1970 the Workshops Division was renamed *British Rail Engineering Limited* (BREL).

As a result of implementing the *British Rail Manufacturing and Maintenance Policy* for locomotives and rolling stock (May 1986), Swindon Works were closed too, and only five of the old Main Works remained in activity: Crewe, Derby, Doncaster, Eastleigh and St. Rollox (renamed as Glasgow Works).

British Rail opted for retaining control over its maintenance depots, because their work was intimately connected with running the railway. The activities of heavy repair, however, would be done by private contractors. In this way, during 1986 and 1987, light and intermediate repair work was transferred from BREL to British Rail depots, although British Rail retained Eastleigh Works, and, on a very much reduced scale, Glasgow, Doncaster and the rolling stock workshops of Wolverton. Finally in 1988 BREL was split into *British Rail Maintenance Limited*, which included its own depots and workshops retained by *British Rail*, and *British Rail Engineering Limited* whose workshops still in activity (Crewe, Derby and, for the rolling stock, York) were about privatisation. The large mechanised foundry at Horwich Works was sold separately in 1988. In April 1989, BREL was purchased by a consortium made up by the Swiss-Sswedish conglomerate ABB (ASEA-Brown Boveri) and other investors, creating BREL Ltd. A little later, ABB bought all shares to create ABB Transportation Ltd. As we have previously related, ABB Transportations Ltd. subsequently merged with Daimler-Benz to form ADtranz, and as a result, since 2001 the workshops at Crewe and Derby and the rest of Bristish Railway workshops belong to *Bombardier Transportation*.

One more example of recent history of railway own workshops is the Portuguese experience. In 1992, the CP (*Caminos de Ferro Portugueses E. P.*, now *Comboios de Portugal*) created a subsidiary firm (EMEF; *Empresa de Manutenção de Equipamento Ferroviário, S.A.*) with the workshops at Porto, Barreiro, Entroncamento and Figuera da Foz. Later, in 1994, the maintenance workshops were integrated in EMEF too.

In other countries, like Spain, after having closed some old workshops in the 1980's, the railway company keeps on being the owner of workshops, as a separate business unit, although there are several mixed firms between the railway company and private contractors. So, manufacturers like CAF (*Construcciones y Auxiliar de Ferrocarriles*) are more and present in repair and maintenance activities. In its web page (http://www.caf.net/ingles/compania/index.php), it is said: «CAF not only manufactures and supplies equipment; it also offers maintenance, upgrading and overhaul of vehicles and components, after sales technical assistance, operation of administrative concessions, and financing».

Only a few old large rail workshops remain in activity. After the end of steam age, great railway workshops lost their fundamental role as a result of the modernization of the rail business.

CONCLUSIONS

Nearly all the railway companies had a little number of large facilities to undertake the heavy repairs of their own locomotives and rolling stock. The great railway workshops have always partaken of industrial as well as railway worlds, and both of them have been undergoing deep modernizing processes.

Even though during the XIXth and the first half of the XXth century the product, that is the steam locomotive, had no significant variation, railway workshops were affected by the great industrial changes in the early years of the XXth century. Two of those changes should have to be underlined: one of technical nature, occurred when electricity stopped being a scientific experiment to become an industry, and the other of organizational nature, when the new scientific management principles were formulated by Taylor and his disciples.

Concerning railway workshops, electric power had an effect not only on processes, but also on workshop layouts, since the new possibilities offered by technical advances required a different space arrangement. Railway companies were conscious of the main problems of their old facilities and the modernization of technical elements was generally undertaken, if not quickly, at least as soon as particular circumstances made it possible.

But railway companies did not adopt the new organizational methods equally, because they rarely believed in scientific management as the best way to do the work with the available resources. Applying Taylor's scientific management was very difficult, because of a lot of causes. So, although new methods of organization knowledge spread quickly, most of railway companies were reluctant to applying in their own workshops.

After World War II, old steam traction was gradually replaced by diesel and electrical locomotives. At the same time, motor vehicles progressively replaced railway as universal means of transport.

At the end of steam age, new smaller facilities with lots of new equipments and fewer working people were required. As a consequence, many ancient workshops simply disappeared or, through liberalization processes, were take over by great railway production Transnational Corporations irrupted in maintenance by means of strategic alliances with railway companies.

The property vacated by the closure of workshops has posed different sorts of problems. In Continental Europe larger workshops were normally located in an existing urban area, but in the United States or Britain, some larger workshops were located in a rural setting or isolated, and they have generated a new town in the surrounding area. Anyway, railway workshops, with thousands of workers in their staff, have often been the largest employer in the city. So, these establishments have an enormous significance in the history of the city and for an important number of townspeople. In addition, could be a heritage worthy of be preserved.

On the other hand, workshops take up a lot of space, now in a privileged location, in the heart of town. Their closure means a great opportunity in town's urban development. As a result, performances in these areas are always polemics and often unleash passionate controversies. There are many reusing examples of these spaces in Europe: cars parking, industrial states, civic centres, museums, shopping centres and more. Even, in some cases, there are such a lot of urban pressures that still active workshops are surged to move to outward sites.

In short, railway workshops have been special industrial establishments of exceptional importance in industrial as well as railway worlds. Today, despite his decreasing role into railway running, are facilities to bear in mind, not only by his technical function, but as urban or heritage value too.

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