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Energy and railway workshops: An archaeology of the FEPASA complex (Jundiaí, Brazil)

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Abstract

Railway workshops overlapped the fields of energy and transport and witnessed profound technological evolution over time due to changes in energy production, distribution and consumption. Here, I use archaeological methods to investigate the railway workshop owned by the *Companhia Paulista de Estradas de Ferro* in Jundiaí (Brazil), in operation from the end of the nineteenth century to 1998 and today known as FEPASA Complex. In doing so, I aim to highlight the role of energy and power supply in the evolution of railway workshops, and how this influenced its organization of space and labour. I state that, even when written sources are available and abundant, archaeology can offer an important angle to understand the transport industry.

Keywords

Archaeology of industrialisation, railway workshops, energy, railway heritage

Introduction

Several authors have addressed the relationships between railways, energy and technology,[1] also analysing its economic and social implications, including the labour force engaged in the industry.[2] Indeed, railway infrastructures and fixed equipment have been laboratories for large enterprises of organisation and innovation everywhere, and a lot has been written about them. And naturally,

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energy is central in the evolution of the railway as a 'large technical system'. Among others, two topics have been widely addressed: the electrification of railway lines,[3] and the emergence and development of the diesel or diesel-electric locomotive.[4] If the relationships between energy and locomotive traction have been the subject of many studies, and while the evolution of railway workshops has already been largely addressed,[5] there has been relatively little mention of how the adoption of energy power sources determined the spatial and technological configuration in railway workshops. The literature on this very specific topic is unfortunately still scarce,[6] especially on an international scale.

In addressing this research gap, I focus on the specific problems related to the production, distribution and consumption of energy. I largely rely on an archaeological approach. In doing so, I aim to highlight the role of energy and power supply in the reparation and maintenance of rolling stock and how energy systems spatially and organisationally shaped railway workshops. This research offers a case study on the workshop built in Jundiaí (São Paulo state, Brazil) by the *Companhia Paulista de Estradas de Ferro* (hereafter CP), later incorporated in the *Ferrovia Paulista S.A.* (hereafter FEPASA). This large workshop, today known as FEPASA Complex, was in operation from the end of the nineteenth century to 1998.

We can already count some works on the archaeology of railways,[7] though the benefits of archaeological methods need to gain more traction. I state that, even when written sources are available and abundant, archaeology can offer an important angle to understand transport past well beyond energy and transport history. Based on the engaging results of the archaeology of industrialisation,[8] this paper aims to be an original contribution in transport history and to present archaeological methods as capable of advancing our knowledge. In my eyes, the lack of a proper and larger archaeological investigation in railways is mainly due to the strong focus on distant past that characterised the emergence and development of archaeology all over the world. But archaeological methods are also capable of advancing our knowledge of transport history, especially when data from written, visual and oral sources are complemented with data from material culture, and when all the information available is cross-read on a physical space.

The marginal role of archaeology in the study of railways is even more visible in Brazil. Brazilian railways have been studied by many researchers, especially about São Paulo state.[9] In this state, with a couple of exceptions, a large amount of physical remains from the railway golden era contrasts with the poor archaeological analysis.[10] Naturally, the evolution of the use of energy, and more specifically, the electrification of railway lines and workshops, was different in each context following the economy, availability of energy sources, policy and adaptation of human power. However, and interestingly enough, the electrification of railways in Brazil started around the same time (1920s) as it did in several leading industrial countries, as well as its use for lighting and powering railway workshops, despite the fact that Brazilian industrialisation was a weak and late process.[11]

The Companhia Paulista and its workshop in Jundiaí (FEPASA Complex)

The first company to operate in the state of São Paulo was the English *São Paulo Railway* (hereafter SPR). The SPR had a crucial role in the industrialisation of the entire territory. With its main objective to facilitate the international exportation of the Brazilian inland agricultural output, in 1867 it opened a line between the city of Jundiai (*c*. 60 km north of São Paulo) and the Atlantic harbour of Santos.[12] The CP was founded precisely for linking the coffee plantations of Campinas territory (further north) with the SPR line (Figure 1). Established in 1868 by a group of landowners and entrepreneurs from Campinas as the *Companhia Paulista da Estrada de Ferro de Jundiahy a Campinas*,[13] the firm quickly became more ambitious and in the 1870s started to expand the railways further inland.[14] In 1912, after forays in river navigation as *Companhia Paulista de Vias Férreas e Fluviais*, the company adopted its final name: *Companhia Paulista de Estradas de Ferro*.[15]

Generally speaking, the CP was considered a model railway and the most successful private company with domestic capitals in the whole country.[16] However, it

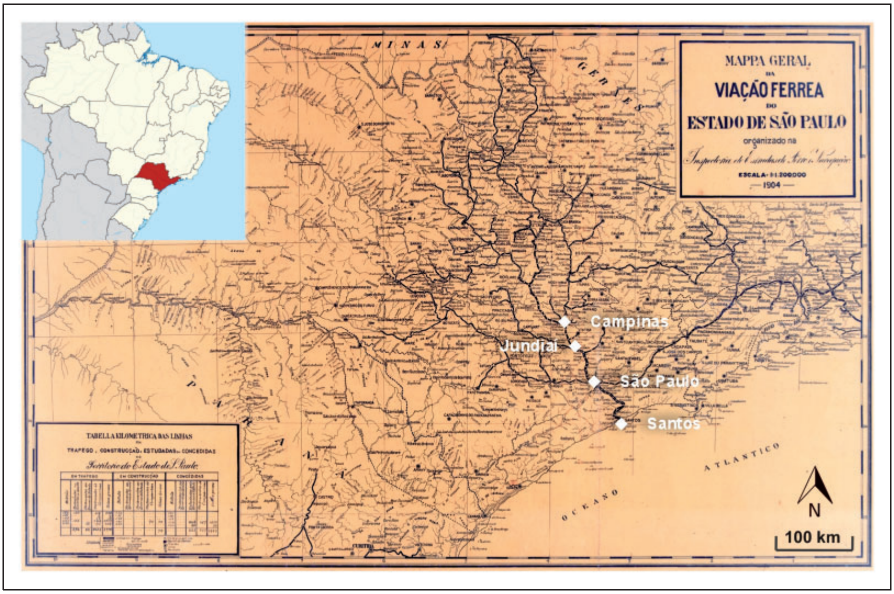

Figure 1. São Paulo railway network in 1905. Source: Author elaboration (Base map: *Mappa Geral da Viação Férrea do Estado de São Paulo*. Location map: TUBS, via Wikimedia Commons). Courtesy of the Public Archives of the State of São Paulo and of the Railway Memory project.

showed a strong overseas dependence and was incapable of avoiding the railways crisis that began in Brazil in the 1930s.[17] In 1961, having already suffered significant decline, the company was taken into public ownership, though this move did not stop the decrease of investments and maintenance on the network.[18] In 1971, the CP was incorporated into the FEPASA, as well as the other four railway companies that were still running in the early 1970s, as a final effort to revitalise the São Paulo railway system.[19] However, the structural problems of the network and the strong political and economic interests placed in motorways and the automotive industry, among others circumstances, condemned FEPASA to failure.[20] Privatisation came back in 1998 and brought a different model and a new phase to Brazil's railway history.[21]

In its heyday, the CP built a number of locomotive sheds and workshops all over São Paulo state in order to repair and maintain its rolling stock, which was mostly imported.[22] Among them, the one situated in Jundiaí played a major role. That workshop was built from 1893 onwards in a 145,091 m^2 area close to the starting point of the Jundiaí–Campinas line.[23] The original construction had a marked SE–NW longitudinal axis (305 m × 65 m). The space was divided into three sections: the northern area was equipped to work with wood (reparation of wagons and passenger cars), the southern for metalworking (steam locomotives) and the central segment space was allocated for warehouses and offices.[24] The workshops showed a continuous evolution until 1998, when the last railway operation coincided with the privatisation of the network.

Several major plans for the redevelopment of the complex have been projected since then. Due to the scale of the site (a municipal property since 2001) and especially to the financial crisis ongoing in Brazil in the second half of the 2010s, none of them has been completed. Facing these problems, the recovery of the complex and its historical and cultural values has been both partial and irregular. Some sheds and buildings have been adapted for cultural, educational, social and industrial new uses, with some architectonical restructuration. However, large parts of the complex remain abandoned and under serious degradation, despite the fact that the site was listed as a National Heritage in 2002. The future of the site, as a whole, is currently still uncertain.[25]

The steam locomotives and wheels workshops

The focus of this research is the sector originally used for repairing and maintaining the steam locomotives and train wheels (Figure 2).

This space has had various functions through time and also provides evidence of the use of different energy systems. Its state of preservation is semi-ruined and not deeply modified after the railway's operation came to an end, a situation which allows an on-site investigation about the role of energy in the outline of working spaces and routines. Aiming to achieve a more comprehensive understanding about the use of energy in the FEPASA Complex, I analysed the surface archaeological

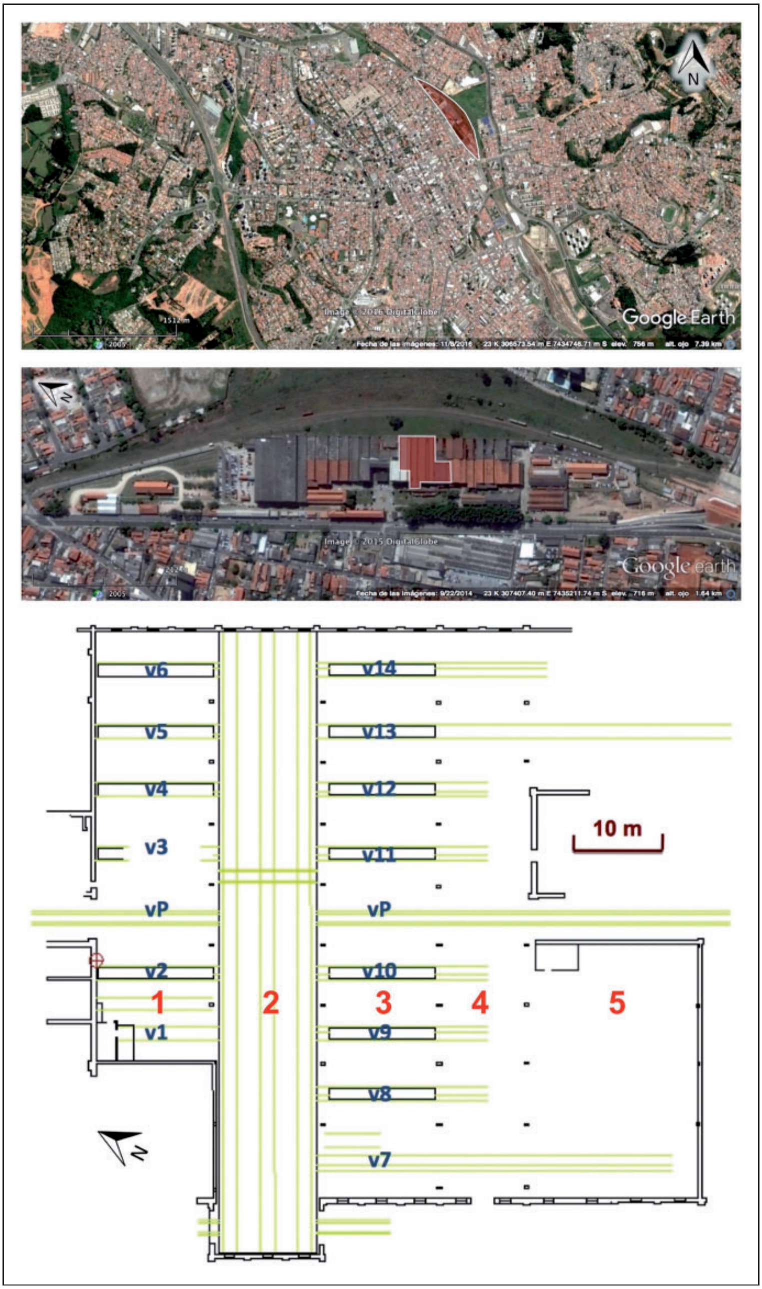

Figure 2. Location of the FEPASA Complex and of the case study, showing the spatial references (bays and rail lines) used in this article. Source: Author elaboration from *Google Earth*, 2016.

record, as much as data provided by other available sources, including a 1929 documentary film, interviews and written and visual archival files.

The steam locomotives and wheels workshop were located on the northern zone of the southern section of the workshop. That is the area selected as the study sample, which has a size of 3280 m^2. It comprises five different bays, all orientated in a NE–SW direction (*see* Figure 2, each bay numbered 1–5). The dimensions and characteristics of the bays are irregular: bay 1 measures 50 m × 14 m; bay 2's size is 71.5 m × 11 m, with traversing table; bay 3 has dimensions of 64.5 m × 14 m; bay 4 is 64.5 m × 9 m; finally, bay 5 measures 29.5 m × 19 m. This last bay is divided in two sections separated by a central building (I took only its westernmost section into consideration). Though there is no interruption between bays, it is possible to distinguish between two main areas, each displaying different physical configurations and functions. The three northern bays were the steam locomotive repair workshop. The two southern ones housed the wheel lathes.

The space in the locomotive workshop is organised around bay 2. The floor in this bay is 60 cm below the level of the rest of the workshops. Three broad gauge tracks (1.6 m) run parallel along the whole length of the bay (E–W axis) allowing a traversing table to circulate. This table, transversally set out, facilitated the distribution of the rolling stock among the tracks and inspection pits situated in bays 1 and 3 (labelled v1–v14 in Figure 2; *v* stands for *vía*, which means *track* in Spanish, the language used in the fieldwork survey). Initially, as can be defined by visual and written sources and confirmed by the archaeological record, there were sixteen tracks and pits, but some of them disappeared with the changing function of some parts of the workshop.[26] On the other hand, the traversing table is fitted with four rails S–N that form broad and narrow gauge tracks. In the SE side of the structure an iron platform protrudes. An electric motor (pillaged and in disrepair) and a control lever are located on this platform.

The space occupied by the wheel lathes workshop is not as homogeneous as the locomotives area. The eastern half of the workshop (from vP – a main rail line that passes longitudinally through the whole complex for internal distribution of the rolling stock, to the east) is in a ruinous condition. The western area was intensely refurbished in the mid-twentieth century.[27] Finally, an examination of the central building that divides bay 5 reveals it was an important place in relation to the production and consumption of energy. It has two floors and two different bodies: to the west, there is a 4 m wide passage for vP (*see* Figure 2); to the east, is the main body (12.5 m long). This structure also presents the general characteristics of the complex: stone baseboard and brick walls covered in green/grey and white paint. The second floor of the central building is not painted and rises above the roof of the bays (Figure 3).

Production, distribution and consumption of energy

It is possible to recognise the footprints of three different energy systems in the study sample: steam, electricity and compressed air. Hydraulic power had little

Figure 3. General view of the building that divides bay 5; eastern and northern sides of the ground floor. Source: Author elaboration.

presence at the FEPASA Complex, although some hydraulic tools can be seen in a short movie recorded by *Rossi Film* in 1929.[28] As it is explained below, these systems, which coexisted, shaped the space and work routines of the workshops.

Steam

In the beginning, the workshop was steam powered. According to some primary written sources, two engines provided the necessary power, one for the north wing and one for the south wing of the complex.[29] The development of equipment for the southern sector (metal works) was completed in September 1895. The CP purchased a high-pressure 60 HP stationary engine from the *C.H. Brown & Co,* based in Fitchburg, Massachusetts, USA. This was installed in a 44 m^2 compartment in the northern area of the southern wing of the complex. The engine was fed by two multi-tubular boilers, located in a 99 m^2 room. The boilers, manufactured by *Knapp*, each had heating surfaces of 30 m^2 and were fuelled with firewood. A 26 m high chimney, located in a patio at *c*. 20 m from the boilers, supplied the necessary air intake. Power was transferred to the main axis of distribution by four cotton cables, and from the secondary axes to machinery by a system of shafts

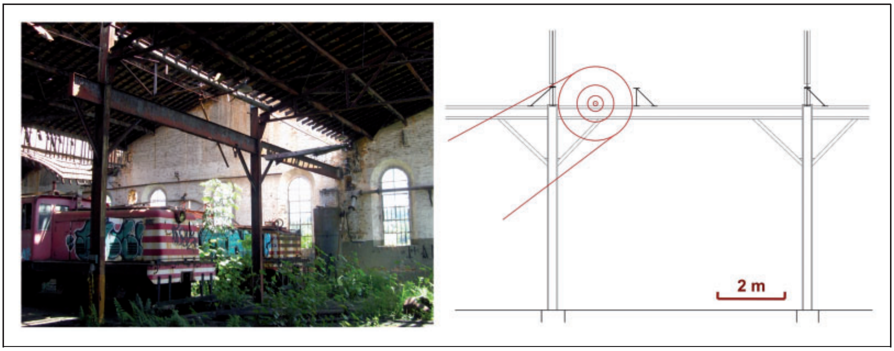

Figure 4. Evidence of the use of steam energy in the study sample: possible infrastructure for the power transmission system. Source: Author elaboration from BMCP, box 358, 1892–96. Courtesy of the Library of the *Museu da Companhia Paulista*.

parallel to the longitudinal axis (e.g. south–north) of the complex. The shafts rested on a series of supports installed on the steel pillars of the bays.[30] The engine for the northern sector (which was devoted to woodworking) was near to the central building in which warehouses and offices were situated. It was a 45 HP compound engine and exclusively served the carpenter's workshop, with the waste used as fuel. In this case, the transmission was underground.[31]

The material evidence for this steam energy system is almost non-existent. According to some primary sources, the *C.H. Brown* engine and its boilers were located on the ground floor of the central building that divides bay 5.[32] It is difficult however to recognise the transmission of the original system of power, although, possibly, the transversal steel beams still observable today in the western area of bay 4 were related to this last function. As can be seen in the original blueprints for the construction of the workshops,[33] pulleys hung from transversal beams inserted in the steel pillars of the bays (Figure 4).

The traversing table is the piece of equipment that best shows the transition from steam power to electricity. Purchased in 1895 (together with a similar one for the boilers workshop), the table was able to transport up to 80 t and was connected to the general transmission system of the southern workshops.[34] In some pictures published at the beginning of the twentieth century, it can be seen that bay 2 was equipped with a system of cables and pulleys anchored to the floor (Figure 5). This infrastructure may have drawn the traversing table over the tracks.

Electricity

The workshop had electric lighting since its inauguration in the 1890s.[35] Different kinds of lamps still hang today from the roof trusses. Among them, several are metallic and circular with a white enamel layer inside. These lamps might be

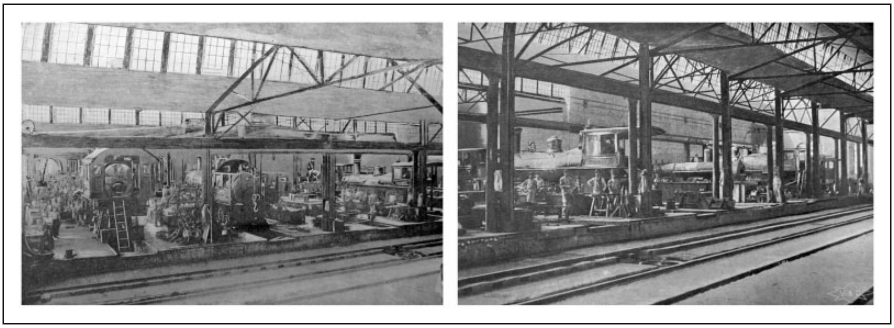

Figure 5. Pulleys for the traversing table in the floor of bay 2. Source: Pinto, *Historia da Viação Publica de São Paulo*, pp. 193 and 197.

original – at least, they seem to be identical to those filmed by *Rossi Film* in 1929. According to Pinto,[36] the electricity for illumination was produced by three dynamos: one 10 kW unit (auto-moved) and two 6 kW units (powered up by a 16 HP engine). As a matter of fact, the CP had consumed electricity since its very foundation. The company had used electric telegraphs since 1869,[37] as well as electric lighting for its first buildings in Campinas (railway station and workshops) since April 1886.[38]

Beyond the infrastructure for illumination and communication, the purchasing of engines and other electric equipment started in 1905. The main aim was to replace the initial energy distribution system of cables, shafts and pulleys with a new one, more direct and independent, facilitating a redesign of previous work processes.[39] CP annual reports do not specify the final destination for electric materials bought in that period, so it is not possible to indicate which ones were installed within the study sample. The first piece that we know with certainty existed therein is a 70 t bridge crane that was installed in bay 1 in 1913.[40] Nonetheless, steam power was not totally discarded due to the arrival of electricity for power: still in 1941, for example, a new steam hammer was installed in the workshops.[41]

As would be expected, the use of the new electrical equipment increased the consumption of electricity. This made it impossible for the CP to continue being self-sufficient with its own dynamos. Since 15 November 1905, electricity for lighting was provided by the company *Luz & Força de Jundiahy*.[42] Later, from 1922 onwards, the CP began purchasing energy from the *São Paulo Tramway, Light & Power Co* for its first electric line: Jundiaí-Campinas.[43] We do not know if the cited electricity companies could also have supplied electricity for the equipment used in Jundiaí's workshops. In any case, the energy consumed by these machines was not produced in the complex. There is evidence of several electrical substations, but none of a power station. According to some witnesses,[44] a main substation reduced

Figure 6. Main electrical substation of the complex: Source: Author elaboration.

Figure 7. Partial view of the transformation substation in the upper floor of the building that divides bay 5. Source: Author elaboration.

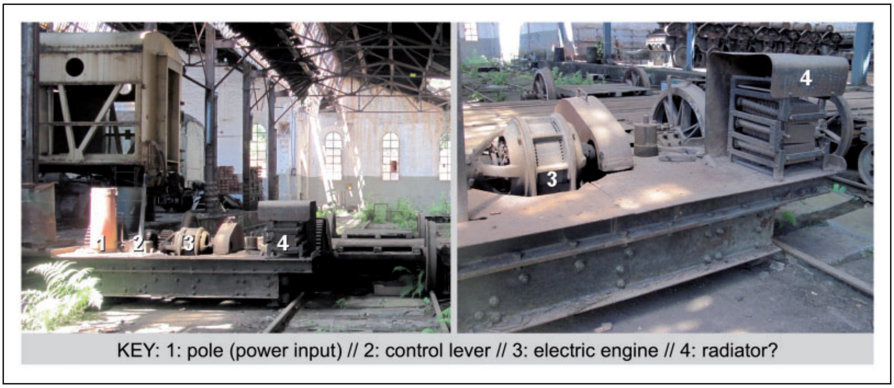

Figure 8. Electrification of the traversing table in the steam locomotive workshop. Source: Author elaboration.

the electricity received in the complex to 2200 V (Figure 6). From there, the current was directed to three secondary substations equipped with several transformers, where it changed to 380 and 220 V. These figures coincide with information readable on the equipment preserved *in situ*.

The substation for the southern section of the workshops was installed on the upper floor of the building that divides bay 5 (Figure 7). The preserved equipment located here was purchased from the American company *General Electric*. Documentary sources confirm that this equipment, together with a pair of transformers from the Swiss firm *Oerlikon*, were already in use in the 1930s.[45] Electricity came from the main substation and travelled through a three-phase high-tension cable (2200 V), isolated and buried, which is still visible on the western wall of the central building. On the same wall there are two small square openings. These probably allowed the wiring carrying transformed current to leave the substation building, but these wires no longer exist.

The infrastructure for the distribution of electricity runs along the roof trusses and perimeter walls. Several stretches of wire extend down the walls until reaching junction boxes, sockets or other points. These wires also descended the steel pillars and were plugged into the machines (the latter not being preserved). Most of the wiring is gone, but its original position can be tracked through the many porcelain insulators that remain preserved.

As has already been pointed out, considering the systematic pillaging of machinery, the traversing table is the element that most clearly represents the transition to an electric power system. Close to its SE end, an L-shaped iron platform was added to install a *General Electric* engine,[46] fed by a pole connected to an overhead power cable. This equipment is only partially preserved, but it can be seen complete and in operation in the movie by *Rossi Film*. This provides a dating *ante quem* for the electrification of the traversing table: 1929. More specifically, it is possible that this

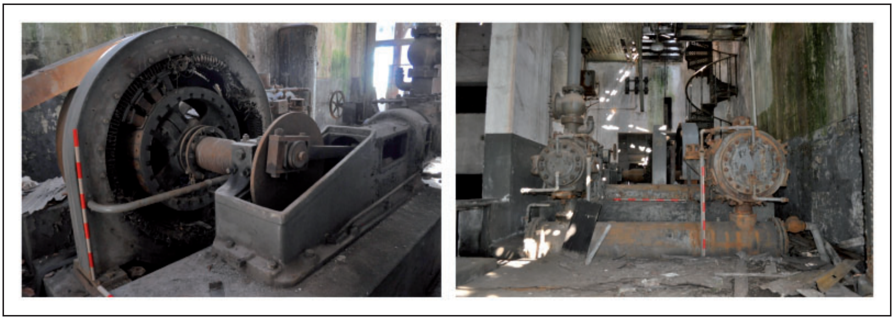

Figure 9. Air compressor in the ground floor of the building that divides the bay 5. Source: Author elaboration.

transformation occurred in 1907. The CP's annual report for that year shows several expenses for '*carretão elétrico*' (electric traversing table), although the source does not indicate its destination (Figure 8).[47]

Compressed air

The installation of the compressed air network, initially fed by *Westinghouse* brake pumps, began in 1905.[48] The purchase of pneumatic materials continued during the years that followed, including compressors, tools (machines for painting, drills, hammers, etc.), freight elevators and cranes.[49] According to the physical remains and ground plans preserved in the Library of the *Museu da Companhia Paulista*,[50] the southern section of the workshops had two compressors: one located in a small shed situated at the SE end of the complex; the other situated on the ground floor of the central building that divides bay 5, in the place initially occupied by the steam engine. This installation, integrating a closed circuit, was already in use in 1932.

Thus, the building in bay 5 is again a key space when taking into account archaeological evidence for the use of energy. There, one can see a compressor built by the American company *Worthington*, equipped with *Mason* regulators and run by a *General Electric* engine (Figure 9). The air was distributed through a network of pipes and tanks manufactured by the CP itself,[51] which is still partially preserved. One of these tanks, cylindrical and composed of riveted iron sheets, may be observed between bays 3 and 4. The distribution pipes go over the walls and the tops of the steel pillars. Several tubes go down the walls and pillars to deliver air to tools, running underground for several meters. The physical configuration of these pipes and tubes and their spatial relation to the tanks and compressor leave no doubts about their interpretation. In any case, the knowledge of the compressed air system may be confirmed and expanded by visual sources (Figure 10).[52]

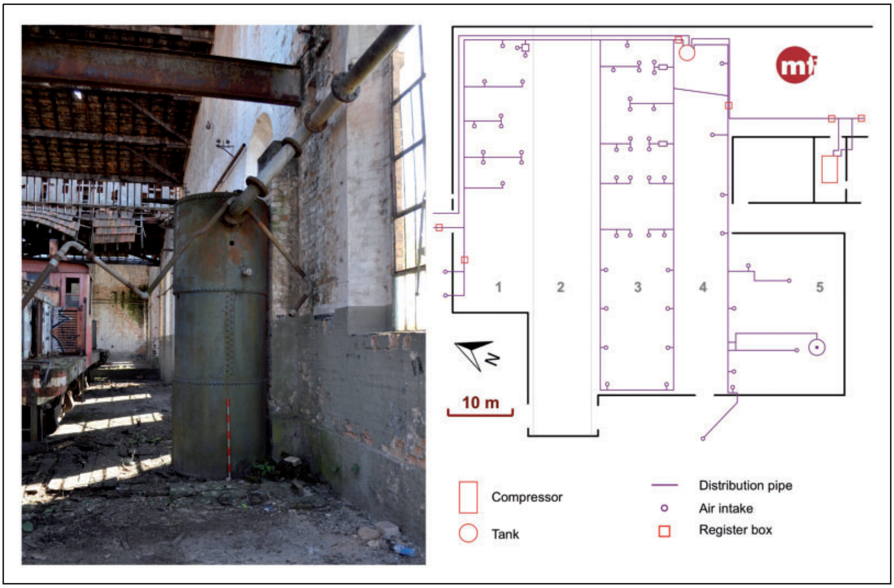

Figure 10. Compressed air in the study sample. Left: Tank between bays 3 and 4; it is possible to distinguish the supply pipe (big one) and distribution tubes (smaller ones): Right: Diagram showing the air distribution network in 1966. Source: Author elaboration. Source: Author elaboration from BMCP, G17D–3732. Courtesy of the Library of the *Museu da Companhia Paulista*.

Interpretation and discussion

Generally speaking, railway workshops were standardised industrial installations. The abundant bibliography on the subject clearly shows that the same morphologic characteristics and spatial configurations are easily traceable in many examples all around the world.[53] This did not impede variations. It is also important to bear in mind that the FEPASA Complex was mainly used for repairs and maintenance of rolling stock and not for constructing locomotives. Nevertheless, main or central repair workshops and construction shops usually shared many common features. This is especially true for the steam era, when railway workshops were designed not just for repairing rolling stock, but also to manufacture any necessary pieces, making them industrial complexes with a strong tendency towards self-sufficiency.[54]

At the FEPASA Complex, the initial use of steam energy determined a specific spatial configuration in which the machines, and the working areas, were arranged lengthwise in the complex (S–N axis) in order to allow access to the shafts and pulleys,[55] while the arrangement of tracks inside the building reinforced this spatial configuration. Thus, in the beginning railway workshops displayed a lineal organisation of work.[56]

Although during the first decades of the twentieth century steam locomotives did not change substantially, the arrival of electricity as a source of energy brought important changes to railway workshops, as well as the contemporary reorganisation of work inspired by Taylorism.[57] While an analysis of Taylorism in railway workshops is not a goal of this paper,[58] it is also worth noting that the arrival of electricity could have further fuelled a Taylorist supervision of the labour force.[59] Among other elements, electricity brought a more centralised working space, and that made control easier. We can still detect two features likely employed for organising and supervising work in the study sample: first, a wooden and glass hut (about $5\,m \times 3\,m$) attached to the eastern perimeter wall of bay 5; second, a two-story space abundantly opened by rectangular windows in the northern wall of bay 1. Their physical characteristics and the stratigraphic relationship between them and other elements indicate that they are later constructions. Both of them could have been installed to organise and supervise the work after some of the rearrangements that took place in the wheels and locomotives sections due to the arrival of new technologies and energy sources.[60] This would indeed confirm a change of pace also in the work force control, fuelled by new energy sources.

On the other hand, as shown previously, more than neatly distinct phases in the use of different energy sources, the FEPASA Complex displays how power systems coexisted. Changes related to electrification were gradual, and often related to different uses: first lighting; then locomotive handling within workshops (traversing tables, bridge cranes, etc.); and then machine tools with independent engines.[61] So, the timing and the impact of those electrical systems were also different, triggering changes, but also facing inertia and, overall, a long process of change, with overlapping energy regimes.

Generally speaking, electric bridge cranes favoured a comprehensive redistribution of the sections of assembly and repair of locomotives. With them, a new longitudinal model substituted the original transversal one, organised around a central traversing table. In the new system, the bridge crane was the key piece (as the traversing table had been before), since it was utilised to distribute the locomotives among the longitudinal tracks on which they were repaired.[62] This new system is observable in many examples around the world, including the Valladolid (Spain) workshops,[63] or the Eveleigh Locomotive Workshops in Sydney (Australia), once the largest railway workshops in the Southern Hemisphere.[64] However, such a shift *did not* take place in the FEPASA Complex, where the traversing table continued to be a key element also *after* the arrival of the electric bridge cranes. There, the sheds composing the workshops are settled perpendicularly to the main axis of the complex and to the direction of both tracks and inspection pits (S–N). In other words: it was possible to make a bridge crane to circulate following the tracks in the longitudinal axis only by demolishing the original steel frame structure, which was out of question due to the renewal costs.

The adoption of electric engines for machine tools was slower and faced inertia, but in the long run those machines played a decisive role in the transformation of railway workshops, both in sense of spatial configuration and labour routines. The introduction of the electric engines brought a more flexible spatial distribution of the machine tools, which outpaced the previous lineal organisation of the workspace.[65] These changes are traceable in the wheels workshop of the FEPASA Complex, which changed to a much more centralised pattern of machine distribution after the arrival of the electric engines.[66] However, this took some time to be accomplished: in the 1929 film by *Rossi Film* the old shafts and pulleys can still be seen in operation. Actually, in the lathes and wheels sections, these changes were remarkably slow. Sometimes, an electric generator replaced the old steam engine, although it continued working with the same infrastructure of shafts and cables, so the distribution of the machine tools remained the same.[67]

Beyond electricity, this case study seems to reflect that changes brought by compressed air were minor when compared to those related to electrification. The introduction of compressed air machines was complementary to the electrification of railway workshops in many cases, including the FEPASA Complex. There, compressed air arrived at the same time as electric equipment. Both technologies were part of the same modernisation plan, implemented just a decade after the inauguration of the complex. This plan aimed to optimise the performance of both machines and workers in the face of the increasing cost of personnel during the initial years of the twentieth century.[68]

Compressed air machines modified the way in which locomotives were repaired, especially considering the time and effort invested in the different tasks. But they did not change the spaces for doing so. As one can see in the case study here presented (*see* Figure 10), the air intakes were distributed along the inspection pits already existent, so there was no modification of space. On the other hand, in the wheels' section the compressed air network was small and complementary to the electric machine tools.

In contrast, the arrival of electric and diesel locomotives brought new and deep changes to railway workshops.[69] For the maintenance of the new machines, which was much simpler,[70] some companies reused the buildings already available, while others preferred to build new sheds, as was the case with the CP. From the 1920s onwards, the CP erected other buildings on the northern sector of the workshops for its electric (first) and diesel (later) rolling stock.[71] But this is a different matter and it is out of this case study.

Finally, a brief comment on how new sources of energy also influenced labour routines must be made. At the FEPASA Complex, energy systems and their related spatial distribution models seem to have had different effects on the working routines carried out in the locomotives and lathes sections. The first one never had a significant number of machine tools. There, the impacts of new forms of energy were limited to handling infrastructure and to the incorporation of a few pneumatic and electric machines, while the spatial distribution remained (almost) the same. The change of function of this area to the repair of bogies and diesel engines in the 1960s obviously involved new working routines,[72] but the tasks developed here did not change when the pneumatic tools replaced the manual ones. In the lathes and wheels sections, machine tools were much more numerous. In the steam era, the energy transmission system obstructed the space and limited the movements of both materials and workers. The arrival of electric engines brought not just more centralised spaces, but also more open and better illuminated ones, all of which helped to improve the work processes and the efficiency of labour.[73] At the FEPASA Complex, this kind of space simplification and task optimisation started in the 1930s.[74] From then onwards, the equipment of the wheels workshop was progressively reduced,[75] which could indicate the adoption of simpler working routines as the use of electric equipment grew.

Conclusion

Railway workshops, as well as mining sites and other industrial installations,[76] are interesting samples to investigate industrialisation and globalisation processes. The FEPASA Complex still preserves the material footprints of these processes as much as its changes throughout time. We have seen how the use of different energy sources (steam, electricity, compressed air) was a slow process of adoption and adaptation according to national and local circumstances. Even more, each company had its own agenda, and moved in a very particular set of social, economic and political environments. This is clearly noticeable in the case of the CP. At the beginning of the twentieth century other railway workshops in the area, like those of the *Companhia Mogiana* in Campinas, were built fully electrified,[77] while the CP chose steam for the first phase of operation of its workshops in Jundiaí. The initial use of steam power was justified by the reuse of the machinery originally installed at the first CP workshops in Campinas,[78] and also by the fact that the boilers of Jundiaí ran on firewood and wood waste, materials that were cheap and easy to get in Brazil at the end of the nineteenth century. So, while energy was responsible for some important shifts in railway workshop management and spatial configuration, it is still possible to trace a strong continuity and resilience dictated by the particular circumstances of each company.

The data presented in this article demonstrate that electricity was responsible for the most important changes in railway workshops. Such changes were incorporated gradually, especially in the case of those workshops that were already in operation before the arrival of electricity. In them, it was more usual that the pre-existing installations were adapted for the use of the new source of energy without significantly modifying the general structure of the buildings,[79] as is observable in the FEPASA Complex. In any case, electricity (complemented with the new pneumatic and hydraulic tools) allowed a more flexible arrangement of machinery, so that the spatial distribution of work became more centralised or concentrated. All of that turned railway workshops into more efficient and economic work centres. It may be concluded, then, that the production and distribution of energy were key elements in the layout of workspaces and routines in the railway industry, as well as in other sectors. Further, the choice of a certain energy system, or the combination of two or more of them, was determined by the efficiency required to run a profitable business.

In this vein, the archaeological approach used in this paper (and backed by other sources) lets us define the FEPASA Complex as an industrial installation that was not behind the times, despite the fact that the electrification of its equipment was slow. The workshops had electric illumination from their opening in the last decade of the nineteenth century. Soon after, electric bridge cranes were introduced. The arrival of this kind of infrastructure to railway workshops often demanded new constructions,[80] but the archaeological evidence in Jundiaí states that, in other cases, refurbishments of the pre-existing buildings were preferred: bay 1 clearly shows the marks of increasing the height of the ceiling to make room for an electric bridge crane in 1913.[81] Finally, the case study also displays how electricity allowed machine tools to be located in a more flexible way and how this permitted the creation of new workspaces and labour routines.

The analysis of the material evidence in the FEPASA Complex revealed some interesting data too, that is sometimes not contained in other sources. Among other advances in knowledge, it helped to identify the manufacturers of the technologies used in the workshops, most of them from overseas (Europe and North America); to explain the evolution of space; to date extensions and refurbishments; or to understand the main (electricity) or secondary (air compressed) roles of the different sources of energy traceable in the complex thanks to their physical remains and their spatial relationships. In other words, archaeology does not just verify the facts registered in the traditional sources used to study contemporary energy and transport history (written, visual and, more rarely, oral ones). It also allows us to achieve a more comprehensive and diachronic interpretation of the spaces related to railways in the general framework of a globalised industrial world, especially when all the sources available are spatially cross-read.

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80. Lalana, 'Establecimientos de Grandes Reparaciones de Locomotoras a Vapor'.
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