

Article

The Resurgence of Education in Railway and Metro Engineering in Brazil

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Abstract: In this paper, an overview of the history of education in railway and metro engineering in Brazil is presented, including its beginnings, its apogee, its near extinction, and its return at the beginning of the 21st century. The trajectory of the Brazilian professional education began with the implementation of small railway workshops located along the railway which were outside of the regular education system. At the end of the 20th century, the economic crisis, privatization, and drastic reduction of investment led to the scrapping and almost eradicating of the Brazilian rail network, followed by the death of railway education in Brazil. In recent years, the railway industry was stimulated, giving way to large investments, impacting and creating new opportunities for development in Brazil. This was one of the fundamental aspects for the development of new professional higher education programs in the railway and metro sector in Brazil. The first project to be implemented in Brazil was the course on railway and metro engineering of the Federal University of Santa Catarina. This course aims to provide structured training in four main areas: vehicle design, operation, maintenance, and train and metro management.

Keywords: railway engineering; education; history; Brazil

1. Introduction

The sustainable growth of Brazil depends on the consistent development and quality of the rail and metro sector. Thus, it is important that new investments for the expansion of the railway and metro are combined with investments in education in order to further strengthen this industrial field in Brazil. The main issue for urban mobility has required resources for new lines of metros and regional trains, and discussions point to the need for passenger trains that connect regions with high population density. Aligned with international and national guidelines, there is a discussion about the educational structure required to train professionals who are able to increase the innovation and quality needed for the metro-rail area.

The naval and rail industries drove the Industrial Revolution. Together, they facilitated the movement of goods and people, as well as commercial and cultural exchanges, and the development of the capitalist system during the 18th century was accelerated.

In Brazil, until the early 20th century, trade depended primarily on rail, naval, fluvial, and port infrastructure. To bring development to remote coastal regions, from the 19th century and early 20th century, large investments were made in railways which drove the country in various directions, impacting and creating new development areas in inland Brazil.

In the mid-20th century, ground transportation gained strength and a new level of development was achieved. Trucks, buses, and cars represented the “modernity” of Brazil. This mode of transport was and still is very important in Brazil because it helped in the industrialization and the movement of urban centers, and it favored the development of regions and areas that were far from sea and rail transportation.

At the end of the 20th century, there came the breaking point for the rail industry in Brazil, as well as the educational centers with them. An economic crisis, privatization, and the drastic reduction of investments in modernization of both private initiatives and the federal government combined with the growth of road transport led to the scrapping and the near-eradication of the Brazilian rail network, which at the time had 38,000 kilometers of railway (currently 30,000 km of railway). In addition to this, education in the railway sector in Brazil was essentially defunct, limited to the training of maintenance in workshops of private companies. All this happened in Brazil, while in other countries there were investments in railways and metros integrated with modes of transport such as road, air, maritime, and inland waterways [1].

In the last 15 years, the railway industry was stimulated, giving way to large investments for railways and metro projects, impacting and creating new opportunities for development in Brazil. But despite the “boom” of the rail sector in the country, it was observed that even with the improvement of teaching practices and the level of training of professionals trained by the educational institutions, the discourse on the lack of a specialized high quality workforce in the railway industry is still encountered. In this way, understanding the importance of the rail and metro mode of transport to overcoming the barriers of infrastructure that hinder the development of Brazil, the opportunity to deploy new and innovative courses, the emphasis on innovation of the courses postulated in the restructuring and expansion programs of universities, and the ability of the Federal University of Santa Catarina (UFSC) to introduce into society the engineering topics for the new challenges of Brazil were the motivating aspects for the development of the educational project in railway and metro engineering at the Mobility Engineering Center at UFSC, Joinville Campus. This course aims to provide academic training to a

new generation of railway and metro engineers able to develop the metro-rail model highlighted among the main sectors of the national economy, helping to promote people and cargo transport with efficiency, low cost, and environmental concern within and beyond the borders of Brazil.

In this paper, an overview of the history of the relation between education and railway and metro engineering in Brazil is presented, starting with the near-extinction and return at the beginning of the 21st century through to the implementation of new projects and educational proposals.

2. The Professional Railway Education in Brazil

2.1. Initial Remarks

In the second half of the 19th century in Europe, the establishment of specialized services for the selection and improvement of staff for working on railways occurred. The expansion of railroads in Europe and other countries led to a growing need for staff to perform the required tasks to maintain and manage each railroad. According to Batista [2], for several decades, railway vocational training had been performed by their own companies, without methodological, technical, and professional assistance, without uniform and safe guidelines, and, as a result of the high level of empiricism, with slow and imperfect results. Therefore, it was necessary to introduce new processes, engendered under rational principles, whose application was based on speed, efficiency, and economy. That purpose was finally realized through the work of organizations created by major railroad companies for the study and organization and implementation of methodical processes of professional instruction. Over the years, according to the achieved results, there was progressive growth of the adoption of professional education by railway companies. At the same time, the services provided were also evolving and expanding their fields of influence and work.

The education service grew to include all functional categories of railway engineering such as the personnel of stations and offices, in addition to the operational staff from the workshops. This situation was due to the importance given to the application of psychometric procedures which the candidates were subjected to in the training schools, as well as the diffusion of courses in expert education [2].

Prussia stood out among the European countries who first thought of professional training for railway staff. This country introduced a professional education system for staff training on railways in the mid-19th century. In addition to Germany, other European countries applied special care to the methodical preparation of their railway staff, always aiming for better professional qualifications [2].

In Brazil, the creation of organizations dedicated to educating young people for working life dates back to the Imperial Period, between 1840 and 1865, when the “Casas de Educandos Artífices” (Houses for Student Craftsmen) were created in 10 different provinces. These houses took care of children and young people in situations of abandonment, giving them the basic knowledge of writing, arithmetic, algebra, sculpture, drawing, and geometry. They also were required to work with printing, tailoring, running a shop, carpentry, and shoemaking, among other things. After the learning period, under strong military-inspired discipline, the students had to work for another three years in workshops in order to compensate the costs of their education and, at the same time, earn a certain sum of money, which was given to the students when they left the house [3].

The trajectory of Brazilian professional education began with the installation of small shops, located along railway lines, where the students learned to perform minor repairs and/or manufacture some locomotive parts. Thus, the need for skilled craftsmen not only for the maintenance of equipment and for the manufacture of parts obliged the railways to create their own learning and training system. These workshops were outside the regular educational system and they were not recognized or validated nationally as educational institutions. According to Zucchi [4], the education in these facilities did not use any methodology. The students, when reaching a certain age, became full professionals. The craft was learned based on the observation and imitation of others. Therefore, it was not a favorable place for learning new techniques and improvement them. There also was no type of selection or evaluation of personal skills.

On reviewing the literature addressing the themes of the railway and metro in Brazil, we reviewed reports, analysis, comments, and documents that demonstrate decisions made in politics, economy, culture, strategy, and so on, throughout a period of many years. These readings were important for understanding the themes and identifying the historical and cultural elements concerning vocational education for the railway and metro in Brazil [5–14].

2.2. The Pioneers on Railway Education

The first attempts of professional education for the railway were introduced by the creation of a school for apprentice craftsmen in the early 20th century by the Central Railway of Brazil (The “Estrada de Ferro Central do Brasil” was one of the principal railways of Brazil, uniting the states of Rio de Janeiro, São Paulo, and Minas Gerais). Due to the results achieved, this company expanded its educational services by introducing new courses, increasing its efficiency, and improving its teaching methodology on railway subjects.

In 1924, the “Escola Profissional Mecânica no Liceu de Artes e Ofícios de São Paulo” (Professional School of Mechanics in the Arts and Crafts School of São Paulo) was created. This creation led to a broader project, introducing the “Centros Ferroviários de Ensino e Seleção Profissional” (Railway Vocational Education and Selection Centers). They were technical schools created by various railway companies in the state of São Paulo, aimed at training young railroaders. Educational practices in these centers were differentiated from other educational institutions by the adoption of methodical progression, the manufacture of parts, and machinery maintenance.

In 1931, the Railroaders Course commenced in the Sorocaba Professional School in the state of São Paulo. Soon, the private sector of the railway companies had received support and grant aid from the São Paulo state government. In 1934, the Railway Centers for Professional Education and Assortment were created by the Department of Education and Public Health and the Department of Transportation and Public Works. This initiative rapidly expanded throughout São Paulo, serving as a model for similar initiatives in other parts of Brazil [15]. In 1937, there were already nine centers located in various cities in Brazil. Such schools held directly focused courses for staff training workshops. This expansion led to the rise of the “Serviço Nacional de Aprendizagem Industrial” (National Industrial Apprenticeship Service or SENAI), an international benchmark in professional education.

According to Salvadori [16], beyond the new educational situation in the country, the railway industry was also impacted by the Organic Laws of 1942, in which two decree-laws were directly

related to professional railway education. The first one expanded the powers of SENAI, extending its services to the railway sector; the second determined the creation of educational services by official enterprises. Subsequently, in 1943, by Decree-Law 5607, the Brazilian government established the Education and Professional Guidance Services for all railways administered by the Union, standardizing the type of apprenticeship service. Thus, the creation of vocational education became mandatory for all railways, private or governmental. Therefore, from 1942, through legal provisions, vocational railway education was regulated. In practice, it changed little for the railway companies, since the educational services had been sponsored within the utilities of national and international railways, moved by the need to qualify their workforce.

It is necessary to understand the involvement of the “Escola Profissional Mista” (Mixed Professional School) in Sorocaba and the “Centro Ferroviário de Ensino e Seleção Profissional” (Railway Center for Professional Education and Selection or CFESP) in São Paulo state to fully understand the origin of railway courses in public professional education in Brazil, or specifically in the state of São Paulo. These initiatives were focused on practices idealized by entrepreneurs, engineers, and teachers for professional railway teaching.

2.2.1. Railway Professional Education in the “Estrada de Ferro Sorocabana”

The relevance of vocational courses for the training of railway workers with specific curricula, vocational testing applications, and stages in learning did not pass unnoticed. Educators, engineers, and participants from the “Instituto e Organização Racional do Trabalho” (Institute and Rational Organization of Labor or IDORT) drafted a proposal to facilitate its expansion. This plan was based on a partnership plan between the railways and the professional education entities.

In 1924, The Professional School of Mechanics for railway workers was created by the Arts and Crafts Lyceum. This school for labor training was created for four railway companies and it was an enterprise that joined professional educational structure with business interests within a perspective of labor rationalization. This effort was inspired by rationalists' purposes and it stood out with its concern that the curriculum should be adopted [10].

At the time, the Brazilian railway network had 35,000 kilometers, with 150,000 employees, of which 70% provided services in sectors of vital importance to the railway system, such as repair of rolling stock, traffic control, and driving locomotives and trains.

Invited to head the newly opened School of Mechanics, Mange created laboratories for aptitude testing, kinematics, mechanical technology, and learning workshops. Also, he established an agreement with the Sorocaba, São Paulo, and Mogiana railways to form mechanical workshops as a way to facilitate the practical extension programs. The learning of mechanical skills was organized in a methodical series: the skill was divided into tasks which were arranged in order of increasing difficulty to be taught in conjunction with the related scientific and technical knowledge. According to Mange [17], the superiority of education through methodical series in relation to learning during the exercise of productive work was the fastest learning process and allowed the employee to get used to the industry discipline.

Once the maintenance shop of “Estrada de Ferro Sorocabana” was transferred to the city of Sorocaba, in 1930, a railroaders' course was created as part of the Professional Education and Selection Service of Sorocaba “Estrada de Ferro Sorocabana” (SESP).

The railroaders' course at Sorocabana had a duration of four years. The first two were dedicated to general and structural formation. The remaining two periods focused on specialized training [18]. Learning was organized by methodical series taking place in specially planned workshops and it was complemented by internships in railway locomotion workshops. At first, this rail course was also planned in order to produce useful parts for the railway, which served to cover the costs of learning and wages paid to apprentices. In 1931, there were 3534 utility parts produced for the railway [18].

In 1934, the federal intervener in the state of São Paulo, Armando de Salles Oliveira, through State Decree 6537, created the railroad courses and determined other measures such as the state contribution to the "Centro Ferroviários de Ensino e Seleção Profissional". It organized, under the state government auspices, courses in professional schools of São Paulo, Campinas, and Rio Claro, and it also created the Professional Education Centers in Jundiaí, Araraquara, Bauru, and in the Lapa district in the capital [19].

2.2.2. The "Centro Ferroviário de Ensino e Seleção Profissional" in São Paulo State (CFESP)

The "Centro Ferroviário de Ensino e Seleção Profissional" (CFESP) in the state of São Paulo was intended to be an organization based on rational technical and administrative standards. Based on State Decree 6537, in 1934, a functional organization was proposed to administer the professional education [20].

The CFESP also created railway courses in the professional schools of Campinas and Rio Claro and in the "Instituto Profissional Masculino" (Professional Male Institute) of São Paulo. In addition to continuing the courses in Sorocaba, it also proposed funding for the creation of professional training centers for rail courses in Jundiaí, Araraquara, Bauru, Bebedouro, and Pindamonhangaba.

According to Carvalho and Batista [21], the process used in railway courses stood out for the fundamental importance of the measures implemented in the learning workshops. It consisted of implementing a methodical series of operations, in ascending order of difficulty, for the apprentices' handicraft and professional development. For the authors, these transactions were made in a succession representing almost a biological development of vocational training.

To look at the practices of CFESP also involves considering the specifics of this school. Although this school would differ from the others of "regular" teaching, it adopted procedures which were clearly tied to education from that period: homogeneous class organization, selection of students, vocational guidance, grading, exams, belief in the regenerator role of education, links between school, education, hygiene, and health as vectors for nation building, and, in particular, the inclusion of knowledge generated by experimental psychology, then considered the foundation of a scientific pedagogy [21].

According to Cunha [22], the network of schools of CFESP were distinguished largely on schools of craftsmen learners from the federal system in many respects, including the restricted clientele (children of railroaders, mainly) and training for a restricted application (railways). Another difference was related to the pedagogy implemented. While schools of craftsmen apprentices did not have their own pedagogy for teaching crafts, seeking only to systematize the craft of practical standards, CFESP had the methodical series, the backbone of a pedagogy which has proven effective in achieving the desired goals.

Table 1 shows the proposed curriculum for the preparation of general education and professional training of the apprentices' rail courses.

Table 1. Proposed curriculum for rail courses of CFESP [23].

Culture	Subjects and Learning Workshops
General: in class; in lecture in charge of “normalistas” (woman trained in middle school to teach in elementary schools); consonant to the programs established by CFESP.	<ol style="list-style-type: none"> 1. Portuguese, geography and Brazilian history; 2. Arithmetic, trigonometry and algebra notions; 3. Geometry and technical drawing; 4. Elements of physics and mechanics; 5. Physical education.
Technique: workshop learning guided by CFESP; installed in the general workshops of railways.	<ol style="list-style-type: none"> 1. Practical work in learning workshops installed by the general workshop of railway; 2. Specialized technical classes.

From 1934 to 1945, CFESP served in selecting and training employees at various levels. The creation of courses in the various railways resulted from these activities, including the supplementary training of engineers in railway engineering, craftsmen instruction, and workers training for workshops and offices. In this center, instruments for the selection of personnel based on work “ergologicals” analyses were developed. The CFESP scope of action extended throughout the national territory. It covered, in 1943, 16 railway companies, controlling 75% of the traffic mileage and 87% of the national railway population. In these companies, 30 training courses, 54 preparation and improvement courses, and three superior courses of specialization were run [24].

Between 1945 and 1948, a transition process began. State Decree 14,550 of 1945 transferred the technical responsibility for oversight of the railway courses in professional schools from “Superintendência do Ensino Profissional” (Professional Education Superintendence) to SENAI [20].

2.3. *The Decline of Railway Education in the Country*

In the 1950s, the Federal Railway Network (RFFSA) was created, which unified 42 existing railways in Brazil as well as creating a regional system composed of 22 railways. The main goal of privatizing the RFFSA and Ferrovias Paulista S.A. (FEPASA) was to end the financial and labor troubles of the railways, mainly due to a lack of investment from Brazil in the 1980s and the 1990s.

Parallel to the creation of RFFSA in 1951, making use of some facilities (workshops) of the SPR (São Paulo Railway) was the creation of the Escola Profissional Ferroviária de Paranapiacaba (Paranapiacaba’s Railroad Vocational School). In 1954, the Escola Profissional Ferroviária da Lapa (Lapa’s Railroad Vocational School) was also founded. After a partnership agreement established between the railway company and SENAI, these two educational institutions, each with their own facilities, were given the names of Escola SENAI Ferroviária de Paranapiacaba (SENAI Railway School of Paranapiacaba) and Escola SENAI Ferroviária da Lapa (SENAI Railway School of Lapa). Later, in 1972, aiming at the unification of the two schools into just one learning center, Centro de Formação Profissional de São Paulo (São Paulo’s Vocational Training Center) was founded and, in 1975, with facilities in Lapa, it received a new name: Centro de Formação Profissional “Eng James C. Stewart” (Engineer James C. Stewart Vocational Training Center), which is currently functioning.

With the oil crisis in the 1970s and the Brazilian economic crises, the RFFSA became unsustainable. To change this situation, the railways under state control were privatized. Between 1996 and 1998, over 22,000 km of rail lines in Brazil (73% of the entire state rail system) were being transferred to

various private organizations, which signed 30-year concessions to operate the railway systems. In 2007, the RFFSA was officially extinct and the national railways were now managed by private operators who exclusively performed freight transportation.

Currently, the Brazilian railway network is obsolete, with old railway tracks and without using the logic of the shortest distance between two points. The passenger services have virtually ended, giving way to freight transport, e.g., the Vale S.A. and agricultural products, steel coils, logs, fuel, containers, coal from other companies such as América Latina Logística (ALL), MRS Logística S.A, Ferrovia Centro-Atlântica—Vale, and Ferrovia Teresa Cristina (FTC—The Railway Tereza Cristina S.A).

Daily long-distance transport services for people were restricted to the suburbs in the cities of São Paulo, Rio de Janeiro, Salvador, Maceio, Joao Pessoa, Natal, Recife, Fortaleza, Porto Alegre, and Teresina. However, there are still some railways used for tourism such as the Curitiba-Paranaguá, Paraná State; Campinas-Jaguariúna, São Paulo State; and the urban line of the Immigrant Memorial, in São Paulo city.

In this context and analogous to the situation of the national rail network, the education of the railway sector in Brazil was essentially defunct, and was limited to the technical training of maintenance in private companies' workshops and technical courses offered by SENAI schools.

In addition to the metro-rail maintenance technician course offered by The Eng James C. Stewart Center, other courses offered since 1980 by SENAI are the courses for railway technicians at SENAI/AL, assistant operator of railway machines at SENAI/VR, and the courses for rail maintenance mechanics, rail maintenance electricians, wagons mechanics, rail signaling, NR-10 (Safety in Facilities and Services in Electricity), station agent, drivers, and sustainers of permanent way at SENAI Railway School of Barra do Pirai/RJ [25].

3. New Pedagogical Projects of Higher Education in Rail and Metro and Engineering

In recent years, mainly from the 2000s on, the rail industry was reinvigorated, giving way to large investments in rail and metro projects impacting and creating new development areas in Brazil. However, despite the “boom” of the rail sector in the country, it was observed that even with the improvement of teaching practices and professional training, and the improvement of education in high school and undergraduate universities, there is still a lack of skilled labor in the railway and metro industry. The option to act on this area of knowledge was motivated by Brazil's need to implement, as soon as possible, the railway and metro infrastructure necessary to maximize the country's development.

New technical courses exist which are being implemented in Brazil: technical courses in railway maintenance offered by SENAI of São Paulo and the Federal Institute of the Espírito Santo (IFES); specialization courses at The Rail Research Center (Centro de Estudos e Pesquisas Ferroviárias, CEPFER) together with The Military Engineering Institute (IME/RJ), The Catholic University (PUC/RJ), and The University of Candido Mendes Campos (RJ). There are also several internal courses provided in the form of specific training within railway companies like America Latina Logistica (SA—ALL) and Vale.

Recently, there was the creation of two undergraduate education programs in railway engineering in Brazil. The creation of these courses can be considered a great event for education in the railway sector in Brazil. These two undergraduate programs are: (a) Railway Engineering and Logistics, Federal University of Pará; (b) Railway and Metro Engineering, The Federal University of Santa Catarina (UFSC), at the Mobility Engineering Center (CEM), Joinville campus.

3.1. Rail and Metro Engineering of the Mobility Engineering Center

The course on Railway and Metro Engineering at CEM/UFSC offers structured training in four main areas: vehicle design, operation, maintenance, and railway and metro management. The arrangement of knowledge of pedagogical projects was planned in order to prepare education and continue training in the area of railways and metros. The graduates of this course will be prepared to perform activities efficiently, will be trained to work in teams and to resolve technical and managerial failures, and will learn to provide solutions to other challenges which may arise in their profession. A major challenge which currently exists for educational institutions of research and industry is to encourage young people to seek necessary training to enable them to act as engineers in a company's metro-rail area. To develop a scenario analysis in a general and detailed sense, it will reveal the importance of deepening the technical, managerial, and operational knowledge of academic training for the stability of investments in the railway and metro transportation sector in Brazil.

3.1.1. The Pedagogical Concept of the Course

During the development process of the project at the campus of EMC/UFSC [26], initiated in 2008, questions were asked to justify the pedagogical projects of the course. Regarding railway and metro engineering, it was asked:

- Why is Brazil so deficient in rail infrastructure for freight and people?
- Why do Brazilian cities not have passenger rail: metros, trains, trams (modern streetcars)?
- Where is the train and metro industry? What materials do they use? What technologies do they have? What design methodology, production, operation knowledge do they have?
- Who prepares professionals for this industrial field? What do they teach?
- How many formal courses exist in technical schools and universities?
- How have the countries that have this mode of transport worked on these issues?

These issues raised the formulation of various hypotheses. Some were formulated in order to help understand the current state of the railway and metro mode of transport in Brazil. In this study, two propositions are discussed:

- (1) Brazil invested little in the metro-rail model because teaching and research institutions did not have the programs to develop the knowledge and the training of professionals for this model.
- (2) The education and research institutions in Brazil did not have programs and courses in the metro-rail area because this industry was weak.

Given this impasse, the UFSC implemented the course on Rail and Metro Engineering to produce professionals to break with the duality presented above. It was decided that the engineering courses would work with two main emphases: The first is centered in the vehicle area, called the course on Rail and Metro Engineering, with educational projects dedicated to clear knowledge in design, production, operation, and disposal of vehicles used for the railway and metro sector. The second emphasis is focused on the field of infrastructure, transport, and logistics, through the course on Infrastructure Engineering and Transportation Engineering and Logistics.

The following main topics are presented for the training of professionals in the Rail and Metro Engineering course.

3.1.2. Skills of the Rail and Metro Engineer of the CEM—UFSC

The course on Rail and Metro Engineering, being the first course with this focus in Brazil, is not regulated by the Resolution of the Federal Council of Engineering, Architecture and Agronomy [27]. The decision to create the course on Rail and Metro Engineering at UFSC, as previously mentioned, was due to the urgent need for Brazil to expand the use of this mode of transport and to help solve basic problems of transport infrastructure. To educate professionals with this knowledge, the curriculum should include subjects such as railways, railway stations, shunting yards, intermodal structures, business plans, the type of company to operate in this sector, types of machines, processes and metrology, types of materials, designs, *etc.*

Figure 1 summarizes the four major areas of the course on Rail and Metro Engineering at UFSC.

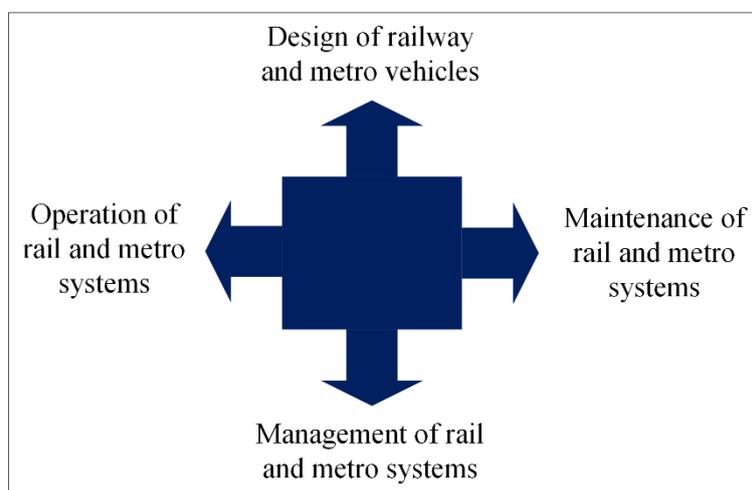


Figure 1. Main areas of the Rail and Metro Engineering course at UFSC-Joinville.

Thus, the graduate in Rail and Metro Engineering is prepared to act in railway and metro dynamics, design and maintenance of rolling stock (locomotives, cars, and wagons), maintenance and installation of pathways, materials for rail transportation systems and the metro, communication systems, signaling and railway and metro operation, railroad, prevention and investigation of railway and metro accidents, train and metro legislation, and management of metro-rail projects, *etc.*

3.1.3. Curricular Structure of the Course

The course structure was divided into two large groups of attributes, referred to as general and specific attributes [26].

The first of those is the general knowledge necessary to understand the specific knowledge relating to the railway and metro sector. This includes calculus, physics, linear algebra, statistics, thermodynamics, static, hydraulic and pneumatic systems, electromagnetism, electrical circuits, analogy electronics, heat transmission mechanisms, ethics and conscious discipline, evaluation of environmental impacts, safety and ergonomics, and the introduction and fundamentals of mobility engineering, among other approaches.

The second group, specific attributes, is related to the acquisition of knowledge and skills required in routine engineering activity, being offered in the form of disciplines and activities as shown in Figure 2.

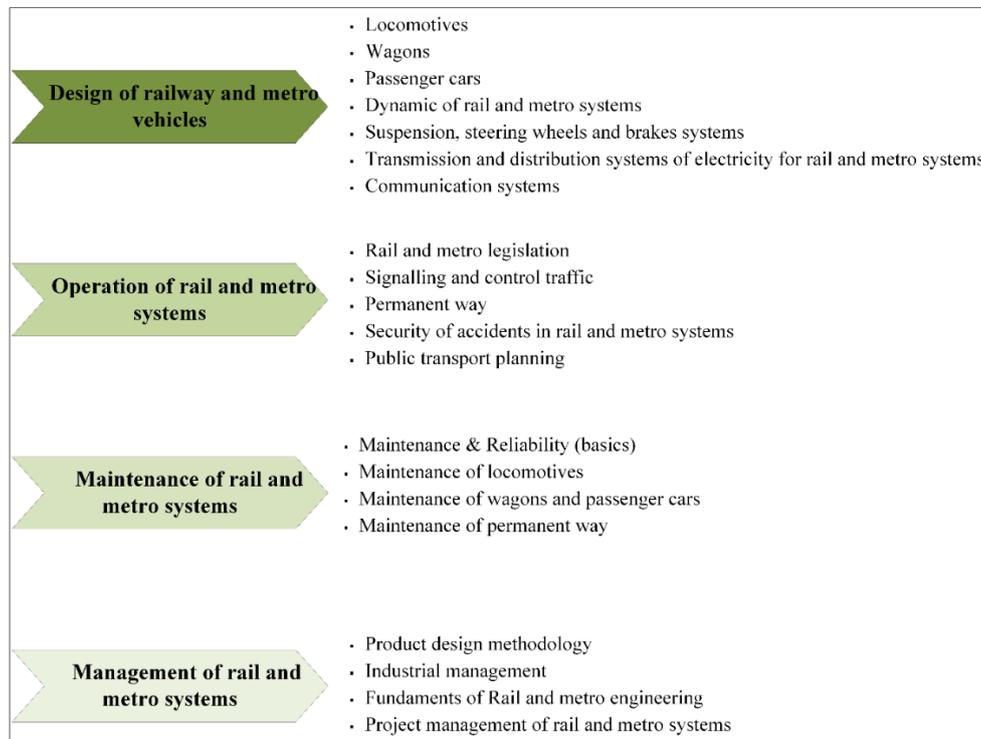


Figure 2. Areas and structural attributes of the course subjects of the Railway Engineering and Metro program at UFSC-Joinville.

The area of the project of the rail and metro vehicle consists of attributes such as working principle, system design, subsystems and components, construction, ergonomics, testing and disposal of vehicles (traction, cars, and wagons), and railway rolling stock and metro.

The area of rail and metro systems operation deals with operational planning issues of a railway, legislation, environment, personnel, operation, and safety, among others. Superstructure concepts and rail and metro infrastructure are presented, as are security settings, risks, accidents, analysis, reconstruction, and prevention of rail and metro accidents.

The maintenance area of the vehicle also includes maintenance of infrastructure, reliability, communication, training of people, and environmental topics.

The systems management area deals with the project management theme, product management, entrepreneurship, innovation, railway and metro marketing, public and private model railways and metros, investment analysis, quality, lean manufacturing, cost analysis of a railway, and metro investments.

Other skills also taught to students by teachers of the course include infrastructure transport engineering, transport and logistics, and mechatronics engineering.

3.1.4. The Professional Performance of the Engineer Rail and Metro

This is new professional training in Brazil. It will require new demands and generate some conflicts with the established professions such as mechanical or civil engineering, *etc.* Just as it happened with

other new engineering courses which were adopted in recent decades, such as environmental engineering, sanitary engineering, mechatronics, automation and systems engineering, computer engineering, *etc.*, this course will not be different from any new engineering course.

It is hoped that with this new engineering vision, teaching and research will influence the development of the railway and metro industry, the infrastructure of trains and metros, the modernization of transport, communication, the loading and unloading of devices, intermodal warehouses, the quality of cars, wagons, and traction machines, cost, safety, the use of new materials, new designs, *etc.*

Brazil already has a suitable industrial field to manufacture all the necessary items for the railway and metro sector. It also has a policy which supports large investments in railways for freight transport with great emphasis on rail infrastructure deployment and metros for passenger transport in urban and metropolitan centers.

Therefore, it is believed that with this new professional education and training, a new way of thinking about solutions for the infrastructure will occur. The graduates of the university together with teachers and researchers will be able to contribute to a new level of development for the transportation infrastructure in Brazil.

4. Final Considerations

Regarding the subject discussed in this paper, it was observed that professional education had important initiatives, most of which bore long lasting fruit in institutions. The teaching methods and vocational education products in Brazil have changed, especially with regard to industrial trades and manufacturing.

The few institutions dedicated to the essential teaching of handmade trades and manufacturing gave way to real school systems due to the initiative of state governments, the federal government, and private investors, with SENAI being the best example in this context.

The teaching methods before were exclusively empirical, or spontaneous, consisting of the reproduction of trade learning practices, which were also the subject of rationalization which, similar to Taylorism, contributed to the reduction of costs. It was in this context that the concepts of vocational education suffered, too, significant changes, both in their contents and in the form in which they were manifested.

The commitment to metro-rail education by higher educational institutions, with the potential for quality education, research at the postgraduate-level, and extension activities to transfer and exchange knowledge, showed the development of the metro-rail sector consistently and robustly, both from an operational point of view and an economic point of view.

Finally, teaching and academic research will enable the constant updating of existing technologies for developing the metro-rail sector, leveraging the industry at work in the country to compete consistently at an international level.

Author Contributions

The first author is the main researcher of this paper and coordinated the research efforts. All the remaining authors contributed equally on the research development, analysis of data, in the writing and review of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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