# Major Impacts of Learning Outcomes of Railway Engineering on the Operation Performance Indicators of the Egyptian Railways

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**Abstract**

The railways were developed in Egypt since 1854 by Jorge Stephenson who invented the steam locomotive in the Great Britain. However, many technical and financial problems affected the operational performance indicators of the railway industry in the last twenty years. One among others of those factors is the drop in the level and backward outcomes of learning of the railway engineering. Thus, the main objective of this paper is studying the qualitative and quantitative demand of the Egyptian railway industry for graduated engineers from the different universities and higher institutes. Also, the paper focuses on the main impacts of the railway education methodologies on the performance of the railway organizations such as Egyptian National Railways and Metro Companies. Analyzing the natures of educational areas and other courses of railway engineering in some local and international universities has been conducted in this paper. Several railway educational aspects and levels of the learning outcomes have also been compared among the local, European Union and North American universities. In addition to clearly illustrating the results of the analysis; selected outcomes of the study were concluded to propose proper solutions for the problem of the railway engineering learning and its influences on the railway safety and levels of the operational service in Egypt.

**Keywords:** Learning outcomes; Practical skills; Railway education; Railway industry

## 1. Introduction

There is no doubt that education and learning outcomes have great effect on the level of service and the performance indicators in the field of railway industry. At the last two decades it was observed that performance indicators of the Egyptian railway industry have declined because of several reasons (Khalil, El-dash and Adel 2017). One among others of those reasons is the drop in the level and backward outcomes of learning of the railway engineering. Learning

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outcomes in the European higher education are defined by (Bologna Working Group on Qualifications, Ministry of Science, Technology and Innovation, 2005) as statements of what a learner is expected to know, understand and/or be able to do at the end of a period of learning. (ECA, 2013) focused on learning outcomes and studied their impacts on quality assurance procedures in higher education. ECA`s first study included the general principles of learning outcomes in accreditation procedures. The second study that was conducted in 2010 included many recommendations for applying principles on learning outcomes in their accreditation procedures. Thus, ECA gathered the practices of different organizations in Spain, France, Denmark, Austria, Netherland, Swiss and Poland, described their profiles and provided contexts in which learning outcomes are taken into account to fully understand the different practices.

(EC, 2018) demonstrated that using a combination of the learning outcomes approach and student workload in program design and delivery puts the student in the heart of the teaching and learning process. Such an approach makes it clearer both to academic staff and students what they need to achieve. Furthermore, it helps in monitoring and rearranging programs, teaching material and methods of delivery to different modes.

Students should be able to practise engineering skills to complement engineering theory that is learnt through lectures. Practice-oriented learning experiences should engage students with the use of facilities, equipment and instrumentation reflective of current industry practice which will help in developing competence in executing applied and experimental work. Students should work in groups, preferably not more than four in a group. Throughout the program, there should be adequate provision for laboratory or similar investigative work, which will develop in the students the confidence to deal with applied engineering problems (ETAC 2016).

(Fiegel, 2013) recommends the incorporation of learning outcomes into the design of every course. The designed outcomes by that author developed for the described introductory geotechnical engineering course helped to improve course organization and more clearly define expectations regarding student learning. At least three basic approaches for estimating the quality of engineering education: Education program outcomes approach, Education potential approach, Education process approach (Miszalski, 2011). However, it was demonstrated that outcomes approach is the most preferable one. In the standards six categories of outcomes have been distinguished: knowledge and understanding, engineering analysis, engineering design, investigations, engineering practice, and transferable skills.

(Evtimova, 2017) demonstrated the importance of the rail higher education in the circular economy as well as the formation of educational programs worldwide with business partnership. Estimova explored the difference between teaching railway engineering and teaching other fields of technology. The reason of that fact is the interconnection between all fields of engineering in the railway system and as a result teaching railway courses should follow an interdisciplinary approach.

In this paper, the author analyzed the data collected about the capabilities and effectiveness of railway engineering education in most of the Egyptian faculties of engineering. Several railway educational aspects and levels of the learning outcomes have also been compared among the local, European Union and North American universities. In addition to clearly illustrating the results of the analysis; selected outcomes of the study were concluded to propose proper solutions for the problem of the railway engineering learning and its influences on the railway safety and levels of the operational service in Egypt.

# 2. Data Collection

## *2.1 Railway Educational Program in Egypt*

The mission of the railway engineering program in Egypt is to provide students with a broad and thorough education in railway engineering fundamentals, applications, and design so as to prepare graduates for the practice of railway engineering at the professional level with confidence and skills necessary to meet the technical and social challenges of the future and for continuing their studies at the graduate level.

### *i. Program Aims*

In pursuit of this mission, the educational objectives of the railway engineering program are summarized as follows:

1. To provide a broadly based educational experience in which the essential scientific and technical elements of the railway engineering curriculum are integrated with the humanities and social sciences to prepare students with competencies needed for personal enrichments, career development, and lifelong learning.

2. To ensure that the graduates have an understanding of the highest standards of personal and professional integrity, and ethical responsibility in the practice of railway engineering.
3. To ensure that the graduates are well trained in several systems of railway engineering, and are able to identify, formulate, and solve a wide range of railway engineering problems using modern engineering tools and techniques.
4. To provide students with a major design experience involving a team approach and alternate solutions, and incorporating realistic constraints that include economic, environmental, ethical, safety, social, and political considerations.

### *ii. Intended Learning Outcomes*

According to the National Academic Reference Standard, the program of railway engineering which intended in Shoubra Faculty of Engineering, Benha University satisfies the learning outcomes shown in Table 1:

**Table 1: Intended Learning Outcomes in Shoubra Faculty of Engineering**

| **Skills Description** | **Intended learning outcomes** |
|---|---|
| **Knowledge & Understanding** | - Recognize concepts and theories of mathematics and sciences, appropriate to railway engineering.<br>- Understand characteristics of engineering materials related to railway engineering.<br>- Understand principles of design including elements design, process and/or a system related to railway engineering.<br>- Recognize methodologies of solving engineering problems, data collection interpretation.<br>- Define quality assurance systems, codes of practice and standards, health and safety requirements and environmental issues.<br>- State current engineering technologies as related to railway engineering.<br>- Apply professional ethics and impacts of engineering solutions on society and environment.<br>- Recognize contemporary railway engineering topics. |
| **Subject Specific Intellectual and Research Skills** | - Select appropriate solutions for railway engineering problems based on analytical thinking.<br>- Think in a creative and innovative way in problem solving and design.<br>- Combine, exchange, and assess different ideas, views, and knowledge from a range of railway engineering sources.<br>- Assess and evaluate the characteristics and performance of components, systems and processes of railway engineering.<br>- Solve railway engineering problems, often on the basis of limited and possibly contradicting information. |
| **Transferable &** | - Collaborate effectively within multidisciplinary team. |

| | |
|---|---|
| **Generic Skills** | - Communicate effectively.<br>- Refer to railway engineering literatures. |
| **Subject Specific Practical Skills** | - Apply knowledge of mathematics, science, information technology, design, business context and engineering practice to solve railway engineering problems.<br>- Professionally merge the railway engineering knowledge, understanding, and feedback to improve design, product and/or services.<br>- Create and/or re-design a process, component or system, and carry out specialized railway engineering designs.<br>- Apply safe systems at work and observe the appropriate steps to manage risks.<br>- Apply quality assurance procedures and follow codes and standards.<br>- Exchange knowledge and skills with engineering community and industry. |

### *iii. Railway Education Facilities*

A survey has been conducted by the author on the state universities to identify the number of faculties, staff and departments where the course of railway engineering is taught and the types of available facilities. It was observed that number of presently Egyptian Faculties of Engineering is 21 faculties belonging to state universities and **9** faculties belonging to private universities in addition to a large number of high technical institutes. Records of the survey are given in Table 2. Laboratories of railway engineering are divided into 2 major types to achieve the requirements of the 4 systems of the railway engineering, i. e. track, signaling, operation and rolling stock. .

Railway operations laboratories are used for different kinds of teaching. The most typical use is to let students run operating sessions in which they staff control stations and run scheduled traffic for a couple of hours in accordance with the operating rules. This also includes doing all the paperwork, telephone and radio communications. To prepare the students for these operating sessions, they get specific lectures on operating rules. After a number of sessions, the students become quite familiar with the regular traffic and they have experienced several types of control technology, technical failures, maintenance works, and emergency situations may be part of the sessions. This provides almost unlimited resources for training ideas (Wendler, Grudzenski 2005)

**Table 2: Records of the Railway Engineering Education in Egypt**

| Description | No. |
|---|---|
| Total No. of surveyed faculties | 21 |

| | |
|---|---|
| Faculties where railway engineering is taught | 8 |
| Specialist lecturers of railway engineering | 10 (2 Associate professors + 8 lectures) |
| Departments where railway engineering is taught | Civil Departments only |
| Railway laboratories | Track Lab: 1 (Track Lab at Faculty of Engineering at Shoubra) |
| | Operation Lab: 0 |

## 2.2 Education of Railway Engineering in EU & USA

Most of the USA and EU universities that provide courses of railway engineering were surveyed by the author through searches on the WEB network to conduct a comprehensive comparison with the local learning of railway engineering. The records of the survey are summarized in Table 3.

**Table 3: Records of US and EU Railway Engineering Programs**

| Description | US | E.U. |
|---|---|---|
| Number of universities with railway programs (research and teaching combined) | 2 | 21 |
| Number of universities with railway research activity | 19 | - |
| Number of universities with railway courses | 12 | - |
| Number of railway courses offered | 19 | 260 |
| Number of railway courses offered per university teaching railway transportation | 1 to 6 | 5 to 20 |

### 2.2.1. Railway Educational Programs

#### i. Program Aims

Course of railway engineering in Southampton Faculty of Engineering as an example for selected railway engineering learning in EU aims to provide students with grounding in the principles of railway engineering and operations, giving them a comprehensive understanding of the main factors involved in constructing, maintaining and operating railway networks. Also, an example has been collected from Pennstate Altoona Faculty of Engineering, USA. Aims of this American course can be summarized as follows:

1. Be employed by industry or government in the fields such as design, development, operation, control, troubleshooting and maintenance of elements of the railroad system and infrastructure.
2. Assume an increasing level of responsibility and leadership within their respective organizations
3. Communicate effectively and work collaboratively in multidisciplinary and multicultural work environments
4. Recognize and understand global, environmental, social, and ethical contexts of their work
5. Progress to an advanced degree, certificate programs, and professional engineering licensure, and be committed to lifelong learning to enhance their careers and provide flexibility in responding to changing social and technical environments.

### *ii. Learning Outcomes in EU*

As an example for the intended learning outcomes in EU, the learning outcomes for railway engineering course shown in Table 4 were selected from Faculty of Engineering at Southampton University.

**Table 4: Learning Outcomes in EU**

| Skills Description | Intended learning outcomes |
|---|---|
| **Knowledge & Understanding** | - The distinctive features of railway systems<br>- The design and engineering of railway track and supporting infrastructure.<br>- The design and engineering of railway rolling stock.<br>- Key aspects of rail vehicle dynamics and the wheel-rail interface.<br>- Principles and practice of railway signaling systems.<br>- The railway timetabling process.<br>- Railway station and interchange design.<br>- Different models of organization, regulation and governance for rail systems.<br>- The role of human factors in railway operations and safety. |
| **Subject Specific Intellectual and Research Skills** | - Critically assess the key engineering and operational constraints on railway operations on a given corridor.<br>- Evaluate the advantages and disadvantages of different models of railway structure and regulation.<br>- Describe key features of railway infrastructure design and engineering.<br>- Identify appropriate features and characteristics for railway rolling stock intended to operate different service types.<br>- Identify appropriate Human Factors methods for the design and evaluation of railway |

| | |
|---|---|
| | operations and processes. |
| **Transferable & Generic Skills** | - Time management.<br>- The use of creativity and innovation in problem solving.<br>- Collating, synthesizing and prioritizing information.<br>- Learning, studying and researching independently.<br>- Reporting your work effectively. |
| **Subject Specific Practical Skills** | - Interpret and use railway timetabling charts.<br>- Apply the elasticity-based model for rail demand forecasting.<br>- Make use of methods for calculating rail capacity utilization. |

#### *iii. Learning Outcomes of PennState Altoona University (USA)*

Graduates of the Rail Transportation Engineering program studied in Faculty of Engineering at PennState Altoona University, USA shall be able to:

1. Apply knowledge of mathematics, science, and engineering
2. Design and conduct experiments, as well as to analyze and interpret data
3. Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
4. Function on multidisciplinary teams
5. Identify, formulate, and solve engineering problems
6. Demonstrate an understanding of professional and ethical responsibility
7. Communicate effectively
8. Demonstrate the understanding of the impact of engineering solutions in a global, economic, environmental, and societal context
9. Recognize the need for, and an ability to engage in, life-long learning
10. Demonstrate knowledge of contemporary issues
11. Use the techniques, skills, and modern engineering tools necessary for engineering practice.

### *2.2.2 Operational and Practical Education*

#### *i. Nature of Railway Systems*

Railway engineering differs from teaching many other applied sciences, as in the railway system all fields of engineering are interconnected as illustrated in Fig.1. As a result teaching railway science must follow an interdisciplinary approach. The main reason of that interconnection is the interference and the direct impact of fundamental knowledge of rail related aspects of civil engineering (permanent way, structures), mechanical engineering (rolling stock), electrical engineering (signaling, electric traction), and computer science (signaling, control systems) on the process of operation **(**Lautala *et al*.**,** 2011).

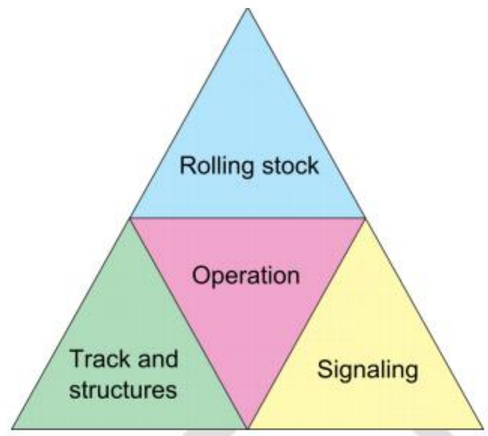


**Fig. 1: The railway system triangle (**Lautala *et al*., 2011)

### *ii. Role of operation Laboratories*

The railway laboratories are playing a very important role in teaching the railway engineering as they contain the principle tools for transferring the practical skills to the students. In modern laboratories, trains are operating using Digital Command Control technology. The control system controls train movements by electronically simulated accelerating and braking profiles that meet the performance of real trains depending on the movement characteristics of the train composition. In signal-controlled areas, trains run automatically in accordance to signal aspects and timetable data. Fig. 2 shows photographs of a typical layout for the railway operation laboratory at Berlin University of Technology (Pachl, 2009). The largest railway operations laboratories in Europe are at the Universities in Dresden and Darmstadt. While the Dresden laboratory has a total track length of 1300 m with 185 switches based on a compressed scale of 2:200, the Darmstadt laboratory has a total track length of 900 m with 260 switches based on a compressed scale of 2:25 (Pachl, 2009).

a) Total view of the layout

b) Dispatching office

**Fig. 2: Photographs of the railway operations laboratory at Berlin University of Technology (Pachl, 2009)**

Several innovating teaching methods and exercises have been introduced by Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC). The faculty from RailTEC takes the students to field trips to work on operational railway infrastructure at the Monticello Railway Museum in Monticello, Illinois, shown in Fig. 3 **(**Lautala *et al.*, 2011). Those visits contribute in enhancing the students experience and teaching them the actual activities of railway maintenance. Additional field visits and tours allow the students to see railway dispatching centers, track construction projects, and new capital projects, and these occur in conjunction with courses that focus on the railway operation topics. The students of UIUC use also software programs that are not available in other transportation courses in North America.

**Fig. 3: UIUC RailTEC performing field work at Monticello Railway Museum in Monticello, Illinois (Lautala *et al*., 2011)**

## 3. Analysis and Results

The collected data of the railway engineering education in Egypt and the international experience that have previously been demonstrated for EU and USA are analyzed and compared in this item. In addition, as it was represented in Fig. 1, the railway operation and its relevant indicators are mainly affected by the other railway subsystems i. e. rolling stock; signaling; track and structures. So, the analysis and comparisons should investigate the learning outcomes of the different courses related to the railway global and subsystems and correlate them with the railway operational indicators. Analyzing the intended learning outcomes of the Egyptian education that were illustrated in Table 1, it was noticed that railway operation was not taken into consideration. Thus, it resulted in neglecting the topic of railway operation in most of the railway courses.

In comparison with the learning outcomes of the international railway education, the skills required for operation in EU and USA were included in all the intended skills such as:

- **The knowledge and understanding skills**: (principles and practice of railway signaling systems, the railway timetabling process and the role of human factors in railway operations and safety).

- **Subject Specific Intellectual and Research Skills**: (identify appropriate features and characteristics for railway rolling stock intended to operate different service types, Identify appropriate Human Factors methods for the design and evaluation of railway operations and processes)
- **The practical skills**: (interpret and use railway timetabling charts, apply the elasticity-based model for rail demand forecasting, make use of methods for calculating rail capacity utilization).

Comparison of the records shown in Table 2 and Table 3 for the Egyptian and the international railway education facilities respectively, demonstrated the big deficiencies in the railway education in Egypt. It was observed that 8 faculties only of 21 in which the course of railway engineering is educated in addition to the huge shortage in the lecturing staff. In addition to this shortage, these educated courses tend to concentrate more on topics related to civil engineering i. e. rail infrastructure engineering.

Also, it was noticed from investigating contents of the advanced railway laboratories in EU and USA that shown in Fig. 2 and Fig. 3 that they represented mainly the discipline of railway operation education. These laboratories are very important for providing the students with the required practical and operational skills which reflecting and impacting on the operational indicators in the developed countries. However, there is no such those laboratories in the Egyptian faculties except minor one in Shoubra Faculty of Engineering which was established for rail infrastructure testing.

# 4. Conclusion and Recommendation

Several railway educational programs and learning outcomes, hence their major impacts on indicators of operation performance of Egyptian Railways have been analyzed compared among the local, European Union and North America in this paper. The conclusions and recommendation of the study have been summarized in the following.

- ***Conclusions***

1- The intended learning outcomes, hence Egyptian railways curriculums mainly concentrate on theoretical and design learning.

2- A huge shortage in the practical skills of the graduates as a result of the big limitations in number of the railway operation laboratories and railway graduation projects in many faculties of engineering.

3- Operation indicators such as safety, level of service and management in Egyptian Railways were deeply affected by the shortages in practical outcomes of railway engineering learning.
4- No railway engineering courses were identified in many faculties of engineering.
5- No specific courses were identified in the potential relevant domains such as mechanical engineering or systems engineering.
6- Shortage in the total staff of railway engineering professors and lecturers.
7- Observed big gap between learning of railway engineering and the Egyptian railway industry.

- ***Recommendations***

In accordance to the conclusions of this study, major recommendations to incorporate the notices can be suggested as follows:

1. Development of course material to include more learning outcomes that emphasize the practical and operational skills.
2. Establishment more hands-on rail laboratories, either physical or virtual.
3. Expanding course content beyond civil engineering and transportation to include electromechanical and systems engineering.
4. Emphasizing the importance of practical skills and provide opportunities to include them to the learning process.
5. Development strategies for railway industry, and develop university/industry collaboration.
6. Take steps to redevelop the Egyptian academic infrastructure in rail higher education.
7. Investigating opportunities for faculty visits by the rail experts in the field of operation to assist in the learning process.

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