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Lidia Żakowska
Politechnika Krakowska
Polish Association of Transportation Engineers SITK RP
WFEO Women in Engineering Standing Committee
e-mail: lzakowsk@pk.edu.pl

Zofia Bryniarska
Politechnika Krakowska
Polish Association of Transportation Engineers SITK RP
WFEO Women in Engineering Standing Committee
e-mail: z_bryn@pk.edu.pl

EQUITY IN STEM, ESPECIALLY IN TRANSPORTATION ENGINEERING

Abstract

Background. Initiatives to promote gender equality in STEM have been developed in Europe over a number of years. However, all specific programmes have proved to be insufficient to increase the number of women in science and in engineering.
Research aims. The main objective is to analyze the barriers that lead to gender inequity in the context of science and the academia, namely vertical and horizontal segregation (under-representation of women in STEM) and asymmetric gender culture in organisations (including structural barriers for women).
Methodology. In this paper location parameters of descriptive statistics, like median 1st and 3rd quartile and rate structure, were compared. Those simple parameters were used to show the scale of differences between males and females, especially in the context of salaries, and to highlight the dynamics of changes in time.
Key findings. The study revealed that there is no equity in salaries at all educational levels in Poland. There is also no equity in R&D personnel salaries and in number of engineering students and in higher level technical university personnel.
Conclusions. Urgent solutions and actions are needed to increase the equity balance in STEM in the context of salaries and careers development, in transportation engineering field.

Keywords: share of women, engineering, scientific career, salaries

Streszczenie

Równość w STEM, szczególnie w inżynierii transportowej

Wprowadzenie. W Europie od wielu lat wprowadzane są inicjatywy mające na celu promowanie równej roli kobiet w nauce, technologii, inżynierii i matematyce (STEM). Jednakże wszystkie

dotychczasowe programy mające ułatwić karierę naukową kobiet okazały się niewystarczające, skoro nie doprowadziły do zwiększenia udziału kobiet w nauce, w szczególności w inżynierii.
Cele badawcze. Głównym celem badań jest analiza barier ograniczających równy udział kobiet w nauce i w wyższych uczelniach, takich jak segregacja pionowa i pozioma (niska reprezentacja kobiet w STEM) oraz asymetryczna kultura w organizacjach (bariery strukturalne).
Metoda. W artykule porównano parametry statystyki opisowej, mediany 1. i 3. stopnia i inne podstawowe parametry, które ukazują skalę zróżnicowania pomiędzy grupami kobiet i mężczyzn, w szczególności w kontekście wynagrodzeń, podkreślając dynamikę zmian w czasie.
Wyniki. Badania ukazały brak równości w wynagrodzeniach na wszystkich poziomach edukacji w Polsce. Ujawniono też brak równości w zarobkach kobiet i mężczyzn naukowców, w liczbie studiujących kierunki inżynierskie i w liczbach pracowników uczelni technicznych na wyższych stanowiskach.
Wnioski. Dla poprawy obecnego stanu braku równości niezbędne jest wprowadzenie pilnych rozwiązań i akcji, które mogłyby zwiększyć balans równości w obrębie STEM, w szczególności dotyczący wynagrodzeń i rozwoju karier inżynierskich kobiet w transporcie.

Słowa kluczowe: uczestnictwo kobiet, inżynieria, kariera naukowa, wynagrodzenia

Introduction

The rapid progress in science and technology development is noticeable and observed in many everyday aspects of life, not only in education, research and production. This development do not bring the parallel change in human culture and attitude to women, to their work or place and role in society. On the one hand it is broadly discussed and accepted that women have the equal rights, namely that they can decide on their own what they are going to do, or what they are interested in, but on the other hand the truth contained in facts and numbers shows quite different phenomena and trends. There is a significant barrier / obstacle that women hardly ever crossed since years. It seems that they have the same starting point, but existing barriers do not allow them to reach the same progress like men achieve.

There are three key topics which are highlighted in the current discussions as most essential in order to reach gender equality in the context of science and the academia [Hofbauer, Wroblewski, 2015]:

1. Reduction of vertical and horizontal segregation (lack of women in decision-making positions, underrepresentation of women in STEM subjects, integration of men in female-dominated sectors).
2. Balancing the asymmetric gender culture in organisations (including changing the prominent/prevailing male-dominated culture in science and academia, work-life balance, removing structural barriers for women).
3. Integration of a gender dimension in teaching and research (including gender awareness- raising among the academic staff and applying gender research methods and actions through the whole research process; applying gender-sensitive didactic actions in classes).

Background

Transportation equity, like transportation safety, is considered today as a civil and human rights priority. When in the year 2000 the Safety Declaration was presented by WHO and signed in Delhi, it became clear to millions that the issue of transport safety is the priority of civil and human rights. After 15 years we are facing the next step in making transportation more human.

Access to affordable and reliable transportation widens opportunity and is essential to addressing poverty, unemployment, and other equal opportunity goals such as access to food, good schools and health care services.

Current transportation spending programs, however, do not equally benefit all communities and populations. Negative effects of some transportation decisions – such as the disruption of low-income neighbourhoods – are broadly felt and have long-lasting effects.

What has been disclosed during numerous studies in the cross-disciplinary fields of engineering education, transportation accessibility and gender equity by the authors is, that the basic rules are universal, namely:

- Transport equity is a basic precondition of independence, mobility and accessibility for all activities and services;
- **Woman are especially dependent on equal mobility conditions in everyday activities**;
- **Transport equity is related to gender and engineering studies**.

Criteria for evaluation were: gender differences in national level, the age, employment seniority and education level. Searching for Higher Education in engineering/transport field the Technical University in local level was evaluated.

Method

The data base for analysis were collected on four levels. First of all the Central Statistical Office of Poland [Science and Technology in 2013, 2014] data and the independent Human Resource Consulting Company [Sedlak & Sedlak, 2014] data from last decade were selected in respect to the STEM, salaries and transportation topics on the national level. The municipality level data were obtained from the Public Transport Company in Krakow [Human Resources Board in Public Transport Company in Krakow – internal data], which collects always and regularly all statistical public transport data for Krakow. The academic level data were used from the Cracow University of Technology (PK) (human resources and students) internal statistics [Human Resources Board and Student Office in Cracow University of Technology (PK) – internal data]. Finally, to compare the female graduates by field in Poland and in EU, the EU [Hofbauer, Wroblewski, 2014] data applied.

The statistical data on Polish and EU level can prove the phenomena that statistically women do not reach the same level of salaries and representation in

decision-making position like men. The main issues taken into account are as follows: salaries and the differentiation between women and men, share of women in STEM like Polish Academy of Sciences, share of women in Cracow University of Technology (PK) among personnel and students and, in the end, share of women in Public Transport Company in Krakow.

The applied research methods consist of location parameters of descriptive statistics like median 1st and 3rd quartile, rate structure. Those simple parameters are used to show the scale of differences between males and females, especially for the problem of salaries, where it is proved that distribution is skewed. It is also highlighted the dynamics of changes in time. Regarding problems mentioned above it is easy to show that the differences between man and woman do not decrease but they are even increased.

Results

The Polish research on the level of salaries carried out in 2014 by Sedlak & Sedlak [2014] confirms the differences in salaries between males and females. The median of salaries in order of seniority is presented in Figure 1. In the beginning of personnel career (1 or less of seniority) men and women earn nearly the same. The differences are about 14% of their income. But the longer they work (9–10 and 11–15 of seniority) the higher is the difference of salaries between them. The more deep gap between men and women salaries is observed among 9–10 year and 11–15 year seniority of workers. Women are paid less than men on about 27–28%. **At all time levels in Poland there is no equity in salaries.**

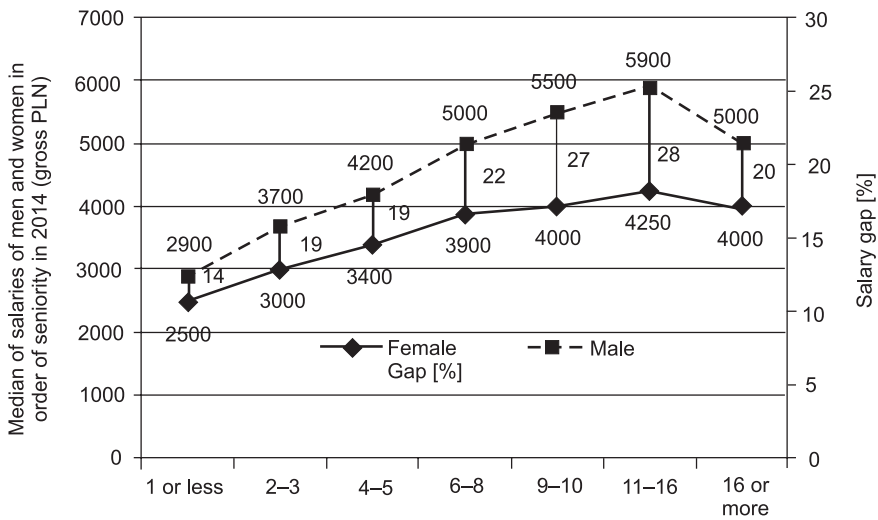

Figure 1. Median of salaries of men and women in order of seniority in 2014

Source: own research on the basis of Sedlak & Sedlak, 2014.

Taking into account people employed at different levels of education the same phenomena can be met (Tab. 1). At each level of education women earn less than men. To make the things worse the differences are the highest in the group of persons who earn above 3rd quartile. Those parameter is much higher for men than for women. For the higher educated person the 3rd quartile for women amount to only 2/3 (68%) the 3rd quartile for men. **There is no equity in salaries at all educational levels in Poland**.

Table 1.

Salaries of men and women from diverse education in 2014 (gross PLN)

Education level	Sex	Sample size	25% earn less than	Median	25% earn more than
Higher	Males	43 865	3516	5500	8960
	Females	36 278	2775	4000	6100
Secondary	Males	20 075	2418	3350	5000
	Females	10 139	2056	2790	4000
Primary	Males	479	1900	2500	4100
Lower secondary	Females	205	1733	2200	3700

Source: Sedlak & Sedlak, 2014.

Comparing salaries of employees of higher level of education in Poland in 2010 (Fig. 2) and in 2014 (Fig. 3) it is easy to notice that the tendency of paying less women, although they gain the same level of education and are at the same level work seniority, is deepen and the gap in salaries between males and females is increasing.

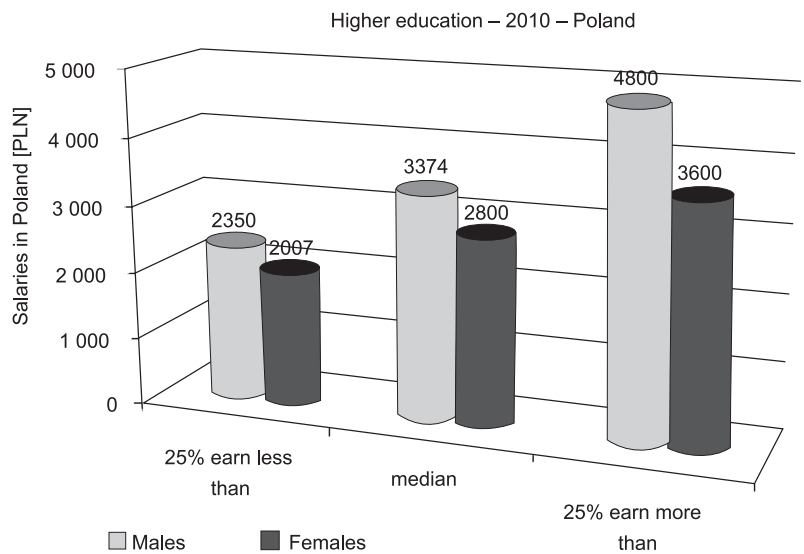

Figure 2. Salaries of employees with higher education in Poland in 2010

Source: own research on the basis of Sedlak & Sedlak, 2014.

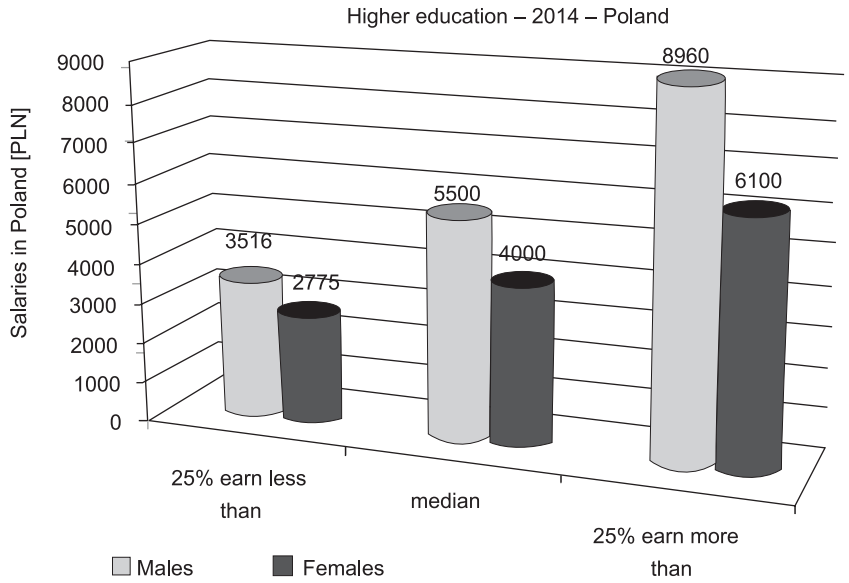

Figure 3. Salaries of employees with higher education in Poland in 2014

Source: own research on the basis of Sedlak & Sedlak, 2014.

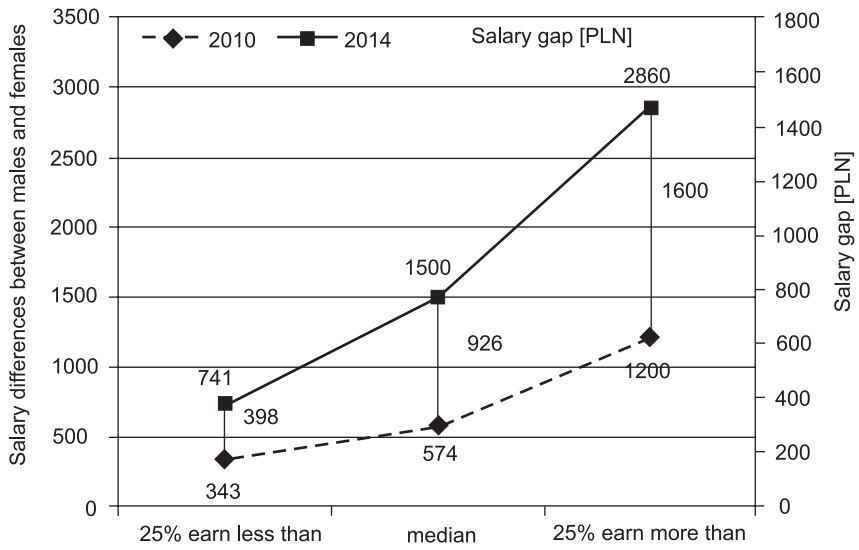

Figure 4. Differences in salaries between males and females

Source: own research on the basis of Sedlak & Sedlak, 2014.

To strengthen the fact that differences in salaries between males and females are not smaller in subsequent years the diagram on Figure 4 has been prepared. At each level of quartile in 2010 the women earned less than men. In 2014 women with higher education earned also less than men, but the differences were more than two times higher than in 2010. It should be stressed, that the process of balancing the size of salaries goes into the wrong direction and every year the gaps in salaries are greater. It is an efficient sign that there is **no equity in salaries at higher educational level**.

The decision-making position are traditionally occupied by men. The number of women, who are members of the Polish Academy of Science varies from 17 to 23 (Fig. 5), and consist of less than 5% of total number of members. But on the other hand, it is worth to remind that Polish professor Agnieszka Zalewska has been the president of the CERN Council since 1st of January 2013 for the next five years.

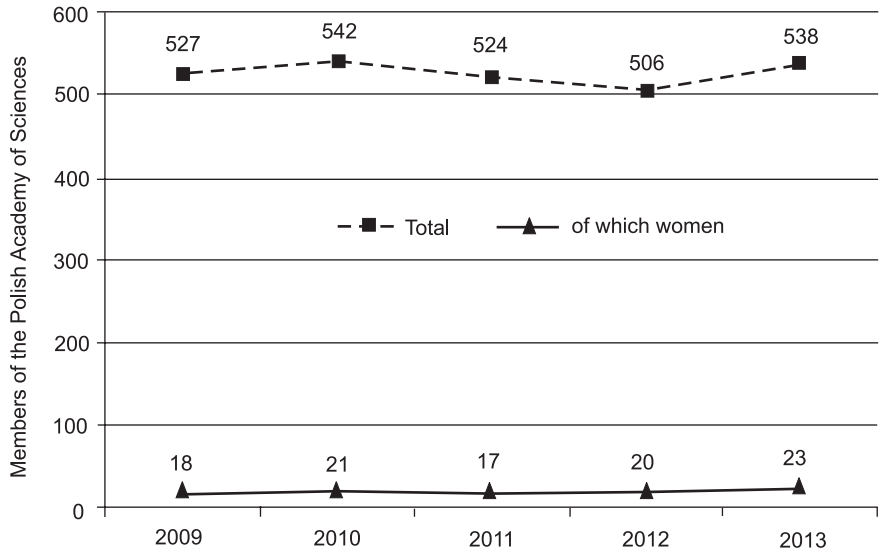

Figure 5. Members of the Polish Academy of Sciences by sex

Source: own research on the basis of Science and Technology in 2013, 2014.

The share of women in research and development (R&D) personnel amount to 45,6% of total employees (Fig. 6). Taking into account the sectors of performance, it is significant that the number of women acting as researches is below the level of balance (43,1%), but the share of women employed as technicians and equivalent staff or other supporting staff is equal to 53,1% and 73,8%, respectively. Women usually occupy positions paid less, where patience, accuracy and precision are required. **No equity in R&D personnel at higher level is observed.**

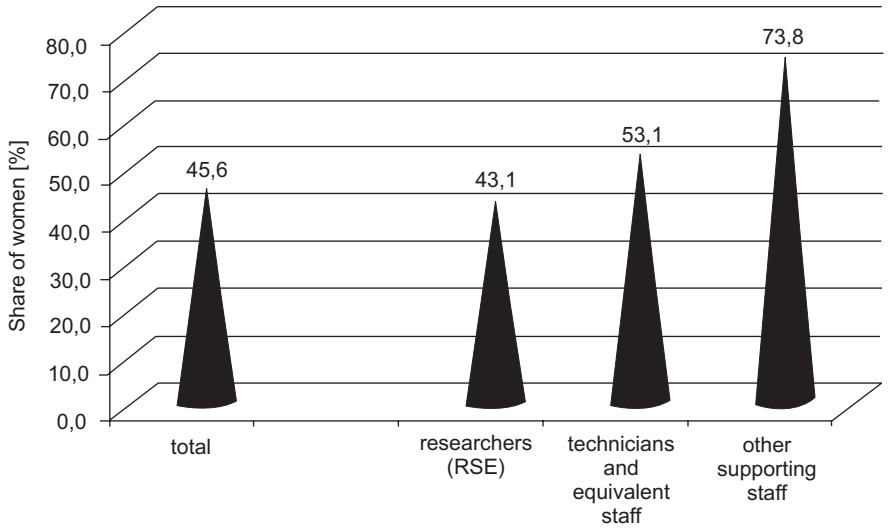

Figure 6. R&D personnel by occupations and sectors of performance

Source: own research on the basis of Science and Technology in 2013, 2014.

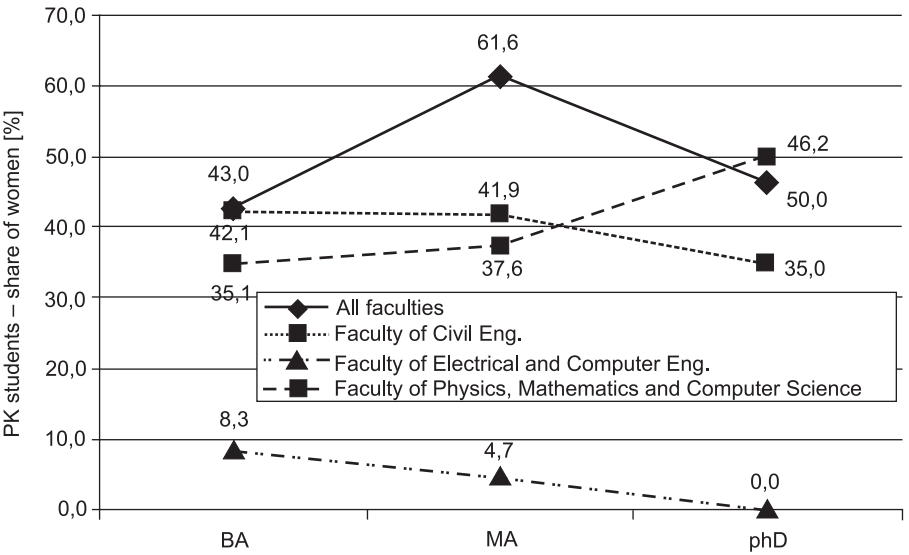

Figure 7. Share of women among PK students at different levels

Source: author's analysis on the basis of Human Resources Board and Student Office in Cracow University of Technology (PK) – internal data.

Cracow University of Technology (PK) is an example of academia that educates highly qualified engineers, among other engineering specializations also in transportation field. The number of women entering the study at bachelor, master and PhD levels varies from faculty to faculty (Fig. 7). Share of women at the first degree (BSc) is 43% of students taking into account all faculties and 35% at the Faculty of Physics, Mathematics and Computer Science and only 8,3% at the Faculty of Electrical and Computer Engineering. At the Faculty of Civil Engineering, where are also educated students in transportation field, this parameter is equal to 42,1% of all students. The number of women raise at the second degree (MSc) to 61,6% and at the third degree (PhD) to 46,2% of total number of students. But the data show significantly that engineering sciences are not so popular among young women, who do not expect to find here their place for life. It seems that young women follow social prejudices that they could not meet this profession. **No equity in number of engineering students at PK is observed**.

At the beginning of career in PK as post doctors share of women is relatively high and the highest as junior professors. Women consist nearly 50% of all junior professors. The next levels of career are rarely met at position of Professor PK and full professor (Fig. 8). There are only 13,5% women who are full professors at all faculties in PK and among them 5,6% at the Faculty of Civil Engineering. But more than 60% of women works at the non-academic positions. There is **no equity in share of woman at higher level personnel at PK**.

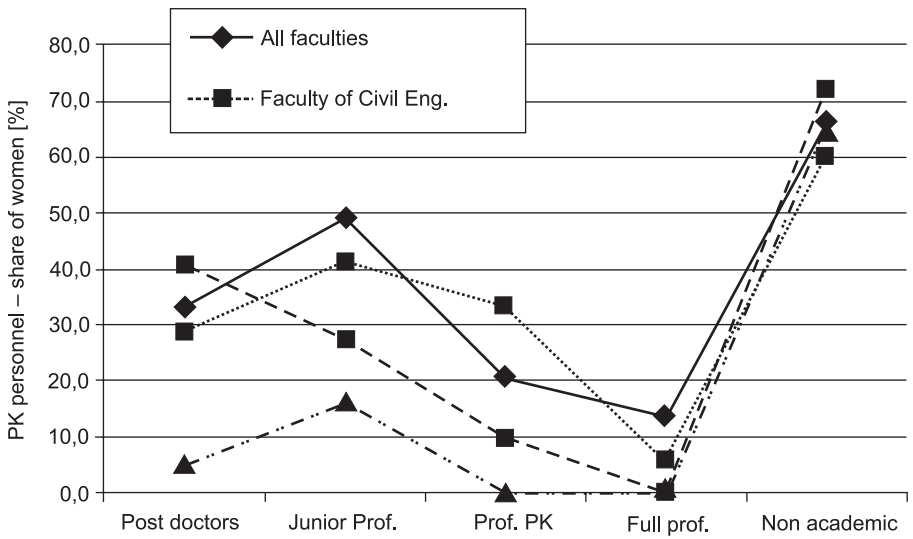

Figure 8. Share of women in PK personnel at different levels

Source: author's analysis on the basis of Human Resources Board and Student Office in Cracow University of Technology (PK) – internal data.

Although there are professions that were, up to now, reserved traditionally for men, and on the one hand thanks to the development of technology, and on the other hand because of changes in perception of the place of women in the labour market, women gained access to some of the "masculine" professions. The share of women in Public Transport Company in Krakow increases in last years (Fig. 9). Women always works as tram drivers and they currently represent over 14% of all tram drivers. First women driving buses were met in 2006. Now share of women working as bus drivers is close to 2,2%. Women works also as a dispatchers and their share at this position amount to 1/4 of all dispatchers. On the other hand they do not work as traffic controllers. There is **no equity in public transport personnel at different levels.**

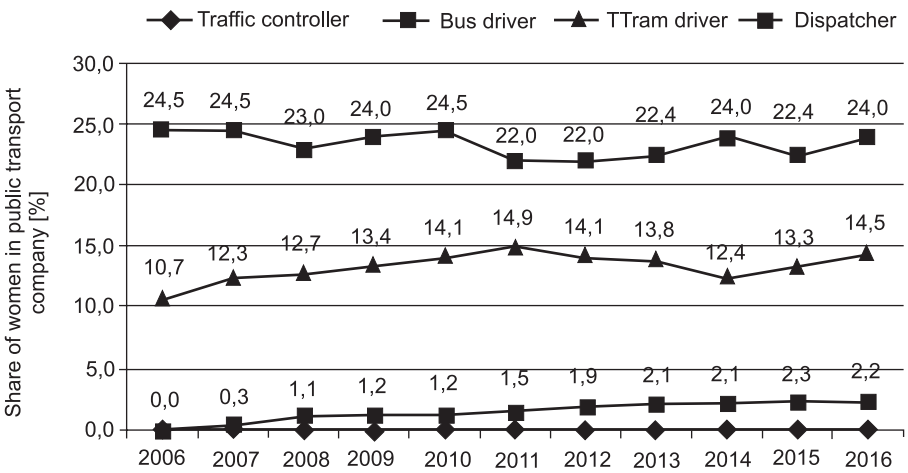

Figure 9. Structure of personnel in public transport at different levels

Source: author's analysis on the basis of Human Resources Board in Public Transport Company in Krakow – internal data.

Stereotypical gender roles

Gender stereotypes have been traditionally strong in all EU countries, but differences among countries are still significant.

In Italy women are still considered "brides and mothers," economically dependent on their husbands and devoted to family care. In addition, they are considered worthless or less capable than men – particularly in STEM disciplines thus decreasing their self-confidence – and for acting at high-level positions – thus preventing them from having the same opportunities for achieving key positions [Zakowska, 2008].

In Spain the discrimination against women was manifested by law in the history of Franco's regime and only changed after his death in 1975. For this specific historical reasons, Spanish women (and men) have lived in a very strong gender role stereotyped environment until the last quarter of the 20th century [Zakowska, 2008].

In the Czech Republic gender roles in society are traditionally different, but especially in bigger cities the erosion of traditional roles and attitudes can be observed. In this regard, a modern education and better conditions for women generally play an important role [6].

In Poland, like in Austria and many countries in central Europe, the traditional stereotypes applied to women is the responsibility for childcare. That is why the family obligations are often the main reason of employers' concerns employing mothers. The role of the man is to ensure the financial security of the family, therefore his earnings should be higher and employment more stable [Zakowska, 2008].

The scientific career is much more difficult for women than for men. Hardly ever they gain the title of full professor. But the position of a member in management board is also rarely occupied by women (Fig. 10). On the one hand 100% of rectors are men and on the other hand 100% of managers of administrative units and heads of deans' offices are women. **No equity at higher educational careers is observed.**

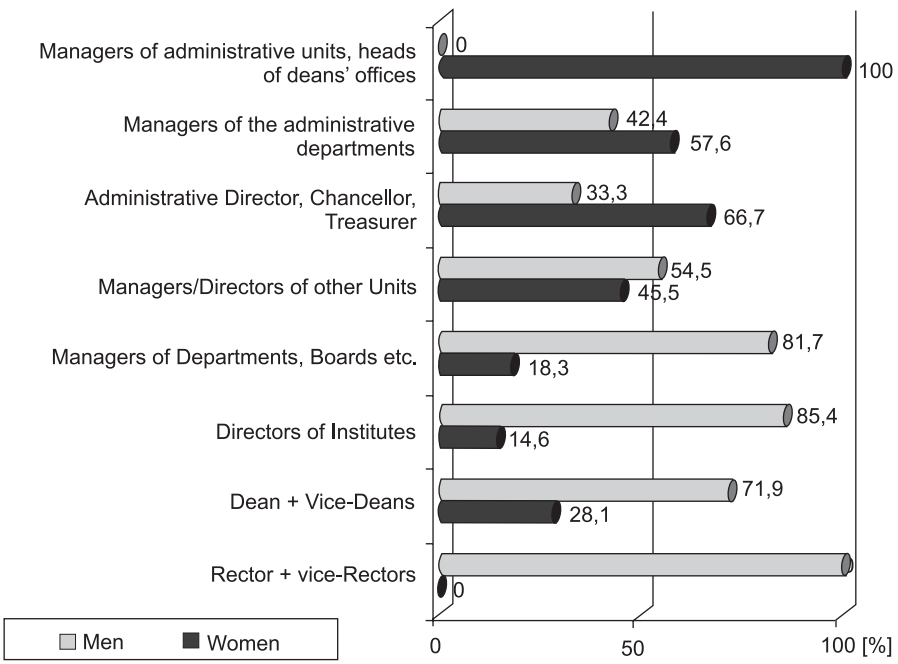

Figure 10. Heads in management boards by sex at PK

Source: author's analysis on the basis of Human Resources Board and Student Office in Cracow University of Technology (PK) – internal data.

The similar situation can be observed in other European countries (Fig. 11).

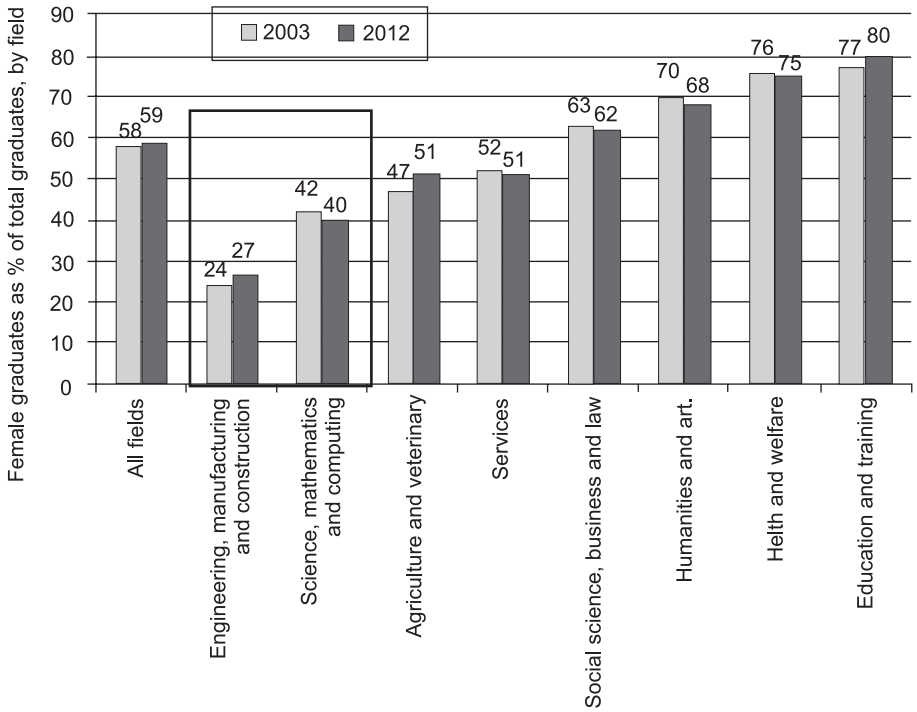

Figure 11. Female graduates by field in EU

Source: Hofbauer, Wroblewski, 2014.

Representation in academia, according to the Report on Equality between Women and Men 2014 (EC 2014), is presented at Figure 11. It is especially recognisable that women are underrepresented in technical fields, such as engineering, manufacturing, construction, science, mathematics and computing, etc. **No equity at higher educational careers is observed.**

Conclusion

In order to reach **equity in STEM, especially in transportation engineering**, there is a strong need for proper regulations or changes in organizational culture, namely:

- Segregations – fact or imaginary explanation of female weaknesses?;
- Increasing the gender balance in decision making;
- Increasing the attractiveness of scientific career for female students;

- Enhancement of recruitment and career progression of female researchers;
- Securing the working conditions for female scientists;
- Integration of gender dimension in research and teaching curricula;
- Promoting a gender-sensitive change of disciplinary cultures;
- Innovative strategies to address gender bias, that should include family-friendly policies (e.g. work schedule's flexibility; parental leave; mobility, dual-career couples).

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