World Universities Strategic Analysis Based on Data from the QS World University Rankings

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Abstract
The article examines indicators of influence on the overall ranking of world universities based on QS World University Rankings data, statistical analysis, smoothing methods, correlation analysis and forecasting. We considered the dynamic change of the Lviv Polytechnic National University rating. The identified trends and regularities, problems and advantages should serve as prerequisites for the development strategy of the worldwide universities, taking into account which will allow the formation of effective mechanisms for the long term. A study of the activities of universities was carried out, which made it possible to systematically, comprehensively and objectively comply with the requirements of information security, among which the confidentiality, integrity and availability of information are key, to determine the level of their potential opportunities and to develop a set of strategic directions and measures that contribute to their strategic development in perspective

Keywords 1
University ranking, QS World University Rankings, information technologies, smoothing, statistical analysis, forecasting, correlation analysis, strategic analysis, information security.

1. Introduction

Recently, information technologies have played key roles in achieving competitive positions by economic entities both in domestic and global markets. Due to the strict conditions of quarantine during the Covid-19 pandemic, the impact of information technologies on achieving commercial results and obtaining profits in educational services has increased. Higher education institutions (HEI) carried out their educational and economic activities only remotely for a long time. The existing information systems of higher education institutions were not ready for uninterrupted operation. It led to an increase in the need for information security in both the educational activity system and the system of ensuring the economic activity of universities.

Large-scale military operations with the beginning of the Russian-Ukrainian war in 2022 proved beyond doubt that ensuring information security in education is a significant factor in achieving Ukraine's victory in the fight against the Russian aggressor. For over a year, the most important issue for the world community has been the good information display of new socio-economic phenomena and processes in Ukraine. Stable implementation of the educational process of higher education in de-occupied territories and territories close to the contact line is impossible without compliance with information security. Information security methods and tools include backups, two-factor authentication, and compliance with access rights policies. There was an urgent demand to limit the circle of people with access rights to important data from higher education institutions.

Under the influence of such critical external environmental changes, universities track and analyse these changes to form a balanced strategy for their development. The data obtained from the strategic analysis will allow HEI to outline its long-term development prospects shortly. There is an urgent need

IntelITSIS'2023: 4th International Workshop on Intelligent Information Technologies and Systems of Information Security, March 22–24, 2023, Khmelnytskyi, Ukraine
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to form an information base that will allow the simulation of various situations due to changes in input indicators and more weighted management decisions based on the research results. Therefore, the study of the activities of universities should be carried out systematically, comprehensively and objectively in compliance with the requirements of information security, among which confidentiality, integrity and availability of information are key. It will make it possible to determine the level of its potential opportunities and develop a set of strategic directions and measures that will contribute to its strategic development in the future. Compilers of the QS World University Rankings rank universities according to six indicators: research, teaching, opinion of employers and career potential, and the number of international students and teachers. To participate in the rankings, a university must offer undergraduate and graduate programs in at least two broad subject areas (e.g., arts and social sciences, engineering and technology, law and business). The QS ranking focuses on the reputation of universities in academic circles. Differences in the criteria and methods of evaluation of higher education institutions used by the members of the leading ratings affect the result - the final positions of higher education institutions in the rating table depend on them. First, let's find out what the QS members pay attention to. An important feature of the QS rating is its great importance for the reputation of universities in the academic environment.

The opinion of experts weighs 40%. The next most important factors - contribution to global scientific research activity and transmission quality - weigh 20%. The contribution to research activity is defined as the citation index of open scientific universities, considered for each of its employees. The number of teachers per student testifies to the quality of teaching. Finally, 5% in the QS world ranking of higher education institutions provides indicators of the ratio of foreign and local students, as well as foreign and local teachers, which together show the degree of internationalisation of the higher education institution.

These indicators cover the key strategic missions of universities of global importance, for which they are accountable to the participants of the process: the academic community, employers, students and their parents. Each year, the study evaluates more than 2,500 higher education institutions worldwide. Based on the QS World University Rankings results, a ranking of the 500 best universities and rankings of universities in individual disciplines are compiled.

2. Related works

The globalisation processes strengthening the transition of the world's developed countries to the digital model of society determine the growth of the role of universities in ensuring the competitiveness of the economy in the 21st century [1-3]. At the end of 2015, Ukraine was among the top ten countries in the world regarding gross higher education coverage of the population; in 2017, it ranked 11th (79% of citizens). Obtaining a higher education becomes a requirement of the time, a kind of social standard that promises its acquirer decent employment and a standard of living.

A network of higher education institutions has been formed in Ukraine (661 institutions, in which 1539 thousand students study) [4-8]. The university plays the leading role in providing higher education in Ukraine, which is designed to ensure the constitutional rights of citizens in obtaining higher education on a competitive basis, acquired knowledge, skills and abilities, relevant profession, adequate to market requirements.

The level of achievements of universities is evaluated based on the results of a combination of statistical analysis of the activity of educational institutions, audited data (including information on the citation index from the Scopus database, the world's largest bibliometric database of scientific publications), as well as data from a global expert survey of representatives of the international academic community and employers who express their opinions about universities.

We will analyse the achievements of the Higher Educational Institutions of Ukraine in the example of the Lviv Polytechnic National University. We took 2015-2018 before covid and the war in Ukraine. Unfortunately, the last two factors significantly impacted Ukrainian universities' ratings as a strong negative restraining factor [9-12].

One of the leading universities in Ukraine is the Lviv Polytechnic National University, declared the oldest higher technical educational institution in Ukraine and Eastern Europe [1]. Lviv Polytechnic is a powerful educational and scientific centre in which fundamental and applied research is carried out at

interdisciplinary and transdisciplinary levels, a centre for the formation and development of educated, intelligent youth. Lviv Polytechnic National University is equipped with a powerful material and technical base, high-quality human resources, and an excellent educational and scientific reputation. These and other factors shape the development potential of the university. The following prerequisites determine the strategic orientations of the university's development [13-18]:

1. The development of globalisation processes in all spheres of social relations and education in general leads to the intensification of competition between universities for leadership in the world market of educational services and, simultaneously, the growth of international scientific cooperation.

2. Relatively low-quality indicators of higher education in Ukraine, substantiated by the low positions of domestic universities in world educational rankings, reflect the need to form a mechanism for improving the quality of higher education.

3. The aggravation of the disproportion between employers' needs for personnel of certain qualifications and appropriate quality and labour market offers from graduates of domestic educational institutions requires training specialists with higher education to meet market requirements.

4. There is a need to implement the provisions of the strategic development of the higher world of Ukraine in forming strategic guidelines for developing the Lviv Polytechnic National University.

The competitive positions of Lviv Polytechnic National University on the world, regional and national markets of educational services are reflected in the positions of the university in the relevant educational ratings and indicators that characterise its competitive advantages (Table 1).

The global rating of Webometrics' internet presence is the first rating that reflected the results of the Lviv Polytechnic National University (over seven years of research). The ranking evaluates the best presence of the university and the Internet based on the number of links to the university's website, the number of pages provided by search engines, and the value of attached files. In general, according to the presentation, influence, openness and advantages of the university website [19-26].

It is worth noting that Lviv Polytechnic National University ranks 6th among Ukrainian universities in this ranking [2].

Table 1

Lviv Polytechnic National University in the world, regional and national educational ratings

The rating name	2015	2016	2017	2018	2023*
			International level		
International rating Internet presence Webometrics [2]	6th place among Ukrainian universities 2159 overall indicator	4th place among Ukrainian universities 2278 overall indicator	7th place among Ukrainian universities 2526 overall indicator	6th place among Ukrainian universities 2551 overall indicator	2th place among Ukrainian universities 2679 overall indicator (January 2023) [10]
Times Higher Education (World University Rankings Times Higher Education) [3]	-	-	>801	1001+	601-800
			Regional level		
QS University Rankings: EECA [4]	-	96	101	101	78
			National level		
Ranking of universities according to Scopus database indicators [5]	10	10	10	9	4
Academic rating "TOP-200 Ukraine" [6, 7]	5	5	5	6	3
Consolidated rating of higher educational institutions in Ukraine [8,9]	6	6	6	7	3

One of the most prestigious world rankings of universities is the Times Higher Education World University Rankings. Experts evaluate universities according to 13 indicators, which reflect five main areas of their activity: teaching (30%), research (30%), citations (30%), international outlook (7.5%), and industry income (2.5 %) [3]. Since 2017, Lviv Polytechnic National University has been included in the influential global educational rating of THE World University Rankings [9]. The key positions that allowed the university to enter this rating are the number of students per 1 research and teaching staff (R&TS), the total number of students and the percentage of international students (Table 2).

Table 2

The main indicators of the Times Higher Education World University Rankings for LPNU [3, 8-10]

Indicator	2017	2018	2023
Place in the rating	>800	1001+	601-800
According to the methodology:			
Key positions			
The number of students per 1 research and teaching staff	13.4	12.1	10.5
The number of students, people.	28037	28691	34000 - 39200
percentage of international students, %	1,1	1	1
Estimates of the main indicators			
Teaching	16.6	18.2	19.4
Research	7.6	7.6	10.7
Citation	1	3,7	53.7
Industry income	32,4	31,8	38.0
International outlook	25	25	25.3

The main indicators evaluation of the LPNU reflects the growth of the education quality assessment and the publication citation of R&TS, and a certain stability in the quality of research work and internationalisation of the university. However, the indicators are quite low in value (the ideal value of the indicator is 100), reflecting the need to implement measures to ensure the growth of the main rating indicators at Lviv Polytechnic University and, thus, its reputation and competitiveness.

A component of the QS World University Rankings is the corresponding regional ranking of universities. Lviv Polytechnic National University is included in the regional ranking of developing European and Central Asian countries (EEA) [4]. The rating is formed according to 6 main criteria: the scientific reputation of the university, the ratio of scientific and teaching staff to students, the reputation of the university among employers, the number of international students and teachers, the number of scientific works and citations of university scientists, the number of employees with scientific degrees. For 2018, the rating was formed based on data from 299 universities in the region. At the same time, LPNU took 101st place, five positions lower than in 2016. The main evaluation indicators' values acquired the following: scientific reputation - 53.9, reputation among employers - 21.8, assessment of the number of scientific works and citations of university scientists - 34.7.

The result of the scientometric monitoring of subjects of scientific and publishing activity in Ukraine, according to the indicators of the SciVerse Scopus database, was the rating of Ukrainian higher educational institutions. The results of the ranking of higher educational institutions are based on the indicators of the Scopus database, which is a tool for tracking the citations of scientific articles published by the educational institution or its employees. The Scopus database constantly indexes over 20,000 scientific journals and hundreds of book series [5]. In 2017, Lviv Polytechnic University ranked 10th in citations of scientific and teaching staff publications among 136 universities in Ukraine. Thus, having acquired a high value of citations of scientific works of university employees, the possibilities of increasing such an indicator have been determined, focusing on the leaders of this rating, which implies the need for an increase in the number of scientific studies and their reflection in cited and prestigious publications.

The "TOP-200" academic rating is based on an expert study of the quality of the R&TS, the quality of education and international recognition of the university according to 24 indicators, which provides 80% of the information about the university. This assessment is supplemented by an indicator of information resources (quality and functional completeness of university websites) - 5% and an expert

assessment with a weighting factor of 15%, which reflects the level of basic and general education of students, the level of their professional training, the level of practical knowledge of information technologies, demand university graduates by the labour market [6]. In 2015-2017, Lviv Polytechnic University took 5th place in this rating, which reflects the university's consistently high position in the domestic market of educational services [8].

In the consolidated rating of higher educational institutions of Ukraine, LPNU took 6th place in 2015-2017 [7-9]. The study of the specifics of the evaluation methodology according to this rating allows us to conclude the university's high position, considering the quality of its educational and scientific activities, openness and availability of information about it.

Also, in 2017, Lviv Polytechnic University took 8th place in the ranking of the magazine "Focus", which was conducted among employers in Ukraine. Leading companies from various fields evaluated graduates' chances of getting a job with prestigious employers. In total, the rating was formed from the 50 best higher education institutions according to employers [7-10].

The prerequisites for the formation of the strategy of the Lviv Polytechnic National University are also the assessment of its economic and financial activity. Every year, the admission campaign results demonstrate and confirm the university's demand and reputation in the educational services market [1-21]. According to fig. 1, the general trends of the decrease in entrants during 2012-2017 are determined.

In 2012-2017, the entrant's admission to LPNU took place both at the expense of the state order and at the expense of legal entities and individuals. Currently, there is no pronounced tendency to decrease the volume of the state order for training specialists.

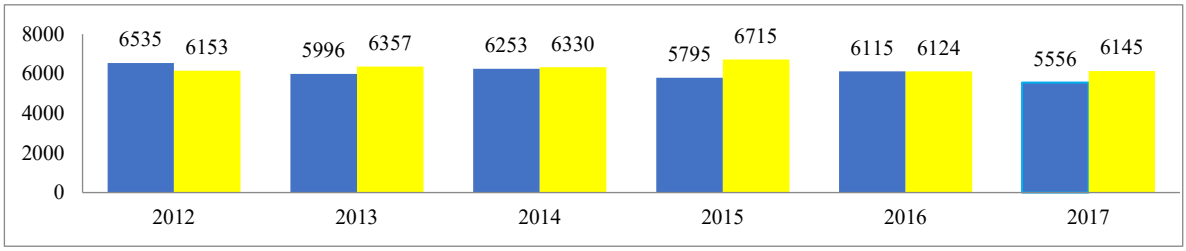

Figure 1: Results of the admission campaign of Lviv Polytechnic National University for 2012-2017 [7-10] (blue colour - enrollment of entrants - state order, persons and yellow colour - enrolling entrants at the expense of individuals and legal entities, persons)

An important factor and, at the same time, an indicator of the university's success in the world educational space is the number of international students. It is one of the key indicators that allowed Lviv Polytechnic University to enter the Times Higher Education World University Rankings. However, the analysis of the dynamics of the number of foreign university students (Fig. 2) reflects the tendency of their gradual decrease - from 2014 to 2017, the number of such students decreased by 24.8%, i.e. by 82 persons.

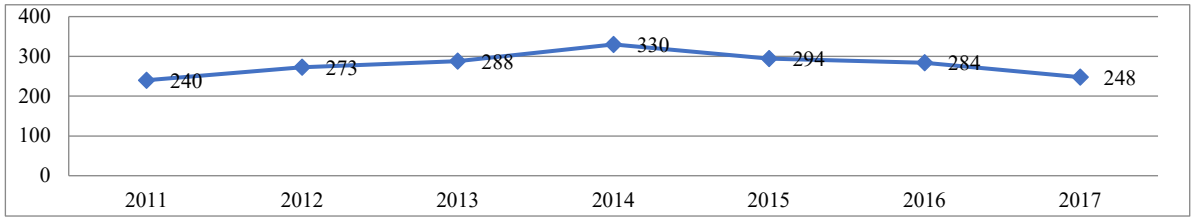

Figure 2: The number of international students of Lviv Polytechnic National University in 2011-2017

Following the principles of the Bologna process and considering the general globalist trends in higher education, it is important to increase the opportunities for students and teachers to learn/teach, learn and share their experience with foreign colleagues through cooperation with foreign higher education institutions. Dynamic changes in cooperation with foreign universities should be studied according to the data in Fig. 3.

From 2011 to 2015, the academic mobility of Lviv Polytechnic University students and teachers increased from 2011 to 2016. Business trips abroad are related to representing the university's interests, gaining experience and knowledge, and reflecting the compliance of the organisation of the university's activities with the principles of the Bologna process and the implementation of the principles of entry

into the European educational space. In recent years, indicators of academic mobility of students and teachers have slightly decreased.

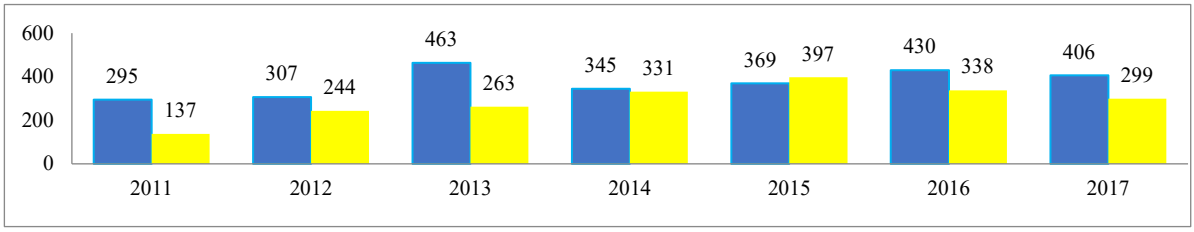

Figure 3: Indicators of academic mobility of employees and students of Lviv Polytechnic National University for the years 2011-2017 (blue colour - number of employees seconded abroad, persons and yellow colour - number of students sent for study, internship and practice abroad, persons)

One of the main activities of the university is its scientific activity. The scientific research of the research and teaching staff (R&TS) is reflected in our publications in Fig. 4.

During 2011-2017, the publishing activity of the R&TS at Lviv Polytechnic National University increased. The total number of publications increased by 1.5 times during the studied period. At the same time, the positive and rather rapid dynamics of the quality of publications are important, which is reflected in the increase in the publication number of R&TS included in scientometric databases.

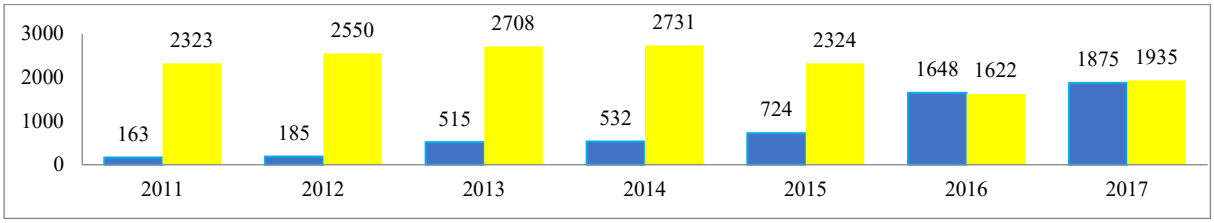

Figure 4: Publications of R&TS of LPNU in 2011-2017 [10, 11] (blue colour marks the publications included in scientometric databases, and yellow – publications in specialised publications of Ukraine)

Such a positive trend guarantees global recognition of the university's scientific activity quality.

Scientific activity at the university is carried out according to the priority directions of Ukraine's science and technology development. Scientific activities were financed from the funds of the special fund and the general fund (Fig. 5).

During 2011-2017, the total volume of financing of the research on commercial contracts (RCC) at the Lviv Polytechnic National University grew. In general, the financing of the RCC increased by 2.3 times, that is, by 19,232.4 thousand UAH. The positive dynamics of financing are observed both from the general and at the expense of the special fund. At the same time, financing from the general fund was carried out in larger volumes and developed faster.

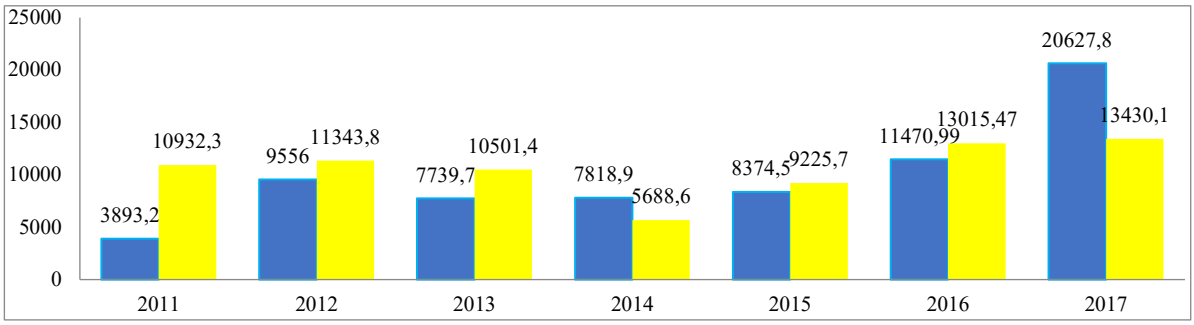

Figure 5: Fig. 5. Sources of financing of the Lviv Polytechnic National University in 2011-2017 [10, 11] (blue colour – the amount of financing from the general fund, thousand UAH, yellow colour – the amount of financing to the special fund, thousand UAH.)

The identified trends and regularities, problems and advantages should serve as prerequisites for the development strategy of the Lviv Polytechnic National University, taking into account which will allow the formation of effective mechanisms for the long term.

3. Methods

For a better understanding of the development of the dynamics of university indicators according to the QS World University Rankings, we will conduct additional research on the relevant dataset. Main research methods:

1. Correlation analysis makes it possible to detect periodic dependencies and their delays within a certain process (autocorrelation) or between several processes (cross-correlation).

2. Spectral analysis determines a time series's periodic components.

3. Smoothing and filtering methods are designed to transform time series to remove high-frequency and seasonal fluctuations from them. 4. Methods of autoregression and moving averages are used to describe and forecast processes that carry out random fluctuations around a certain average value.

5. Forecasting methods that make it possible to estimate its most probable values in the future based on the selected time series model.

4. Experiments, results and discussions

We started working with the dataset (https://data.world/education/world-university-rankings) by downloading it and doing an initial analysis. Thus, the original dataset looked like this.

The main attributes of the dataset are world_rank (place in the world rating), institution (university name), country (main branch office), national_rank (place in the national rating), quality_of_education, alumni_employment, quality_of_faculty, publications, influence, citations, broad_impact, patents, score, year. Next, the dataset was loaded into RStudio:

The given information complies with the norms of ensuring information security and is carried out using information protection per the legal requirements for creating a Comprehensive Information Protection System.

Information security entities (universities) implement an information security policy by the legislation requirements, including ISO international standards: ISO/IEC 17799:2005, ISO/IEC 27001:2013 (Sarbanes-Oxley Act), as well as by creating an information management system security based on own developments. Confidentiality, integrity and availability of information are also achieved by exchanging data with international rating systems. The obtained results are shown in Fig. 7.

```
library(readr)
#Download the data set
universityRate= read_csv('cwurData.csv', col_names = TRUE)
head(universityRate, 100)
```

institution	country	national_rank	quality_of_education	alumni_employment	quality_of_faculty	publications	influence	citations	broad_impact	patents	score
Harvard University	USA	1	7	9	1	1	1	1	NA	5	100.00
Massachusetts Institute of Technology	USA	2	9	17	3	12	4	4	NA	1	91.67
Stanford University	USA	3	17	11	5	4	2	2	NA	15	89.50
University of Cambridge	United Kingdom	1	10	24	4	16	16	11	NA	50	86.17
California Institute of Technology	USA	4	2	29	7	37	22	22	NA	18	85.21
Princeton University	USA	5	8	14	2	53	33	26	NA	101	82.50
University of Oxford	United Kingdom	2	13	28	9	15	13	19	NA	26	82.34
Yale University	USA	6	14	31	12	14	6	15	NA	66	79.14
Columbia University	USA	7	23	21	10	13	12	14	NA	5	78.86

Figure 6: Dataset in its original form

```
head(universityRate, 100)
A tibble: 100 x 14
 world_rank institution          country    national_rank quality_educat~ alumni_employme~ quality_facu~ publications influence citations broad_impact patents score
      <dbl> <chr>                <chr>             <dbl>           <dbl>           <dbl>         <dbl>        <dbl>     <dbl>     <dbl>        <dbl>   <dbl> <dbl>
          1 Harvard University   USA                   1               7               9             1            1         1         1           NA       5 100
          2 Massachusetts Instit~ USA                  2               9              17             3           12         4         4           NA       1  91.7
          3 Stanford University  USA                   3              17              11             5            4         2         2           NA      15  89.5
          4 University of Cambri~ United Ki~           1              10              24             4           16        16        11           NA      50  86.2
          5 California Institute~ USA                  4               2              29             7           37        22        22           NA      18  85.2
          6 Princeton University USA                   5               8              14             2           53        33        26           NA     101  82.5
          7 University of Oxford United Ki~            2              13              28             9           15        13        19           NA      26  82.3
          8 Yale University      USA                   6              14              31            12           14         6        15           NA      66  79.1
          9 Columbia University  USA                   7              23              21            10           13        12        14           NA       5  78.9
         10 University of Califo~ USA                  8              16              52             6            6         5         3           NA      16  78.6
... with 90 more rows
```

Figure 7: Dataset in the RStudio environment

Let's present it graphically using ggplot.

```
library(ggplot2)
data<-iris
plot(universityRate$world_rank, universityRate$score, col=universityRate$world_rank)
legend(70,40.3,unique(universityRate$world_rank),col=3:length(universityRate$world_rank),
pch=10)
p1 <- ggplot() + geom_line(aes(y = universityRate$world_rank, x =
universityRate$score),data = RGR)
p1 + labs(title = "The ratio of world_rank to score .", x = "world_rank", y = "score")
```

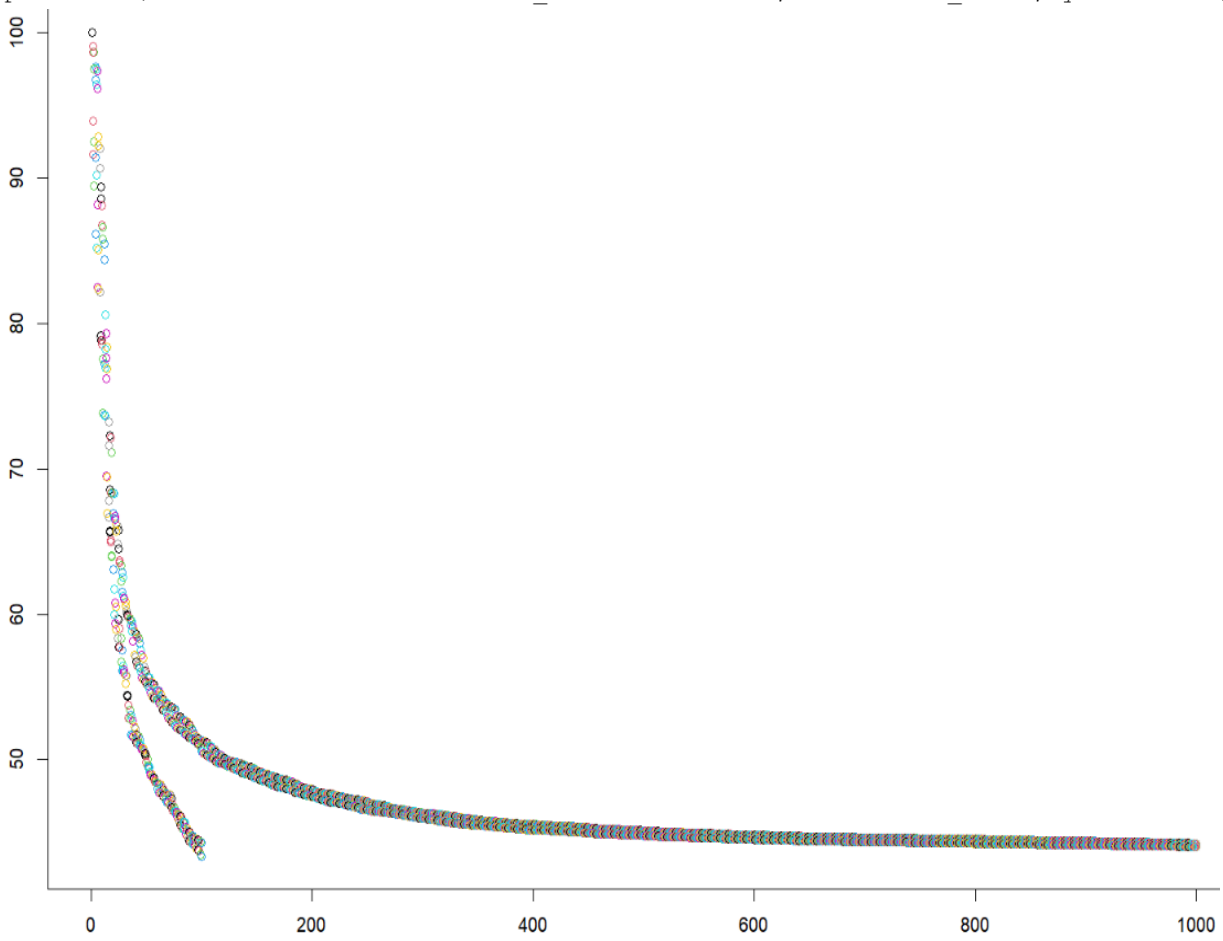

Figure 8: The ratio of the world rank number of university rates to the total number of world scores (x – unversityRate$world_rank, y- universityRare$score)

A histogram is a way of graphically presenting tabular data and their distribution. To display data in the form of histograms, use the hist function. Program code that implements a histogram, which depicts the statistics of the rating for the university:

```
library(plotrix)
std.error(universityRate$score)
mean(universityRate$score)
hist(universityRate$score,main="Histogram of univercities score", xlab="Score",
     ylab="Univercities", border="Red", col="Orange", xlim = c(40,100),
     ylim=c(0,600), breaks=100)
hist(universityRate$score, main="Score",xlab="S",col="blue")
```

Program code that implements a histogram depicting statistics of the quality of education:

```
hist(universityRate$quality_of_education, main="quality_of_education",
xlab="S",col="green")
```

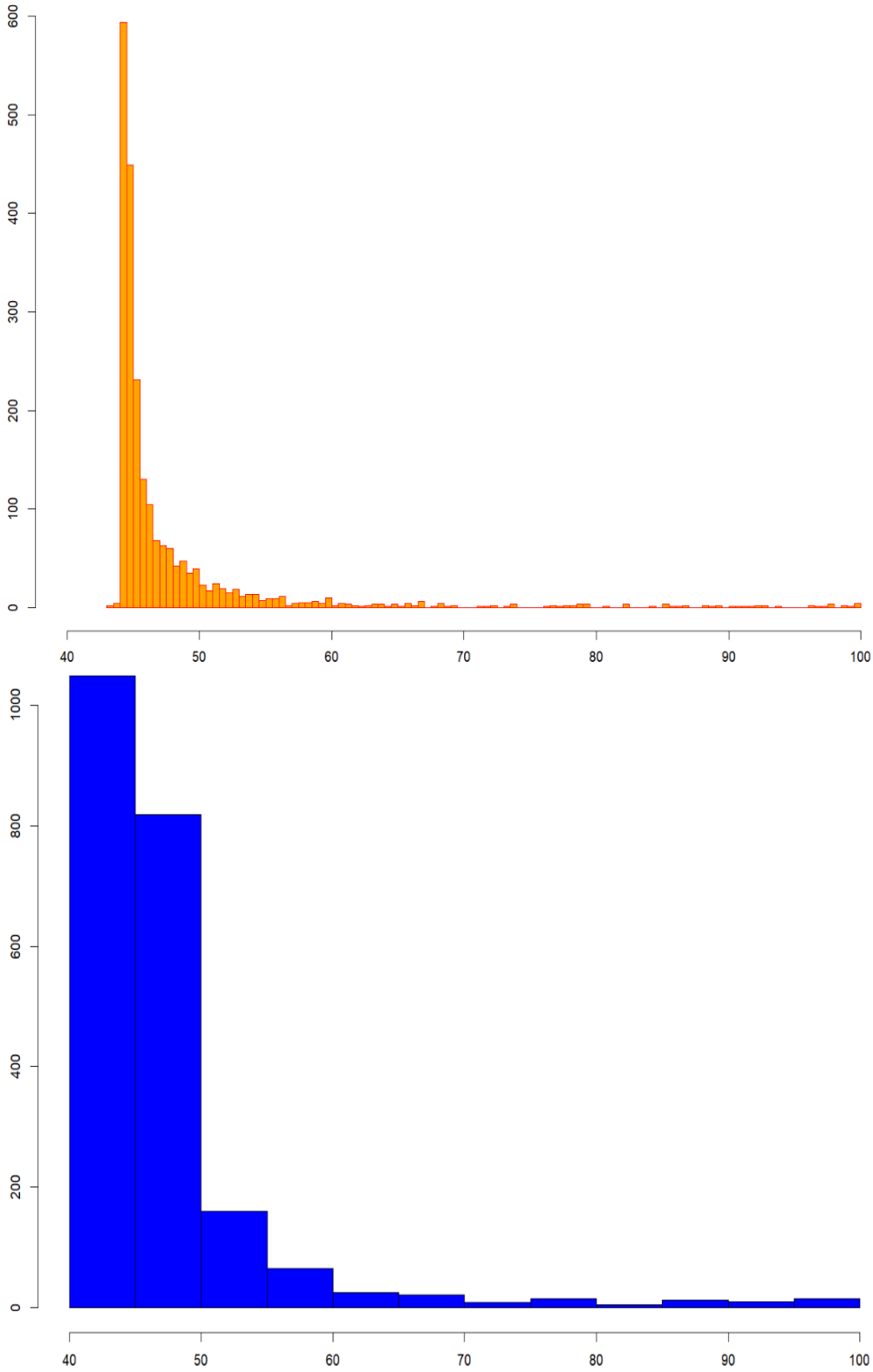

Figure 9: Histogram of the dependence of ranking statistics on the university (x – s, y- frequency)

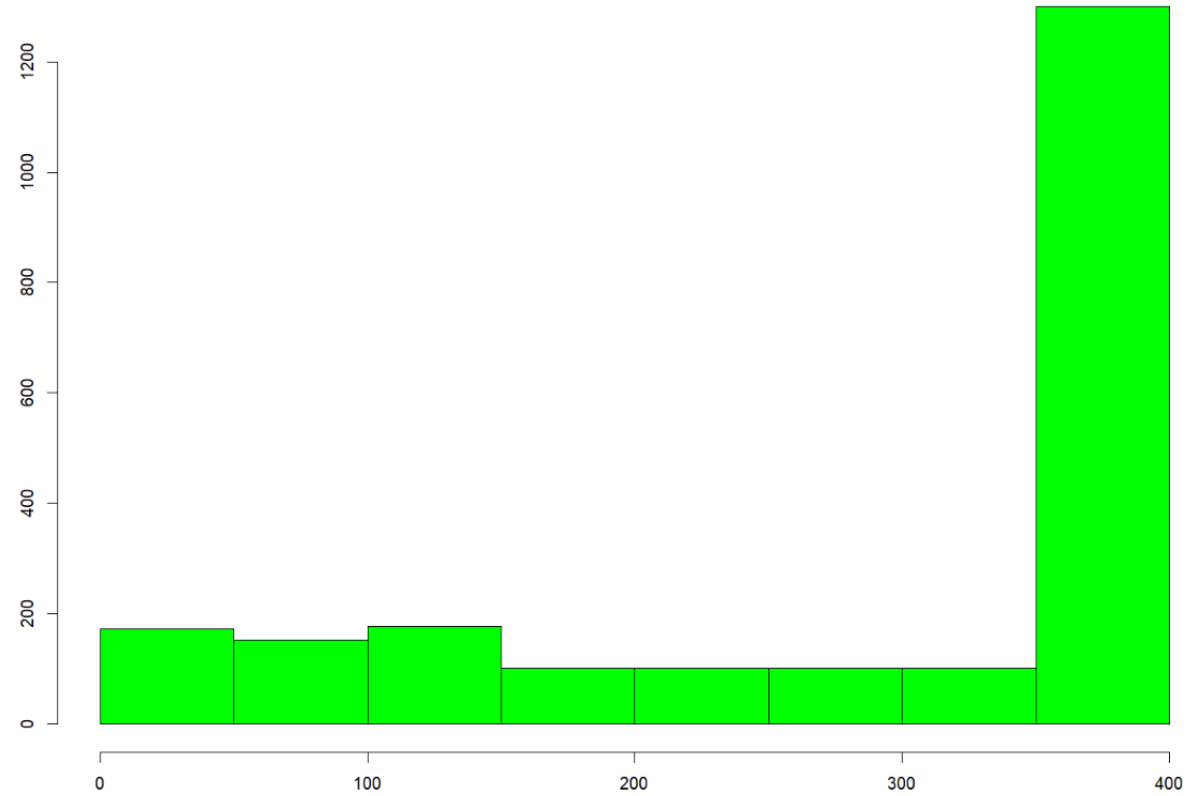

Figure 10: Histogram of dependence of education quality statistics (x – s, y- frequency)

Program code that implements a histogram that displays influence statistics:

```
hist(universityRate$influence, main="influence", xlab="S",  col="grey")
```

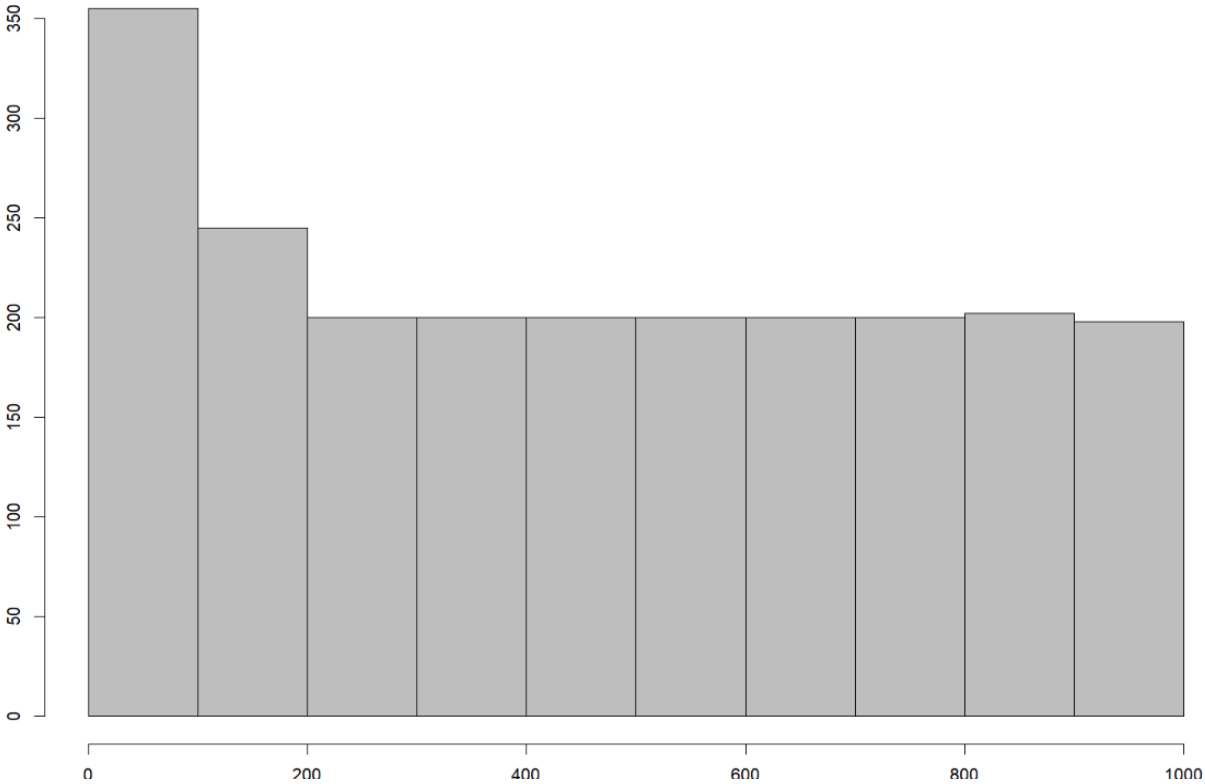

Figure 11: Histogram of influence statistics dependence (x – s, y- frequency)

Program code that implements a histogram depicting the national rating:

```
hist(universityRate$national_rank, main="national_rank",
     xlab="S",col="brown")
```

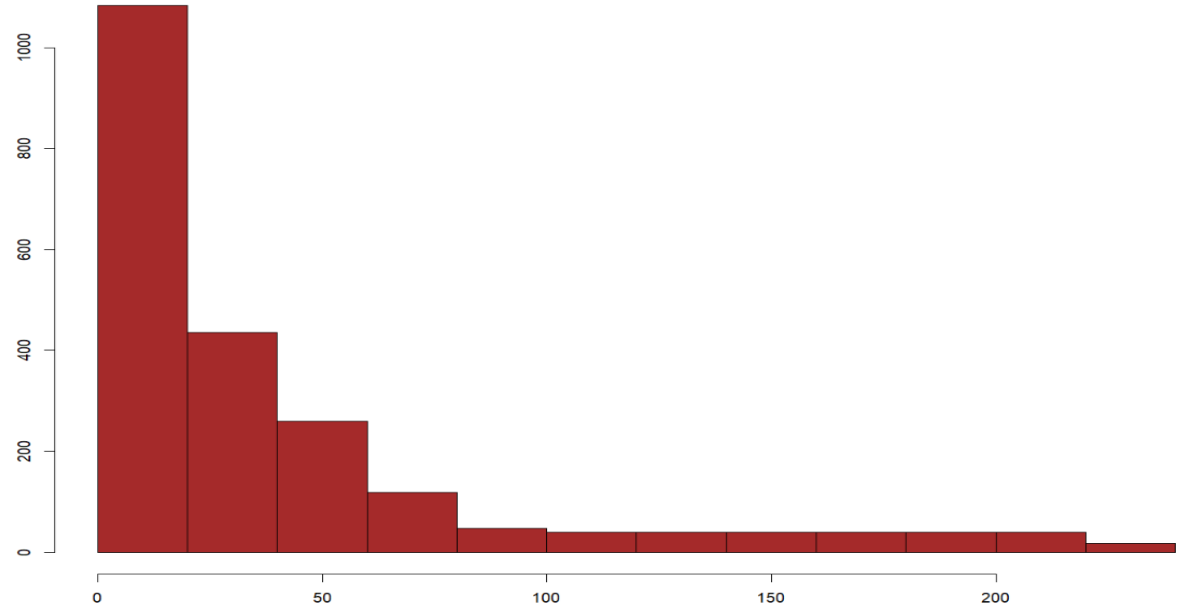

Figure 12: Histogram of the national rating (x – s, y- frequency)

```
library(ggplot2)
data<-iris
plot(universityRate$patents, universityRate$world_rank, col=universityRate$patents)
legend(7,4.3,unique(universityRate$patents),col=1:length(universityRate$patents),pch=1)
```

This histogram shows that the number of US universities in our ranking is many times greater than in other countries.

```
ggplot(universityRate,aes(x=universityRate$country,fill="USA"))+theme_bw()+
geom_bar()+labs(y="USA",title="Ratio USA to all countries")
```

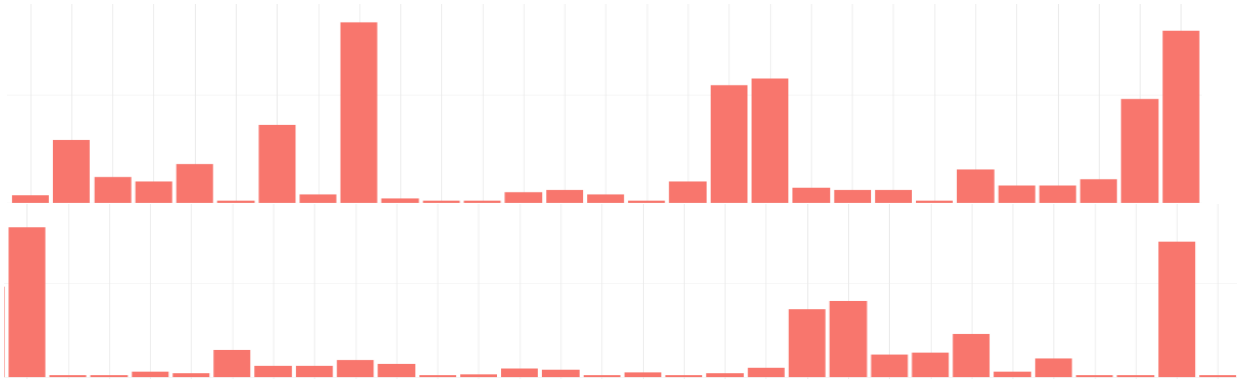

Figure 13: Histogram of universities by country of affiliation (x – countries alphabetically, y- USA)

```
ggplot(universityRate,aes(x=universityRate$score,fill=universityRate$country=="USA"))+theme_
bw()+geom_bar()+labs(y="USA",title="Ratio USA to all countries")
```

Japan's universities' relationship with other countries are following:

```
ggplot(universityRate,aes(x=universityRate$score,fill=country=="Japan"
))+theme_bw()+geom_histogram(binwidth=5)+labs(y="Japan",title="Ratio Japan to all countries")
```

Cumulative is a graphically continuous curve, giving a more accurate result than a histogram. Construction algorithm: we select intervals and build an interval table. Based on the table, we build a factor with cumulative amounts and display the result on the graph. Let's build a cumulative score indicator using intervals and built-in functions:

```
UR = universityRate$score
breaks = seq(44, 100, by=1)
UR.cut = cut(UR, breaks, right=FALSE)
UR.freq = table(UR.cut)
cumfreq0 = c(0, cumsum(UR.freq))
plot(breaks, cumfreq0, main="World_Rank", xlab="score", ylab="World_Rank")
lines(breaks, cumfreq0)
```

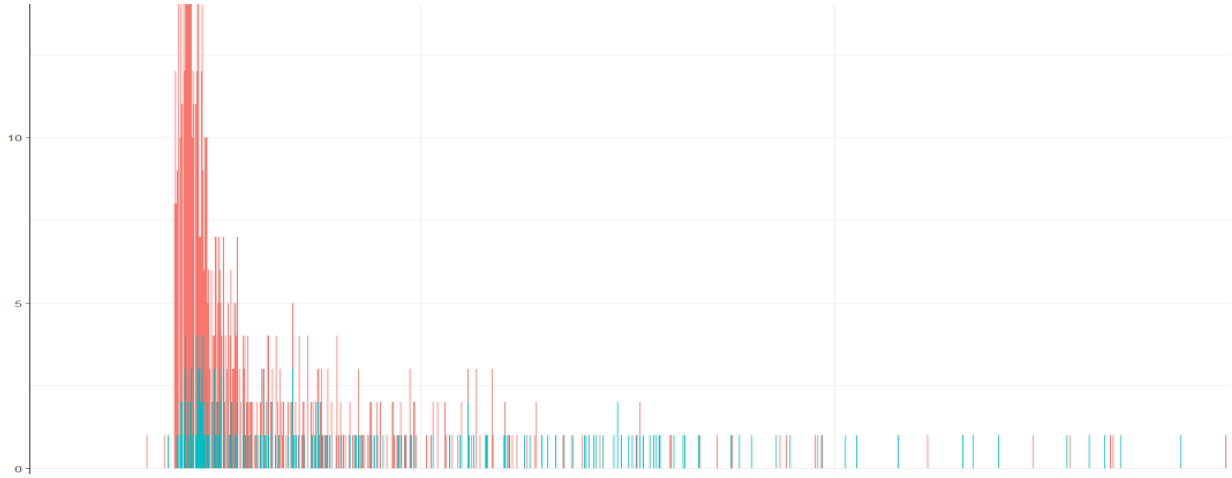

Figure 14: Histogram of US universities compared to other countries (orange - FALSE, green - TRUE)

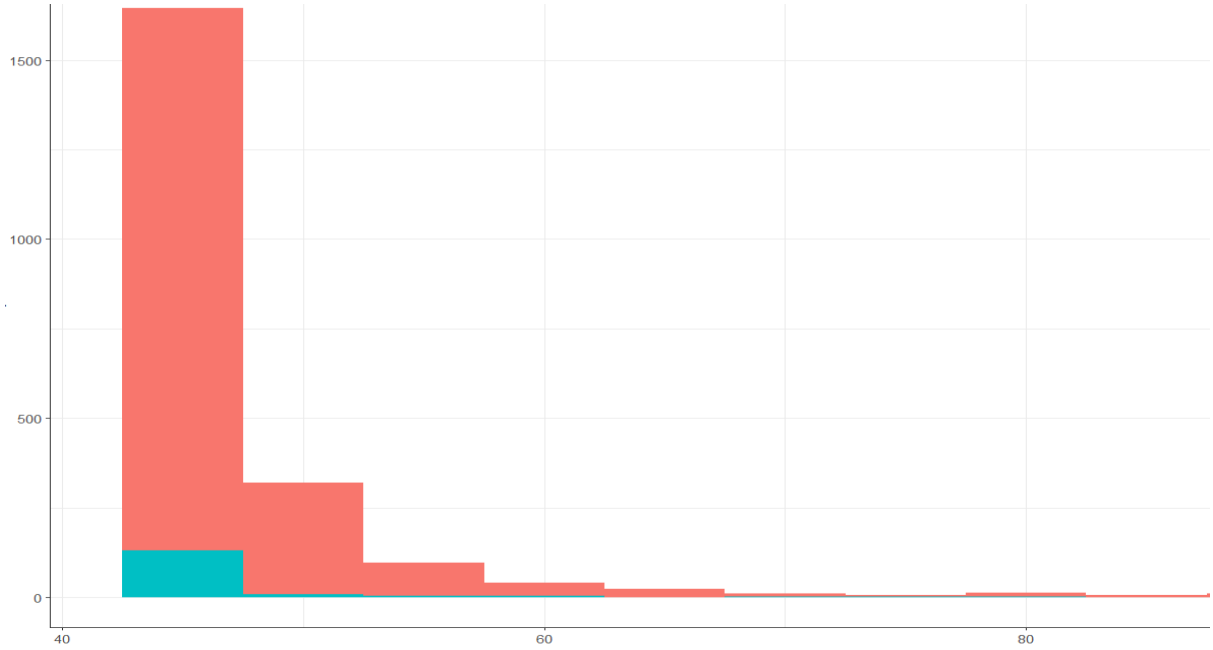

Figure 15: Universities in Japan Histogram compared to other countries (orange - FALSE, green - TRUE)

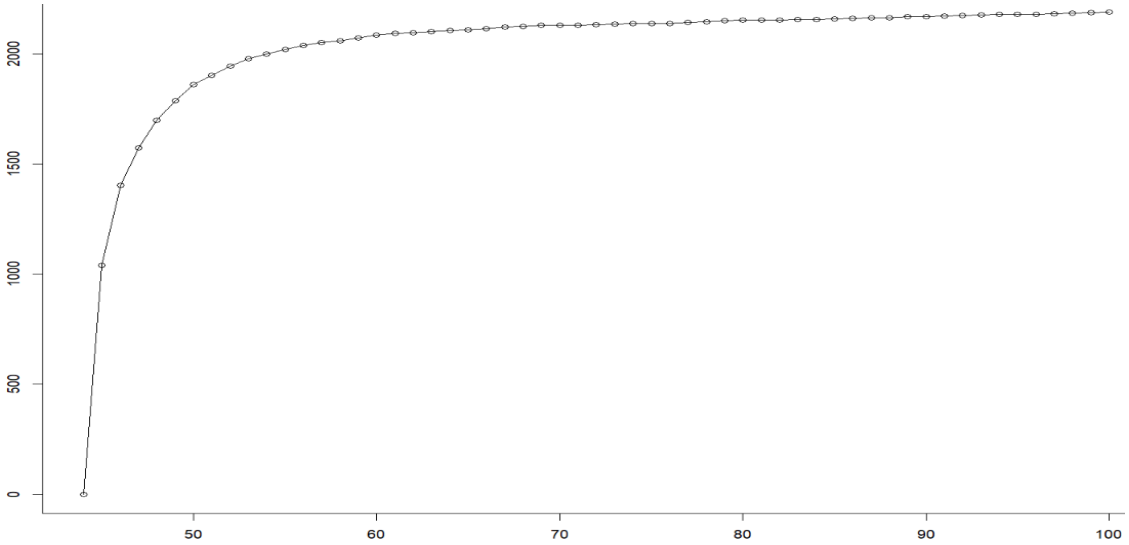

Figure 16: Cumulative the score indicator world_Rank (x – score, y- frequency)

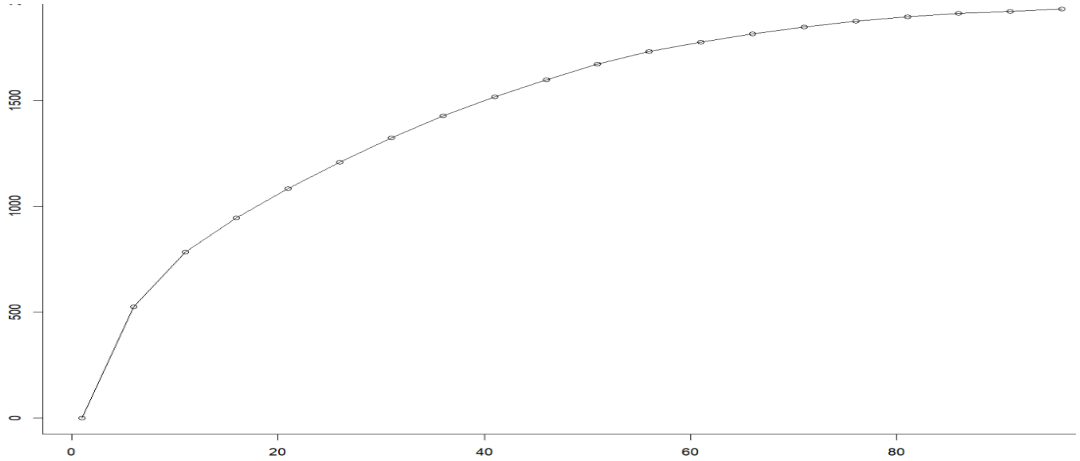

Figure 17: Cumulative for the national_rank indicator (x – score, y- frequency)

Let's build a cumulate for the national_rank indicator using intervals and built-in functions:

```
national_rank = universityRate$national_rank
breaks = seq(1, 100, by=5)
national_rank.cut = cut(national_rank, breaks, right=FALSE)
national_rank.freq = table(national_rank.cut)
cumfreq0 = c(0, cumsum(national_rank.freq))
plot(breaks, cumfreq0, main="national_rank", xlab="national_rank", ylab="")
lines(breaks, cumfreq0)
```

Let's build a cumulate for the influence indicator using intervals and built-in functions:

```
influence  = universityRate$influence
breaks = seq(1, 340, by=10)
influence.cut = cut(influence , breaks, right=FALSE)
influence.freq = table(influence.cut)
cumfreq0 = c(0, cumsum(influence.freq))
plot(breaks, cumfreq0, main="Influence Univercity Rank", xlab="influence",
     ylab= "Univercity")
lines(breaks, cumfreq0)
```

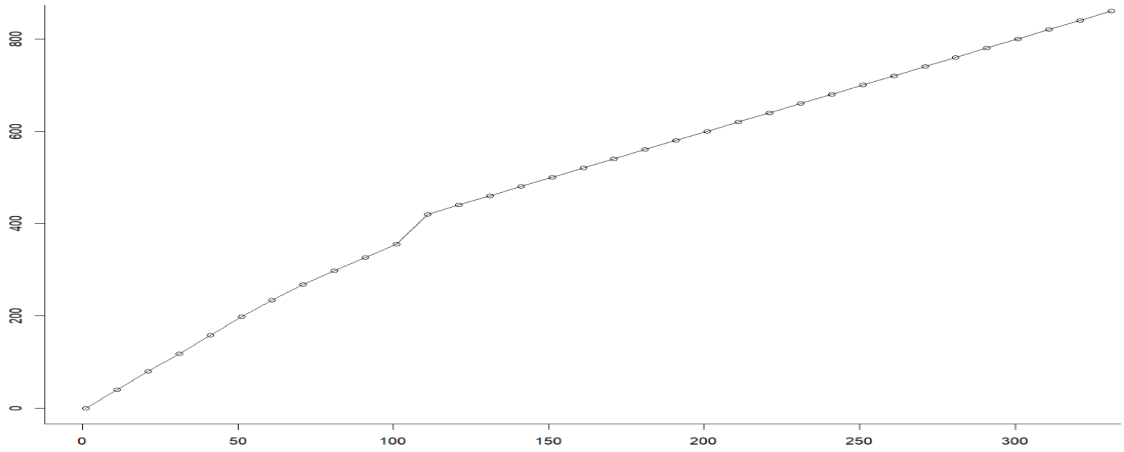

Figure 18: Cumulative for the influence indicator rank (x – score, y- frequency)

Let's construct a cumulate for the quality_of_faculty indicator using intervals and built-in functions:

```
quality_of_faculty  = universityRate$quality_of_faculty
breaks = seq(7, 360, by=5)
quality_of_faculty.cut = cut(quality_of_faculty, breaks, right=FALSE)
quality_of_faculty.freq = table(quality_of_faculty.cut)
cumfreq0 = c(0, cumsum(quality_of_faculty.freq))
plot(breaks, cumfreq0, main="Univercity quality of faculty Rank",
     xlab="quality_of_faculty", ylab="")
lines(breaks, cumfreq0)
```

Let's construct a cumulate for quality_of_education indicator using intervals and built-in functions:

```
quality_of_education = universityRate$quality_of_education
breaks = seq(44, 100, by=1)
quality_of_education.cut = cut(quality_of_education, breaks, right=FALSE)
```

```
quality_of_education.freq = table(quality_of_education.cut)
cumfreq0 = c(0, cumsum(quality_of_education.freq))
plot(breaks,cumfreq0,main="quality_of_education",
     xlab="quality_of_education",ylab="")
lines(breaks, cumfreq0)
```

To highlight the behaviour trends of the studied indicator, represented by the nature of its trend, with the help of time series smoothing methods and presentation of the obtained results using the R programming language and the R Studio environment, we will perform smoothing by various methods: library(zoo) # moving averages, library(tidyverse) # all tidyverse packages, library(hrbrthemes) # themes for graphs, library(socviz) # %nin%, library(geofacet) # maps, library(usmap) # lat and long, library(socviz) # for %nin%, library(ggmap) # mapping, appRate = universityRate$patents, my_moving_average_2 <- rollmean(appRate, k = 3), my_moving_average_2, my_moving_average_2 <- rollmean(appRate, k = 5), my_moving_average_2, my_moving_average_2 <- rollmean(appRate, k = 7), my_moving_average_2

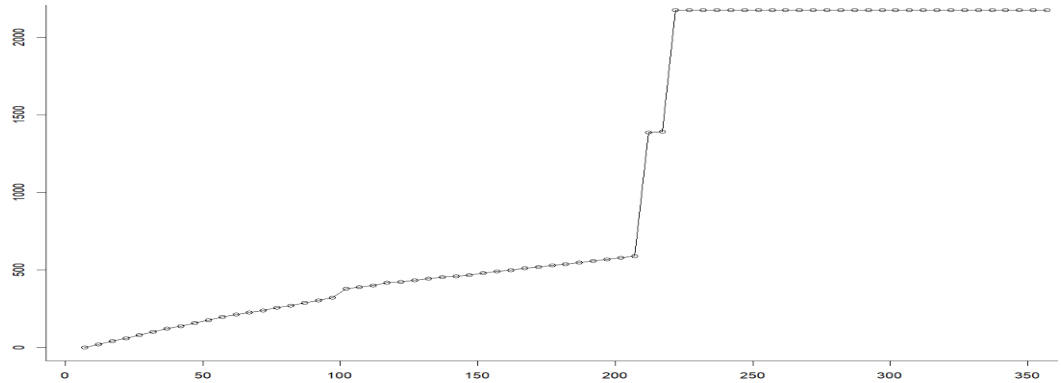

Figure 19: Cumulative for the quality_of_faculty indicator (x – score, y- frequency)

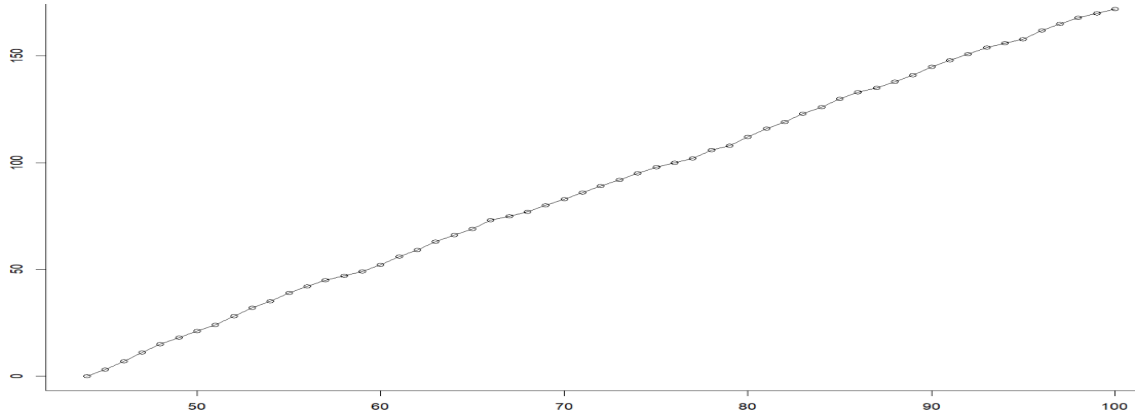

Figure 20: Cumulative for the quality_of_education indicator (x – score, y- frequency)

Let's build a moving average linear smoothing for the indicator Z(Number of connectors) using intervals and built-in functions:

```
> my_moving_average_2 <- rollmean(appRate, k = 3)
> my_moving_average_2
  [1]   7.000000  22.000000  27.666667  56.333333  48.333333  64.333333  32.333333
 [16]  28.666667  21.666667  21.333333  45.333333  50.333333  63.666667  41.000000
 [31]  44.000000  18.000000  48.000000  46.000000  48.000000  18.333333  42.333333
 [46]  89.000000  83.333333  70.666667  54.000000  44.000000  55.666667  72.333333
 [61] 101.000000 100.333333 100.333333 100.333333 101.000000 101.000000  92.000000
 [76] 101.000000  77.000000  59.666667  41.333333  65.333333  82.666667  96.000000
 [91]  82.666667  72.000000  90.333333  90.000000  97.666667  97.666667  98.000000
[106]  43.333333  73.666667  81.333333  53.333333  24.333333  12.666667   8.666667
[121]  39.000000  53.333333  40.333333  37.000000  30.666667  32.666667  59.666667
[136]  79.333333  59.000000  26.666667  48.333333  44.000000  74.666667  63.333333
[151]  83.666667  83.333333  66.333333  70.000000  47.333333  77.666667  77.666667
[166]  91.666667  82.000000  72.666667  60.000000  79.000000  61.333333  74.000000
[181]  77.666667  77.666667  85.333333 101.000000  76.333333  76.333333  72.666667
[196]  94.333333  94.333333  78.000000  45.000000  13.333333   3.000000  18.333333
[211]  11.666667  17.000000  17.333333  18.666667  25.333333  50.000000  45.000000
[226]  54.333333  55.333333  76.666667 105.000000 108.000000  85.666667  89.000000
[241] 110.666667 104.000000  48.666667  70.666667  58.666667 291.666667 281.000000
[256] 185.333333  85.666667  85.666667  51.333333  56.000000  76.000000 152.333333
[271] 269.666667 260.333333 318.000000 185.000000 202.666667 153.000000 200.666667
[286] 127.333333 171.000000 226.000000 237.666667 193.666667 147.000000  44.000000
```

Figure 21: Linear smoothing when w=3

Let's build a moving average linear smoothing for the indicator Z (Number of connectors) using intervals and built-in functions:

```
my_moving_average_2 <- rollmean(appRate, k = 5)
my_moving_average_2
  [1]  17.8  37.0  42.0  52.2  43.2  42.8  42.8  39.6  28.2  27.8  26.0  12.6  15.2  19.2
 [29]  58.0  39.4  48.2  36.8  37.4  32.8  51.4  51.4  65.8  66.8  84.6  69.0  55.2  55.2
 [57]  99.2  99.2 101.0 100.6 100.6 100.6 100.6 100.6  95.6  95.6  87.6  84.4  84.4  78.8
 [85]  88.8  88.8  88.8  90.0  90.0  83.6  83.6  83.4  92.6  92.6  99.0  99.0  80.4  64.2
[113]   7.8  18.4  27.6  29.4  31.8  44.0  38.0  41.2  41.6  40.8  37.8  37.8  44.6  54.4
[141]  78.4  78.4  93.2  90.2  97.0  90.2  90.2  82.0  83.8  83.6  72.0  72.0  66.4  68.4
[169]  60.2  71.6  77.2  74.8  74.8  91.0  91.0  91.0 101.0  96.4  87.0  87.0  87.0  87.0
[197]  63.4  48.4  28.4  17.8  14.6  15.0  19.4  49.0  80.2  86.0  87.6  83.8  56.8  21.6
[225]  47.2  65.8  87.2  86.6  84.6 107.4 230.6 237.0 271.6 271.0 246.0 139.4 122.0 117.4
[253] 123.2 146.6 114.2 126.4  80.6  71.4  60.8 120.6 234.4 255.0 296.0 290.4 247.8 181.8
[281] 110.6  82.2  49.2 112.0 127.0 144.4 213.4 215.6 156.2 137.2 121.0  55.2  88.6 125.8
[309] 257.2 289.0 208.4 281.2 301.0 292.0 279.0 315.2 206.6 228.8 264.6 373.2 344.4 325.6
[337] 211.6 196.4 242.2 366.6 307.0 327.0 318.0 261.8 142.0 191.0 195.2 248.6 304.8 362.4
[365] 548.6 548.6 548.6 428.8 291.6 222.6 236.2 129.6 142.8 178.0 299.8 315.8 371.2 398.0
[393] 228.4 235.2 193.0 210.8 266.2 297.4 295.4 221.0 323.0 256.6 241.4 277.2 300.4 220.6
```

Figure 22: Linear smoothing when w=5

```
my_moving_average_2 <- rollmean(appRate, k = 7)
my_moving_average_2
  [1]  30.85714  39.57143  40.14286  40.28571  47.57143  46.42857  33.28571  30.00000  21.57143  25.71429
 [18]  41.14286  40.00000  44.42857  44.14286  35.57143  46.00000  45.28571  52.85714  51.42857  50.14286
 [35]  65.57143  53.85714  64.14286  65.42857  68.28571  68.28571  63.14286  63.14286  72.42857  61.85714
 [52]  63.85714  70.57143  76.14286  76.14286  90.28571  99.71429  99.42857 100.71429 100.71429 100.71429
 [69]  67.42857  71.28571  71.28571  77.00000  69.00000  61.57143  61.57143  75.42857  75.42857  73.28571
 [86]  84.42857  84.42857  88.57143  88.57143  88.42857  87.14286  87.14286  95.00000  95.00000  86.14286
[103]  40.85714  44.71429  47.00000  43.42857  43.00000  41.00000  28.42857  15.71429  10.00000  16.14286
[120]  35.71429  39.42857  40.28571  45.71429  51.85714  49.57143  47.00000  51.00000  50.14286  48.28571
[137]  57.85714  53.00000  62.28571  71.00000  84.85714  82.00000  92.57143  88.42857  93.28571  87.42857
[154]  77.71429  69.14286  82.28571  82.28571  92.14286  92.28571  88.28571  88.28571  97.00000  88.85714
[171]  76.85714  82.28571  82.28571  93.85714  93.85714  90.57143  91.00000  91.00000  91.00000  91.00000
[188]  80.00000  69.28571  70.85714  68.00000  74.14286  81.71429  74.71429  63.42857  60.57143  46.28571
[205]  65.42857  64.42857  65.85714  65.85714  46.00000  19.42857  19.85714  30.14286  29.28571  29.14286
[222]  42.42857  43.14286  51.71429  72.28571  76.00000  77.71429  92.28571 188.42857 207.85714 223.00000
[239]  97.42857 106.85714  83.14286 175.00000 155.57143 199.00000 193.14286 190.57143 185.42857 204.28571
[256] 104.57143  79.00000 113.14286 178.28571 203.00000 225.71429 228.85714 239.14286 264.71429 228.14286
[273] 270.57143 185.00000 206.00000 204.14286 159.28571 160.42857 167.42857 102.71429  85.28571 109.28571
[290] 118.57143 120.42857  99.57143 110.00000 195.14286 218.42857 218.42857 224.14286 207.57143 215.14286
[307] 194.57143 229.42857 231.85714 322.85714 286.57143 256.00000 265.42857 273.28571 264.00000 301.14286
[324] 269.57143 269.57143 262.85714 259.71429 272.28571 279.85714 218.28571 253.42857 159.28571 166.00000
[341] 279.00000 260.00000 250.57143 260.00000 194.71429 237.28571 244.14286 282.28571 347.28571 335.71429
```

Figure 23: Linear smoothing when w=7

The content of the median smoothing algorithm of the time series consists of the defined median values for the smoothing interval levels. Next, the time series level value corresponding to the middle of the smoothing interval is replaced by the median value. Median smoothing completely removes single extreme or anomalous values of levels separated by at least half of the smoothing interval. Median smoothing preserves sharp changes in the trend, but moving average and exponential smoothing smooth them. It effectively removes single levels with large or small random values that stand out sharply from other levels. We smooth the data using the sizes of the smoothing interval w = 3, 5, 7, 9, 11, 13, 15 to obtain seven columns using the function runmed():

```
library(ggplot2)
data<-iris
plot(universityRate$patents, universityRate$world_rank, col=universityRate$patents)
legend(7,4.3,unique(universityRate$patents),col=1:length(universityRate$patents),pch=1)
require(graphics)
myNHT <- as.vector(universityRate$patents)
plot(myNHT, type = "b", ylim = c(0,1000), main = "Running Medians")
lines(runmed(myNHT, 10000), col = "red")
```

Smoothing according to formulas from Pollard

```
Key Function =WMA()
d <- read.csv('cwurData.csv',strip.white = TRUE,stringsAsFactors = FALSE)
head(d)
summary(d)
nrow(d)
library(TTR)
kingstimeseriesSMA3 <- SMA(universityRate$patents,n=3)
plot.ts(kingstimeseriesSMA3)
ggplot(aes(id,dataR$Reviews, color = metric)) +  geom_line()
```

```
> summary(d)
   world_rank     institution          country          national_rank    quality_of_education alumni_employment quality_of_faculty  publications
 Min.   :   1.0   Length:2200        Length:2200        Min.   :  1.00   Min.   :  1.0        Min.   :  1.0      Min.   :  1.0      Min.   :   1.0
 1st Qu.: 175.8   Class :character   Class :character   1st Qu.:  6.00   1st Qu.:175.8        1st Qu.:175.8      1st Qu.:175.8      1st Qu.: 175.8
 Median : 450.5   Mode  :character   Mode  :character   Median : 21.00   Median :355.0        Median :450.5      Median :210.0      Median : 450.5
 Mean   : 459.6                                        Mean   : 40.28   Mean   :275.1        Mean   :357.1      Mean   :178.9      Mean   : 459.9
 3rd Qu.: 725.2                                        3rd Qu.: 49.00   3rd Qu.:367.0        3rd Qu.:478.0      3rd Qu.:218.0      3rd Qu.: 725.0
 Max.   :1000.0                                        Max.   :229.00   Max.   :367.0        Max.   :567.0      Max.   :218.0      Max.   :1000.0

   citations      broad_impact       patents          score             year
 Min.   :  1.0   Min.   :   1.0   Min.   :  1.0   Min.   : 43.36   Min.   :2012
 1st Qu.:161.0   1st Qu.: 250.5   1st Qu.:170.8   1st Qu.: 44.46   1st Qu.:2014
 Median :406.0   Median : 496.0   Median :426.0   Median : 45.10   Median :2014
 Mean   :413.4   Mean   : 496.7   Mean   :433.3   Mean   : 47.80   Mean   :2014
 3rd Qu.:645.0   3rd Qu.: 741.0   3rd Qu.:714.2   3rd Qu.: 47.55   3rd Qu.:2015
 Max.   :812.0   Max.   :1000.0   Max.   :871.0   Max.   :100.00   Max.   :2015
                 NA's   :200
> nrow(d)
[1] 2200
```

Figure 24: Smoothing according to formulas from Pollard

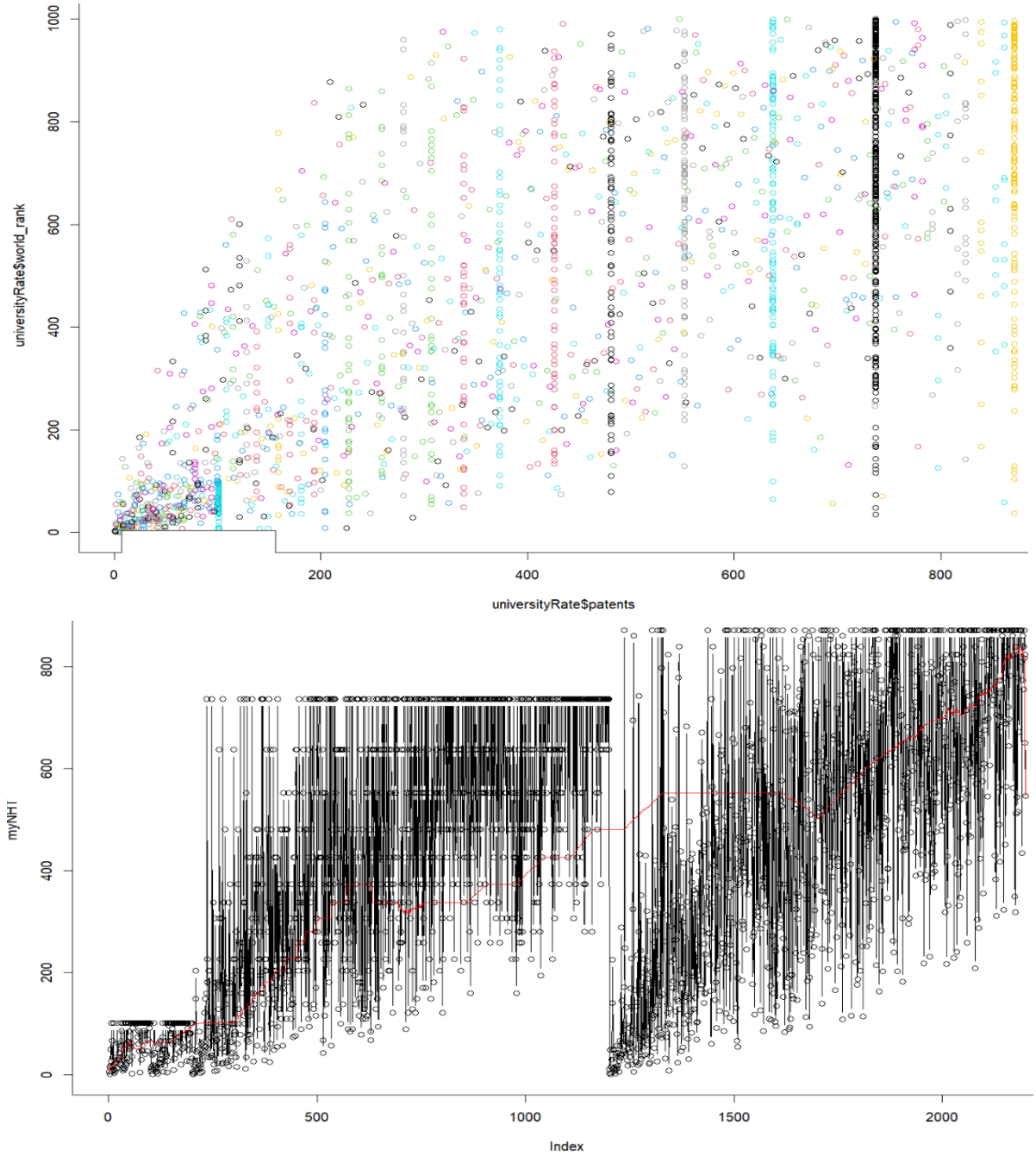

Figure 25: Median smoothing results

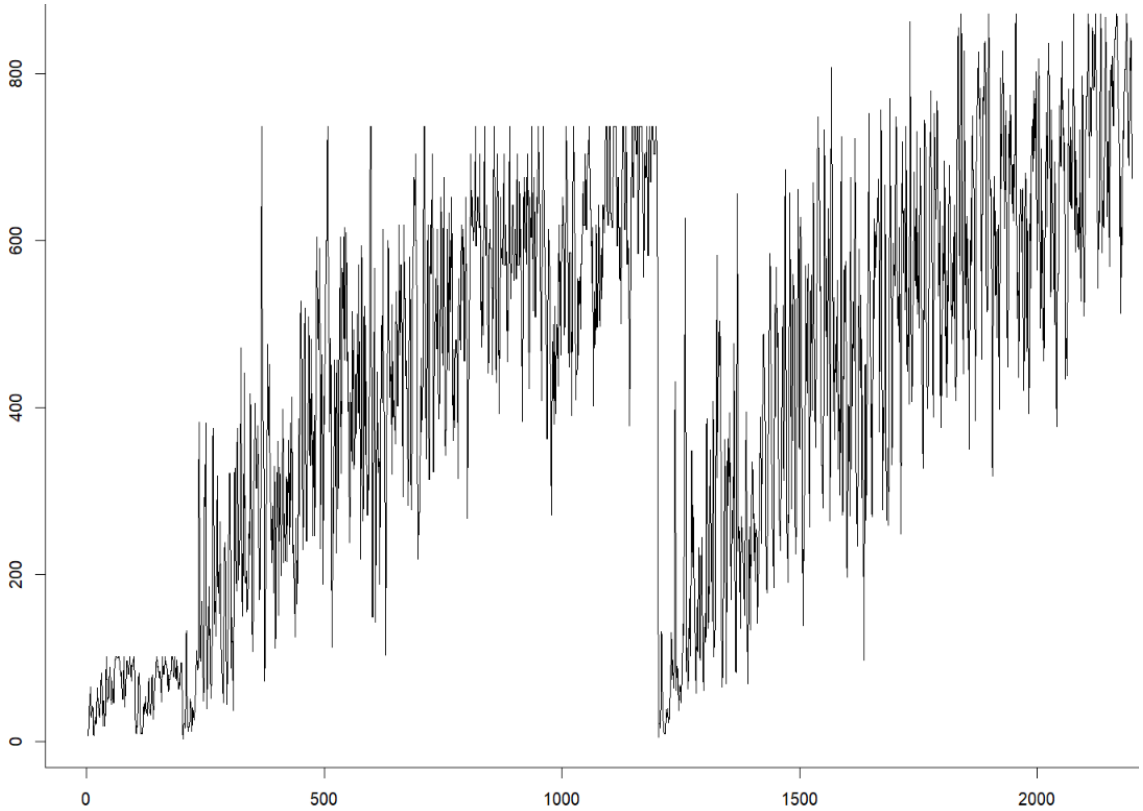

Figure 26: Results of smoothing according to formulas from Pollard (x – time, y- kingstimeseriesSMA3)

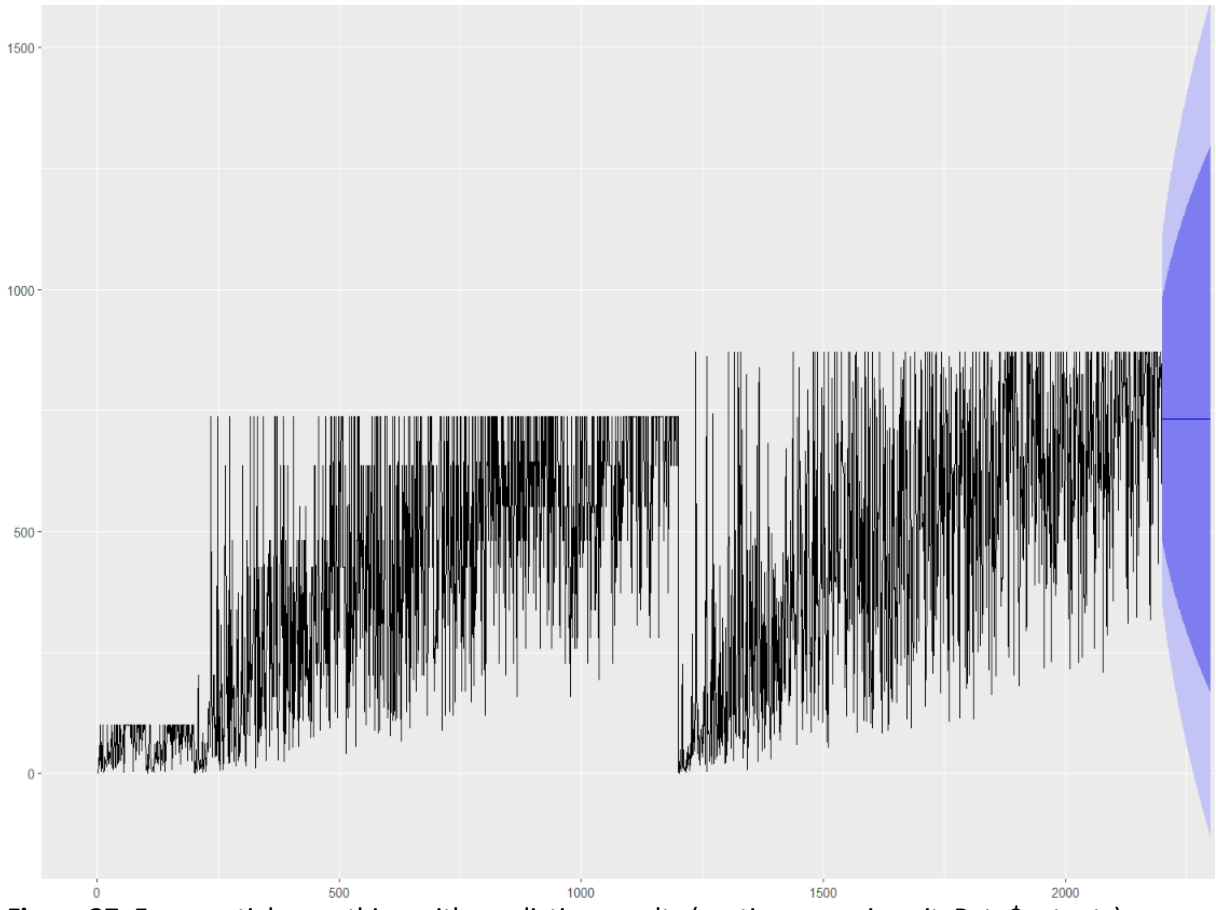

Figure 27: Exponential smoothing with prediction results (x – time, y- universityRate$patents)

Correlation is following:

```
library("ggpubr")
cor(universityRate$world_rank, universityRate$score, method = c("pearson", "kendall", "spearman"))
cor(universityRate$world_rank, universityRate$quality_of_education, method = c("pearson", "kendall", "spearman"))
cor(universityRate$world_rank, universityRate$publications, method = c("pearson", "kendall", "spearman"))
cor.test(universityRate$world_rank, universityRate$quality_of_education, method=c("pearson", "kendall", "spearman"))
```

```
> cor(universityRate$world_rank, universityRate$score, method = c("pearson", "kendall", "spearman"))
[1] -0.5490984
> cor(universityRate$world_rank, universityRate$quality_of_education, method = c("pearson", "kendall", "spearman"))
[1] 0.6761658
> cor(universityRate$world_rank, universityRate$publications, method = c("pearson", "kendall", "spearman"))
[1] 0.9230371
> cor.test(universityRate$world_rank, universityRate$quality_of_education, method=c("pearson", "kendall", "spearman"))

        Pearson's product-moment correlation

data:  universityRate$world_rank and universityRate$quality_of_education
t = 43.028, df = 2198, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.6528222 0.6982264
sample estimates:
      cor
0.6761658
```

Figure 28: The obtained data of the different types of correlation

```
library("ggpubr")
ggscatter(universityRate, x = "world_rank", y = "quality_of_education", add = "reg.line", conf.int = TRUE, cor.coef = TRUE, cor.method = "pearson", xlab = "world_rank", ylab = "quality_of_education")
```

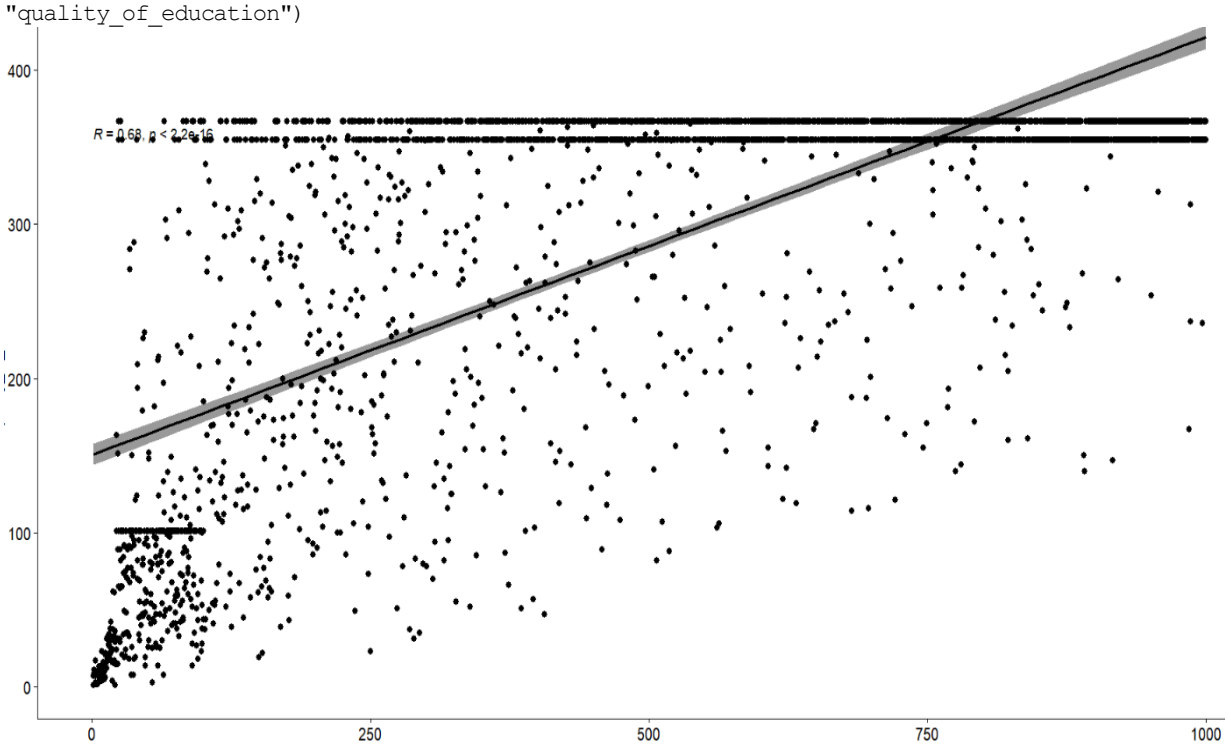

Figure 29: The correlation results for the education quality (x – world_rank, y- quality_of_education)

```
library("ggpubr")
ggqqplot(universityRate$quality_of_faculty, ylab = "quality_of_faculty")
ggqqplot(universityRate$publications, ylab = "publications")
The following code was used to gain the empirical correlation relation.
data <- data.frame(Appearance = c(universityRate$score),
                   Thickness = c(universityRate$quality_of_education),
                   Spredability= c(universityRate$publications))
cov(data)
```

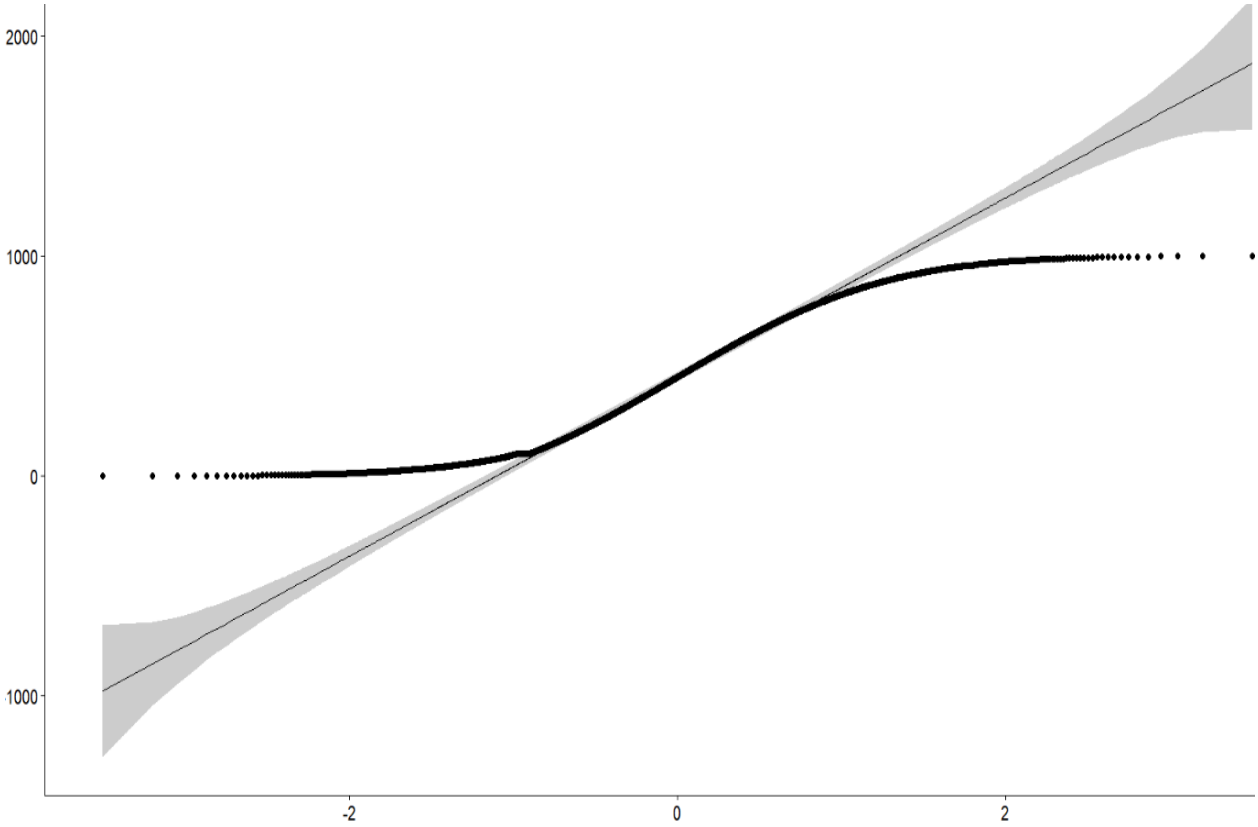

Figure 30: The correlation results for the faculty quality (x – theoretical, y- publications)

```
> cov(data)
                Appearance  Thickness Spredability
Appearance       60.23012  -568.3004    -1230.838
Thickness      -568.30043 14868.1686    23136.694
Spredability -1230.83844 23136.6945    92270.351
```

Figure 31: Correlation empirical relation

The correlation matrix allows us to find the relationship between more than two variables of different higher educational institutions worldwide.

```
data("universityRate")
my_data <- universityRate[, c(1,3,4,5,6,7)]
# print the first 10 rows
head(my_data, 6)
res <- cor(universityRate)
round(res, 2)
```

world_rank	country	national_rank	quality_of_education	alumni_employment	quality_of_faculty
<dbl>	<chr>	<dbl>	<dbl>	<dbl>	<dbl>
1	USA	1	7	9	1
2	USA	2	9	17	3
3	USA	3	17	11	5
4	United Kingdom	1	10	24	4
5	USA	4	2	29	7
6	USA	5	8	14	2

Figure 32: The correlation matrix

Discussing the obtained results of the rating analysis, they indicate the possibility of their use as part of economic methods for processing information about the current state and prospects for developing business processes in HEI. It will make it possible to make balanced management decisions based on objective information about the development of business processes in universities.

The identified structural regularities of the development of universities and the possibilities of information technologies testify to the effective application of the economic and statistical information analysis method.

Adapting the obtained results depends on the internal environment of each university.

However, it contributes to adopting effective management decisions based on financial and statistical information analysis on the ranking positions of each higher education institution.

A thorough analytical review and informational notes based on the results of the analysis of rating positions by specific needs will enable the university management, with the help of the proposed method of collecting statistical information, its processing and analysis, to form the necessary database (personal, integral and accessible) for the formation of plans for the development of higher education institutions.

We can use the proposed method of strategic analysis of the rating position to forecast the set goal. It will also contribute to developing a comprehensive information system and analytical support for the university's development strategy. The following stages can be distinguished in the proposed methodology:

1. Formation of an information base for the study of subjects of economic activity
2. Organisation and processing of internal and external information about business entities.
3. Organisation and monitoring of business entities.
4. Coordination with the regulatory framework regarding economic and financial analysis organisation.
5. Compilation of an information note, analytical report and review by the needs of interested organisations.
6. Development of a proposal for effective decision-making, adaptation and support based on information analysis and compliance with information security requirements.
7. Organisation of the collection, collection and systematisation process of available information, using scientific methods of its primary and secondary evaluation at the university.
8. Implement mixed methods, including hall tests, home tests and mystery shopping.
9. Formation of the structure of the decision-making information support system.
10. Information provision of the processes of optimisation of university activities.
11. Development of the university's strategic management system, determination of possible strategies, and selection strategic economic zones and centres.
12. Implementation of strategic analysis, selection of areas of strategic analysis, formation of single business strategy, growth and development strategy of the university, analysis and management of the university portfolio.

The proposed method of strategic analysis by ranking the university along with its advantages has one significant drawback - the rating position and its changes (growth or decline) may not indicate the university's true positive or negative development but is only a relative indicator. It is important to understand that the position is relative to the number of universities included in the rating and changes in their quality characteristics.

5. Conclusions

The competitive positions of any higher educational institution in the world, regional and national markets of educational services are reflected in the positions of the university in the relevant educational ratings and indicators that characterise its competitive advantages. Improving these positions improves the competitiveness of these higher primary institutions.

Using the example of Lviv Polytechnic National University, the peculiarities of the impact of some indicators on changes in the value of the rating in the well-known world, regional and national educational ratings are considered.

Correcting these indicators, for example, by encouraging employees, creating suitable working conditions for them, and improving the quality of educational services, helps support the competitiveness of a higher institution in the struggle for leadership in the world market of educational services and at the same time, affects the growth of international scientific cooperation of this institution in the world market useful services.

The relatively low-quality indicators of higher education in Ukraine are justified by the low positions of domestic universities in world educational rankings, which reflects the need to form a mechanism for improving the quality of higher education.

The aggravation of the disproportion between the needs of employers in personnel of certain qualifications and the appropriate quality and the labour market offers from graduates of domestic educational institutions requires training specialists with higher education, which is adequate to the market's requirements.

There is a need to implement the provisions of the strategic development of the higher world of Ukraine in the formation of strategic guidelines for the development of the corresponding higher educational institution, taking into account the needs and requirements of the world market of educational services, as well as based on the peculiarities of the formation of the university rating based on the QS World University Rankings research.

Among the 2,679 universities included in the rating, Lviv Polytechnic National University takes 2nd place among Ukrainian universities according to data as of the end of January 2023, is included in the list of 200 universities that share the position between 600 and 800 according to the Times Higher Education World University Rankings, takes 78th position according to the QS University Rankings for the EECA region, and at the national level it has significantly improved its position: it ranks 4th in the ranking of universities according to Scopus database indicators, 3rd in the Academic rating "TOP-200 Ukraine" and 3rd in the Consolidated rating of higher educational institutions in Ukraine.

The proposed method of strategic analysis through university rating has several limitations, among which the most significant is the constant change in the quantitative and qualitative composition of rating participants.

Therefore, the rating position and its changes (growth or decline) may not indicate the real positive or negative development of the university but is only a relative indicator. It is important to understand that the position is relative to the number of universities included in the rating and changes in their quality characteristics.

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