Doing Hirsch proud; shaping H-index in engineering sciences

L. CZARNECKI[1]*, M.P. KAŹMIERKOWSKI[2], and A. ROGALSKI[3]

[1] Building Research Institute, 1 Filtrowa St., 00-611 Warsaw, Poland
Faculty of Civil Engineering, Warsaw University of Technology, 16 Armii Ludowej Ave., 00-637 Warsaw, Poland
[2] Institute of Control and Industrial Electronics, Warsaw University of Technology, 75 Koszykowa St., 00-662 Warsaw
[3] Institute of Applied Physics, Military University of Technology, 2 Kaliskiego St., 00-908 Warsaw, Poland

Abstract. The h-index concept has been analysed in aspects of a contemporary tendency of parameterisation of everything and as the potential measure of the knowledge progress, which recognises individuals, institutions and Engineering sub-disciplines that best generate new knowledge. Considerations have been presented at the level of universality of knowledge which implies permanent progress and on the base of careful thoughts of the domestic experience. The h-nature of things has been described, and several axiomatic characterisations of the Hirsch index have been gathered. The mechanism how to increase the h-index has been presented. Some similarities between h-index and the journal impact factor (JIF) have been stressed. Also the universal role of H-index in ranking countries in all areas and in Engineering has been exampled in extended tables.

The Glänzel's model which connects the h-index with two fundamental scientometric indicators: number of publications and the rate of citation, has been analysed. Following the Microsoft Academic Search, the lists of 15 top scientists from various academic disciplines and separately in Engineering have been composed. It has been found that the population of the best keeps basically the same relations between the h-index and a number of publication, and between the h-index and a citation number. However, even the best in Engineering should publish 2 times a year or more papers to receive the same h-index as top scientists in overall domains.

The h-index distribution of domestic Engineering sub-disciplines has been presented and analysed in statistic categories. The suitable h-histograms and the cumulative probability density function (CPDF) have been elaborated for 21 sub-disciplines and thereupon the Engineering sub-disciplines have been arranged into three clusters. It has been demonstrated that Engineering as the whole and Engineering sub-disciplines are underestimated, compared to other academic disciplines. The adequate normalisation factors have been suggested.

Several other conclusions considered the h,H-indices as the measure of the knowledge progress addressed to individual researchers and to collective, e.g., journals, institutions, organisations, countries, adequately have been written. The h,H-indices are the general measure of the position of the given subject (person or organisation) but cannot be universal.

Key words: bibliometric indicators, citations, citation metrics, h-index, H-index, country rank, SCImago indicator, disciplines, domestic Engineering sub-disciplines, statistics.

1. Introduction

The paper aims at defining new challenges to the engineering community which result from the research policy and dominant tendency of parameterization of everything. Of course, it is the subjective and preliminary opinion. Mainly, it concerns effects of assessments of people and groups by taking into consideration their bibliometric measures, especially the Hirsch Index. The "parameterized" evaluation has features of objectivity and can be a useful tool while preparing ranking lists. However, it is necessary to mention that the evaluation applies to groups of researchers consisting of outstanding personalities, e.g., in the discipline civil engineering the evaluation concerns groups which deal with designing, building up, maintenance, repairing, demolition and lastly recycle the building structures. Those activities, consume huge amounts of matter (mass and energy); it is 40% of the overall world consumption. The durability/working life of the building objects, can be measured by multiplicity of a designer's life expectancy. Specific obligations are imposed on the creators, moreover, for that reason the "conservative" actions can be

taken. This can be reflected in their work and determine the discipline [1]. Compared to the computer estimations, results are verified by experience and based on test results. Exactly the same rule for the parameterized evaluations of people can be used.

Interestingly, nobody asks a question why we should classify people by just a single number. It seems that there exists an inexpressible axiom that "course is inescapable" [2]. It is part of the general civilization madness enumerating everything. More than 267 million pages [3] on unstructured research data are available on line and thereby create dizzying sense of the knowledge infinity [4]. The ranking list of researchers could make sense of order in appearing chaos. There is the measure for measures [5]. "Trust in numbers" is treated as the synonymous of objectivity in science [6]. The point is even more delicate in the Engineering Science area where science and technology are interpenetrated. Once numbers are received, the conclusion often could be elaborated by mechanical methods, that is usually done by computer. However, it should be refreshed that numbers should firstly serve as a strategy of communication. K. Życzkowski statement [7]

*e-mail: l.czarnecki@il.pw.edu.pl

should be shared *bibliometric indices can be further developed but it is difficult to claim that exists a single number capable to quantity scientific achievement in an ambigious way*. However, it only concerns the actual value not the virtual space. A. Sawicki [8] said that only comparisons of similar with similar could be made. It is a far-reaching proposal, however, surely for the assessment and during the creation of ranking lists it is necessary to select, in a proper way, the "scale and tools". Paradoxically, parameterization is a common and well accepted way in the engineering methodology. The same method used, ad extremum, to evaluate engineering researches seems to provide erroneous conclusions.

Conditions. Considerations have been elaborated at two levels:

- careful thoughts of domestic experiences,
- universality of knowledge which implies permanent progress and the particularity of h-index as the potential measure of knowledge progress.

The parameterization of science and scientific researchers is the over-world tendency [9]. However, the direct inspiration for this study has been taken from domestic experiences. The Committee for Evaluation of Scientific Units is a consultative and advisory body to the Minister of Science and Higher Education. The main task of the Committee is to draw up the project of parameters and criteria for comprehensive evaluation of scientific units. Moreover, the Committee indicates to the Minister the leading scientific units taking into account the quality of their scientific activity in order to determine the level of financial support granted to fund their research potential. The National Science Centre is a government executive agency set up to fund basic research. Basic research is original experimental or theoretical research work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without the direct practical application or use. KEJN and NCN in most of the announced grants and projects have special criteria for the applicants. Namely, the applicants must give the number of all publications and H-index[1]. The division into a number of publications and a number of citations is important. The expectations that the publications will or should be noticed, especially by the browsers, are high. There are no additional limitations and comments about the H-index and the results not only will be important during the parameterisation of scientific units but also in the process of acquiring grants. The above tendency has been presented in the regulation of the Minister of Science and Higher Education which concerns the criteria, conditions and procedures of applying for obtaining the status of the Leading National Research Centre. There the following is said:

- when assessing applications in science, in the areas of technical science (...) the following is taken into account (...) the number of citations and H-index estimated from the works published in journals, which are on the Journal Ci-

tation Report list, prepared for every research worker or university teacher,
- the number of published works has been limited to 25% of the best journals taken from the list of Journal Citation Report for the restricted areas of science and prepared by the Thomson's Reuters Scientific.

There are some similarities between a journal impact factor (JIF) and h-index. Particularly that the term "impact factor" has gradually evolved into description both journal and author impact. The journal impact factor is the average number of citations for an article in a particular journal during a given period of time (usually the last two years, sometimes previous five years). It has been found [10, 11] that between JIF and h-index there exists a strong and significant relation, which is not a surprise. The creation of h-index allowed to discern scientists who really did science that had an impact and JIF became a tool that underlines in which journal that science make an appearance. Now, after more than 50 years of JIF using, still arises the fundamental question: what is the JIF? If the JIF is not an outdated artifact rather than a stepping-stone to journal certification [12]. The answer (Fig. 1) seems to be very close to the first option [12, 13]. Moreover, E. Garfield, 1955 [14], the creator of the JIF published paper [12, 13] entitled "The Agony and the Ecstasy – the History and Meaning of the Journal Impact Factor". Simultaneously, E. Garfield [14] by himself considered that more adequate to the situation would be another title: "Citation Sanity and Insanity – the Obsession and Paranoia of Citations and Impact Factors" [15].
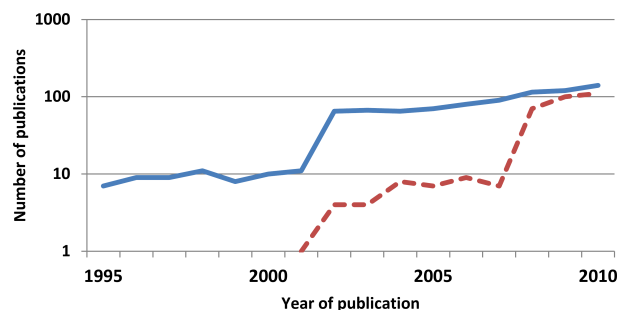

Fig. 1. Exponential increase in documents according to J.K. Vanclay (after Ref. 12) found with Scopus search for "journal impact factor" showing all documents (continuous line) and critical documents (dotted line) with words: "bias", "limitation", "problem", "manipulate", "misuse" or "flaw" placed in the abstract

On the margin of JIF discussions three groups of journals have been categorized [13]:

- high quality journal – published breakthroughs, new proposals and new types of applications,
- standard journal – published standard, yet interesting applications of known techniques,
- ordinary journal – published really routine applications which basically have only an archiving function.

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[1] h or H – see Sec. 3 and the first conclusion. In the Ministry documents the capital letter H is used.

This categorization could be a contribution of interest to the trial of evolution of the state of Polish Engineering Science [16]. A. Osielawska [17] statistically proved that the fact of low contribution of Polish authors, dealing with Economy, into "international" journals does not mean that this community of researchers is limited only to the Polish science circle. The conclusion has been done on the base: which journals are mainly cited in the papers published in Polish journals. It is the most likely that the same statement could be done towards Engineering. One of the fundamental results of the JIF controversy is expressing a doubt if the science really progresses by measuring the impact of journals.

R. Rousseau [13] states the reason, that an impact factor is measured, as not scientific but as underlying cause which simply is involved with a human nature. If we try to transform the question into the h-index domain the situation will be even more delicate. After 2 years, since J. Hirsch declared his index J. Kuan-Teh, USA (h = 39), Editor-in-Chief of Retrovirology (JIF = 6.47) in the title of his paper [18] has put a question: *is it time to individualize citation metrics?* As his reply could be the sentence: *like it or not, use it or not, each author's personalized citation number and h-index are there for all to compare.* It means come back to a human case. The perception of a personal prestige is even the more murky subject than the perception of the journal prestige. It will be a pity if the function of h-index diminishes mainly to a visibility. As aforementioned in the Introduction we need the "scale and tool". For this reason we should distinguish an "artifact" [12] and a "tool". An "artifact" becomes a tool when knowledge and understanding about the proper use of the artifact develops in a person's mind [13]. On the following pages we try to answer to what extend the h-index is understood as a tool for research evaluation, particularly, in the engineering area. Perhaps it is necessary to get rid of some illusions of the illusionless territory. In this context Albert Einstein statement *Not everything that can be counted counts and not everything that counts can be counted* is sometimes remembered [19]. The great dramatic words can also be quoted *Are all thy conquests, glories, triumphs, spoils, shrunk to this little measure* (W. Shakespeare, Julius Caesar). The past experiences are not very promising. "Lost in publication", "measurement harms science" [20], "abuses" [13], "rank injustice" [21] are the phrase from titles and abstracts of relevant papers. The fundamental questions are [19]:

- does our academic system of activity rewarding, that addresses the question, matter most to the society?
- how to promote the advancement of knowledge if real power comes from great ideas?
- how to recognize individuals and institutions that best generate new knowledge?

2. h-nature of things

Jorge E. Hirsch is an Argentine American professor of physics at the University of California, San Diego. He published in 2005 the article 'An Index to Quantify an Individual's Scientific Research Output' in the Proceedings of the National Academy of Science [22]. Hirsch wrote: *I propose the index h, defined as the number of papers with citation number higher or equal to h, as a useful Index to characterise the scientific output of a researcher.*

Such proposition was quickly accepted. The article which was cited more than 2 000 times increases the author h-index (h = 25!) of only one point. It well reflects the significance of h-index and discloses one of the index peculiarities: how difficult it is to increase the index. Thus, the h-index reflects both the number of publications and the number of citations per publication. It can be expected that an author who has N-publications has certain h-index and h publications have been at least cited h times and N-h has been less cited or at all (Fig. 2). Although J.E. Hirsch created small h, in the NCN and KEJN documents capital letter H appears. R. Kierzek [23] in his proposal used $h_m = \Sigma h/N^{0.4}$ where N – stands for the number of publications in one institution. It seems to be rational to accept small h for an individual output and capital letter H, the collective indicator, e.g. for organisations, institutions and countries, $H = h_m = \Sigma h/N^{0.4}$. It should be stressed that all non-productive publications decrease the H-index.

J. E. Hirsch measures related to the Nobel Prize laureates in Physics from 1985 to 2005 (Fig. 3). The author proved that the h-index would present productivity-quality-visibility. So it was. People, however, would have some questions to the visibility. Nowadays, in a professional CV prepared by a scientist h-index is indicated. It can be expected that in future h will be placed on a visiting card, near the e-mail address. Additionally, in 2007 Hirsch added some prediction values to the h-index [24].
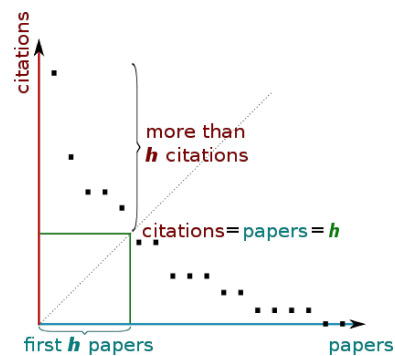

Fig. 2. H-index from a plot of decreasing citations for numbered papers (after Ref. 22)
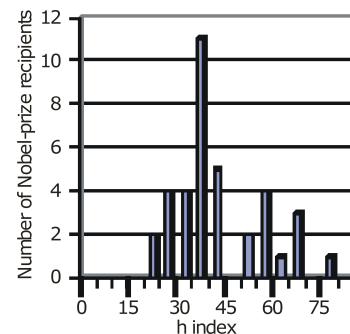

Fig. 3. The Nobel Prize laureates in physics (after Ref. 22)

The h-index can be measured with the use of different citation databases, e.g.:

- ISI Web Knowledge/Web of Science, Thomson-Reuters,
- SCOPUS, Elsevier,
- Publish or Perish (PoP), Google Scholar,
- Academic Search Microsoft.

There is a well known example that one of the most cited computer scientists, Hector Garcia-Molina ($h = 120$), Stanford, USA has gathered nearly 60 000 citations in PoP, but in ISI has received just a few hundred citations [19]. It is due to the fact that the most of his papers have been published and cited in conference proceedings which are appreciated by Google Scholar but they were not recognized by Thomson Reuters ISI. The PoP browser seems to be the most favourable to engineering disciplines. Moreover, this database frequently recognises books not only papers in journals; books and articles written in Polish are also in its resources. It should be claimed that h-information always goes together with an adequate citation database. However, the author should have a right to free selection of a suitable database yet, under the condition that unnoticed citation does not mean non-existing. Even so, it can be assumed that PoP finds only 1/5 publications and 1/3 citations of Polish scientists (see Sec. 6). The concept of H-index gained huge popularity, appreciation and, contributed to the development of scientometrics, the science of knowledge measurements.

The H-index can also be created for countries. Poland is on the 24th position with H = 2 81, in comparison USA = 1305 (Table 1). Poland ranks 33rd in classification by population whereas by Gross Domestic Product, GDP the country holds the 20th position. In the area of 'Engineering', Poland is on the 30th position with H = 82 where USA is still on the top with H = 485 (Table 2).

Table 1
Country Ranking according to H-index, all areas 1996–2011: SJR (December 5th, 2012) (after Ref. 25)

	Country	Documents	Citable documents	Citations	Self-Citations	Citations per Document	H index
1.	United States	6 149 455	5 738 593	114 546 415	54 226 872	20.51	1 305
2.	United Kingdom	1 711 878	1 550 373	27 919 060	6 703 673	18.03	802
3.	Germany	1 581 429	1 490 140	23 229 085	6 171 727	16.19	704
4.	France	1 141 005	1 073 718	16 068 688	3 749 874	15.58	646
5.	Canada	885 197	836 836	13 928 114	2 727 913	18.19	621
6.	Japan	1 604 017	1 563 732	18 441 796	5 520 032	12.09	602
7.	Italy	851 692	803 004	11 279 167	2 639 721	15	550
8.	Netherlands	487 784	457 933	8 928 850	1 524 755	20.82	545
9.	Switzerland	350 253	329 198	6 873 551	966 536	22.46	537
10.	Sweden	337 135	321 725	6 111 804	1 005 775	19.78	484
11.	Australia	592 533	551 667	8 180 664	1 770 774	16.65	481
12.	Spain	665 977	623 236	7 640 544	1 958 835	13.66	448
13.	Belgium	265 913	251 632	4 161 308	630 041	17.81	428
14.	Denmark	183 880	173 771	3 444 509	514 632	21.17	399
15.	Israel	204 262	194 752	3 283 119	483 335	17.35	393
16.	Austria	188 440	177 324	2 688 324	387 884	16.51	355
17.	China	2 248 278	2 226 529	9 288 789	5 014 506	6	353
18.	Finland	170 476	165 195	2 771 982	462 377	18.28	352
19.	South Korea	497 681	487 459	3 988 716	917 147	10.32	309
20.	Norway	141 143	133 311	2 021 938	339 172	17.19	308
21.	Russian Federation	527 442	521 993	2 811 862	837 763	5.49	308
22.	Brazil	391 589	378 540	2 884 793	965 615	9.96	285
23.	India	634 472	602 868	3 860 494	1 335 686	7.71	281
24.	**Poland**	**304 003**	**297 361**	**2 149 143**	**571 333**	**8.13**	**281**
25.	Hong Kong	144 935	139 331	1 722 546	262 368	13.52	268
26.	New Zeland	114 495	107 441	1 504 946	248 529	15.43	264
27.	Ireland	91 125	85 341	1 149 729	141 683	16.18	254
28.	Taiwan	351 610	343 223	2 825 736	696 835	10.08	249
29.	Greece	160 760	152 000	1 589 963	289 460	11.93	247
30.	Singapore	126 881	122 436	1 330 684	191 033	12.51	240
31.	Hungary	100 137	96 842	1 058 391	182 169	11.57	239
32.	Czech Republic	142 090	137 882	1 103 719	272 685	9.14	223
33.	Portugal	117 469	113 411	1 150 280	234 405	12.77	218
34.	Mexico	144 997	140 713	1 174 802	259 075	9.83	216
35.	South Africa	107 976	101 434	1 013 102	225 507	11.11	216

Table 2
Country Ranking according to H-index; Engineering area 1996–2011: SJR (December 5th, 2012) (after Ref. 25)

	Country	Documents	Citable documents	Citations	Self-Citations	Citations per Document	H index
1.	United States	646 693	628 373	6 054 196	2 335 391	9.68	485
2.	United Kingdom	142 413	138 050	1 179 649	280 089	8.65	242
3.	Germany	136 590	133 452	892 300	224 568	7.05	218
4.	Canada	95 254	93 085	753 251	158 979	8.7	194
5.	France	101 268	99 498	772 071	212 178	8.45	193
6.	Japan	198 677	196 307	1 015 526	346 698	5.35	193
7.	Italy	78 870	77 069	607 837	158 080	8.59	173
8.	China	506 147	503 812	1 235 737	823 142	3.23	172
9.	Switzerland	26 898	26 208	292 015	42 731	12.02	167
10.	Netherlands	36 915	35 983	364 479	64 523	10.94	163
11.	Australia	44 571	43 368	371 136	73 709	10.08	153
12.	South Korea	90 685	89 555	513 995	128 489	6.62	141
13.	Spain	50 243	49 276	353 652	100 834	8.59	140
14.	Hong Kong	29 610	29 065	283 544	46 871	10.01	140
15.	Singapore	29 567	29 098	270 686	43 233	9.65	136
16.	Taiwan	76 165	75 212	480 568	150 780	7.24	136
17.	Sweden	28 956	27 553	239 100	42 815	8.67	134
18.	Belgium	22 273	21 845	203 861	37 026	10.15	129
19.	Israel	17 375	17 069	173 818	28 678	10.5	129
20.	India	59 190	58 065	309 724	89 493	6.27	126
21.	Denmark	11 333	11 053	118 625	18 151	11.84	112
22.	Finland	16 240	15 992	120 949	23 178	8.03	104
23.	Brazil	26 297	25 902	133 008	34 172	6.09	98
24.	Greece	18 078	17 658	130 342	26 629	8.16	97
25.	Turkey	22 541	22 074	152 590	41 232	8.01	92
26.	Russian Federation	64 657	64 164	138 659	51 133	2.14	91
27.	Norway	10 200	9 992	75 834	12 759	8.85	90
28.	Austria	14 491	14 092	87 562	16 802	7.14	87
29.	Portugal	13 414	13 071	90 178	21 194	8.19	84
30.	**Poland**	**28 669**	**28 286**	**102 202**	**32 926**	**4.13**	**82**
31.	Ireland	8 523	8 346	57 152	10 158	7.69	78
32.	New Zealand	6 626	6 455	49 934	8 244	8.6	77
33.	Mexico	12 871	12 672	58 819	15 213	5.39	76
34.	Iran	21 853	21 484	86 710	32 965	6.85	71
35.	Czech Republic	9 421	9 280	46 369	11 975	6.11	70

Some categories[2] of Engineering remain close in rank: Biomedical Engineering (33), Civil & Structural Engineering (32), Electrical & Electronic Engineering (32), Mechanical Engineering (30). Some categories are slightly better ranked: Ocean Engineering (28) and Safety Risk, Reliability and Quality (25). The Architecture falls significantly behind (69!). In the recent 15 years the number of papers published by the Polish authors in all areas has increased almost 3 times including the Engineering area as well (Fig. 4a,b). Over the same period, the relevant world increase is 2 times bigger. A published article should have enough time to be cited. The period of 7 years since the publication date seems to be needed (Fig. 5). However, the papers which achieved a high impact factor are believed to be usually cited within months since publication and certainly within a year or so [14]. The relation between cited and uncited Polish papers after more than 7 years since publication has been established at the level of 20% uncited for all area and 40% (!) uncited for Engineering (Fig. 4c,d). Respective numbers for the world are around 25 and 30%; for USA 15 and 30%. All the data in this section have been taken out from SJR Scimago Journal & Country Rank, where they are published under meaningful motto from Horatio "Est modus in rebus" – "There are proper measures in things".

There are several axiomatic characterizations [26] of the Hirsch index:

- Hirsch index reflects simultaneously the number of publications and the number of citations per publication,
- authors with very few high-impact publications and authors with very low-impact publications will score weak h-index,
- the h-index of a given scientist never decrease on timeline,

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[2]Categorisation according to Scientific Journal Ranking
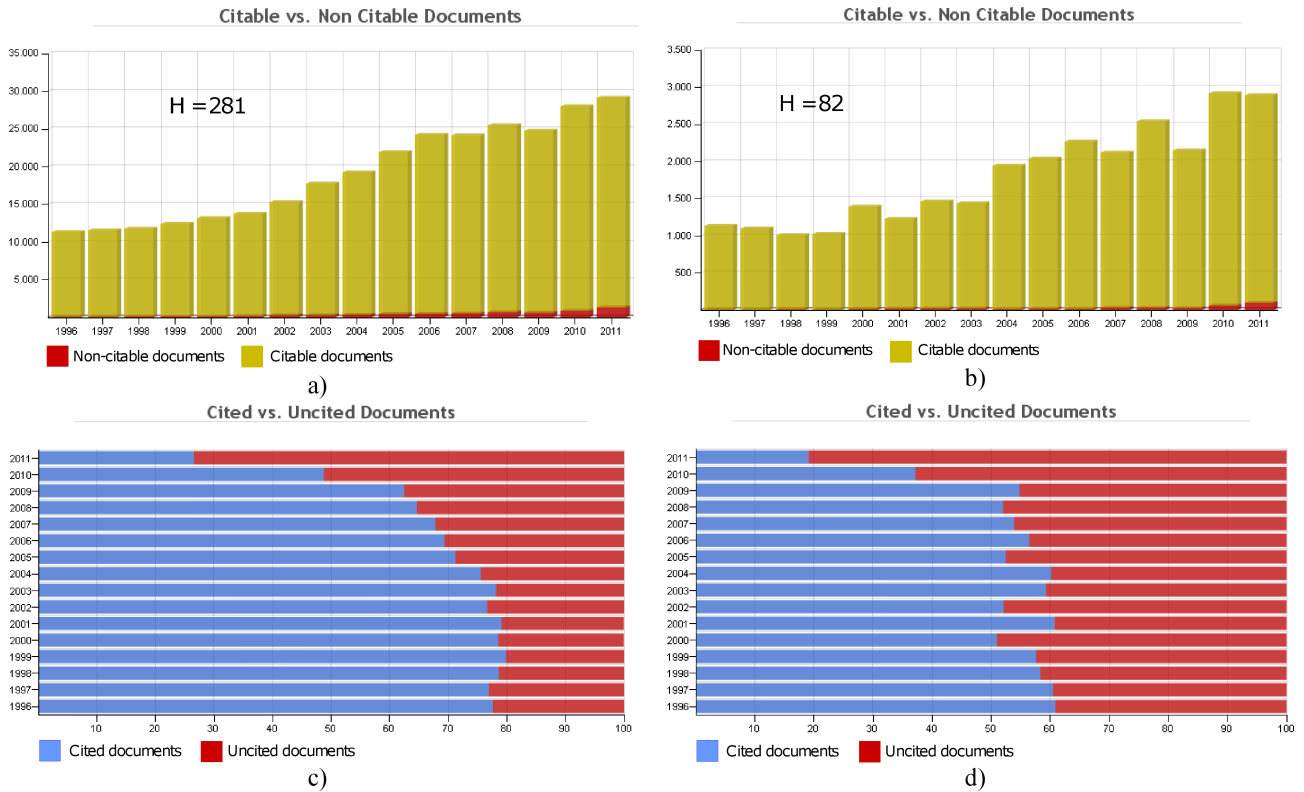
a)

b)

c)

d)

Fig. 4. Number of papers of Polish authors (a, b) in all areas (a) and in Engineering (b) and relation of cited and uncited papers (c, d) in all areas (c) and in Engineering (d) (after Ref. 25)
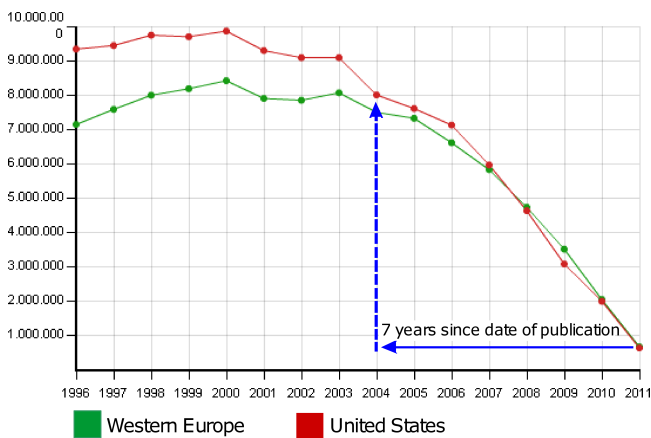

Fig. 5. Citations number in the USA and Western Europe; the justification taken out in 7 years period of time for data stabilization (after Ref. 25)

Fig. 6. Citations per papers (C/P) vs. paper numbers (p_i) ordered according to decreasing citations (after Ref. 26). The area under curve gives the total number of citations. The square yields suit h-index. W_{-Pl} -waste top area, potential less – even significant increment of citations change nothing in h-index. $W_{-p!}$ – waste area at the bottom but still with a potential. The ways of h-index increase until $h+1$: a) existing paper, e.g. number 9, attracts new readers and received citations above the current h-value, b) new paper gained more than h citations and will be located on the new position $p_i = 8$, if the number of citation is higher than current h (C/P>h)

- the h-index of a given scientist may increase when a new paper is published and will attract citations significantly, vis. above current h-level,
- if a new publication is only "average" with respect to the current index it should not raise the index; publications cited less frequently than h-times are "wasted",
- if an existing paper attracts new citations it should raise the index only if the number of citations per paper increase above the current index value (Fig. 6),
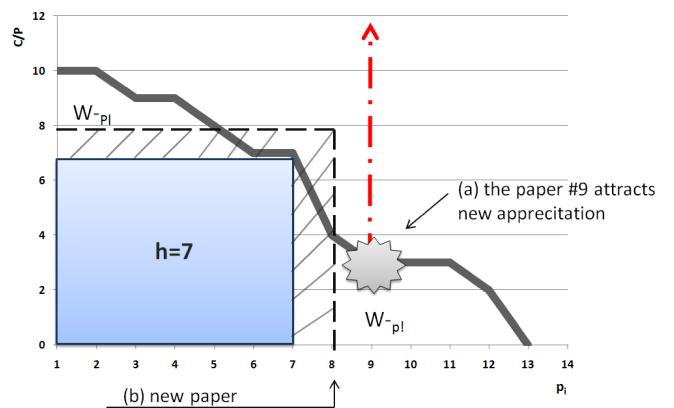
- h-index is an integer number by increasing the number of citations to a single article, the h-index should not increase by more than 1; the "extra top publication" cited more (even much more) than h-times are "wasted",
- the h-index is absolutely neutral to the context of citations: affirmative or negative,

- a research institution has H-index [27,28] of i when at least i researchers from that institution have h-index of at least i, (it is not the same as R. Kierzek proposal [23]),
- the co-authorship effect, could be calculated [29], by dividing h by the mean number $<Na>$ of authors (author multiple occurrences are allowed) in the considered h papers: $<Na> = Na^{(T)}/h$ where $Na^{(T)}$ – is the total number of authors. Thus, we obtain a new index h_I: $h_I = h/<Na> = h^2/Na^{(T)}$. A research with index h_I has h_I collective author papers with at least h_I citation if he/she had published alone. If a given researcher is the only author of his/her h papers, than $Na^{(T)} = h$ and $h_I = h$ in this case. The justification for this procedure is that more authors could produce more future self-citations which in turn could affect more readers and finally may produce statistical biases. Till now it is just a suggestion of P.D. Batista et al. [29], which seems to be rational, not yet accepted in common.

3. Shaping the H-index in various Engineering sub-disciplines

Despite all attempts to refine [26, 30], adjust [2, 31] or improve [28, 32, 33] h-index; Hirsch's original measure prevailed and has already become a standard tool in evaluative bibliometric [29]. On the other hand, there is an unquestionable opinion that citation of Engineering science is much lower than, e.g., of a majority of Physics and Chemistry [16, 29]. From an extensive and statistically proved studies made by E. Lillquist et al. [30] someone could learn that the selected sciences could be categorized as in Fig. 7 according to the decreasing median of h-index value, as follow: Physics, Biology, Chemistry, Chemistry Engineering, Electrical, Mechanical, Math, Civil Engineering. The limit values are: 32 and 5. J. Hirsch suggests that the $h = 12$ is the value adequate for "matured" scientists. In this context, the situation of Engineering and its sub-disciplines do not look very nice. Comparison of the publication and citation profiles as cumulative probability density functions (CPDF) (Fig. 8) shows a shift in a greater number, more citations than publications by factor more than 10 but the order of disciplines are basically the same (compare Fig. 7).
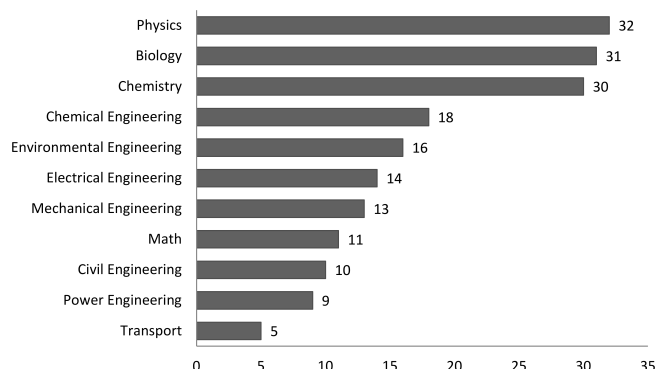
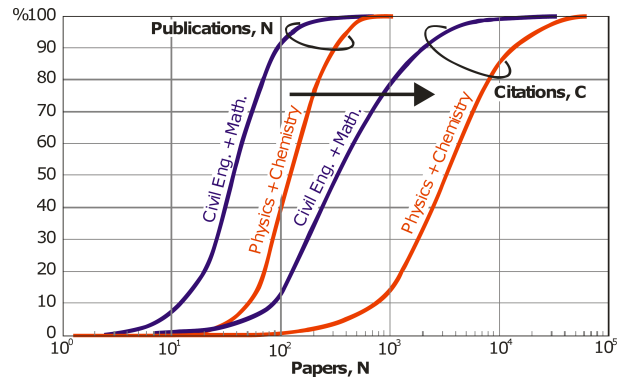Fig. 7. The median – H-index value for full professors community in various sciences (after Ref. 30)

Fig. 8. The profile of publication and citation for full professors (Ref. 30); the field of outline covers disciplines: mathematics and civil engineering (the same line), mechanics, electrical engineering, chemical engineering, biology, chemistry, physics are in the same order in both cases.

Various attempts have been done to scaling or normalizing of h-index for different scientific fields [2]. The situation is even more complicated due to the fact that h-index represents simultaneously influence of total number of papers, N, and the rate of citation, $R : h = f(N, R)$. The Glänzel's model [34, 35] connects the h-index with those two fundamental scientometric indicators:

$$h = k \cdot N^{1/3} \cdot R^{2/3}. \tag{1}$$

On this base E. Csajbok et al. [36] elaborated the master curve (Fig. 9) for 20 disciplines of 40 countries. Taking this opportunity, authors made several points on the country of origin effects:

- when the h-index combines effort of size (number of papers) with that of impact (citation rate), smaller countries have not got much chance to compete with giants,
- EU countries have a strong positions in each field but none of them can successfully compete with the USA,
- newly accessed countries, like Poland, which belongs to large countries, is permanently ranked bellow smaller EU-55 countries like Belgium, Denmark or Austria.
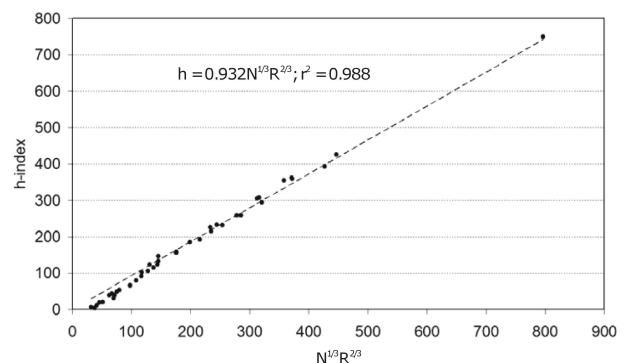
Fig. 9. Master curve $h = f(N, R)$ (after Ref. 36)

J. Podlubny [31] has found, that in the given period of time, the ratio of citations number, C, in any two fields of science remains close to constant, e.g.

$$C_{Ph}/C_E = 4, \tag{2}$$

where C_{Ph} – number of citations for Physics and C_E – number of citations for Mathematics.

Using the Glänzel's model (1) verified by E. Csajbok et al. [36] it could be calculated that for the same number of publications $N_{Ph} = N_E = N$ the relation between h-indices for Physics and Engineering is like below:

$$h_{Ph} = 2.5h_E. \qquad (3)$$

From the same relation comes that to receive the same value of h for scientists in engineering he or she should publish two times more papers than scientists in physics.

$$N_{Ph} = 2N_E. \qquad (4)$$

More general scaling of the h-index has been proposed by J.E. Iglesias and C. Pecharroman [22]. Following the extend study of h-index distribution they proposed the normalized h_N:

$$h_N = f \cdot h, \qquad (5)$$

$$h_N = 1.7h. \qquad (6)$$

Table 3
The normalizing factor f: $h_N = f \cdot h$

Discipline	f
Agricultural Sciences	1.27
Biology & Biochemistry	0.60
Chemistry	0.92
Clinical Medicine	0.76
Computer Science	1.75
Economic & Business	1.32
Engineering	1.70
Environment/Ecology	0.88
Immunology	0.52
Materials Science	1.36
Mathematics	1.83
Microbiology	0.63
Molecular Biology & Genetics	0.44
Neuroscience & Behaviour	0.56
Pharmacology & Toxicology	0.84
Physics	1.00
Plant & Animal Science	1.08
Psychiatry/Psychology	0.88
Social Sciences, general	1.60
Space Science	0.74

4. Lesson from the best

It is the fact that there exists a different science citation custom [2] which is reflected in the significant statistical measures such as mean, mode and median which value is counted per paper. It is also demonstrated in [2] that in Physics, Chemistry or Biology there exist many researchers with $h > 10$, on the other hand, in mathematics dominates $h < 10$, similar to

Civil Engineering [30]. Moreover, the h-index of the top scientists in various academic disciplines (Table 4) could differ even several times ($h_{min} = 23$, $h_{max} = 111$ (146)). However, it is valid not only on the overall level, e.g., in Engineering or other disciplines, but also among Engineering sub-disciplines ($h_{min} = 12$, $h_{max} = 53$) (Table 5).

Here (Tables 4 and 5) an unique set of "the best" 15 Top Scientists in various domains and 17 Top Scientists from Engineering has been gathered. Generally, even "the best" should work hard, which means more papers – higher index (Fig. 10):

- for overall disciplines:

$$h_o = k_o\sqrt{N} = 4.2\sqrt{N}; \quad r = 0.79, \qquad (7)$$

- for Engineering sub-disciplines

$$h_e = k_e\sqrt{N} = 2.7\sqrt{N}; \quad r = 0.83 \qquad (8)$$

where h_o, h_e – Hirsch index for overall disciplines and for Engineering sub-disciplines (adequately), N – number of publications, k_o and k_e – constants of proportionality, and r – correlation coefficient.

However, to receive the same h-index, engineering sciences should publish even 2 times more papers $\left[(k_o/k_e)^2 = 2.4\right]$ than in overall domains. There exists a factor which differentiates an individual author's effort in the given domain. It is the citation rate $R_c = C/N$ – a number of citations per paper. Coefficients R_c are significantly different ($R_{c,min}^o = 18$, $R_{c,max}^o = 282$) for various disciplines, moreover, the same occurs taking into consideration Engineering (Table 5) sub-disciplines ($R_{c,min}^E = 13$, $R_{c,max}^E = 133$). It could be estimated that "the best" who receive $h = 40$ should publish more than 200 papers in Engineering but in overall disciplines 100 papers appears to be sufficient. They should work hard but in Engineering harder.
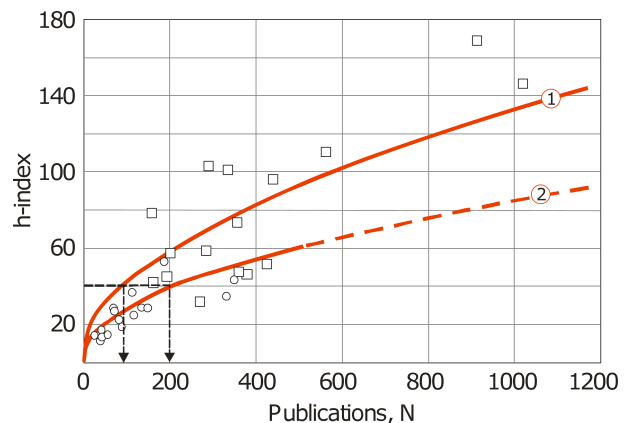

Fig. 10. The h-index vs. number of publications, N for top scientists in various (see Table 4) academic disciplines (1) and for Engineering (see Table 5) sub-disciplines (2). It shows how many papers should be published to receive $h = 40$

Table 4
The h-index ranking of top scientists in various academic disciplines: Academic Search Microsoft, January 9th, 2013 (after Ref. 37)

No.	Academia discipline*	Top author	Organisation	h-index**	Number of publication, N	Number of citations, C	Average Rate of citation per paper, R=C/N
1.	Art and Humanities	Robert E.M. Hedges	University of Oxford	23	85	2 907	34.2
2.	Agricultural Science	Patrick F. Fox	University College Cork National University of Ireland	32	271	4 921	18.3
3.	Social Science	Douglas S. Massey	Princeton University	42	163	8 747	52.0
4.	Mathematics	Pierre-Louis Lions	Paris Dauphine University	45	194	12 378	68.8
5.	Environmental Sciences	Kevin C. Jones	Lancaster University	46	379	8 632	22.8
6.	Material Science	Anthony G. Evans	University of California Santa Barbara	47	361	11 385	32.0
7.	Multidisciplinary	Herbert Simon	Carnegie Mellon University	52	424	52 978	125
8.	Chemistry	Janet Thornton	European Bioinformatics Institute EMBL	57	202	32 017	158.5
8A		[G. M. Whitesides]	Harvard University	[169]	[910]		
9.	Engineering	Ted Belytschko	Northwestern University	58	283	18 284	64,6
10.	Geosciences	Yoram Kaufman	National Aeronautics and Space Administration, USA	74	356	20 168	56.7
11.	Economics and Business	Andrei Ikjkl Shleifer	Harvard University	78	159	44 758	281.5
12.	Computer Science	Scott J. Shenker	University of California Berkley	96	440	45 621	103.7
12A		[Herbert A. Simon]	Carnegie Mellon University	[146]	[1018]		
13.	Physics	Edward Witten	Institute for Advanced Study	101	337	41 013	121.7
13A				[120]	[398]		
14.	Biology	Eric S. Lander	Massachusetts Institute of Technology	103	292	10 638	36.4
15.	Medicine	Karl Friston	University College London	111	561	57 434	196.7

* Categorisation according to Microsoft Academic Search

** The Microsoft Academic Search has indexed 38 million publications and 18 million authors. H-index values may differ from other search engines. In a few cases in square brackets someone can find data from other sources: 8A [38], 12A [39], 13A [40]

Table 5
The h-index ranking of top scientists in various sub-disciplines of Engineering: Microsoft Academic Search, January 9th, 2013 (after Ref. 37)

No.	Engineering sub-discipline*	Top author	Organisation	h-index	Number of publication, N	Number of citations, C	Average Rate of citation per paper, R=C/N
1.	Mining Engineering	Lanru Jing	Royal Institute of Technology	12	39	689	17.7
2.	Construction	H. Randolph Thomas	Pennsylvania State University	14	44	567	12.9
3.	Nuclear Engineering	G. C. Sih	East China University of Science and Technology	15	56	787	14.1
4.	Nanotechnology	Yusuf Altintas	University of British Columbia	15	26	3 022	116.2
5.	Ocean Engineering	James Kirby	University of Delaware	17	41	3 003	73.2
6.	Reliability and Risk Analysis	Mihailo D. Trifunac	University of Southern California	19	90	3 458	38.4
7.	Transportation Engineering	Chandra R. Bhat	University of Texas Austin	24	79	3 050	38.6
8.	Aeronautics and Aerospace Engineering	Yaakov Bar-Shalom	University of Connecticut	25	117	11 730	100.3
9.	Chemical Engineering	Ignacio E. Grossmann	Carnegie Mellon University	26	75	7 780	103.7
10.	Manufacturing Technology	Petar V. Kokotovic	University of California Santa Barbara	28	72	9 589	133.2
11.	Biomedical Engineering	Julian C. R. Hunt	University College London	29	148	5 301	35.8
12.	Civil Engineering	Zdenek P. Bazant	Northwestern University	29	139	3 544	25.5
13.	Energy	Roy Billinton	University of Saskatchewan	35	331	7 200	21.8
14.	Industrial Engineering	Thomas A. Lipo	University of Wisconsin Madison	37	113	10 768	95.3
15.	Electrical and Electortnic	Tatsuo Itoh	University of California Los Angeles	44	349	10 261	29.4
16.	Mechanical Engineering	Ted Belytschko	Northwestern University	53	189	18 284	96.7
17	Engineering – overall	Ted Belytschko	Northwestern University	58	283	18 284	64.6

* Categorisation according to Microsoft Academic Search. It is not clear what the difference between Construction (2.) and Civil Engineering (12.) is.

To be a Top Scientists one should not only be talented and hard-working but also should be interested in his/her scientific progress in a degree enabling him/her to get results or at least work in the field with an adequate citation to attract readers to citation. J.E. Hirsch Fig. 11 [22] found that between h-index and a number of citations, C is exponential relation

$$C = \alpha h^2, \qquad (9)$$

where α is proportionally constant, empirically $\alpha = 3$–5. It means:

$$h = k\sqrt{c} = \frac{1}{\sqrt{\alpha}} \cdot \sqrt{c}, \qquad (10)$$

$$h_o = 0.42\sqrt{c}; \quad r = 0.62, \qquad (11)$$

$$h_e = 0.38\sqrt{c}; \quad r = 0.89. \qquad (12)$$

It means that $\alpha_o = 5.7$ and $\alpha_e = 6.9$. Probably, it is the biggest influence of "big hits". In such case J. Hirsch [22] implies untypical value $\alpha > 5$.
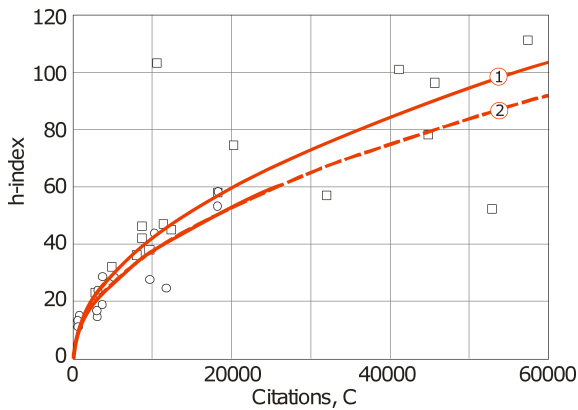
Fig. 11. The h-index vs. citation number for top scientists in various (see Table 4) academic disciplines (1) and for Engineering (see Table 5) sub-disciplines

5. The h-index distribution of domestic Engineering sub-disciplines

The Representative Set (RS) of scientists from various domestic Engineering sub-disciplines: Architecture and Urban Planning (A), Production Engineering (PE), Transport (T), Mining (M), Management of Mineral Resources (MM), Machine Building (MB), Civil Engineering & Hydroengineering (CEH), Geodesy (G), Metallurgy (Met), Metrology and Scientific Instrumentation (MSI), Electrical Engineering (E), Electronics & Telecommunication (E&T), Informatics (I), Automatic Control & Robotics (A&R), Biocybernetics & Biomedical Engineering (B&B), Acoustics (Ac), Environmental Engineering (EE), Thermodynamics & Combustion (TC), Chemical & Process Engineering (ChE), Mechanics (Mech), Mate-

rials Science (MS) has been selected. It is obvious (Table 6, Fig. 12a–x) that the histograms of h-index for RSs are sometimes very dispersed (E, E&T, I, Mech, MS, B&B, A&R, ChE). Often positive outliers are observed, usually with h-value several times larger than mode. In the case of Automatic Control and Robotics even 12 times. However, the common feature, it is sorry to say, is a relatively low median (2–12) and even lower mode (2–10). Following the verification of the significance of differences between RS variances (Table 7) and means (Table 8) the top cluster (E, E&T, I, A&R, B&B, ChE, Mech, MS), upper medium cluster (EE, Met, MSI, Ac, T&C) and lower medium cluster (T, M, MM, MB, C&H, G) can be recognised from "others" (A, PE) (Fig. 13). It allows to restructure statistics measures of the h-index distribution of domestic Engineering sub-disciplines (Table 9).

In many cases, if not in all, the domestic medians (Fig. 14) are significantly lower than the world median (compare Fig. 7). We can assume several reasons for that, which are valid generally for "domestic" output:

- country-of-origin effect,
- non-English authors,
- publishing (partially) in domestic journals.

However, some particularities concerning Engineering sub-disciplines should be considered. The very low median is an attribute of the discipline which "applied product" is addressed basically to local-domestic: A, T, M, C&H, G. It should be also stressed that behind some publications contribution to the lab-experimental works in many engineering sub-disciplines stands high.

Table 6
Statistic measure of h-index distribution of domestic Engineering sub-disciplines

| No. | Engineering sub-discipline | Observation number, n | H | | | | | | Standard deviation σ | Variation coeff. σ/H | Skewnes coeff. |
			min	max	range	mean	median	mode			
1.	Architecture and Urban Planning, A	29	1	5	4	2.07	2	2	1.13	0.55	1.13
2.	Production Engineering, PE	22	0	9	9	2.82	2	2	2.28	0.81	1.54
3.	Transport, T	30	0	10	10	3.07	3	3	1.80	0.59	1.95
4.	Mining, M	39	0	12	12	3.30	3	2v4	2.72	0.82	1.49
5.	Management of Mineral Resources, MM	30	0	9	9	3.53	3	3	2.03	0.57	0.82
6.	Machine Building, MB	37	0	12	12	4.14	4	4	2.50	0.60	1.06
7.	Civil Engineering and Hydroengineering, CEH	43	1	18	17	4.56	3	3	3.25	0.71	2.17
8.	Geodesy, G	33	2	12	10	4.79	4	4	2.34	0.49	1.33
9.	Environmental Engineering, EE	38	1	32	31	5.08	3	1v3	5.50	1.08	3.42
10.	Metallurgy, Met	30	0	16	16	5.40	4	2	4.14	0.76	1.11
11.	Metrology and Scientific Instrumentation, MSI	33	0	24	24	5.85	4	1v2	5.84	1.00	1.80
12.	Electrical Engineering, E	46	1	28	27	5.89	5	2v3	5.69	0.97	2.41
13.	Acoustics, Ac	31	1	17	16	5.97	6	6	4.14	0.69	1.05
14.	Thermodynamics & Combustion, TC	28	1	19	18	6.39	6	5v6	3.92	0.61	1.85
15.	Electronics & Telecommunication, E&T	46	0	29	29	7.13	6	4	6.33	0.89	1.63
16.	Informatics, I	43	0	33	33	7.67	5	0v3	7.7	1	1.43
17.	Automatic Control and Robotics, A&R	37	1	46	45	8.3	5	4	8.52	1.02	2.81
18.	Biocybernetics & Biomedical Engineering B&B	32	2	38	36	9.97	8	4v10	7.35	0.74	2.06
19.	Chemical and Process Engineering, ChE	29	3	27	24	10.14	9	4	5.95	0.59	0.89
20.	Mechanics, Mech	44	3	36	33	11.66	10	6	7.33	0.63	1.33
20a	Mechanics, Mech (Scopus)*	44	1	23	22	7.07	6	4	5.19	0.73	1.12
21.	Materials Science, MS	37	1	34	33	11.78	10	6	8.51	0.72	1.30

* This data, according to Scopus, is for comparison. It confirms that Publish or Perish sees more (see Sec. 3).

Table 7
Matrix of significance evaluation of differences between the variances

Cluster	Discipline	A	IP	T	M	Sus	MB	CEN	G	Met	Env	Metr	Acou	TC	E	E&T	I	A&R	B&B	ChE	Mech	MS
others	A&U		Y																			
others	IP	Y		Y	Y	Y					Y											
lower medium cluster	Transport, T		Y		Y	Y	Y		Y		Y											
lower medium cluster	Mining, M		Y	Y		Y	Y	Y	Y	Y	Y											
lower medium cluster	Sustainable		Y	Y	Y		Y	Y	Y		Y											
lower medium cluster	MB			Y	Y	Y		Y	Y	Y	Y	Y				Y						
lower medium cluster	C&H			Y	Y	Y			Y	Y	Y	Y	Y									
lower medium cluster	Geodesy, G			Y	Y	Y	Y	Y		Y	Y	Y	Y									
upper medium cluster	Metallurgy, Met			Y		Y	Y	Y			Y	Y	Y	Y	Y	Y					Y	
upper medium cluster	Environmental	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y	Y			Y	
upper medium cluster	Metrology						Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y			Y	
upper medium cluster	Acoustic						Y	Y	Y	Y	Y			Y	Y	Y	Y	Y			Y	
upper medium cluster	T&C								Y	Y	Y	Y	Y		Y	Y	Y	Y			Y	
top cluster	EE									Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
top cluster	E&T					Y				Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
top cluster	Informatics, I									Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y
top cluster	A&R									Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
top cluster	B&B														Y	Y	Y	Y		Y	Y	Y
top cluster	ChE														Y	Y	Y	Y	Y		Y	Y
top cluster	Mech (*Scopus*)									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
top cluster	MS														Y	Y	Y	Y	Y	Y	Y	

Y – Yes, the hypothesis that the variances differ significantly may be rejected (on the basis of F-Snedecor test)

Table 8
The matrix of significance verification of differences between means

Cluster	Discipline	A	IP	T	M	Sus	MB	CEN	G	Met	Env	Metr	Acou	TC	E	E&T	I	A&R	B&B	ChE	Mech	MS
Others	A&U																					
Others	IP			Y	Y	Y																
Lower medium cluster	Transport, T		Y		Y	Y	Y		Y													
Lower medium cluster	Mining, M		Y	Y		Y	Y	Y	Y	Y												
Lower medium cluster	Sus		Y	Y	Y		Y	Y	Y													
Lower medium cluster	MB			Y	Y	Y		Y	Y	Y		Y				Y						
Lower medium cluster	C&H			Y	Y	Y			Y	Y			Y									
Lower medium cluster	Geodesy, G			Y	Y	Y	Y	Y		Y												
upper medium cluster	Metallurgy, Met			Y			Y	Y	Y		Y	Y	Y	Y	Y	Y					Y	
upper medium cluster	Env									Y		Y	Y	Y	Y	Y	Y				Y	
upper medium cluster	Metr						Y			Y	Y		Y	Y	Y	Y	Y	Y			Y	
upper medium cluster	Acou							Y		Y	Y	Y		Y	Y	Y					Y	
upper medium cluster	TC									Y	Y	Y	Y		Y	Y					Y	
top cluster	EE									Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
top cluster	E&T						Y			Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
top cluster	Informatics, I									Y	Y				Y	Y		Y	Y	Y	Y	Y
top cluster	A&R										Y				Y	Y	Y		Y	Y	Y	Y
top cluster	B&B														Y	Y	Y	Y		Y	Y	Y
top cluster	ChE														Y	Y	Y	Y	Y		Y	Y
top cluster	Mech (*Scopus*)									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
top cluster	MS														Y	Y	Y	Y	Y	Y	Y	

Y – Yes, the hypothesis that the mean values differ significantly may be rejected (on the basis of t-Student test)

a)

b)

c)

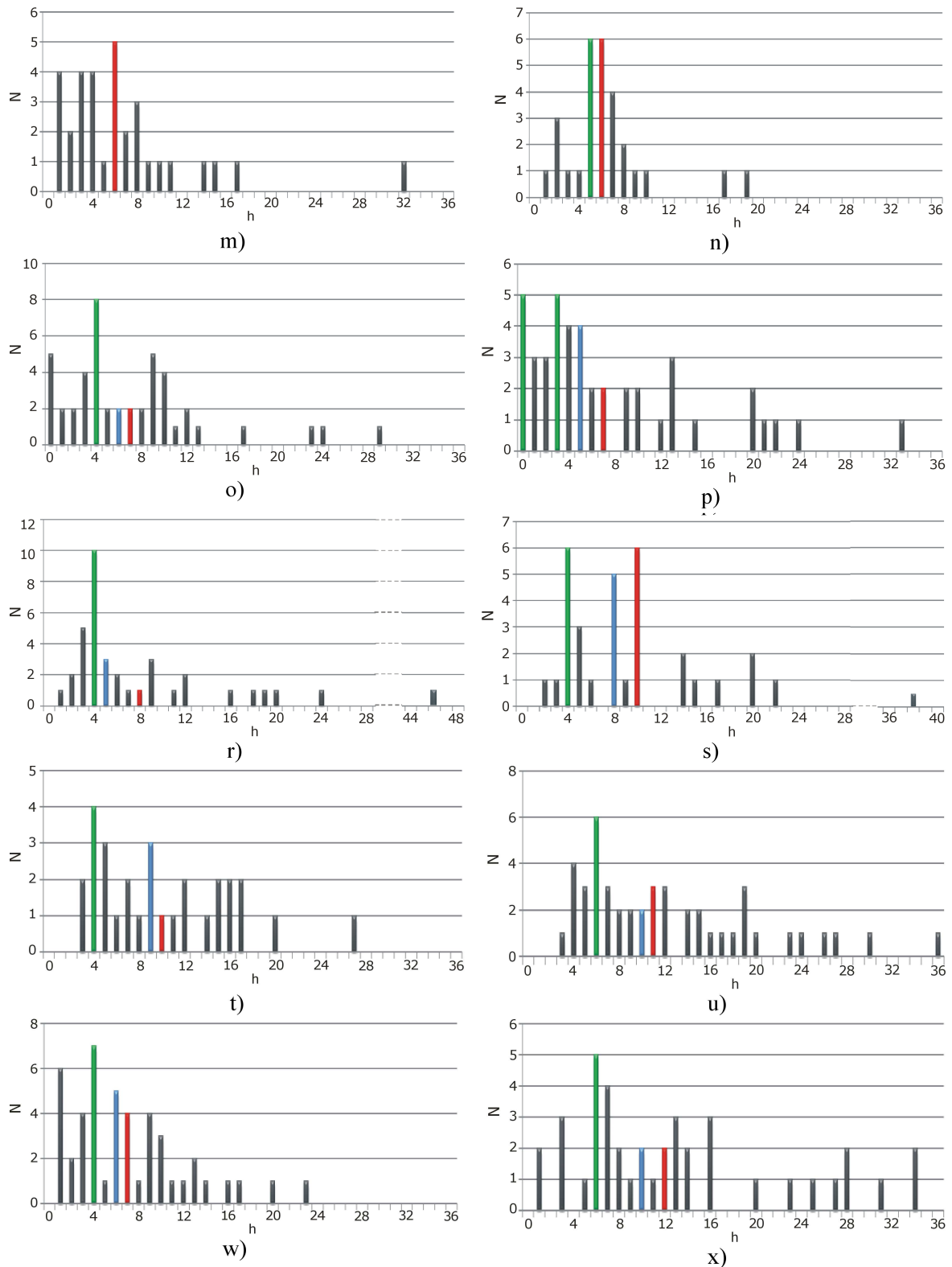d)

e)

f)

g)

h)

i)

j)

k)

l)
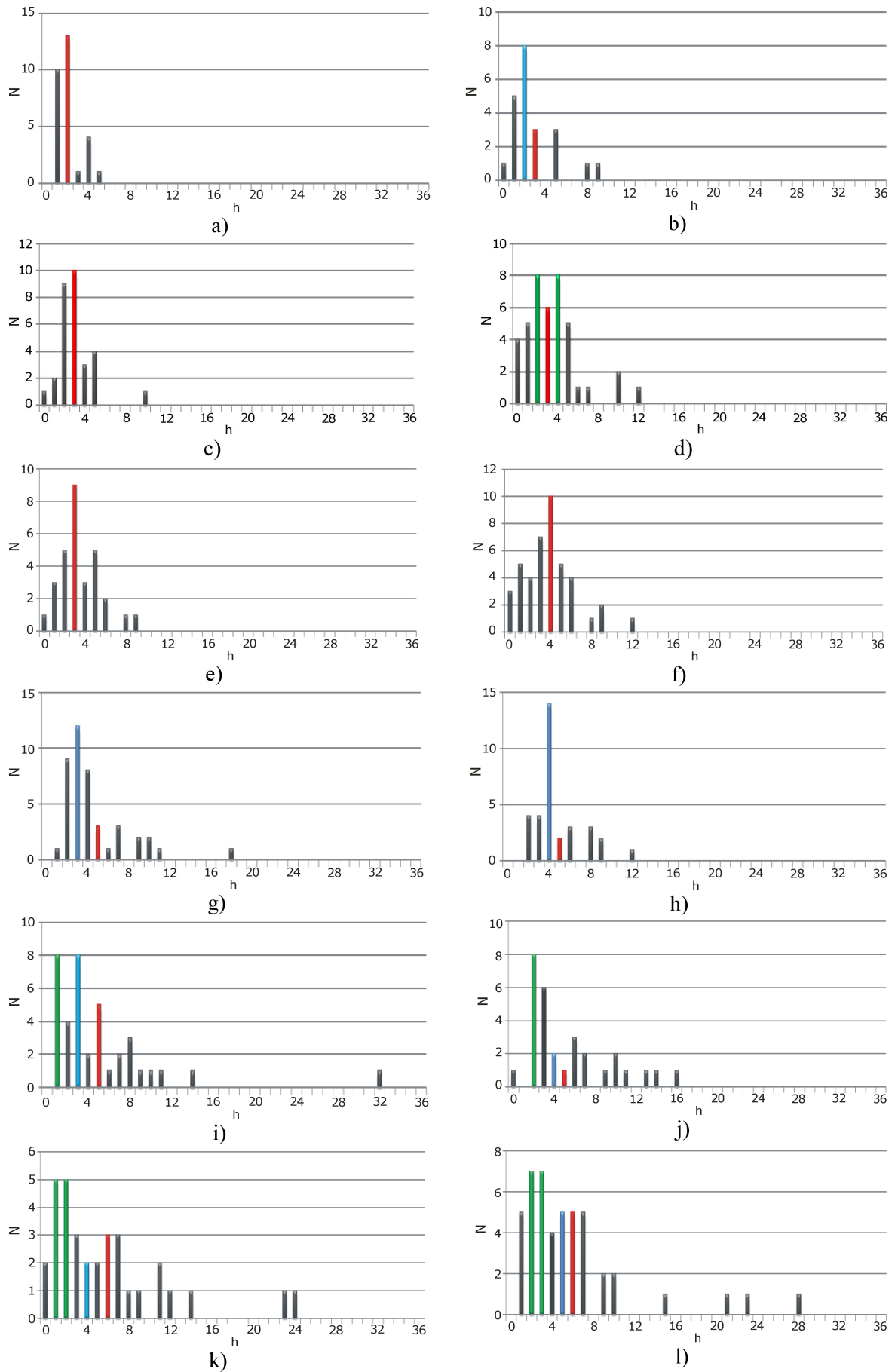
Fig. 12. Histogram of h-index distribution for various domestic representative populations, SRP: Architecture and Urban Planning (a), Production Engineering (b), Transport (c), Mining (d), Management of Mineral Resources (e), Machine Building (f), Civil Engineering and Hydroengineering (g), Geodesy (h), Environmental Engineering (i), Metallurgy (j), Metrology and Scientific Instrumentation (k), Electrical Engineering (l), Acoustics (m), Thermodynamics and Combustion (n), Electronics & Telecommunication (o), Informatics (p), Automatic Control & Robotics (r), Biocybernetics & Biomedical Engineering (s), Chemical and Process Engineering (t), Mechanics (u), Mechanics – Scopus (w), Materials Science (x); mean – red, mode – green, median – blue
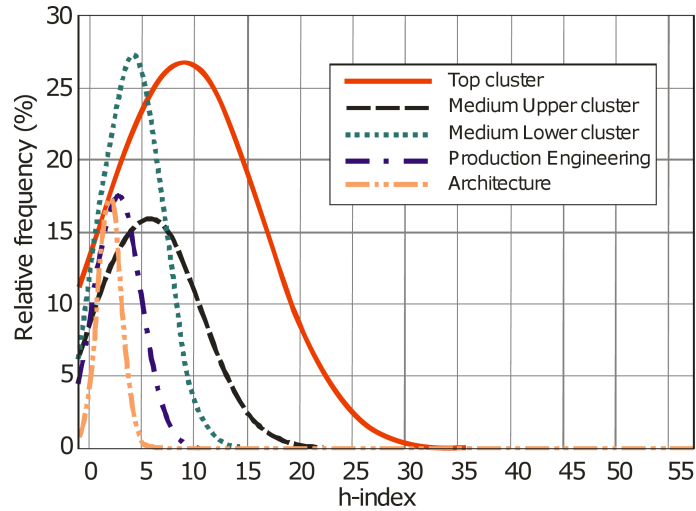
Fig. 13. Statistical distribution of h-index for top cluster, Medium Upper cluster, Medium Lower cluster, Production Engineering, and Architecture

Table 9
Restructured statistics measures of h-index distribution of domestic Engineering sub-disciplines

No.	Engineering sub-discipline	Observation number, n	H						Standard deviation σ	Variation coeff. σ/H	Skewnes coeff.
			min	max	range	mean	median	mode			
1.	Top Cluster	296	0	46	46	8.91	7	4	7.43	0.55	1.67
2.	Medium Upper Cluster	178	0	32	32	5.64	5	2	4.97	0.88	2.27
3.	Medium Lower Cluster	212	0	18	18	4.19	4	3	2.92	0.70	1.69
4.	Production Engineering	22	0	9	9	2.82	2	2	2.28	0.81	1.54
5.	Architecture and Urban Planning, A	29	1	5	4	2.07	2	2	1.13	0.55	1.13
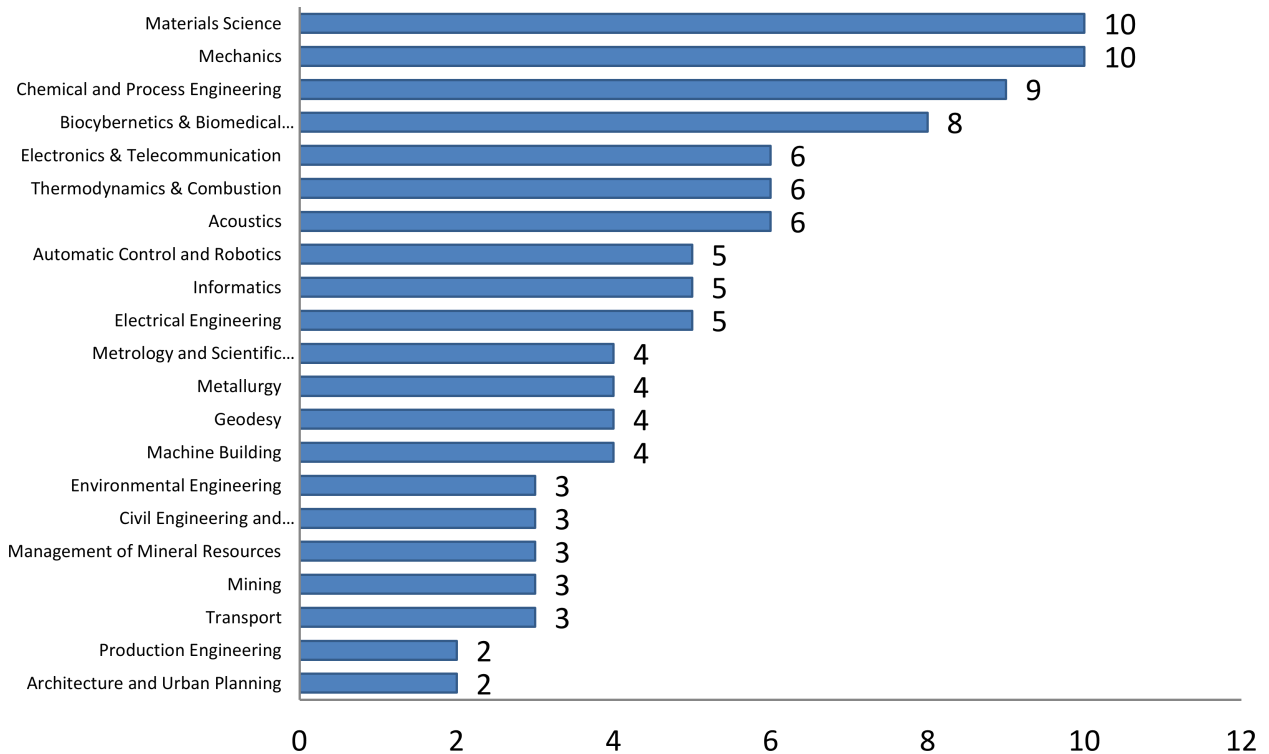
Fig. 14. The median – H-index value for domestic Engineering sub-disciplines
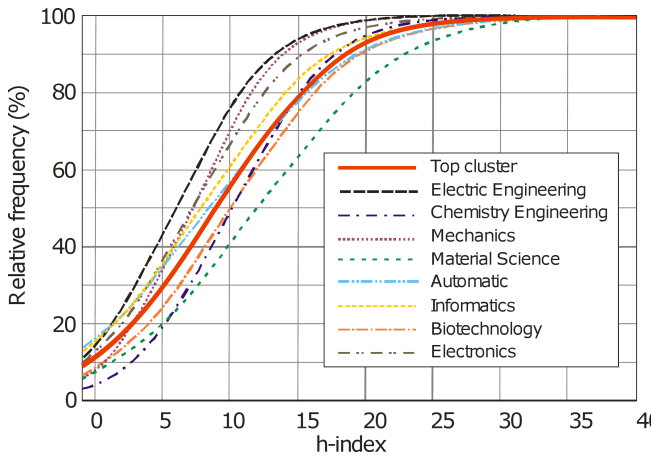
Fig. 15. Cumulative probability density function (CPDF) of h-index for Electrical Engineering, Chemical and Process Engineering, Mechanics, Material Science, Automatic, Informatics, Biotechnology, and Electronics. Joint CPDF for this "top cluster" is shown by red line
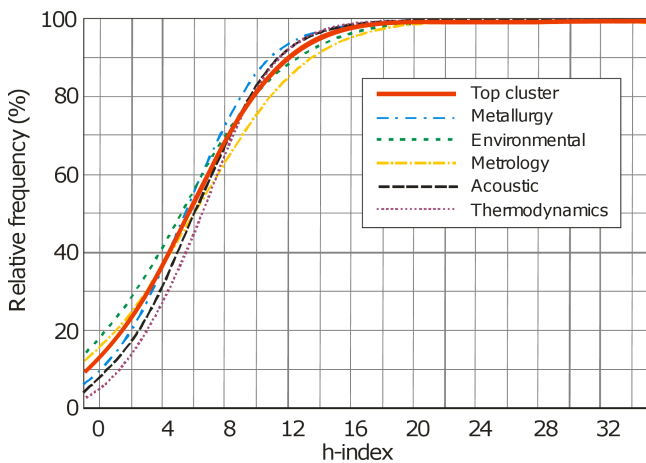

Fig. 16. Cumulative probability density function (CPDF) of h-index for Metallurgy, Environmental, Metrology, Acoustic, and Thermodynamics. Joint CPDF for this "upper medium cluster" is shown by red line
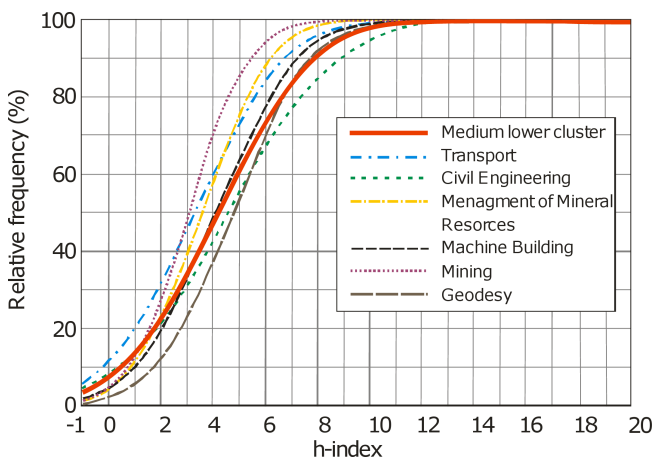

Fig. 17. Cumulative probability density function (CPDF) of h-index for Transport, Mining, Management of Mineral Resources, Machine Building, Civil Engineering, Geodesy. Joint CPDF for this "medium lower cluster" is shown by red line

As it has been already revealed the H-index of Engineering, as a whole, is undercounted and should be upgraded by the factor $f = 1.7$ (Sec. 4). However, internally among sub-disciplines of Engineering there also exist differences. It is particularly visible if we present the cumulative probability density function (CPDF) of the h-index for each engineering sub-discipline (Figs. 15–17). Someone could notice that in the Engineering only 30% of population show relative similarity in h-index. On the level above 30% of population, the difference between the top and medium clusters and others are significant.

It goes to the position that some sub-disciplines in Engineering need an additional normalization factor:

$$H_{e,s} = 1.7 \cdot f_s \cdot h, \qquad (13)$$

where f_s is the engineering sub-discipline factor. A defining f_s value should be the subject of another study. It suggest that f_s should be based on the characteristic median. There are medians (Fig. 18): 9:6:4:3 adequately for top, upper medium, lower medium and others. It seems that $f_s = 1.5$ and 2.3 for upper and lower medium cluster, respectively and 3 for other sub-disciplines have been already justified.
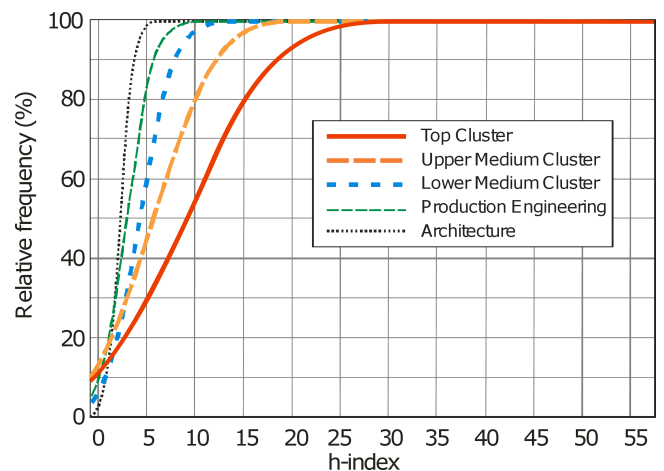

Fig. 18. Joint CPDF for clusters: top, upper medium, lower medium and "others": Production Engineering and Architecture

6. Conclusions

In general:

- It should be useful to recognize small letter h, as J.E. Hirsch originally suggested for individual researcher, and the capital H, as the collective indicator for journals, organizations, institutions and countries,
- published article should have enough time to be cited. The period of 7 years, since publication date, has been shown as needful for setting up stable h-value,
- h, H-indices are the ***general*** (commonly used) measure of the position of the given subject (person or organisation) and a change of the h,H-value, which never decreases in time, is a measure of progress. Guessing from the past the development of h,H-application seems to be inevitable. However, h,H-indices ***cannot be universal***. The challenge

for future is to find rationality between "necessity" and a potential limit which is comprised in the h,H-indices,

- there is a danger of confusion between the goal and a tool, or a tool and a game. If it is a game, the human nature should be a winner. The goal is the knowledge progress and h,H-indices are just the tool for measure, not otherwise,

- authors should have the right to free selection of a suitable database and machine for establishing the h-index. It is justified by the condition that unnoticed citation does not mean non-existing. In consequence, each h,H-value should be given with the adequate database/search machine,

- the position of Poland in the general country ranking and in the Engineering area is respectively 24 and 30. It is worse or even "much worse" in comparison with the Gross Domestic Product, GPD where Poland is on the 20th position.

In Engineering:

- the citation ratio – the number of citations per paper could differ among various academic disciplines, even in the case of top scientists by the factor of 15, and between various Engineering sub-disciplines 10 times,

- the H-index of Engineering, as a whole, is undercounted, when compared to other academic disciplines. Even the top scientists in Engineering should publish 2 times more papers to receive the same h-index as top scientists in overall area. There are various nominalization factors for Engineering relative to overall disciplines or to Physics:

Reference	$h = f_h \cdot h_E$	$N = f_N \cdot N_E$	
	f_h	f_N	
W. Glänzel [34, 35], J. Podlubny [31]	2.5	2.0	to Physics
J.E. Iglesias and C. Pecharroman [2]	1.7	2.5	to overall disciplines
in this paper is according to "the best" – section 6	1.6	2.4	to overall disciplines

The compensation factor equals to 1.7, suggested by Iglesias and Pecharroman [2] seems to be utterly justified,

- the Polish Engineering sub-disciplines, similar to world situation, show differentiation in H-index in the extreme case by the factor of 5. The Engineering sub-disciplines are categorized into four groups and the compensation factors are proposed, when similarity with the Engineering situation versus other academic disciplines is considered.

- Concluding, on the base of H-median, the Polish Engineering sub-disciplines represent at least 30% of an adequate world value. However, in many Engineering sub-disciplines there exist outliers with h-index 2 times or more higher than the world median. There are many reasons for undercounting the Polish Engineering: country-of-origin effect, non-English authors, publishing (partially) in domestic journals written in the Polish language could be mentioned among others.

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