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Cluster Analysis of Knowledge Sources in Standardized Electrical Engineering Subfields

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Abstract: The paper presents a cluster analysis of innovation of knowledge sources based on the standards in the field of Electrical Engineering. Both local (SRPS) and global (ISO) knowledge sources have been analysed with the aim of innovating a Knowledge Base (KB). The results presented indicate a means/possibility of grouping the subfields within a cluster. They also point to a trend or intensity of knowledge source innovation for the purpose of innovating the KB that accompanies innovations. The study provides the possibility of predicting necessary financial resources in the forthcoming period by means of original mathematical relations. Furthermore, the cluster analysis facilitates the comparison of the innovation intensity in this and other (sub)fields. Future work relates to the monitoring of the knowledge source innovation by means of KB engineering and improvement of the methodology of prediction using neural networks.

Keywords: Electrical engineering, Increment analysis, Innovation, Knowledge Source (KS)

1 Introduction

Innovations in the field of Electrical Engineering bring changes that directly affect the quality of products and life. Innovations at local and global levels vary depending on the economic, human, social, institutional, and other circumstances. This difference results in the need for a systematic and comparative review of innovations at local and global level, through the standardized knowledge sources (knowledge source (KS) in [1], term 28.04.03) as a measure of innovation. The local level is analysed on the examples of local sources (SRPS: designation of a standard in Serbia [2]), while the global level refers to ISO/IEC KSs.

According to the International Classification of Standards (ICS) [3], the field of "electrical engineering" is the 29th field (ICS_1 = 29) and consists of 19 subfields (ICS2).

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Each field of human endeavour, from the perspective of artificial intelligence, is an object, domain knowledge (DK), on the first level of the ICS classification (or ICS1 = DK1, domain knowledge in [1], term 28.04.04). Each subfield represents a DK on the second level of the classification (or ICS2 = DK2). The next level in the “knowledge tree” (knowledge tree in [1], term 28.02.11) occupies DK3 objects analog to the ICS3 classification level, and so on.

A large number of innovations at the local and global level require analysis and systematization by cluster analysis. This analysis provides a better understanding of the changes that are brought by the innovations, as well as establishing and updating of the knowledge base (KB) (KB or K-base in [1], term 28.04.06).

The remainder of this paper has the following structure. Related work is given in Section 2. Section 3 highlights the purpose, tasks, and goals of the study. The methodology is presented in Section 4. The results are given in Section 5 and the discussion in Section 6. Finally, concluding remarks are found in Section 7.

2 Overview of Related Research

There are a large number of studies dealing with Electrical Engineering and its 19 subfields (DK2 level). However, little research deals with the analysis of standardized fields regarding the increase in the number of KSs (ΔKS) and their clustering in the local and global knowledge bases. According to [4], a positive effect on innovation performance is obtained by sharing knowledge.

From the point of standardization, the paper presented here can be compared with a number of other studies. According to the scope, contents, and applied methodology of innovation analysis, the work of the authors of [5] is the most similar one. The authors of [6] deal with an 'international' electrical unit that was defined by the *International Electrical Congress* held in Chicago in 1893. The paper deals with the issue of the standards’ adequacy for the purposes of engineering, commerce, and science. The authors of [6] pointed out the advantages and disadvantages of the adopted standards, with the conclusion that there is no such thing as a "perfect" standard. The study provides an answer to the questions relating to the universality of the adopted standards and their applicability on the local and global levels. As compared to [6], the conducted research also deals with the standards at local and global levels, but with different goals: a comparative analysis of KSs, clustering according to the indices of innovation, and innovation of the knowledge base at local and global levels, towards the knowledge base system (KBS) (KBS: abbreviation in [1], term 28.01.05). In the research presented in [7], clustering is applied to the subfields of Information Technology relating to hardware.

The authors of [8] give an overview of the research in the field of standardization related to the process of clustering and innovation. The conclusion reached in [8] was that the standards would be one of the most important ways for “national economic growth and for unconventional strategies of businesses” to take place. A similar conclusion can be found in the paper presented here.

The method of clustering used in this study is the same as in [8 – 11]. However, unlike the works in which the clustering is applied to specific problems in certain subfields of Electrical Engineering [9 – 20], the clustering in this study is applied to all subfields of Electrical Engineering, according to the international standardization, with particular emphasis on the subfields with the most and least innovations in a given period of time.

Similarities and differences of this research compared to similar studies include the following:

- This paper deals with the research in the field of Electrical Engineering standardization, which is the same as in [5], but with a different research goal,
- The research methodology entails the process of clustering, as in [8], [19, 21], but not in individual subfields as in the mentioned works; however it takes into account all the standardized subfields of Electrical Engineering.

3 Purpose, Tasks, and Goals

Given the importance of innovations on the standardization platform and their increase on both global and local levels, there is a need for analysis and clustering of standardized KSs to allow better understanding, planning, and prediction for the years to come, as well as creating a system for knowledge base management.

Research goals in this study include the following:

- Identification of the current situation on the local and global levels in terms of innovation in all standardized subfields of Electrical Engineering (DK1 level, which is analogous to ICS_1);
- Examination of the possibilities of clustering methods in order to obtain DK2 groups, based on innovations with “similar” characteristics, for comparison with other fields (of DK2 level);
- Improvement of the existing analyses in the mentioned field by introducing the original methodology;
- Enabling planning of the activities of researchers based on the prediction of the innovations in the next year, as well as resource and local economy planning.

The research tasks include the following:

1. Collection of data from global and local bases of KSs;
2. Selection and processing of data;
3. Determination of the growth rate of KS innovation and creation of clusters;
4. Creation of trend lines with the elements of resource planning;
5. Analysis of the obtained results.

4 Methodology

The statistical methodology of dynamic analyses and deductive-inductive reasoning methods has been used for predicting future innovations. SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis has also been used in the concluding remarks. Moreover, some specially designed applications have been used for searching local bases of the Institute for Standardization of Serbia [2], which are comparable with the global ISO/IEC KSs according to [3]. Measurements for comparisons have also been established:

- quantity indices (Iq), which include: samples (Iqs) or KSs, published standards (Iqp), standards under development (Iqu), standards withdrawn from use (Iqw), deleted projects (Iqd), and innovations in different stages of development (Iqu);
- value indices (Iv); and
- ranking index (Iqv).

4.1 Collection of data on knowledge sources from global and local databases

Collection of the data on local and global KS units from the databases has been performed using Java software [7]. The data have been grouped into three levels of "knowledge tree" or DK according to the ICS (ICS_1, IC2, and ICS3 or DK1, DK2, and DK3).

In a general case, equation (1), given in [7], applies for the population Iqs:

$$\text{Iqs (KS)} = \text{Iqp} + \text{Iqw} + \text{Iqd} + \text{Iqu}. \tag{1}$$

4.2. Data selection and research frame

Comparative data on the global and local KSs in the analysed domain (ICS_1) have been used in the research. The methodology enables data selection in all standardized fields (ICS_1 = 1 to 99), 40 domains of knowledge (DK1) in total, as well as in the subfields of all three levels. For the monitoring of the innovation trends, the samples (Iqs or KS) have been selected in a four-year period (2011, 2012, 2013, and 2014). The subfields (ICS_2) in which the entire sample size is less than 30 have been excluded from the research.

4.3 Creation of knowledge source growth (ΔKS)

The proof for goals (see Section 3, goals: 1, 2, and 3) has been methodologically simplified using approximate equality (2) for the KB and periodical updating of the knowledge base increment is continued (ΔKSt) and (ΔKBt).

$$\Delta KS/t/ICS \approx (Iqu + Iqp + Iqw + Iqd)/global{+}local/t{-}1/ICS. \quad (2)$$

The relation (3) has been applied to the research examples in this paper.

$$\Delta KS/year/ICS \approx (IquISO/year + (Iqp + Iqw)/ISO{+}SRPS/year{-}1/)ICS. \quad (3)$$

The indices of time innovation intensity (ΔKSt) provide clustering by subfields of work and further periodical updating of knowledge. The periodic frequency of ΔKSt is defined on the basis of the quantitative index Iq, which is in a direct multicriteria qualitative and financial dependence, according to [22]. The values of periodic checks (Check) of the research for practice are as follows:

ΔKS/annual Check (4), ΔKS/annual – yearly Check (5), ΔKS/monthly Check (6),

ΔKS/weekly1+: One to two innovations a week, according to the relation (7),

ΔKS/weekly2+: Two to three innovations a week, according to the relation (8),

ΔKS/daily1+ = ΔKS/weekly5+: One innovation every working day or five innovations a week, according to the relation (9),

ΔKS/weekly12+ = ΔKS/daily2+weekly2+: Twelve innovations a week, according to the relation (10) according to the intensity of KS innovation, which requires intensive daily checks and innovation of the KB.

$$\Delta KSt = \Delta KS/annual, \text{ for } \Delta KSt = 0, \quad (4)$$

$$\Delta KSt = \Delta KS/yearly, \text{ for } 1 \le \Delta KSt < 12, \quad (5)$$

$$\Delta KSt = \Delta KS/monthly, \text{ for } 12 < \Delta KSt \le 50, \quad (6)$$

$$\Delta KSt = \Delta KS/weekly1+, \text{ for } 50 < \Delta KSt \le 100, \quad (7)$$

$$\Delta KSt = \Delta KS/weekly2+, \text{ for } 100 < \Delta KSt \le 150, \quad (8)$$

…

$$\Delta KSt = \Delta KS/daily1+ \text{ (or } \Delta KSt = \Delta KS/weekly5+\text{), for } 250 < \Delta KSt \le 300, \quad (9)$$

…

$$\Delta KSt = \Delta KS/weekly12+ \text{ (or } \Delta KSt = \Delta KS/daily2+weekly2+\text{), for } 600 < \Delta KSt \le 650, \quad (10)$$

In practice, this “clustering” of innovation levels relates to 50 working weeks, that is, 250 working days in a calendar year.

4.4 Creation of trend lines

Data analysis, creation and analysis of trends, and the review of the results have been done in OpenOffice 4 [23]. The results are graphically presented cumulatively, through the trends, and also through the original mathematical relations: a) including quantitative indices (Iq), indices of value (Iv), and time aspects for the entire period of the study research, by the years of all the editions; b) including annual indices of value (Iv/year and a cumulative index ΣIv) and also financial trend lines, according to the data from all previous years (or by selecting characteristic years of the twenty-first century) for the formation of the regression equations.

In mathematical relations (trend lines), the designation Iv/y has been used instead of the index Iv (while only the designation y has been used in the figures).

5 Results

5.1 Comparative Analysis

The results of the analysis are given for all standardized subfields within the field of Electrical Engineering. Initial results are given in **Table 1**, where the indices of quantity (Iq), presented in the methodology (Section 4), are given for each subfield.

Bearing in mind the results shown in **Table 1**, it can be concluded that the KSs within 29 fields (DK2) are innovated significantly faster at the local level (SRPS) as compared to the global level (ISO).

Note:

- Columns 4, 6, 8, 11, and 13 in Table 1 refer to SRPS, that is, the current state of SRPS development, the sum of newly developed SRPSs in 2014.
- CHF stands for the ISO-selling currency (in Switzerland).

5.2 Knowledge Trend Analysis by Subfield

The results for all subfields of Electrical Engineering are shown in this chapter. The innovation level in every subfield (DK2) has been analysed, as well as the possibility of clustering according to the relation (2), on the specific KSs according to the relation (3) and the clustering model according to the relations (1) to (4) given in Section 4.3. The result is shown in **Table 2.**

Table 1
Comparative elements of knowledge pathways ISO – SRPS
(for ICS_ 1 = 29, January 2015).

I	Subfield	Samples (**Iqs - KS**)		Published (**Iqp**)		Withdrawn (**Iqw**)		Developed (**Iqu**)		**2014** (Iqp/2014)		Innovat. values **Iv/2014**		∑Ivalues (CHF) **∑Iv/2014.01**	
	ICS	ISO	SRPS	ISO	SRPS	ISO	SRPS	ISO	SRPS	SRPS	ISO	SRPS	ISO	SRPS	ISO
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	29.020	-	225	-	189	-	35	-	1	16		422,89		5764,87	-
2	29.030	-	19	-	29	-	0	-	0	1		26,59		468,07	-
3	29.035	-	325	-	289	-	36	-	0	11		182,24		6539,88	-
4	29.040	-	68	-	58	-	10	-	0	-		-		1724,94	-
5	29.045	-	1	-	1	-	0	-	0	-		-		57,48	-
6	29.050	-	26	-	22	-	4	-	0	5		153,67		736,30	-
7	29.060	-	406	-	346	-	53	-	7	23		578,31		8965,90	-
8	29.080	-	100	-	83	-	15	-	2	4		114,75		2466,48	-
9	29.100	-	64	-	61	-	2	-	1	-		-		1423,77	-
10	29.120	-	311	-	268	-	40	-	3	20		664,37		8806,82	-
11	29.130	-	139	-	125	-	14	-	-	13		510,63		5510,75	-
12	29.140	-	490	-	366	-	121	-	3	12		278,83		11353,45	-
13	29.160	45	84	19	59	20	15	6	10	2		80,94		1841,40	2066
14	29.180	9	122	4	2	3	16	2	2	2		51,61		2628,20	314
15	29.200	-	57	-	50	-	7	-	-	3		41,87		1944,57	
16	29.220	6	69	2	54	4	5	0	10	2		73,90		1629,18	216
17	29.240	-	142	-	133	-	7	-	2	11		335,07		4748,69	
18	29.260	6	122	2	100	0	16	4	6	1		21,91		3499,17	410
19	29.280	-	75	-	67	-	7	-	1	10		197,88		1573,94	
	∑ 29	**66**	**2844**	**27**	**2391**	**27**	**405**	**12**	**48**	**136**	**1**	**3735,5**	**138**	**70975,4**	**3006**

Table 2
Knowledge sources growth (ΔKSt) in the analysed field (ICS_1 = 29)
and all subfields (19).

ICS→	020	030	035	040	045	050	060	080	100	120	130	140	160	180	200	220	240	260	280	∑ 29
	1	2	3	4	5	6	7	8	9	10	11	12	**13**	14	**15**	16	17	18	19	∑
2012	86	10	73	14	0	0	104	19	1	68	37	185	**43**	23	**13**	6	39	53	13	787
2014	52	1	**47**	10	0	9	83	21	3	63	27	**136**	**53**	25	**10**	21	20	**27**	18	629
(ΔKSt)	W1	Y	**M4**	M1	A	Y	W1	M1	Y	W1	M2	**W2**	**W1**	M2	**M1**	M1	M1	**M2**	M1	D2+W2

5.2.1 Very high (daily) degree of innovation (ΔKBD)

The analysed field (ICS_1 = 29), in total, has a very high degree of innovation: more than one innovation a day. More precisely, the time degree of innovativeness is 12 innovations during a workweek, which is shown by ΔKSt = ΔKSD2+W2.

After examining the global and especially local KSs based on the published standards in all subfields of Electrical Engineering, it can be concluded that this field has a very high degree of local innovation. The very value of the indicators of innovation intensity (ΔKSD2+W2) shows over 600 novelties in the course of 50 workweeks (250 workdays).

5.2.2 Subfields with a high (weekly) degree of innovation (ΔKSW)

Subfields with a high degree of innovation include those in which the time-weekly intensity of innovation is ΔKSt = ΔKSW.

After examining the analysed results (see **Tables 1** and **2**), in all subfields, it can be concluded that within the field of Electrical Engineering there are subfields with a high degree of innovation: five subfields in aggregate, **Table 3**. **Table 3** presents the names of these subfields as well as the expected trend (January 2015) and value index until January 2013.

Table 3

Ranking of subfields (ICS_2 = 29.xy0) with weekly intensity of innovation.

	ICS_2	Subfield name	ΔKSt t (2015.01)	ΔKSt t (2013.01)
(1)	(2)	(3)	(4)	(5)
1	29.020	Electrical engineering in general	W1 (52) ↓	W1 (86)
2	29.060	Electrical Wires and Cables	W1 (83) ↓	W2 (104)
3	29.120	Electrical Accessories	W1 (63) ↓	W1 (68)
4	29.140	Lamps and Related Equipment	W2 (136) ↓	W3 (185)
5	29.160	Rotating Machinery	W1 (53) ↑	W1 (43)

Tabular display of W-cluster shows a declining trend in the intensity of innovation in all the subfields (columns (4) and (5) in **Table 3**), except that the mutual order (rank) of the subfields has not remained the same.

For the selected ones from the abovementioned subfields (29.060, 29.120, 29.140 and 29.160) there are:

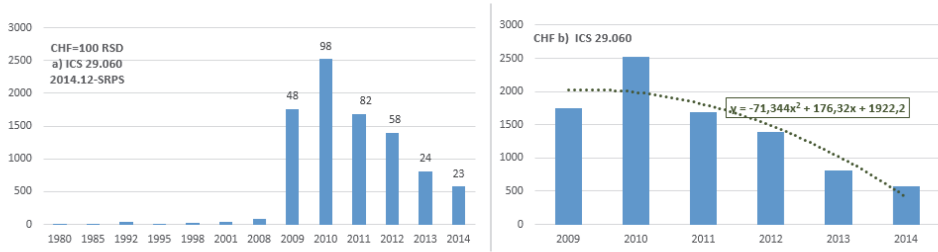
a) aggregate analyses, from the initial available year up to and including 2014 (Fig. 1);

b) the trend line of planned (future) annual requirements according to the relations 11,12, 13 (Fig. 1).

Fig. 1 includes: a) aggregate analyses over 1980–2014 and b) the trend of planned (future) annual requirements according to the relation (10) (Fig. 2b).

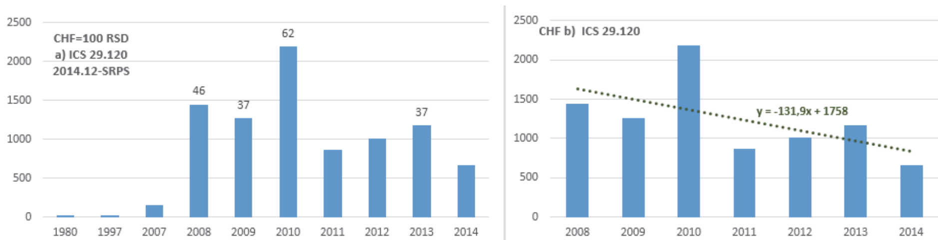
$$Iv/y29.060/SRPS/2009\text{-}2014.12 = -71.344x2 + 176.32x + 1922.2. \quad (11)$$

$$Iv/y29.120/SRPS/2008\text{-}2014.12 = -131.x + 1758. \quad (12)$$



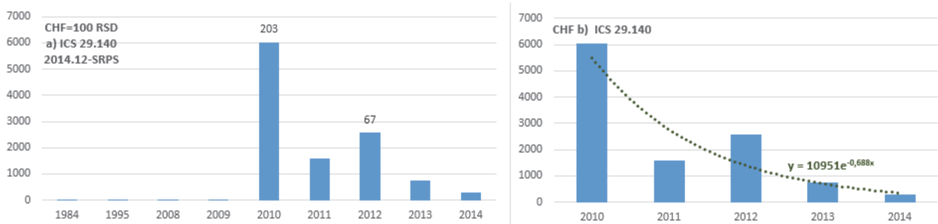
a) b)

Fig. 1 – *Analysis results for ICS_2 = 29.060: Electrical Wires and Cables, SRPS.*



a) b)

Fig. 2 – *Analysis results for ICS_2 = 29.120: Electrical Accessories, SRPS.*



a) b)

Fig. 3 – *Analysis results for ICS_2 = 29.140: Lamps and Related Equipment, SRPS.*

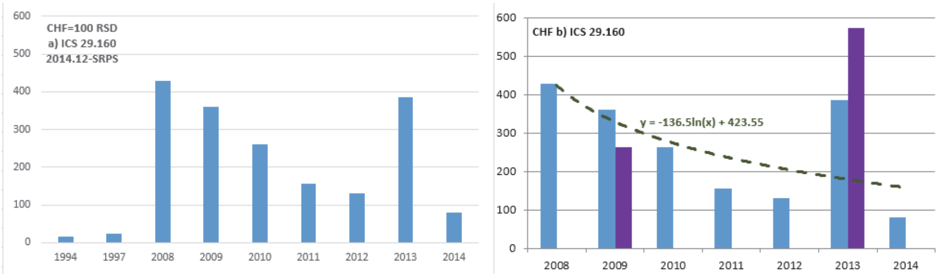
Fig. 2 includes: a) aggregate analyses over 1980–2014 and b) the trend of planned (future) annual requirements according to the relation (11) (Fig. 3b). Fig. 3 includes: a) aggregate analyses over 1984–2014 and b) the trend of planned (future) annual requirements according to the relation (13) (Fig. 4b).

$$Iv/y29.140/SRPS/2010\text{-}2014.12 = 10951e^{-0,688x}. \qquad (13)$$

Fig. 4 includes: a) aggregate analyses over 1994–2014 and b) the trend of planned (future) annual requirements according to the relation (14) on the local (SRPS) and global (ISO) levels (15) (Fig. 5b).

$$Iv/y29.160/SRPS/2008\text{-}2014.12 = -136.5\ln(x) + 423.55, \quad (14)$$

$$Iv/y29.160/ISO/2008\text{-}2014.12 = 67.427\ln(x) + 37.311. \quad (15)$$



a) b)

Fig. 4 – *Analysis results for ICS_2 = 29.160: Rotating Machinery, SRPS and ISO.*

5.2.3 Subfields with medium (monthly) intensity of innovation (ΔKSM)

Subfields with a medium degree of innovation include those in which the time degree of innovation is ΔKSt = ΔKSM, according to the relation (3) and **Table 2**.

By analysing the results in **Tables 1** and **2** for all the subfields within the field of Electrical Engineering, we can separate those with a medium (monthly) degree of innovation (**Table 4**). **Table 4** presents the names of these subfields, as well as the expected trend (January 2015) and value index until January 2013.

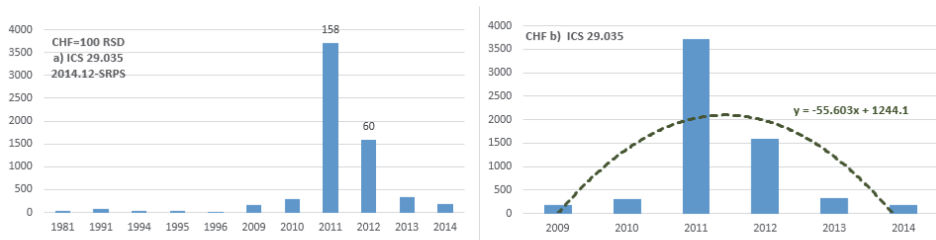
Table 4

Subfields (ICS_2 = 29.xyz) with monthly intensity of innovation.

	ICS_2	Subfield name	ΔKSt t(2015.01)	ΔKSt t(2013.01)
(1)	(2)	(3)	(4)	(5)
1	29.035	Insulating Materials	M4 (47) ↓	W1 (73)
2	29.040	Insulating Fluids	M1 (10) ↓	M1 (14)
3	29.080	Insulation, Insulating Fluids, Insulating Materials, Insulating Fluids	M1 (21) ↑	M1 (19)
4	29.130	Switchgear and Controlgear	M2 (27) ↓	M3 (37)
5	29.180	Transformers, Reactors, *Instrument Transformers*	M2 (25) ↑	M2 (23)
6	29.200	Rectifiers, Converters, Stabilized Power Supply	M1 (10) ↓	M1 (13)
7	29.220	Galvanic Cells and Batteries	M1 (21) ↑	Y (6)
8	29.240	Power Transmission and Distribution Networks	M1 (20) ↓	M3 (39)
9	29.260	Electrical Equipment for Working in Special Conditions	M2 (27) ↓	W1 (53)
10	29.280	Electric Traction Equipment	M1 (18) ↑	M1 (13)

Tabular analysis of M-cluster shows a declining trend of innovation intensity in all subfields (columns (4) and (5) according to **Table 4**). However, the order of the subfields has not remained the same …

Bearing in mind that the number of subfields grouped into the cluster with monthly growth of KS (ΔKSM) is significantly large (13), only two (characteristic) subfields are presented in the results: these are the subfields with a significant number of standards on the global level as well (29.035 and 29.240).

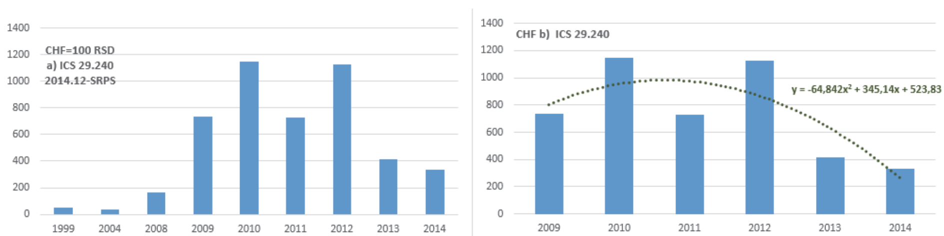


a) b)

Fig. 5 – *Analysis results for ICS_2 = 29.035: Insulating Materials, SRPS.*

Fig. 5 includes: a) aggregate analyses over 1981–2014 and b) the trend of planned (future) annual requirements according to relation (16) (Fig. 1b).

$$Iv/y29.035/SRPS/2009\text{-}2014.12 = -55.603\,x + 1244.1. \quad (16)$$



a) b)

Fig. 6 – *Analysis results for ICS_2 = 29.240: Power Transmission and Distribution Networks, SRPS.*

Fig. 6 includes: a) aggregate analyses over 1999–2014 and b) the trend of planned (future) annual requirements according to the relation (17) (Fig. 6b).

$$Iv/y29.240/SRPS/2009\text{-}2014.12 = -64.842\,x2 + 345.4\,x + 523.83. \quad (17)$$

5.2.4 Subfields with low (yearly) degree of innovation (ΔKSY)

Subfields for which the time intensity of innovation (ΔKSY) have a low (yearly) degree of innovation.

By analysing the results in **Tables 1** and **2**, it is possible to draw conclusions and discuss the trends in the subfields with yearly intensity of innovation in the field of Electrical Engineering (**Table 5**). **Table 5** presents the names of these subfields as well as the expected trend (January 2015) and value index until January 2013.

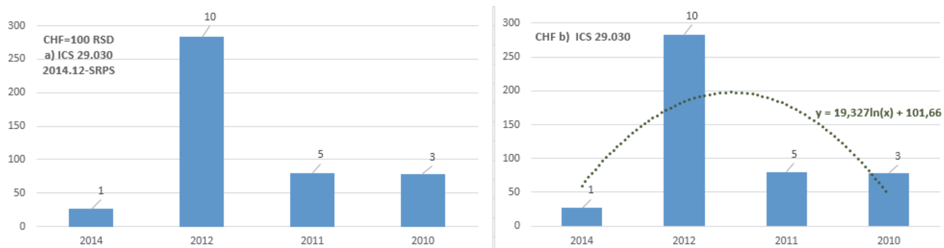
Table 5

Subfields (ICS_2 = 29.xyz) with yearly intensity of innovation.

	ICS_2	Subfield name	ΔKSt t(2015.01)	ΔKSt t(2013.01)
(1)	(2)	(3)	(4)	(5)
1	29.030	Magnetic Materials	Y (1) ↓	Y (10)
2	29.050	Superconductivity and Conducting Materials	Y (9) ↑	Y (0)
3	29.100	Components for electrical equipment	Y (3) ↑	Y (1)

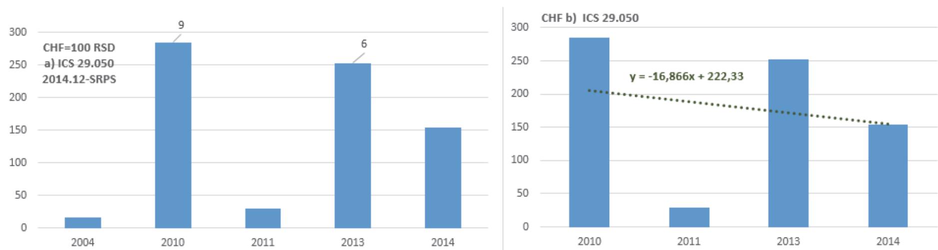
Tabular analysis of Y-cluster shows the "diverse" trend of innovation intensity in the presented subfields (columns (4) and (5) in **Table 5**). However, the order (rank) of the subfields has not remained the same.

Subfields 29.030 and 29.050 are presented.



a) b)

Fig. 7 – *Analysis results for ICS_2 = 29.030: Magnetic Materials, SRPS.*



a) b)

Fig. 8 – *Analysis results for ICS_2 = 29.050: Superconductivity and Conducting Materials, SRPS.*

Fig. 7 includes: a) aggregate analyses over 2010–2014 and b) the trend of planned (future) annual requirements according to the relation (18) (Fig. 7b).

$$Iv/y29.030/SRPS/2010\text{-}2014.12 = 19.27\ln(x) + 101.66. \qquad (18)$$

Fig. 8 includes: a) aggregate analyses over 2004–2014 and b) the trend of planned (future) annual requirements according to the relation (19) (Fig. 8b).

$$Iv/y29.050/SRPS/2010\text{-}2014.12 = -16.866x + 222.3. \qquad (19)$$

6 Discussion

Taking into account the results shown in Section 5, the fulfillment of the set objectives of the paper is discussed. Moreover, what follows are the conclusions and planning of future activities of professionals in one or more of the mentioned subfields (DK2 level). The analysis of available KSs shows the current state on both local and global levels, reflecting the fact that in the field of Electrical Engineering (DK1 = 29), the local KB is innovated significantly faster in relation to the global one, where the intensity of innovation of KSs (ΔKS) is lower. This fact provides a prerequisite for the development and further innovation in the subfields of Electrical Engineering with daily, weekly, and annual intensity.

The proposed methodology provides a clear and practical distribution of activities by subfields (DK2) and by levels that are formed on the basis of the intensity of innovation of KSs. This also enables clearer understanding, monitoring, and management of the subfields that have the maximum and/or minimum amount of innovations.

The original methodology stands out in comparison with other studies and imposes a unique approach on the analysis of standardized KSs and comparison between the current situations on local and global bases in this field as well as with other fields (DK1) and subfields (DK2).

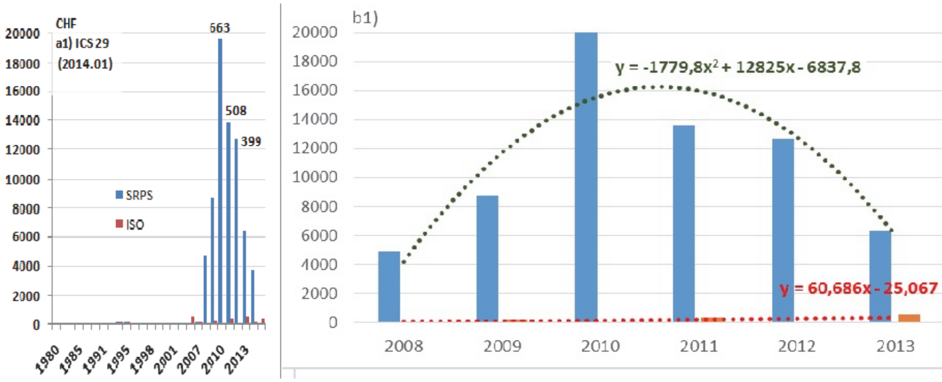
An approach that includes the creation of the trends provides the ability to predict future innovations and planning of resources for the future. In addition to the intellectual (human), financial requirements can be also predicted in every subfield and the field in general.

6.1 Discussion on daily innovation intensity (ΔKSD)

The domain of daily intensity can be discussed according to Fig. 9, which relates to the results from January 2014 and Fig. 10 (January 2015). Compared with the research presented in [5], it can be seen that the KS increased for the year 2011, from 428 innovations to 508 (in January 2014). The same research [5] shows that in this period, 40 standards were under development.

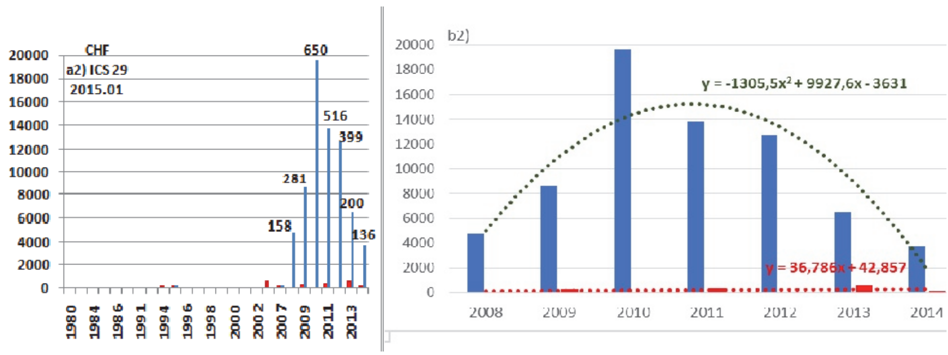
Fig. 9 includes: a) aggregate analyses over 1980–2014 and b) the trend of planned (future) annual requirements according to the data from 2014.

Fig. 10 includes: a) aggregate analyses over 1980–2014 and b) the trend of planned (future) annual requirements according to the data from January 2015.



a) b)

Fig. 9 – *Analysis of results for ICS_1 = 29: Electrical Engineering (January 2014).*



a) b)

Fig. 10 – *Analysis results for ICS_1 = 29: Electrical Engineering (January 2015).*

Analysis of the global and local KSs from 2008–2015 shows the importance of innovations, as well as their usefulness in practice, for the innovation of KBs.

In addition to the four clusters shown (or four classes of innovation intensities), there are no samples in subfield 29.045 (Semiconducting Materials). Therefore, it has not been taken into account in the analysis.

6.2 Discussion on weekly innovation intensity (ΔKSW)

The analysis of innovation with weekly intensity, based on the results shown in 5.2.2, provided the selection of five fields with the mentioned level of innovation. Compared to other levels, it can be concluded that the number of subfields with weekly innovation intensity is higher than the number of subfields with a low level of innovation. This suggests that these are the subfields within which there is continuous work on improvement and new innovations.

In comparison with the research presented in [7], there are differences in the level of innovation, and, based on the presented results, it can be concluded that this field (Electrical Engineering) has a very high degree of local innovation.

6.3 Discussion on monthly innovation intensity (ΔKSM)

What follows is an insight into the analysis of monthly innovation, for example, for the first and second months of 2015 (January and February). In accordance with the presented results (Section 5.1: daily monitoring of innovation, and Section 5.2: weekly monitoring of innovation), the results for January and February 2015 (or the first eight weeks) have been extracted. It can be discussed on the monitoring of these results in actual practice, on the trend of local KSs and necessity for innovating the knowledge base. Fig. 11 shows the value of standardized KSs by subfield (in the final phase of preparation or publication on 31 January and 28 February 2015).

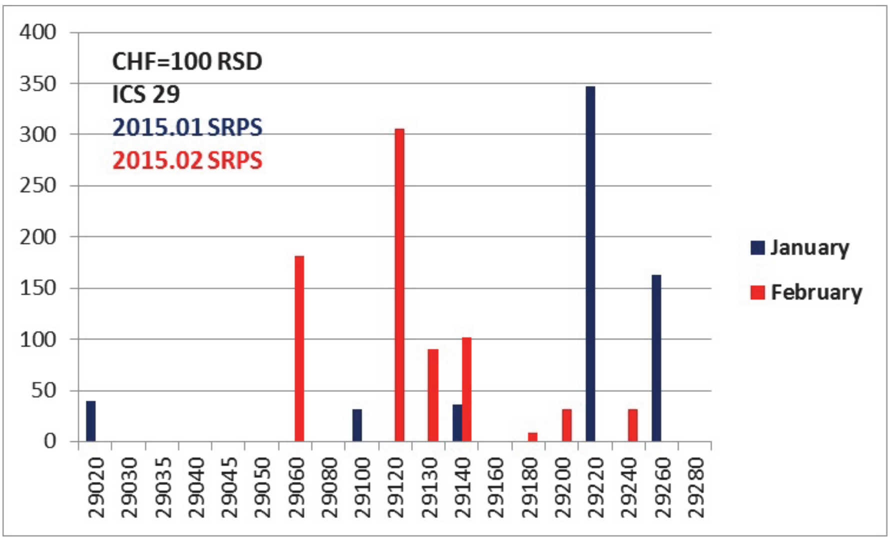


Fig. 11 – *Analysis results for ICS_2 = 29.xyz, (January and February 2015).*

Taking into account the presented results on the largest number of innovations in the first and second months of 2015, the largest number of standardized KSs (in preparation or published standards) refers to the subfields 29.220 (January) and 29.120 and 29.060 (February). In the previous year, 2014, these subfields were grouped into those with a medium level of innovation (29.120 and 29.060: weekly; 29.220: monthly). The results from January and February 2015 indicate the possibility of changes in the clusters, that is, different groupings by subfield.

The analysis of data from February shows that there are changes in terms of the largest number of standardized KSs. Subfields with the highest number of innovations are in February, 29.120 and 29.060. These are also the subfields that are classified into the sub-group with a high (weekly) level of innovation.

7 Conclusion

In relation to the results presented and the proposed methodology, conclusions can be drawn by using a SWOT analysis:

S (Strengths)

- The original trend lines, original methodology, original research, and original results presented, which lead to conclusions important for the national level.
- The universal solution given by relations (1), (2), and (4) – (7) in the study, comparison of local and global knowledge sources (KSs), and increase of knowledge sources (ΔKS) as a basis for monitoring the innovation of the knowledge base (KB).
- A basis for the management of the Knowledge Base System (KBS) has been obtained: modeling, creation, monitoring, usage for instructional purposes, improvement, and so on.

W (Weaknesses)

- The weakness regarding the repeatability of the research relates to the "containment" of some local KSs and unavailability of the data for analysis and comparison of innovation at the local level.

O (Opportunities)

- The opportunities provided by forecasting the financial resources relate to the creation of short-term and long-term plans for the development of the field of Electrical Engineering;
- The same methodology can be applied to other local parameters of innovation: ΔKS, KB, and innovation bases, and a comparative review can be made with respect to the global base.

T (Threats)

- The unstable and unpredictable economic situation at the local level can be identified as a threat, which may affect the creation of new KSs.

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