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Comparative analysis of ISO/IEC and IEEE standards in the field of Internet of Things

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Abstract: *In this paper, standardized knowledge sources (standards) and statistical analysis of published standards in the field of the Internet of Things by the IEEE and ISO (International Organization for Standardization), are presented. The purpose of the study is to compile various knowledge sources from the listed fields, employ a qualitative and quantitative methodology, and statistically compare them using the T-test method. The analysis's findings show parallels and contrasts between the two groups of standards, ISO/IEC and IEEE, in terms of cost and page count (two crucial dependent variables). It was determined that the organization should participate more in the creation of standards for the Internet of Things, in order to achieve maximum quality of future products and services.*

Keywords: *comparison; ISO/IEC; IEEE; standards; statistical analysis; Internet of Things.*

1. INTRODUCTION

The Internet of Things involves connecting different types of devices to the Internet, most commonly sensors and actuators. Using these devices allows you to create smart environments that can automate the execution of everyday tasks. Sensors are devices that can respond to stimuli from the physical environment, such as heat, light, sound or pressure. Actuators are devices that perform physical tasks. They often have a switch function and are used to control lighting, air conditioning, heating systems and more.

Smart environments rely on sensor networks that are used to monitor physical conditions such as temperature, sound, vibration, pressure, movement, and pollutants. Such networks are arranged in space and consist of sensors and other devices that communicate with each other. Communication between smart devices (Machine to Machine communication, M2M) is a critical element for the realization of the Internet of Intelligent Devices. M2M communication allows devices to bidirectionally exchange information with business applications over a communications network. HTTP is most often used as a communication protocol in combination with web services based on the REST architecture. A special CoAP (Constrained Application Protocol) has been developed, which is similar to the HTTP protocol, but is optimized for device communication. CoAP defines simple message formats that can also be processed on resource-limited devices, such as wireless sensor network nodes [1].

The integration of embedded devices into the Internet introduces several new challenges, since many of the existing Internet technologies and protocols were not designed for this class of devices [2].

As authors in [3] point out, the development and wide application of Internet of Things requires standardisation. As 'things' are connected with each other the interfaces between the 'things' must be defined at technical and at application levels in order to achieve the full benefits from the Internet of Things. Standards should be designed to support a wide range of applications and address common requirements from a wide range of industry sectors as well as the needs of the environment, society and individual citizens [4]. Standardization plays a significant role in how fast the general approach and the industrial internet technologies will be taken into use [3].

Authors in [5] emphasizes that international standards provide general methods by listing protocols, rules, guidelines, and characteristics that are defined and approved by authorized organizations, helping develop and manage systems efficiently by applying these standards. Therefore, the adoption of international standards is required to overcome the barriers in Internet of Things.

As the number of Internet of Things products as well as platforms keeps growing, the number of professional security organizations, initiatives and standards for IoT have also started to emerge, because they are essential for enabling the fast growth of Internet of Things [6].

By studying reality, collecting different data and accessing different sources of knowledge, we come to expand scientific knowledge in existing fields, and create new information and knowledge.

The aim of this paper is to collect, qualitative and quantitative approach and analysis of various sources of knowledge in the field of Internet intelligent devices.

1.1 Related work

By studying reality, collecting various data, and accessing various sources of knowledge, new information is created, and, first and foremost, scientific knowledge is expanded in certain areas. There are a number of related studies that deal with standardization and standard analysis in specific areas.

A statistical analysis of standards in the field of e-learning was performed in the paper [7], and the obtained comparison results show significant differences in terms of the number of published standards and their prices between the analyzed sets of standards, i.e. between the national standards of Serbia and nearby countries such as Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Albania, Hungary, Romania, and Slovenia, as well as internationally.

A related study [8] examines existing knowledge bases in the field of expert systems and artificial intelligence, including published standards, eKspertise2Go web pages, and standardized and non-standard dictionaries. According to the results, the International Organization for Standardization has published the most standards, while the eKspertise2Go website has the most consistent information on the use and construction of expert systems.

In [9] the author presents a comparative analysis of ISO and regional standards in the field of e-learning. The survey results show similarities and differences in terms of publishing trends as well as the price of the standard.

The following chapters will present standardization organizations as well as sources of knowledge in the fields of Internet of Things.

2. ORGANIZATIONS FOR STANDARDIZATION IN THE IoT AREA

A standard is an established norm or requirement for a repeatable technical task which is applied to a common and repeated use of rules, conditions, guidelines or characteristics for products or related processes and production methods, and related management systems practices. Technical standard includes definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, designs, or operations; measurement of quality and quantity in describing materials, processes, products, systems, services, or practices; test methods and sampling procedures; or descriptions of fit and measurements of size or strength. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes, and practices.

A technical standard may be developed privately or unilaterally, for example by a corporation, regulatory body, military, etc. Standards can also be developed by groups such as trade unions and trade associations. Standards organizations often have more diverse input and usually develop voluntary standards: these might become mandatory if adopted by a government (i.e., through legislation), business contract, etc. [10].

Standardization is the process of establishing and applying certain rules in order to regulate and regulate activities in the field, for the benefit and with the participation of all stakeholders, and especially to achieve overall optimal savings, taking into account the functional purpose and technical safety requirements [11].

Three basic levels of standardization by geographical scope are defined, namely: international, regional (European) and national level of standardization [12].

International standardization organizations are:

- ISO - International Organization for Standardization,
- IEC - International Electrotechnical Commission,
- ITU - International Telecommunication Union,
- IEEE - Institute of Electrical and Electronics Engineers,
- European standardization organizations are:
- CEN - European Committee for Standardization,
- CENELEC - European Committee of Electrical Engineers,
- ETSI - European Telecommunications Institute,

State organizations for standardization are:

- ISS - Institute for Standardization of Serbia,
- BAS - Institute for Standardization of Bosnia and Herzegovina,
- DIN - German Institute for Standardization,
- BSI - English Institute for Standardization,
- AFNOR - French Institute for Standardization,
- NEN - Dutch Institute for Standardization,
- ON - Austrian Institute for Standardization,
- SIST - Slovenian Institute for Standardization,
- HZN - Croatian Institute for Standardization.

ISO/IEC JTC 1, entitled "Information Technology", is a joint technical committee (JTC) of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Its purpose is to develop,

maintain and promote standards in the field of information and communication technologies (ICT).

The JTC/SC41 Committee was established by JTC 1 at its plenary session in November 2016 in Lillehammer, Norway. Standardization in the field of Internet of Intelligent Devices serves as the focus and advocate of the JTC 1 standardization program. Internet of Intelligent Devices is a system concept that uses many technologies that are standardized by other JTC 1 entities and SDOs. IoT systems are software-intensive and can be quite complex, ranging from simple architecture to multi-layered distributed computing cyberphysical systems. IoT systems are the key drivers of "smart everything" [13].

With the development of the Internet of Intelligent Devices, the requirements for new standards and revision of existing ones will be more pronounced. The next chapter presents important standards, ie sources of knowledge in the field of Internet intelligent devices.

3. KNOWLEDGE SOURCES

Sources of information can be formal or informal, depending on whether scientific information is obtained through formal or informal channels of communication. Standards, scientific journals, textbooks, monographs, dictionaries, etc. represent formal sources of information (knowledge).

International Standards in the Field of Internet of Things, published by the International Organization for Standardization (ISO), are [14]:

Table 1. *Overview of published international ISO / IEC standards in the field of Internet of Things*

Standard title
• ISO/IEC 20922:2016 Information technology — Message Queuing Telemetry Transport (MQTT) v3.1.1
• ISO/IEC 21823-1:2019 Internet of things (IoT) — Interoperability for IoT systems — Part 1: Framework
• ISO 19079:2016 Intelligent transport systems — Communications access for land mobiles (CALM) — 6LoWPAN networking
• ISO/IEC TR 22417:2017 Information technology — Internet of things (IoT) use cases
• ISO/IEC 23093-3:2019 Information technology — Internet of media things — Part 3: Media data formats and APIs
• ISO/IEC 23093-2:2019 Information technology — Internet of media things — Part 2: Discovery and communication API
• ISO/IEC 30162:2022 Internet of Things (IoT) — Compatibility requirements and model for devices within industrial IoT systems
• ISO/IEC 30163:2021 Internet of Things (IoT) — System requirements of IoT/SN technology-based integrated platform for chattel asset monitoring supporting financial services
• ISO/IEC 30161:2020 Internet of Things (IoT) — Requirements of IoT data exchange platform for various IoT services
• ISO/IEC 30118-1:2021 Information technology — Open Connectivity Foundation (OCF) Specification — Part 1: Core specification
• ISO/IEC TR 30166:2020 Internet of things (IoT) — Industrial IoT
• ISO/IEC TR 30164:2020 Internet of things (IoT) — Edge computing
• ISO/IEC 30165:2021 Internet of Things (IoT) — Real-time IoT framework
• ISO/IEC 5055:2021 Information technology — Software measurement — Software quality measurement — Automated source code quality measures
• ISO/IEC 21823-3:2021 Internet of things (IoT) — Interoperability for IoT systems — Part 3: Semantic interoperability
• ISO/IEC 21823-2:2020 Internet of things (IoT) — Interoperability for IoT systems — Part 2: Transport interoperability
• ISO/IEC TR 30148:2019 Internet of Things (IoT) — Technical requirements and application of sensor network for wireless gas meters.
• ISO/IEC TR 30167:2021 Internet of Things (IoT) — Underwater communication technologies for IoT
• ISO/IEC 30147:2021 Information technology — Internet of things — Methodology for trustworthiness of IoT system/service
• ISO 19731:2017 Digital analytics and web analyses for purposes of market, opinion and social research — Vocabulary and service requirementsISO/IEC 30141:2018 Internet of Things (IoT) — Reference Architecture
• ISO/IEC/IEEE 42030:2019 Software, systems and enterprise — Architecture evaluation framework
• ISO/IEC TR 29181-9:2017 Information technology — Future Network — Problem statement and requirements — Part 9: Networking of everything
• ISO/IEC TR 30174:2021 Internet of Things (IoT) — Socialized IoT system resembling human social interaction dynamics
• ISO/IEC TR 30176:2021 Internet of Things (IoT) —- Integration of IoT and DLT/blockchain: Use cases

• ISO/IEC 30118-9:2021 Information technology – Open Connectivity Foundation (OCF) Specification — Part 9: Core optional specification
• ISO/IEC 23093-4:2020 Information technology — Internet of media things — Part 4: Reference software and conformance
• ISO/IEC 23093-1:2020 Information technology — Internet of media things — Part 1: Architecture
• ISO/IEC 29161:2016 Information technology — Data structure — Unique identification for the Internet of Things
• ISO/IEC 21823-4:202 Internet of things (IoT) — Interoperability for IoT systems — Part 4: Syntactic interoperability
• ISO/IEC 20924:2021 Information technology — Internet of Things (IoT) — Vocabulary
• ISO/IEC 30071-1:2019 Information technology — Development of user interface accessibility — Part 1: Code of practice for creating accessible ICT products and services
• ISO/IEC 30141:2018/COR 1:2018 Internet of Things (loT) — Reference Architecture — Technical Corrigendum 1

The IEEE Institute of Electrical and Electronics Engineers has set the following standards in the field of Internet Intelligent Devices [15]:

Table 2. *Overview of published international IEEE standards in the field of Internet of Things*

Standard title
• 2144.1-2020 IEEE Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management
• 1528.7-2020 - IEEE Guide for EMF Exposure Assessment of Internet of Things (IoT) Technologies and Devices
• 2413-2019 - IEEE Standard for an Architectural Framework for the Internet of Things (IoT)
• 802.11ba Battery Life Improvement - IEEE Technology Report on Wake-Up Radio: An Application, Market, and Technology Impact Analysis of Low-Power/Low-Latency 802.11 Wireless LAN Interfaces
• P1924.1/D14, 2021 - IEEE Draft Recommended practice for developing energy efficient power-proportional digital architectures
• 2857-2021 - IEEE Standard for Wireless Smart Utility Network Field Area Network (FAN)
• White Paper - Pre-Standards Workstream Report: Clinical IoT Data Validation and Interoperability with Blockchain
• 802.15.4-2020 - IEEE Standard for Low-Rate Wireless Networks
• P2144.1/D3, Aug 2020 - IEEE Draft Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management
• P1528.7/D1.00, Feb 2020 - IEEE Draft Guide to Assess the Electromagnetic Fields (EMF) Exposure of Internet of Things (IoT) Technologies/Solutions
• IEEE 1901a-2019 IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications -- Amendment 1: Enhancement for Internet of Things Applications

4. RESEARCH METHODOLOGY

Standards, or standardized sources of knowledge, can be distinguished by comparing the values of specific characteristics (price, status, publication date, etc.) in relation to the group of standards to which they belong (ISO/IEC or IEEE standards).

The differences between the previously mentioned groups of standards - ISO/IEC and IEEE standards - were statistically analyzed.

SPSS software was used for the standard analysis. SPSS is an IBM platform for statistical analysis, text analysis, open source extensibility, big data integration, and it includes a large library of machine learning algorithms [16].

A t-test is a statistical test that is used to compare the means of two groups. It is often used in hypothesis testing to determine whether a process or treatment actually has an effect on the population of interest, or whether two groups are different from one another. The independent-samples t-test is a test used to compare the mean of a continuous variable in two different groups of subjects [17].

Standard.sav, a database containing standards from the categories ISO/IEC and IEEE, was the source of the data set used in the analysis. Figure 1 illustrates the display of variables, where one variable is categorical Group and denotes a group of standards (1-ISO/IEC or 2-IEEE), two variables are continuous dependent variables – Price (denotes the price of the standard) and NumberOfPage (denotes the number of pages), while other variables are nominal.

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	Group	Numeric	8	0	Grupa	{1, ISO/IEC}...	None	20	Left	Nominal	Input
2	Name	String	200	0	Naziv standarda	None	None	20	Left	Nominal	Input
3	Price	Numeric	8	2	Cena	None	None	20	Right	Scale	Input
4	Status	String	100	0	Status	None	None	20	Left	Nominal	Input
5	PublicationDate	Date	10	0	Datum objavljivanja	None	None	20	Right	Unknown	Input
6	NumberOfPa...	Numeric	8	0	Broj strana	None	None	20	Right	Scale	Input

Figure 1. *Review of variables used in standard analysis*

1	ISO/IEC 21823-2:2020 Internet of things (IoT) — Interoperability for IoT systems	88.00	Published	18
1	ISO/IEC TR 30148:2019 Internet of Things (IoT) — Technical requirements and	138.00	Published	28
1	ISO/IEC TR 30167:2021 Internet of Things (IoT) — Underwater communication	178.00	Published	60
1	ISO/IEC 30147:2021 Information technology — Internet of things — Methodolog	138.00	Published	31
1	ISO 19731:2017 Digital analytics and web analyses for purposes of market, op	88.00	Published	17
1	ISO/IEC 30141:2018 Internet of Things (IoT) — Reference Architecture	198.00	Published	77
1	ISO/IEC/IEEE 42030:2019 Software, systems and enterprise — Architecture eva	178.00	Published	77
1	ISO/IEC TR 29181-9:2017 Information technology — Future Network — Probler	118.00	Published	23
1	ISO/IEC TR 30174:2021 Internet of Things (IoT) — Socialized IoT system resen	138.00	Published	28
1	ISO/IEC TR 30176:2021 Internet of Things (IoT) —- Integration of IoT and DLT/b	158.00	Published	39
1	ISO/IEC 30118-9:2021 Information technology – Open Connectivity Foundation	198.00	Published	100
1	ISO/IEC 23093-4:2020 Information technology — Internet of media things — Pa	58.00	Published	8
1	ISO/IEC 23093-1:2020 Information technology — Internet of media things — Pa	118.00	Published	20
1	ISO/IEC 29161:2016 Information technology — Data structure — Unique identif	88.00	Published	18
1	ISO/IEC 21823-4:202 Internet of things (IoT) — Interoperability for IoT systems -	158.00	Published	38
1	ISO/IEC 20924:2021 Information technology — Internet of Things (IoT) — Vocat	58.00	Published	10
1	ISO/IEC 30071-1:2019 Information technology — Development of user interface	158.00	Published	50
2	2144.1-2020 IEEE Standard for Framework of Blockchain-based Internet of Thi	53.00	Published	18
2	1528.7-2020 IEEE Guide for EMF Exposure Assessment of Internet of Things (I	92.00	Published	88
2	2413-2019 IEEE Standard for an Architectural Framework for the Internet of Thir	184.00	Published	264
2	802.11ba Battery Life Improvement - IEEE Technology Report on Wake-Up Rad	398.00	Published	11
2	P1924.1/D14, 2021 - IEEE Draft Recommended practice for developing energy	75.00	Published	64
2	2857-2021 - IEEE Standard for Wireless Smart Utility Network Field Area Netwc	149.00	Published	177
2	White Paper - Pre-Standards Workstream Report: Clinical IoT Data Validation a	.	Draft	.
2	802.15.4-2020 - IEEE Standard for Low-Rate Wireless Networks	269.00	Published	800
2	P2144.1/D3, Aug 2020 - IEEE Draft Standard for Framework of Blockchain-base	.	Draft	18
2	P1528.7/D1.00, Feb 2020 - IEEE Draft Guide to Assess the Electromagnetic Fie	.	Draft	.
2	IEEE 1901a-2019 IEEE Standard for Broadband over Power Line Networks: Me	439.00	Published	1586
2	IEEE 1451.7-2010 IEEE Standard for Smart Transducer Interface for Sensors a	141.00	Published	99

Figure 2. *View a data set for analysis*

Statistical analysis by the T-test method in this paper was conducted to determine the differences in price and number of pages in these two groups of standards.

5. RESULTS AND DISCUSSION

Using the t-test approach, this chapter compares the test findings for the ISO/IEC and IEEE standards in terms of cost and the number of pages.

5.1 Comparison of price test results with ISO/IEC and IEEE standards

During the conducted t-test statistical analysis, a brief overview of the first t-test of independent samples was given, and a research question was asked: Is there a statistically significant difference in the price of standards between Group 1 standards (ISO/IEC) and Group 2 standards (IEEE)?

The results of testing the price of ISO/IEC and IEEE standards were compared. The analysis requires two variables, namely:

- One category (indicates a group of standards)
- One continuous dependent variable (indicates the price of the standard)

Assumptions and hypotheses set during the analysis are as follows:

H0: The difference between the two groups of standards in price is not statistically significant.

H1: The difference between the two groups of standards in price is statistically significant.

Table 3. *T-test results - comparison of difference in the price of ISO/IEC and IEEE standard*

Group Statistics

	Grupa	N	Mean	Std. Deviation	Std. Error Mean
Cena	ISO/IEC	31	143.1613	42.72946	7.67444
	IEEE	9	311.1111	424.44241	141.48080

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig	t	df	Significance One-Sided p	Significance Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
Cena	Equal variances assumed	18.239	<0.001	-2.236	38	.016	.031	-167.95	75.12764	-320.04	-15.86
	Equal variances not assumed			-1.185	8.047	.135	.270	-167.95	141.68880	-494.35	158.45

Table 3 represents the results of the t-test, which compares the results of testing the differences in the price of ISO/IEC and IEEE standards.

The value of significance level of the Levene test Sig. (<0.001) is less than 0.05, which implies that the assumption of equality of variance is violated, and to reach the final conclusion we take t-value of the second order t (-1.185). How is the value of Sig. (2-tailed) (0.270) greater than 0.05, the difference between the two groups of standards is not significant but accidental, thus confirming the null hypothesis - H0.

The final conclusion is, as follows: There is no statistically significant difference between the mean values in the price of ISO/IEC (Mean = 143.16, Std. Deviation = 42.73) standards and IEEE standards (Mean = 311.11, Std. Deviation = 424.44), t (-1.185). The table also contains the mean value of the difference between the two groups (Mean difference = -167.95), as well as the lower (Lower=-494.35) and upper (Upper=158.45) limit, which with a probability of 95% contains the actual size of this difference.

5.2 Comparison of page number test results for ISO/IEC and IEEE standards

The second conducted T-test compared the results of testing the number of pages of ISO/IEC and IEEE standards. The analysis requires two variables, namely:

- One category (indicates a group of standards)
- One continuous dependent variable (indicates the number of pages of the standard).

Assumptions and hypotheses set during the analysis are as follows:

H0: The difference between the two groups of standards by the number of pages is not statistically significant.

H1: The difference between the two groups of standards in the number of pages is statistically significant.

Table 4 represents the results of the t-test, which compares the results of testing the differences in page number of ISO/IEC and IEEE standards.

The value of significance level of the Levene test Sig. (<0.001) is less than 0.05, which implies that the assumption of equality of variance is violated and for the final conclusion is taken t value of the second order t (-1.591). How is the value of Sig. (2-tailed) (0.146) greater than 0.05, the difference between the two groups of standards is not significant but accidental, thus confirming the null hypothesis - H0.

The final conclusion is as follows: There is no statistically significant difference between the mean values in the number of standards of ISO/IEC (Mean = 57.38, Std. Deviation = 62.336) standards and IEEE standards (Mean = 312.5, Std. Deviation = 505.774), t (-1.591). The table also contains the mean value of the difference between the two groups (Mean difference = -255.125), as well as the lower (Lower = -617.27) and upper (Upper =

107.02) limit, which with a probability of 95% contains the actual magnitude of this difference.

Table 4. *T-test results - comparison of difference in the page count of ISO/IEC and IEEE standard*

Group Statistics

	Grupa	N	Mean	Std. Deviation	Std. Error Mean
Cena	ISO/IEC	32	57.38	62.336	11.020
	IEEE	10	312.50	505.774	159.940

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig	t	df	Significance One-Sided p	Significance Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
Cena	Equal variances assumed	25.974	<0.001	-2.861	40	.003	.007	-255.125	89.160	-435.325	-74.925
	Equal variances not assumed			-1.591	9.086	.073	.146	-255.125	160.319	-617.272	107.022

6. CONCLUSION

As more products and services in the field of the Internet of Intelligent Things (IoT) are developed, the necessity for standardized sources of knowledge is inevitable.

The data set used for the statistical analysis in this work includes worldwide standardized knowledge sources such as ISO/IEC and IEEE, in the field of IoT.

The aim of this paper was to collect, qualitative and quantitative approach and statistical analysis of different sources of knowledge in this area, to determine potential differences in price and number of pages (as key dependent variables) between two groups of standards - ISO/IEC and IEEE.

Based on the findings of this study, it was concluded that the differences in the cost of standards produced by ISO/IEC and IEEE organizations are not statistically significant. Differences in the amount of pages between these two groups of standards were also discovered. According to the T-test method of independent samples, the differences in the number of pages are not statistically significant.

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