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UV Curing Effect(s) on Colorimetric Properties of Test Specimens Created via Stereolithography

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Abstract: This paper presents the results of observing colorimetric change obtained by the impact of UV curing. The test specimens were made by stereolithographic process from photopolymer materials with the addition of cyan, magenta, and yellow dye. To better understand the impact of UV curing on colorimetric permeability properties, specimens were made in five different thicknesses (1 mm, 2 mm, 3 mm, 4 mm, and 5 mm). The UV curing time was divided into eight intervals of 15 minutes, at the end of which spectral and colorimetric values of each specimen were measured. The difference in color change was defined and shown using the CIELab color system. The conclusion of the conducted tests indicates that specimens with smaller thickness have a greater color change. The correlation between the time interval of UV radiation and the direction of color change was determined.

Keywords: color distance; color quality; stereolithography; UV curing

1 INTRODUCTION

Additive manufacturing technologies are increasingly used in areas where the visual properties of the obtained 3D prints are essential. Research on materials used in additive manufacturing technologies is mainly focused on testing mechanical properties. Prior research on materials in the stereolithographic process of additive manufacturing has studied the relationship between mechanical properties and the degree of polymerization. Studies have shown that increasing the time interval of curing with UV radiation changes the material's mechanical properties. Y. Yang et al. (2019) investigated the influence of UV radiation on the tensile strength and hardness of test specimens. Materials with longer intervals of UV curing by UV radiation change the mechanical properties to increase their tensile strength and hardness to a certain extent. After a longer UV curing interval (16 hours), the tensile strength and hardness decrease. Based on these findings, a mathematical model was developed to predict the mechanical properties of the material. In addition, Y. Yang et al. (2019) investigated the anisotropy of the material, and the orientation of the model during additive production has a significant influence on the mechanical properties of the material [1]. In their study, Puebla et al. (2012) presented the influence of model orientation on mechanical properties and material aging degradation on photopolymer resins [2]. Statistical analysis of DOE proved that the materials are not isotropic. The mechanical characteristics of the test specimens differed depending on the orientation in regards to the model on the building platform of the additive production device. Puebla et al. investigated the effects of accelerated aging of the material on the mechanical properties of test specimens. Application of accelerated aging over 50 days does not show a significant difference in the material properties. In their work by DSC analysis, Mansour et al. (2007) showed the influence the degree of polymerization has on mechanical properties of the material when exposed to accelerated aging. [3].

Due to rapid developments in the additive production industry and the spread of its agency to new applications, the standards do not cover all areas of additive production [4], [5]. There are currently no standards and guidelines for the visual or colorimetric properties of materials. The color of the obtained 3D prints is an essential element in their user's experiences, and the stability and durability of 3D print's colors need to be experimentally determined. There are standard ways of defining and measuring color in the graphics industry to control and adjust reproduction [6]. A study by Stanic et al. (2012) examined the reflective colorimetric properties of 3D prints. The influence of accelerated aging on color properties, colorimetric stability, and colorfastness on a 3D impression expressed by the additive binder imprinting process on materials was investigated. After exposing specimens to accelerated aging, significant color changes expressed as a ΔE_{00} value were measured on the 3D print. Changes in brightness, chromaticity, and tone were observed. The changes vary depending on the thickness of the ink coating and the final type of 3D print processing [7, 8]. The influence of aging on the properties of color, and colorimetric stability and durability of a 3D impression made by the additive process of binder jetting materials, was investigated. Coon et al. (2016) conducted a study on the protective covering for prototypes made by additive manufacturing technologies in which experts from the field of product design and development participated. The study showed that 68% of respondents believe that a physical print is more valuable than a digital record, and 81% of respondents noticed changes in the 3D print over a more extended period of time [9]. Also, due to physical damage, material, and color degradation, 84% of respondents said they would like to replicate and create new 3D prints. M. Neumüller et al. (2014) explores the application of additive technologies in the protection of cultural heritage, where visitors are provided with a multi-sensory and especially haptic experience using 3D prints. One of the crucial aspects of multi-sensory is the color of 3D prints. The visual properties of the material, due to degradation and discoloration of the material in additive manufacturing, are an essential factor in the choice of reproduction technology, and they need to be investigated further [10, 11]. Yuan et al. (2018) describe six

procedures of additive manufacturing technologies and their colorimetric properties when outlining possibilities of making 3D color prints [12]. The paper describes the indicators for assessing the color quality of 3D prints: color measurement, color specification, and color reproduction. In addition, color stability and consistency are essential properties for 3D prints, especially when 3D prints are applied as final products (functional prototypes and museum exhibits). Current research in color in additive manufacturing technologies focuses are on using classical colorimetric methods and their application to the 3D print.

2 EXPERIMENTAL PART

The stereolithographic process of additive manufacturing was selected for the production of test specimens. Stereolithography is the oldest commercially available additive production technology [13, 14]. The 3D impression obtained by the stereolithographic process visually shares visual similarities with the characteristics of the products similar to the products obtained in classical manufacturing processes such as injection molding. It is characterized by a very smooth surface, and the development of new materials improves the material's mechanical properties. Furthermore, dimensional accuracy is very precise, which allows the production of small details. Therefore, this additive manufacturing process is well accepted in the early stages of development, development of functional prototypes, and applicable products.

Colorimetric properties of materials were investigated in the stereolithographic process of additive manufacturing. The photopolymer materials used to create the 3D impression are in a liquid state before the photopolymerization process. Such a fluid state of the photopolymer allows us to interact with colors and pigments to produce 3D color prints. The stage of 3D printing is then followed by additional processing required by the stereolithography additive manufacturing process before obtaining the final product. Firstly, the model needs to be rinsed with a liquid that will remove all unpolymerized material from the surface of the 3D print. Additional UV curing is then required to complete the polymerization process. The duration of exposure to UV radiation was divided into specific time intervals to enable tracking of the effect each period has on the mechanical and colorimetric properties of measured specimens. Because of the need for strict measurement tolerances Computer-aided design - CAD environment is used to make a 3D model of test specimens.

Test plates were made in thicknesses of 1 mm, 2 mm, 3 mm, 4 mm, and 5 mm. Formlabs photopolymer RS-F2-PKG-CR was used for the stereolithographic process, in which dyes cyan (RS-F2-CRCY-01), magenta (RS-F2-CRMA-01), and yellow (RS-F2-CRYL-01) were added. Test 3D specimens were created using Formlabs Form 2. The Formlabs Form 2 stereolithographic additive manufacturing device uses a 405nm UV laser with a power of 250 mW. All models were oriented along the Z-axis to make better use of the build platform surface. The height of the fabrication layer (Z-axis) was set to 0.1 mm. The mixing ratio of the based photopolymer and dye was defined by the ratios prescribed by the manufacturer in order not to disturb the mechanical properties of the material [2]. The scheme of experimental work is shown in the Fig. 1.

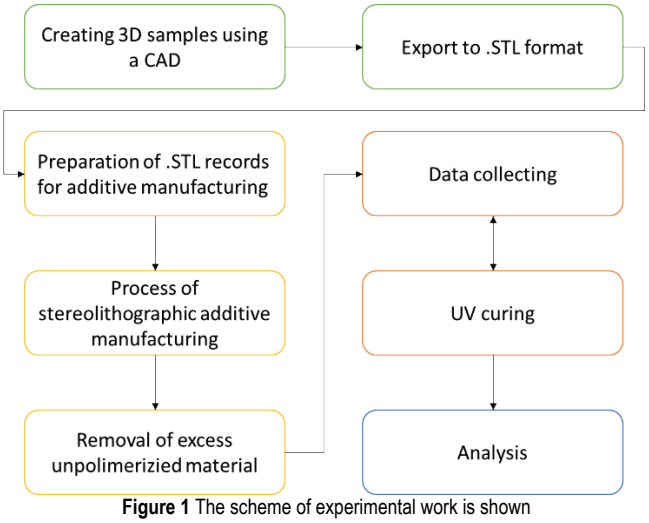

Figure 1 The scheme of experimental work is shown

After the test specimens were made by the stereolithographic additive production process, they were washed in a solvent to remove residual unpolymerized materials. Colorimetric and spectral properties of the test specimens were measured before the UV curing procedure using a spectrophotometer. The test specimens were then dried at 15-minute intervals using a UV chamber with controlled measurement conditions. After each UV curing interval, the colorimetric and spectral properties of the test specimens were measured to determine the effect of UV curing on the material. An analysis of the influence of UV radiation on the colorimetric properties of 3D prints was made based on the measured spectral and chromatic data. The difference in the color of the test specimens is shown as a ΔE_{00} value with a description of the direction of the tone change. The evaluation of the colorimetric color difference is shown in Tab. 1.

Table 1 Evaluation of colorimetric color difference

$\Delta E^* < 1$	a deviation that is not noticeable
$\Delta E^* = (1\text{-}2)$	very small difference; noticeable only to the experienced to the observer
$\Delta E^* = (2\text{-}3{,}5)$	mean difference; noticeable even to the inexperienced to the observer
$\Delta E^* = (3{,}5\text{-}5)$	great difference
$\Delta E^* > 6$	a very big difference

The total color change is shown as the value of ΔE_{00}, and the color difference equations are specified in Eqs. (1) through (4). The change in lightness between two test specimens is expressed by Eq. (1), change in chromaticity is expressed by Eq. (2), and change in hue is expressed by Eq. (3).

$$\Delta L' = L'_b - L'_s \tag{1}$$

$$\Delta C'_{ab} = C'_{ab,b} - C'_{ab,s} \tag{2}$$

$$\Delta H'_{ab} = \left[2\left(C'_{ab,b}\, C'_{ab,s} \right)^{0.5} \sin\left(\frac{\Delta h'_{ab}}{2} \right) \right] \tag{3}$$

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L} \right)^2 + \left(\frac{\Delta C'_{ab}}{k_C S_C} \right)^2 + \left(\frac{\Delta H'_{ab}}{k_H S_H} \right)^2 + R_T \left(\frac{\Delta C'_{ab}}{k_C S_C} \right) \left(\frac{\Delta H'_{ab}}{k_H S_H} \right) \right]^{0.5} \tag{4}$$

3 REASERSCH RESULTS WITH DISCUSSION

The research results show color change differences between the specimens before and after UV curing. Test specimens are translucent solid materials. Data represented in tables show color change through different curing intervals and CIE values of *L* a* b* C* h* before and after UV curing. UV curing intervals spaced by 15-minute increments.

Tabs. 2, 3, and 4 show the total color changes expressed as the ΔE_{00} value for the test specimens with cyan, magenta, and yellow dye. The tables show the color changes described as ΔE_{00} for eight UV curing intervals of 15 minutes for test specimens 1 mm, 2 mm, 3 mm, 4 mm, and 5 mm thick. Tabs. 2, 4, and 6 show that the most significant color change occurs after the first curing interval. It can be seen that the most significant total color change expressed as the value of ΔE_{00} occurs in the test specimens with cyan dye, while the smallest changes were recorded in the test specimens with magenta dye. Tab. 6 shows that the yellow dye test specimens have a uniform color change expressed as a ΔE_{00} value, regardless of the thickness of the test specimens.

Table 2 Color change through different curing intervals for cyan dye specimen tests

Cyan	ΔE_{00}				
Interval	1 mm	2 mm	3 mm	4 mm	5 mm
1	1.22	0.99	1.44	1.14	0.57
2	1.51	1.72	1.86	1.4	0.63
3	1.8	2.12	2.05	1.38	0.56
4	1.85	2.72	2.43	1.97	0.78
5	2.05	2.95	2.65	2.16	0.77
6	2.1	3.08	2.83	2.32	0.83
7	2.29	3.4	3.11	2.53	1.06
8	2.16	3.57	3.2	2.59	1.11

Table 3 Color change through different curing intervals for magenta dye specimen tests

Magenta	ΔE_{00}				
Interval	1 mm	2 mm	3 mm	4 mm	5 mm
1	0.84	0.42	0.62	0.84	0.79
2	1.01	0.59	0.59	0.94	0.82
3	1.07	0.64	0.66	0.96	0.82
4	1.09	0.75	0.63	1.07	0.84
5	1.11	0.8	0.58	0.9	0.69
6	1.19	0.85	1.64	1.06	0.86
7	1.11	0.76	0.69	1.01	0.95
8	1.21	0.9	0.79	0.88	0.85

Table 4 Color change through different curing intervals for yellow dye specimen tests

Yellow	ΔE_{00}				
Interval	1 mm	2 mm	3 mm	4 mm	5 mm
1	0.95	0.6	0.7	0.76	0.63
2	1.2	0.86	0.84	0.94	0.77
3	1.36	1.01	1.08	1.04	0.91
4	1.33	1.11	0.94	0.89	0.87
5	1.38	1.13	1.17	1.15	1.1
6	1.46	1.28	1.33	1.26	1.21
7	1.49	1.38	1.35	1.24	1.19
8	1.5	1.38	1.42	1.34	1.33

Table 5 CIE values *L* a* b* C* h* before and after UV curing the specimens with cyan dye

C	Values before UV curing					Values after UV curing				
	*L**	*a**	*b**	*C**	*h*	*L**	*a**	*b**	*C**	*h*
1 mm	46.2	–31.93	–43.03	53.59	233.43	45.59	–34.41	–38.86	51.9	228.47
2 mm	29.61	–23.01	–46.48	51.86	243.66	29.03	–28.63	–40.69	49.75	234.87
3 mm	19.07	–12.98	–43.04	44.95	253.22	18.59	–18.06	–38.35	42.39	244.78
4 mm	11.66	–6.59	–38.06	38.63	260.18	11.25	–10.72	–34.34	35.97	252.66
5 mm	6.31	–2.53	–32.39	32.49	265.53	6.02	–4.35	–30.15	30.47	261.79

Table 6 CIE values *L* a* b* C* h* before and after UV curing the specimens with magenta dye

M	Values before UV curing					Values after UV curing				
	*L**	*a**	*b**	*C**	*h*	*L**	*a**	*b**	*C**	*h*
1 mm	41.54	68.35	-6.55	68.66	354.53	40.42	66.54	–5.22	66.74	355.52
2 mm	30.15	63.92	16.94	66.12	14.85	29.32	62.85	17.93	65.36	15.92
3 mm	23.41	56.97	30.64	64.68	28.27	22.4	55.83	30.23	63.49	28.44
4 mm	18.7	51.62	30.27	59.84	30.39	17.74	50.59	28.88	58.25	29.72
5 mm	14.91	47.05	25.36	53.45	28.32	14.07	46.08	23.96	51.94	27.47

Table 7 CIE values *L* a* b* C* h* before and after UV curing the specimens with yellow dye

Y	Values before UV curing					Values after UV curing				
	*L**	*a**	*b**	*C**	*h*	*L**	*a**	*b**	*C**	*h*
1 mm	73.39	–5.02	93.68	93.82	93.07	71.71	–3.54	92.3	92.37	92.2
2 mm	64.57	0.74	91.98	91.98	89.54	63.39	2.47	91.24	91.27	88.45
3 mm	57.42	4.69	87.2	87.32	86.92	56.22	6.21	86.31	86.53	85.89
4 mm	50.87	7.76	80.46	80.84	84.49	49.82	9.08	79.56	80.08	83.49
5 mm	45.74	10.28	74.13	74.84	82.11	44.61	11.27	72.68	73.55	81.18

Tabs. 5, 6, and 7 show CIE *L* a* b** and *C* h* values for test specimens in the initial green state and CIE *L* a* b** and *C* h* values after the end of eight UV curing intervals. It can be seen that all test specimens have different colorimetric values depending on the thickness of the pieces. It is also seen

that curing reduces the brightness and chromaticity of all test specimens.

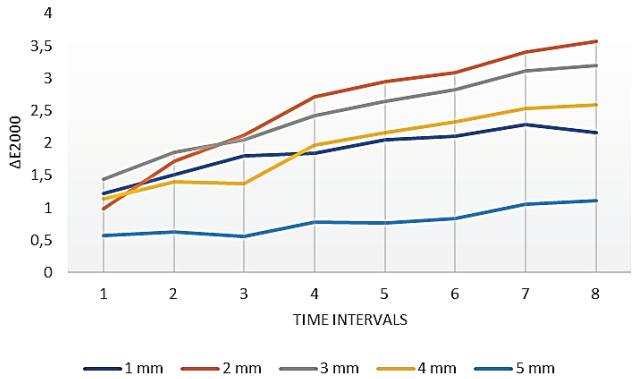

Figure 2 Color change graph ΔE_{00} with respect to UV curing intervals and specimen thickness for cyan dye specimens

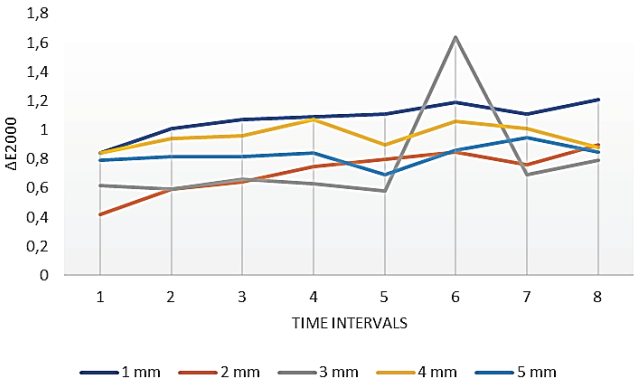

Figure 3 Color change graph ΔE_{00} with respect to UV curing intervals and specimen thickness for magenta dye specimens.

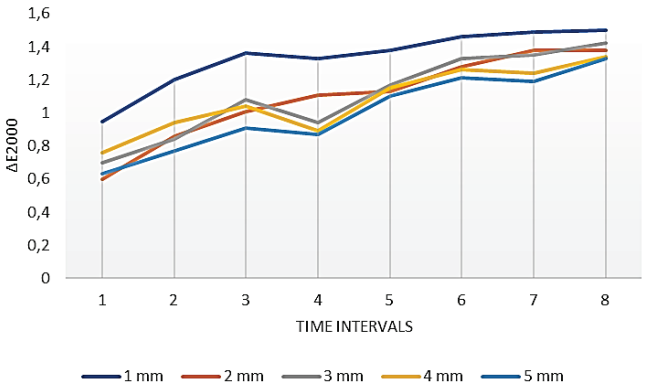

Figure 4 Color change graph ΔE_{00} with respect to UV curing intervals and specimen thickness for yellow dye specimens

Figs. 2, 3 and 4 show the measured total color changes expressed as ΔE_{00} value over eight UV curing intervals of 15 minutes. Fig. 2 shows the changes in the cyan-colored test specimens. The most significant color change is visible in the 2 mm thick test specimen, while a minor color change is seen in the 5 mm thick specimen. Test specimen 5 mm has a slightly noticeable impact of UV curing on color change than other test specimens. Fig. 3 shows the changes of the test specimens with magenta staining. The most considerable color change is visible in the 1 mm thick test specimen, while a minor color change is seen in the 3 mm thick specimen. A peak is visible for the specimen 3 mm during the 6th drying interval, but the change is still insignificant. However, the peak value of ΔE_{00} after the sixth interval is not large enough for the changes to be noticeable to the standard observer. Therefore, the total color change after the last UV curing interval is less than 1, which according to Tab. 1, color change is not noticeable.

Fig. 4 shows the changes in the yellow test specimens. The most significant color change is again shown in the 1 mm thick test specimen, while a minor color change is seen in the 5 mm thick specimen. It is visible that all test samples have similar color changes during UV curing, except the thinnest specimen.

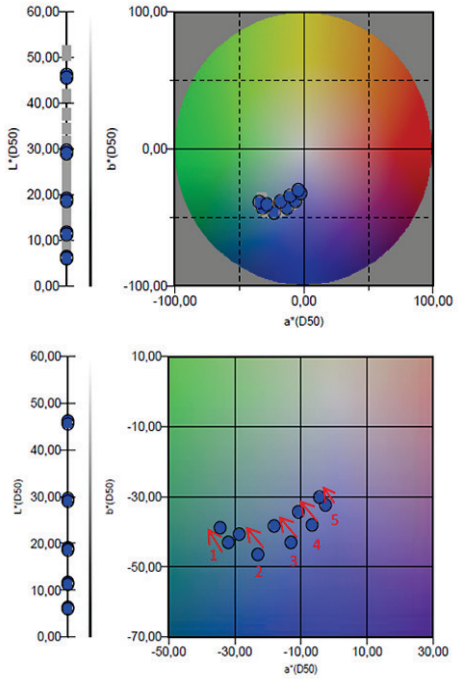

Figure 5 CIELAB colorimetric properties of cyan test specimens

Figs. 5, 6, and 7 show the chromatic values of the test specimens in the CIELAB color system. The initial values and the final values of the color change are shown, in which the direction in which the color changes after a series of curing intervals is visible. Specimens are marked with numbers from 1 to 5, and this number represents the thickness of the test specimens expressed in millimeters.

4 CONCLUSION

To achieve complete photopolymerization, the workflow of stereolithographic additive manufacturing includes the process of curing by UV radiation. During the UV curing process, the extent to which UV radiation affects the colorimetric transmission properties of the test specimens was investigated. Color changes expressed as ΔE_{00} occur in all test specimens and are most pronounced in cyan dye test specimens where ΔE_{00} is greater than 2. Color changes on cyan dye test specimens are visible to the standard observer.

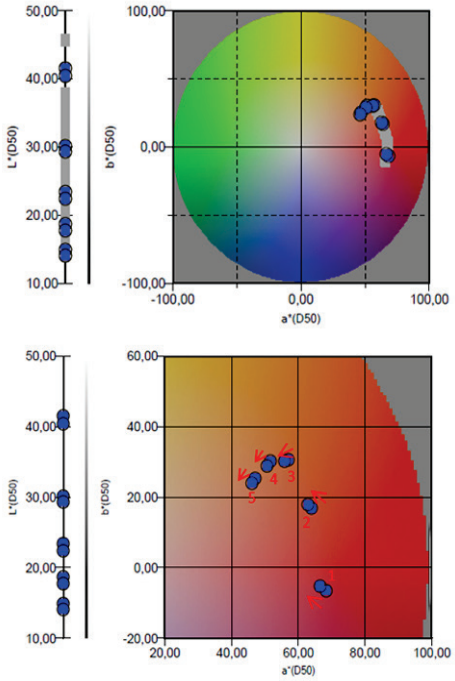

Figure 6 CIELAB colorimetric properties of magenta test specimens

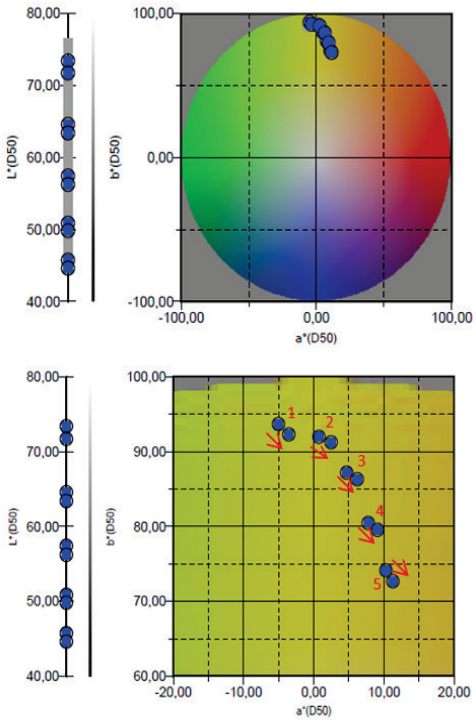

Figure 7 CIELAB colorimetric properties of yellow test specimens

The change in brightness and chromaticity is most salient in the test specimens with the addition of magenta and yellow dye. However, the total color change value of ΔE_{00} is less than 2, so it is not visible to the standard observer. Measurements established a correlation between curing and the direction of color change. All test specimens show that curing reduces the brightness. In test specimens with cyan dye, thinner specimens have a more significant color change. Chromaticity decreases, and the tone changes towards the green area. For test specimens with magenta dye, change direction is of a different shape than for test specimens with cyan and magenta dyes. The direction of change of thinner specimens is different from thicker specimens. In all specimens, the brightness and chromaticity are reduced, and the direction of the tone change cannot be determined precisely due to too small changes. For test plates with yellow dye, the total color changes expressed as ΔE_{00} are uniform for test specimens of all thicknesses. Brightness and chromaticity decrease equally, and the tone changes toward the orange area. The most significant recorded ΔE_{00} color change occurs after the first curing interval. In this paper, the influence of UV curing on the colorimetric properties of test samples is presented. In most cases, the difference in color change shown as a ΔE_{00} value was not higher than 2. Due to such a slight difference, the color change values would not be noticed. However, additional studies are needed, such as the effect of short and extended aging on colorimetric properties. With such tests, the direction of color change, colorimetric change difference could be determined more precisely.

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Exploring the Use of Software Metrics in Saudi Enterprises: A Case Study

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Abstract: This study was aimed to evaluate the application of software metrics used by the software enterprises present in Saudi Arabia. Extensive literature reviews were conducted to comprehend the current body of knowledge on the use of software metrics in Saudi enterprises. These literature review and studies elapsed approximately two decades. Based on the drawbacks, shortcomings, and fallacies of the existing studies a series of interview questionnaires were developed. Interviews were conducted for collection of real-time and actual data. Around seven Saudi enterprises were selected, and each enterprise was considered and regarded as a unit, and the manager of the enterprise was acting as a unit for our case study. 40 managers were interviewed, and their responses were analyzed. Respondents' responses indicate that the software is useful enough to support business processes. In an attempt to assess the complexity of implementing this software, effective feedback was received, suggesting that there is a lack of communication between the developers and managements' intent. Moreover, the findings of this study showed that the organization need to give more attention to quality and productivity management. In addition, the results indicate that when agile development is undertaken through software effectiveness, the enterprise's services are implemented appropriately.

Keywords: Agile Approach; ISO 9000; Saudi Enterprises; Software Metrics, Software Processes

1 INTRODUCTION

Software metrics are the measurement of measurable or numerical properties of software. The studies by Psomas et al. [2] and Fenton and Bieman (2019), stated that Software metrics are an essential part of the software engineering situation. More and more customers are quoting software reports or quality metrics as part of their contractual requirements [38, 39]. Measurement standards include industry standards such as ISO 9000 and industry models such as the Integration of the Functional Maturity Model (CMMI®) of the Institute of Software Engineering (SEI). Enterprises use metrics to understand better, monitor, manage, and forecast software projects, processes, and products. Measuring software metrics can provide engineers with the information they need to make technical decisions and manage them. If metrics are intended to convey useful information, its definition and purpose should be understood by all those involved in the selection, design, implementation, collection, and use of the scale. Sometimes one metrics can become a management problem, overestimated at the expense of other signals, and eventually disrupt behavior [40]. In recent years, examples from many of the agency's user departments have focused too much on the number of services per client. Software metrics are useful: the willingness of customers to purchase several services can be a sign of an enterprise's health. In this case, however, the first is an important issue, and there is no right balance in customer care. In some cases, frontline workers have tried to improve cross-selling, but have harmed the enterprise and customers at the expense of trust and relationship. Moreover, many enterprises were facing issues that which software metrics they should go for in terms of reliability; software quality forecasting is another area where software units can play an important role [41]. Again, some special models on the market can help with this problem, but the debate over their accuracy continues. Whether the customer or developer's point of view needs to control the cost of testing and certification, this need exists [40]. Various technologies are currently available, and this area will become more critical in the future [2]. The software measurements are all related to the measures, and the measurements contain numbers. Use numbers to improve things, improve the software development process, and improve all aspects of managing that process. Software metrics are valid throughout the development lifecycle, from the initial phase (the price should be assessed) to monitoring the reliability of the final product in this area and how the product is continuously being improved over time [5, 42, [43]. According to Aba and Badar [4], the software metric is explained as "Continue to implement the software development process and measurement technology for its products to provide relevant and timely management information and use these methods to improve the process and its products."

Software metrics are essential for several reasons, including measuring software performance, scheduling tasks, measuring productivity, and more [1]. Some measurements reflect only a portion of an enterprise's performance, but no other significant factors. The study by Begosso et al. [3] stated that call centers that can track the average waiting time for customers are great. Still, there may be more important information in calculating the percentage of issues resolved during the first call. Another example is that click revenue analysis is a popular part of "performance marketing". Compared to metrics such as brand value, how marketing costs affect the value of enterprises and revenues that can be directly related to marketing, these figures make more sense. Although they are more challenging to measure than to click, these measurements are precious [3]. Measuring sales performance can be challenging. It is easy to inflate the income of each sales representative (joint action) with marketing costs and discounts, but the problem is that not all income is of equal value. Like most enterprises, enterprises that sell a variety of ROI products must recognize that some of the revenue is more profitable. At the same time, an enterprise may want to encourage sales from new regions or customers who are more challenging to get than upgrading

existing accounts, but love is helpful. Software enterprises share all revenues equally for several years when calculating the price of sales quotas. Thus, there is no difference between the software's income (high margin) and the professional service that the enterprise provides for software management (very low or even negative margins). Finally, the enterprise solved the problem by carefully assessing the margin of each product and resorting to quotas limited to these numbers. Today, more sophisticated enterprises use digital escape to test their metrics [40]. For example, you can use your email traffic and calendar analysis to determine how often your sales channel interacts with critical customers. In the weeks leading up to the end of the quarter, if this use does not show significant interaction with customers, it is best to reduce the likelihood of sales to that customer carefully. Many business organizations and measures have taken the opportunity to introduce improved hygiene measurements, which may change their performance in the future. This includes retailers moving from economic valuation to business value assessment; sales representatives are replacing general sales efficiency standards, converting leading division valuation and R&D in general from business monitoring to recycling and sustainability calculations [3].

The software measurements involve the use of technicians by engineers or programmers to identify faulty components as long as they encode and manage the project to detect as early as possible that it has a lifespan of half a year delay instead of days [6]. There are many ways to use software metrics, some of which are almost professional on their own. There are many ways to share the field of software measurement [7]. The most advanced area of software measurement is cost and size estimation technology [37] [44]. There are many custom software packages on the market that provide estimates of the size of the software system, the cost of the development system, and the duration of the development or improvement project. This software is based on planning models, the best known of which the construction cost model is developed by Barry Boehm, which was then updated based on the experience of many enterprises and individuals [3, 34]. Extensive research has been conducted in this area, and research is continuing in the United States, Europe and elsewhere. Most are funded by the United States Department of Defense, governments around the world, and the European Economic Community. The result of this study is one thing, which means that organizations cannot rely solely on the use of their software packages [8]. Measuring software development projects through measurement has received a lot of attention in Europe and the United States. This has become more relevant for the increase in fixed price agreements and the use of fines for software development customers, not to mention outsourcing, facility management or "cooperation" agreements [9]. The enterprises should use metrics to decide where their changes should go. Early measurement of soft factors can often provide a useful overview of how a process works and provide business benefits by improving performance in key areas such as time to market [10, 13, 32, 43].

This study helps us in examining the agile method of in the Saudi enterprises that is the framework to address the adaptive complication issues for the product delivery with the high possible value. The result of this article is focusing on the software metrics which are not meaningful, or imperfect can have the significant impact on the overall performance and the leading management of the enterprises' situated in the Saudi. Due to the poor performance of the software metrics leading the management of Saudi enterprises were making the poor decisions which hurt the overall performance of the enterprise.

2 LITERATURE REVIEW

2.1 Software Processes Used by Saudi Arabian Companies

Saudi Arabian enterprises need software methods that are offered quickly. In most cases, employees of a Saudi enterprise expect that agile methods are more useful and relevant than forecasting methods. Although engineering methods have been applied, special instructions must be followed. It has been found that the use of forecasting methods does not accept possible changes in roadmap modification [11]. As an expert in business analysis, the availability of agar software solutions is becoming increasingly popular. Also, it should not further complicate software operations compared to forecasting solutions. As there is evidence of more excellent resistance to consent whenever they try to make new changes, the ideal approach is to establish a collaborative and agile approach with strong predictive power [32]. Agile methods can make significant changes and achieve satisfactory results [12]. To support an eternal plan, they can support the changes required to achieve long-term success in any business. Changes are welcome with agile methods. Managing the Saudi environment is a human rather than a process-based process, and enterprises prefer to use agile approaches to implement agile methods effectively. Using agile methods, develop short-term adaptive plans [24, 45].

Software measurement is the measurement of measurable or numerical properties of software [46]. Software metrics are essential for several reasons, including measuring software performance, scheduling tasks, measuring productivity, and many other purposes [14]. There are many interconnected invoices in the process of software development. Software indicators relate to four management functions: planning, organizing, managing, or improving.

2.2 Impact of Software Metrics on Saudi Arabian Enterprises

Several studies stated that if the Saudi enterprises implement software metrics, so it helps the enterprises in monitoring and managing through qualitative measurements is essential for the success of any project [4, 14, 16]. Relevant metrics explain how measures can be applied to improve processing of Saudi enterprises by providing objective methods for characterizing processes and assessing the impact of process changes [15, 35, 38]. Saudi enterprises can also be used as a diagnostic tool to help the quality control team identify the cause of problems or fail to achieve

pre-defined objectives. The same is true of the Ministry of Education's GRP project [16].

2.3 Improve Transport Performance

The decision to go to the next level depends mainly on the availability of all current/previous period deliveries. As the implementation of an ERP system on Saudi enterprises requires a lot of investment, it can lead to considerable time costs, additional investments, and business losses even if the deadlines are not met. To avoid such costs for customers, Saudi enterprises should implement software metrics which helps in identifying effective measures and collect relevant data to ensure that all deadlines are completed before the deadline and, where necessary, implement software metrics [18, 29]. Achieving satisfactory delivery results is the most important challenge for ERP implementation and development of Saudi enterprises. When implementing ERP, the planning method (waterfall) is usually followed, where each step gives some achievements [17, 28].

2.4 Improve the Quality of Processes

Improving data quality is essentially a series of steps to achieve quality objectives by identifying, analyzing, and improving existing processes [38]. This requires a continuous review of the implementation of current strategies and the necessary corrections in case of problems [48]. Saudi enterprises can achieve this with appropriate metrics that can clearly show whether the process is in line with pre-defined objectives and meets customer expectations by providing quality ERP systems. Metrics can provide an overview of all aspects of the process and identify areas for improvement for the Saudi enterprises. Therefore, there must be appropriate evidence to manage quality control throughout the lifecycle of ERP implementation [19].

2.5 Improve Product Quality

Product quality is generally measured according to pre-defined specifications, standards, and expectations [38]. Deviations from these criteria, standards and expectations can lead to product degradation, such as loss of functionality, poor reliability, and reduced deliveries. Improving the quality of the ERP system is essential for Saudi Arabian enterprises, as it is the basis of all future enterprises. The poor quality of an enterprise's disruption can have severe consequences for the organization [39]. Also, operators need to ensure the high quality of the ERP system on offer, as failure to achieve this goal may lead to its exclusion from ERP consulting in a competitive environment [20].

2.6 Improving Productivity (Efficiency)

Appropriate resources can be used to improve the implementation and development efficiency of ERP in the Saudi Arabian enterprises. Resources must be used in a way that lacks resources and does not create competition for the enterprises working in Saudi Arabia. The productivity meter provides an overview of the reasons for high and low productivity. Poor productivity can be due to inexperienced teams, inability to use the right resources, poor management control over team members, and early evaluation of efforts. Higher productivity can also be misleading, for example, because the product quality objective was not achieved at the beginning of the project and was not adequately implemented [21, 41, 47]. Therefore, the quality assurance team of Saudi Arabian enterprises needs to identify and collect appropriate productivity measurements and investigate the reasons to ensure that the implementation of ERP can achieve the set goals. Sufficient productivity and that there are no false-positive results that would undermine the objectives of ERP implementation [22].

3 DATA ANALYSIS

This section of the study explains, and analyses of the data gathered through qualitative methods using interviews conducting with the top management and the managers of the Saudi companies that are using and working on the software metrics [23]. The results of the study are further divided into different parts to formulate the themes. Moreover, this section of the article represents the correct image of the companies that are involved in the study while collecting the data and conducting an interview with the top management and the managers of the selected companies [24].

3.1 Software Process Implemented by the Saudi Companies

The results of the interview conducted by the manager of Saudi company showed that the companies in Saudi Arabia needed to adopt the mechanism of the software like this is provided by the Methods of Agile [25]. The managers of the Saudi company generally expect the Agile techniques are more effective and useful than the other predictive methods. Moreover, the different methods of engineering are mainly implemented effectively so fulfil the needs of the individual roadmaps to track the records. The results of the interviews also showed that the when the software metrics and predictive approach have been applied the changes are not effectively adopted well when making the change with the help of roadmap [26].

Changes in management policy reviews are positive and related to changes in management techniques. It is also found that as management technology changes, all operations continue to run smoothly [27, 33]. Some have commented negatively on the ineffectiveness of the policy, mainly due to staff, lack of communication and poor policy implementation. Managers and managers respond positively to results and procedures, and managers should interact with users and employees [28].

End-user feedback was positive, and lessons learned. The level of understanding of the system is high, and the efficiency of implementation is high. However, there are still some complaints, but they are optimistic about the choice of software. The comments on the basic structure are favorable due to problems in the work of the technology group. For all challenges, material costs are very profitable [29]. Some comments on this basic structure are negative because the

system is complex, and the server-to-server relationship is unsatisfactory. However, the organizational culture of the organization has a positive effect. All problems were resolved on time with negative consequences, as the issues were not resolved quickly and the IT team also resolved IT issues efficiently [30].

Respondents said they did not have enough cost experience and decided to take advantage of profitability. However, the quality of staff training is high and positive, as the study materials and documents are good [31]. The staff handbook and the training process are very useful, and the people responsible for the training are well organized. The shortcomings of the training have not received enough attention from the management [32].

3.2 Identify the Software Processes Used by Saudi Arabian Companies

For a Saudi company, the value of the people adds unique qualities to the project, not sensible organization and management. When efficient software is used to develop agile development, the company's services are implemented correctly. There are many possibilities for implementing engineering services [33]. Scrum, Extreme Programming and Lean Development are the methods commonly used in the proposed methodological approach. Agile methods are created in the form of a manifesto, which is considered a universal element. They can build software reliability to prove their pros and cons. When scrum has implemented various programming software technologies for enterprise management services, it has proven to be very effective.

Saudi Arabian companies need to develop management-oriented services. Scrum is effective in software programming and generally focuses on management performance. The software must be developed through scrum with efficient management-based performance [26]. Thanks to the careful monitoring, inspection and control of scrum's software technology, these management tasks can be implemented effectively. Saudi Arabian companies need to hold regular meetings to manage scrum's software development most efficiently. Engineering practice in Saudi Arabian companies has proven to be the most suitable for scrum's development software [34]. Some have found that employees work best in a controlled environment through on-site meetings. The success of a project is rarely emphasized because the effectiveness of the Scrum method can be used in project management. Extreme programming practices in inter-engineering development create software with scrum's methodology that gets the best control. Saudi Arabian companies need to adopt significant results and implement them where possible to promote effective engineering management [35].

4 CONCLUSION

The result of this article showed that the use of software metrics for quantitative software review is also a recognized area. Extensive research has been done, and some organizations have used this technology successfully. This software measurement area is also used to monitor current software products that need improvement. Reasons for choosing existing software for this area are accessibility, low prices and other value-added services, such as the ability to create applications and projects between departments. Agile scrum was chosen as analysis or business management software due to its ability to compare project schedules. Respondents' responses indicate that the software is useful enough to support business processes. In an attempt to assess the complexity of implementing this software, positive feedback was received, suggesting that such issues are not being addressed. Extensive production and processing capacity and availability are the most interesting factors in assessing the benefits of the software. Analysis of the advantages and disadvantages of using software that needs to restore the integrity of the management team.

This study is helping in understanding the root cause that lies in the company related to the historical metrics, which mainly measures what is effectively possible to tract when these measures were developed not what can or should be measure. This study also contribute to the management and the operations of the Saudi enterprises so that the management can be able to use the results of this study to underline the types of metrics can be suitable for the company. This study also helps the companies in gaining the competitive edge among their competitors in the Saudi Market.

Finally, this study helps in understanding the most common uses of software metrics: providing administrative information. This includes information on the productivity, quality and efficiency of processes. It is essential to understand that this is an ongoing activity. They can use a snapshot of the current situation, but when they see progress in the data, the most valuable information is displayed [36]. Does productivity or quality improve or decrease over time? If so, why is that? What can leaders do to make things better? Communicating management information is both an art and a science. Statistical analysis is one of them, but it must be presented at the right time and for the right reason in a way that managers can use [37].

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Faculty Members' Attitudes towards the Objectives of Cognitive Behaviour: A Survey Study

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Abstract: Knowledge management is one of the issues that closely touches the core of organizations, and its application greatly contributes to improving the performance of academic institutions and achieving a competitive advantage. In addition, it is also so important to know the cognitive behavior, as human behavior is affected in general by environmental conditions and variables, and the needs differ according to different age stages. Thus, the behavior knowledge helps to deal accurately with others and choose the appropriate approaches to do so. Added to that, the study of behavior must not be limited to the individual behavior, but it should necessarily include group behavior as well. Accordingly, and standing upon the previous premises, this study seeks to identify the cognitive behavior, as we will define the concept of the cognitive behavior, its most important objectives, its characteristics, the factors that affect it, its forms, in addition to knowing the trends of faculty members in the Department of Information Science at King University Abdul Aziz in Jeddah (Female Section) towards the cognitive behavior goals. The study relied on the descriptive survey method, and to achieve the objectives of the study, a questionnaire was designed that includes two parts where the first part deals with general data (personal), and the second part stresses questions related to the objectives of cognitive behavior. The researcher used the Likert quadruple scale (strongly agree, agree, disagree, strongly disagree). This study reached a set of results, the most prominent of which were that it became clear through the study the extent of the cognitive awareness possessed by the sample members. In fact, most of the results indicated the extent to which the sample members realize the importance of practicing cognitive behavior and achieving its goals. The current study reached a set of recommendations, including the necessity of advance planning and direct use of the latent energies within the faculty members (study community), and encouraging them to manage knowledge and adhere to its behavior through providing the appropriate environment for that.

Key words: Behavior; Cognitive Behavior; Knowledge; Knowledge Sharing Behavior; Objectives of Cognitive Behavior

1 INTRODUCTION

Psychology has gone in depth in the study of human psychology and its aspects until it reached the clear foundations of its formation, which are personality, education, and behavior. The study of behavior had the greatest share of research and follow-up from psychologists because it represents the visible and most direct part of the human being, which largely indicates the nature of his/her formation. The concept of behavior in psychology includes both the general definition of human behavior and its different types. In fact, the behavior represents any action or reaction that comes from a human being directly or indirectly, intended or unintended or mechanical occurring in the subconscious, whether it is in the form of an action, a speech or a body language that appears on the human being [1]. The determinants of behavior include the complex effects that occur before the behavior itself occurs. They include physiological, emotional, and cognitive variables as well as the effects that follow the behavior represented in external or internal forms of reinforcement, consolidation or punishment [2]. On the other hand, the growth of the phenomenon of globalization and the spread of modern means of communication have caused knowledge to become one of the precious wealth that must be possessed in all life areas as it has become an essential factor for measuring the strength of society and the level of its progress. As a result, knowledge has become the human intellectual capital in organizations and has even become a strategic source that contributes to their success or failure. Therefore, organizations interest speed in knowledge has accelerated and they developed the so-called knowledge management as a management method for the optimal use of the knowledge resource to achieve effectiveness, continuity and raise the quality of its outputs. The concept of knowledge management refers to the various processes and activities related to the discovery of new knowledge, the acquisition of current knowledge, the sharing of knowledge with others, the application of the knowledge obtained, and the systems, mechanisms, technology and infrastructure required by those processes [3]. Universities are one of these institutions that have adopted the principle of knowledge management and investment to develop the performance of its employees, which contributes to raising the university's performance and building a sustainable competitive advantage.

The current study tries to shed light on cognitive behavior, and to know the attitudes of faculty members in the Department of Information Science at King Abdulaziz University in Jeddah (female section) towards the goals of cognitive behavior.

2 STUDY METHODOLOGY AND PROCEDURES

The study relied on the descriptive survey method, as the researcher believes it is appropriate for this study. It helps in providing information and facts about the reality of the current study. To achieve the objectives of the study, a questionnaire has been designed that includes two sections: the first section includes general data (personal), and the second section consists of questions related to the objectives of cognitive Behavior. The latter included sixteen objectives that were quoted from the study of David De, 1997 [4]. The researcher used the Likert quadruple scale (strongly agree, agree, disagree, strongly disagree). The data were analyzed and processed in addition to determining their frequency and percentages.

3 STUDY COMMUNITY AND SAMPLE

The current study aims at identifying the attitudes of faculty members in the Department of Information Science at King Abdulaziz University in Jeddah (female section)

towards the goals of cognitive behavior. The total number of the study community was (25) members of the faculty members (the subject of the study), and the questionnaire was distributed to the total community. The number of the retrieved questionnaires was (18) questionnaires at a rate of 72%, as shown in Tab. 1. Some of the reasons for not completing the questionnaires is that a number of faculty members were in the scholarship stage (internal and external) to complete their doctoral studies.

Table 1 The study community and sample

Job title	Total number	Respondents' number	Percentage (%)
Teaching Assistant	None	-	-
Lecturer	8	4	50
Assistant Professor	9	8	89
Associate professor	4	2	50
Professor	4	4	100
Total sum	25	18	72

4 THE CONCEPT OF COGNITIVE BEHAVIOR

The term cognitive behavior consists of the two words (behavior - knowledge), so we will first begin by defining these two terms, and then define the cognitive behavior:

- **Definition of behavior:** It is the activity carried out by the organism because of its relationship to certain environmental conditions, as it tries to continuously develop and modify these conditions until it achieves survival and satisfy its needs. Indeed, it is a series of choices among a set of possible responses [5].
- **Definition of knowledge:** Psychiatrists believe that knowledge is a feature that distinguishes the mental state of a person, and it governs his performance of complex activities emanating from mental content based on the ability to think and remember. This definition includes possession of facts mixed with the feelings and emotions of a person and groups, which affects the extent of his awareness and perception of things, as well as the extent of his familiarity with the environment in which he lives [6].
- **The Concept of Cognitive Behavior:** The cognitive Behavior includes all actions or reactions a person performs towards new or old knowledge as a way of sharing, learning or teaching.

The cognitive behavior is defined through two theories [7]:

- **First: The action Theory:** The individual is driven by the environment, which depends heavily on temperaments and social norms.
- **Second: The Behavioral Planning Theory:** It shows behavioral control, which is an important factor in the behavioral analysis of individuals.

Moreover, the cognitive behavior is also defined as a broad concept that includes human-related information activities such as seeking, using, and sharing knowledge [8].

4.1 The Cognitive Behavior Goals

In his scientific paper in 1997, David De mentioned many goals of the cognitive behavior as follows [4]:

1) Share your knowledge with others.
2) Help someone learn something.
3) Have an open dialogue on specific issues.
4) Discuss and explore assumptions.
5) Talk to all minds with mutual respect.
6) Find out if the work has been done before, and use what was done instead of creating something new.
7) Communicate with people in the same field of knowledge, and see if they do things that we can use.
8) Take some time to think about what happened and discuss it with co-workers or friends.
9) Find the best people to help with something.
10) Try to combine ideas from different fields.
11) Recognize the intellectual efforts of others towards a topic.
12) Form teams to collaborate on a specific project.
13) Desire to contribute in a certain glory.
14) Be trustworthy.
15) Enhance confidence in the person and in his work.
16) Verify the existence of reliable sources of information.

4.2 Cognitive Behavior Characteristics

In terms of characteristics, the same features that are applied to behavior in general are also applied to cognitive behavior which are [9]:

- It is a causative behavior: the behavior does not start except from a reason or for a reason.
- It is a purposeful behavior: meaning that it seeks to achieve a goal or satisfy a person's need.
- It is a diverse behavior: that is, it appears in multiple forms so that it can adapt to the situations facing it.
- It is a flexible behavior: it can be developed, modified and added according to situations and reactions.
- It is a motivated behavior: that is, it does not come from emptiness, as many factors stand behind it.
- Behavior is a continuous process: every behavior is a part or link of a long integrated chain the links of which are constantly merging.
- The cognitive sharing behavior is an individual act carried out by individuals within the community.

4.3 Factors Affecting Cognitive Behavior

When studying cognitive behaviors, we find that they are related to the behavior of the individual, which is affected by several basic factors as follows [10]:

1) **Inheritance:** Parents pass it on to their children through the genes, so the individual is born with those traits he has since his birth, including positive and negative ones.
2) **Environment:** the environment to which he belongs affects the behavior of the individual. The environment leaves an impact on the behavior of the individual from several aspects. We find that the city-originated individual is characterized by a behavior that differs

from the desert or the countryside originated individuals. We also find that the eastern environment differs from the western environment, which has an impact on the behavior of the individual belonging to it.

3) **Learning:** An individual's behavior is affected by what he acquires and learns of knowledge, which affects the individual's behavior positively and negatively. The higher the education level of the individual, the more positively affected his behavior.

4.4 Forms of Cognitive Behavior

The cognitive behavior has many forms mentioned by David Long in the introduction of a scientific paper published in 1997, [4]:

Create, use and share knowledge. Thus, we can say here that the forms of cognitive behavior go in the same line with the processes of knowledge management, starting with diagnosis, passing through generation, then storage, sharing and finally application.

The exchange of knowledge is subject to a number of concepts, values and theories, including [11]:

- Theories based on economic cooperation and interaction, called the Economic Erection Theory (EET).
- The Social exchange theory (SET), in which social relations have an important role in their formation.

Based on the theory of economic exchange (EET) and the theory of social exchange (SET), the following factors can be determined for the exchange of knowledge between members of society, after taking into account that the exchange of "sharing" knowledge is one of the most important knowledge behaviors [12]:

1) **Rewards:** Rewards are among the factors affecting the behavior of knowledge, specifically the behavior of knowledge exchange. Rewards can help encourage knowledge sharing but not in the long run as they encourage knowledge sharing for a specific time.
2) **Organizational culture:** Organizational culture is one of the most important factors affecting the exchange of knowledge due to the need of knowledge exchange for a conscious organizational culture that cannot be manipulated so that members of society can trust it, which encourages them to share knowledge within that organization.
3) **Link to work tasks:** If the members of the organization in their work tasks do not find enough time to communicate with each other, then this is an influential factor among the factors affecting the cognitive behavior, specifically the sharing of knowledge between individuals, the organization, and then the community.
4) **Modern Technology:** Modern technology is one of the factors that has a positive impact on the cognitive behavior, as it assists the organization members and the community in their communicating with each other, which facilitates the exchange of knowledge between the members of the organization and then the community.
5) **The behavioral aspect of the person:** The behavioral aspect of individuals and society, and specifically what characterizes each individual's behavioral aspects, whether inherited or acquired, is an important factor affecting the cognitive behavior. Indeed, there are those who are characterized by non-positive behavioral characteristics in their interaction with society members, such as selfishness or love of possession, and we find that they are unable to exchange knowledge with others.

5 DATA DESCRIPTION AND ANALYSIS

In this axis, the data collected via the questionnaire including the answers of the sample will be presented, described and analyzed. It also contains the statistical treatment of the data using frequency tables and percentages for the following sections:

1) The first section: Personal information (public data).
2) The second section: The goals of cognitive behavior.

5.1 The First Section: Personal Information (Public Data)

This section includes an analysis of the demographic (personal) data of the study sample, according to the following elements: Academic qualification, academic degree, and years of service (experience), as follows:

5.2 Academic Qualification

Tab. 2 shows the academic qualifications of the study sample members from the faculty members in the Department of Information Science at King Abdulaziz University.

Table 2 Distribution of the sample members by academic qualifications

Qualification	Frequency	Percentage (%)
Bachelor	0	0
M.A.	4	22
PhD	14	78
Total sum	18	100

From the previous table, we notice that the number of respondents who got a doctorate degree topped by 78%, while the number of individuals who got a master's degree was four individuals with a rate of 22%. It is also noted that there is no B.A holder among the sample, which shows the high academic level of the sample members.

5.3 Job Title

The job titles occupied by the sample members differ as shown in Tab. 3.

Table 3 Distribution of the sample members according to job titles

Job title	Frequency	Percentage (%)
Teaching Assistant	0	0
Lecturer	4	22
Assistant Professor	8	45
Associate Professor	2	11
Professor	4	22
Total sum	18	100

It is clear from the previous table that most of the sample members occupy the rank of assistant professor, and their number reached 8 individuals, representing 45%. This category, from the researcher's point of view, is one of the most important groups that needs practicing cognitive behavior in conducting studies and scientific research. In the second place, comes both the individuals holding the rank of lecturer and the individuals holding the rank of professor, four individuals each, representing 22% of each rank. In the last rank comes the individuals who hold the rank of associate professor, and their number is two, representing 11%. It is noticed that none of the sample members has the rank of teaching assistant, and this is related to the data of the academic qualification that was analyzed in the previous part, as it indicated that there is no member of the sample holding a bachelor's degree. Thus, as a logical result, there will be no one occupying the rank of teaching assistant.

5.4 Years of Service (Experience)

The years of service in the Department of Information Science represent the experiences and skills acquired by the sample members over the work years in the field of teaching and scientific research in the department. The owners of these experiences and skills can be a benefit in practicing cognitive behavior effectively. Tab. 4 shows the years of service for the sample members, which are as follows:

Table 4 Distribution of sample members according to years of service

Years of Service (Experience)	Frequency	Percentage (%)
1-5 years	0	0
5-10 years	4	22
10-15 years	6	33
15-20 years	3	17
More than 20 years	5	28
Total sum	18	100

Table 5 The results of the questionnaire related to the objectives of cognitive behavior

Objective	The cognitive behaviour goals	Approval degree								Result
		Strongly agree		Agree		Disagree		Strongly disagree		
		Frequency	Percentage, %	Frequency	Percentage, %	Frequency	Percentage, %	Frequency	Percentage, %	
1	Share your knowledge with others.	17	95	1	5	-	-	-	-	Strongly agree
2	Helping someone learn something.	16	89	2	11	-	-	-	-	Strongly agree
3	Conduct an open discussion on specific issue.	12	67	6	33	-	-	-	-	Strongly agree
4	Discuss and explore assumption.	13	72	5	28	-	-	-	-	Strongly agree
5	Talk to all minds with mutual respect.	18	100	-	-	-	-	-	-	Strongly agree
6	Find out if the work has been done before, and use what was done instead of creating something new.	7	39	3	17	8	44	-	-	Strongly agree
7	Communicate with people in the same field of knowledge, and see if they do things that we could use.	11	61	7	39	-	-	-	-	Strongly agree
8	Take some time to think about what happened and discuss this with co-workers or friends.	11	61	7	39	-	-	-	-	Strongly agree
9	Find the best people who can help with something.	12	67	6	33	-	-	-	-	Strongly agree
10	Try to combine ideas from different fields.	14	78	4	22	-	-	-	-	Strongly agree
11	Recognize the intellectual effort others make towards an issue.	15	83	3	17	-	-	-	-	Strongly agree
12	Form teams to collaborate on a specific project as unified work teams.	15	83	3	17	-	-	-	-	Strongly agree
13	Willingness and desire to participate in a certain glory.	14	78	5	17	1	5	-	-	Strongly agree
14	Being trustworthy.	13	72	5	28	-	-	-	-	Strongly agree
15	Enhancing confidence in the person and in his work.	17	95	1	5	-	-	-	-	Strongly agree
16	Check the existence of reliable source of information.	17	95	1	5	-	-	-	-	Strongly agree

The results of the previous table indicate that the largest proportion of the sample members' fall within the category with experience between 10-15 years, and the number of its members is six, at a rate of 33%. In the second place comes the individuals who have served for more than 20 years, and their number is five individuals at a rate of 28% which is a good indicator because the more years of service for the sample members, the more this helps to provide a balance of skills and experiences that help in practicing cognitive behavior. Then comes in the third place the individuals who have served between 5-10 years and their number is four individuals, at a rate of 22%. In the fourth place comes the individuals who have served between 15-20 years and their number is three individuals at a rate of 17%. It is noted that there are no individuals of the sample members whose number of years of service is less than five years, and this is an important indicator, as the increase in the number of years of experience means an increase in experience and in the awareness of the importance of practicing cognitive behavior.

- **The second section: The goals of cognitive behavior:** In this section, the results of data analysis related to the 16 cognitive behavior goals that were mentioned previously will be presented. Tab. 5 reflects the way the sample members think in terms of the degree of approval and the degree of disapproval towards these goals. Each objective will be discussed separately and described quantitatively and qualitatively.

Objective 1: Share your knowledge with others.

Table 6 First Objective: Share knowledge with others

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	17	95
Agree	1	5

Through the previous table, we find that everyone supported the first goal, which is to share knowledge with others, and the majority opted for the phrase "strongly agree". Their number was seventeen at a rate of 95%. One respondent chose the phrase "agree" at a rate of 5%. This is a positive indicator, as agreement reflects the nature of the academic community, which realizes the importance of practicing cognitive behavior and the need to share knowledge with others, which is thanks to the influence of the organizational culture factor possessed by the academic community to which the sample members belong.

Objective 2: Helping someone learn something.

Table 7 The second objective: Helping others learn

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	16	89
Agree	2	11

Through the previous Tab. 7, we find that everyone showed their agreement with the second goal, which is the initiative to help others in learning, as 16 respondents opted for strong agreement with a percentage of 89%, and two of them chose the phrase "agree" with a percentage of 11%. This result is supportive and complementary to the result of the first goal, where we find that whoever has the ability to share knowledge with others will naturally be willing to help teach others what they need.

Objective 3: Conducting an open discussion on specific issues.

Tab. 8 shows the agreement of all study sample members to conduct an open discussion to deal with certain issues with others. Twelve of the sample members opted for the phrase "strongly agree" at a rate of 67%. Six of the sample members preferred the phrase "agree" with a percentage of 33%. This reflects the democratic thinking and flexibility of the sample members in the discussion and exchange of attitudes with other parties in the issues in which there is a lot of controversy. In fact, this helps in the exchange of experiences and knowledge, especially the tacit knowledge between the interlocutors, and this greatly contributes to supporting the practice of cognitive behavior.

Table 8 The third objective: Conduct an open discussion

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	12	67
Agree	6	33

Objective 4: Discussing and Exploring Assumptions.

Table 9 The fourth Objective: Discuss and explore assumptions

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	13	72
Agree	5	28

Tab. 9 shows everyone's agreement and support for discussing, exploring and verifying assumptions. Thirteen respondents chose the phrase "strongly agree" at a rate of 72%, and five respondents preferred the phrase "agree" at a rate of 28%. This is a logical result as it is related to the nature of the academic sample community, which includes elite researchers and explorers who seek, through their scientific research, exploring and testing scientific hypotheses and verify their validity to prove or disprove them through the results they reach in their research studies.

Objective 5: Talk to all minds with mutual respect.

Table 10 The fifth objective: Talk to others with mutual respect

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	18	100

The fifth objective of the cognitive behavior ranked first in strong approval by all 18 members of the sample, without exception, with a percentage of 100%, as all sample members are keen on the commitment to respect others in conversations and discussions. This refers to the professional ethics that characterize the sample members. Indeed, this feature is one of the important characteristics that must mark the cognitive behavior, as without a commitment to respect others in conversations, the desired goal of discussion and dialogue is not achieved, especially in discussing scientific issues within the academic community.

Objective 6: Find out if this work has been done before, and use what was done instead of creating something new.

Table 11 The sixth objective: Start work by building on what others have done

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	7	39
Agree	3	17
Disagree	8	44

This goal is considered as the first goal about which the attitudes of the sample members conflicted ranging between approval and disapproval. The highest percentage was 44%, with eight sample members showing their disagreement with this goal, which is to ensure and know that a certain work has been done and benefit from it in a new work. However, seven members showed their strong agreement with a percentage of 39%. In addition, three sample members opted for the phrase "agree" for this goal by 17%. This result reflects the keenness of some members of the sample to build new knowledge and business from the fruits of their own ideas, instead of depending on others' work, in order to achieve and fulfill their love of excellence and creativity.

Objective 7: Communicate with people in the same field of knowledge, and see if they do things that we can use.

Table 12 The seventh objective: Communication with others in the same field of knowledge

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	11	61
Agree	7	39

Tab. 12 shows the consent of all sample members to communicate with specialists in the same field of knowledge to find out the extent of benefit from their ideas or scientific research. The majority of eleven members showed their strong approval for this goal by 61%. Seven members agreed representing 39%. The researcher believes that the reason for the approval of all members of the sample for this goal is due to the keenness of the academic community to achieve knowledge integration in their ideas in order to support and activate them by benefiting from the knowledge of others and sharing knowledge with them.

Objective 8: Take some time to think about what happened and discuss it with co-workers or friends.

Table 13 The eighth Objective: Discussing with others about certain issues

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	11	61
Agree	7	39

This result is similar to the results of the previous goal in the choices and percentages in the answers of the sample members, as the previous Tab. 13 indicated that eleven of the sample members showed their strong agreement with this goal at a rate of 61%, seven members agreed with the goal representing 39%. We find that all members of the sample are keen to think about what happened and discuss it with colleagues, and this indicates their commitment to achieve credibility in their work and in their scientific research. We notice that there is a similarity between the results of this objective and the results of the previous one in terms of choices, frequency and percentages.

Objective 9: Find the best people who can help with something.

Table 14 The ninth objective: search for the best people to get help

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	12	67
Agree	6	33

Tab. 14 shows that twelve respondents expressed their strong agreement in searching for the best people to provide the required assistance with a percentage of 67%, while six sample members chose the phrase "agree" at a rate of 33%. The agreement of all respondents with this goal indicates the interest of the sample members in communicating with the best people to benefit from them and get their assistance. We notice that there is a similarity between the results of this goal and the results of the third goal in terms of choices, frequency and percentages.

Objective 10: Attempting to combine ideas from different fields.

Table 15 The tenth objective: Combining ideas from different fields

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	14	78
Agree	4	22

In the response of the study sample members about their attempt to combine ideas from different fields, everyone expressed their agreement towards this goal, as fourteen respondents showed their strong agreement with a percentage of 78% and four members expressed their approval, representing 22%. This objective is consistent with the seventh objective, which is (Communicating with people in the same cognitive field, and searching whether they do things that we can use). Both seek to achieve cognitive integration of ideas and knowledge, as we find that the seventh goal aims at achieving knowledge integration from within the field or specialization, while the tenth goal aims at achieving knowledge integration with other fields outside the specialization or the field of knowledge to which the individual belongs.

Objective 11: Recognize the intellectual effort others make towards an issue.

Table 16 The eleventh objective: Recognition of the intellectual effort of others

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	15	83
Agree	3	17

All members of the sample expressed their agreement about recognizing others' intellectual efforts. Fifteen respondents showed their strong agreement, representing 83%, while three members expressed their approval with a rate of 17%. We find that everyone agreed with recognizing the intellectual efforts of others, which proves the ethics hold by the sample members, as a matter of commitment to scientific honesty in documenting ideas to their actual owners.

Objective 12: Forming teams to cooperate in a specific project as unified work teams.

Table 17 The twelfth objective: Forming cooperative teams

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	15	83
Agree	3	17

All members of the study sample showed their consent to forming unified cooperative teams to work on a particular project, where fifteen respondents chose the phrase "strongly agree" with a rate of 83%, and three members opted for the phrase "agree" representing 17%. This reflects the cooperation spirit of the sample members, which is one of the important requirements in practicing cognitive behavior and sharing knowledge with others. We notice that there is a

similarity between the results of this goal and the results of the previous one in terms of choices, frequency and percentages.

Objective 13: Willingness and desire to participate in a certain glory.

Table 18 The thirteenth objective: Participation in a certain glory

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	14	78
Agree	3	17
Disagree	1	5

The sample members' opinions varied about the thirteenth goal, which is the willingness and desire to participate in a certain glory, as we find that the majority expressed their strong agreement with this goal by fourteen respondents, at a rate of 78%. Three members showed their approval, at a rate of 17%, while we find that there is one respondent disagreed with this goal at a rate of 5%. Despite the opposition of one person to this goal, the majority have the ambition to achieve a certain glory on their own or to participate in achieving it with others. This positive indicator reflects the effectiveness of the cognitive behavior of the sample members.

Objective 14: Being Trustworthy.

Table 19 The fourteenth objective: trust in the parties that are addressed or share knowledge with

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	13	72
Agree	5	28

From the above table Tab. 19 we notice that the majority expressed their strong agreement towards this goal, with thirteen individuals and a percentage of 72%. Five members chose the phrase "agree" with a percentage of 28%. This indicates the importance of having confidence in the person who will be addressed and exchange knowledge with. The greater the trust between the people involved in knowledge, the more effective the practice of cognitive behavior. We notice that there is a similarity between the results of this goal and the results of the fourth goal in terms of choices, frequency and percentages.

Objective 15: Enhancing confidence in the person and in his work.

Table 20 The fifteenth objective: strengthening confidence in the person and in his work

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	17	95
Agree	1	5

In regard to enhancing confidence in the person and in his work or achievements, all agreed with this goal, as the majority of seventeen people chose the phrase "strongly agree" with a percentage of 95%, while one individual chose the phrase "agree" with a percentage of 5%. In fact, enhancing confidence is an important factor during the practice of cognitive behavior, because the more a person feels others' confidence in him and in his work and achievements, the more this will motivate him to present more of his ideas and share knowledge with others. However, with the lack of confidence it becomes difficult to practice cognitive behavior effectively with others. We notice that there is a similarity between the results of this goal and the results of the first goal in terms of choices, frequency and percentages.

Objective 16: Check the existence of reliable sources of information.

Table 21 The sixteenth objective: Relying on reliable sources of information

Respondents' attitude (sample members)	Frequency	Percentage (%)
Strongly agree	17	95
Agree	1	5

We notice from Tab. 21 that the results of this goal are similar to the results of the previous goal, where the majority expressed their strong agreement with verifying the validity and reliability of the information sources they rely on by seventeen members representing 95%, while only one person agreed, with a percentage of 5%. Due to the nature of the academic community, to which the members of the sample belong, this is a logical result. They belong to the information science discipline that is concerned with information sources and verifying their reliability and validity for reliance in studies and scientific research. The validity of the results depends on the validity of the information quoted or found in reliable sources of all kinds and forms.

6 STUDY RESULTS

This study dealt with the subject of the objectives of cognitive behavior by exploring the attitudes of the faculty members in the Department of Information Science at King Abdulaziz University in Jeddah (female section) towards the objectives of cognitive behavior, through a questionnaire that included a set of questions related to the sixteen objectives of the cognitive behavior. The study resulted in the following:

1) It became clear through the study that all members of the sample have high academic qualifications, as the percentage of those who hold a master's degree reached 50%, the percentage of those who hold a doctorate degree reached 50%, and this indicates the high scientific level of the sample members.
2) The number of the "Lecturer" rank occupants had the largest share of the sample by 50%, then those holding the "Professor" rank at a rate of 22%, followed by the "Assistant Professor" rank holders by 17%, and finally came the "Associate Professor" rank holders at a rate of 11%.
3) As for the years of service or experience, the category (10-15) years was the most chosen category by the sample members, with a percentage of 33%. In the

second place comes the category (more than 20) years, with a percentage of 28%, followed by the category (5) - 10 years, with a rate of 22%, then comes the last category (15-20) years with a rate of 17%, and this indicates the long experience of the sample members.

4) It became clear through the study the extent of the cognitive awareness of the sample members, as most of the results indicated the high awareness of the sample members for the importance of practicing cognitive behavior and achieving its goals. Indeed, this is not surprising for a study community that belongs to the specialty of information science, which includes a doctoral program in the specialization of Knowledge Management. Thus, they are the most suitable people to deal with understanding, managing, and practicing knowledge and its behaviors.
5) The study revealed the superiority of the fifth goal, which is (talking with all minds with mutual respect) by getting the strong agreement of all members of the sample by 100%. This indicates the ethics of the sample members in terms of democratic thinking in accepting and respecting the others' opinions.
6) Most of the responses of the sample members about the objectives of cognitive behavior were marked by agreement ranging from the phrase "strongly agree" and the phrase "agree", except for the sixth goal, there were eight responses that expressed disagreement, and the thirteenth goal only one of the sample members opted for disagreement.
7) The phrase "strongly agree" ranked first in answering fifteen of the goals of cognitive behavior, except for the sixth goal that topped by the phrase "disagree".
8) It became clear through the study, the similarity and convergence in the attitudes of the sample members towards the goals of cognitive behavior. Thus, we find that there are goals that are equal in the frequency of the answers and percentages such as the first goal, the fifteenth goal, and the sixteenth goal. The third and the ninth goals are similar, as well as the fourth and the fourteenth goals, in addition to the seventh and the eighth goals and finally, the eleventh and the twelfth goals. The reason for this similarity in viewpoints may be due to the belonging of all members of the sample to the same specialty or scientific department, which is the information science department.

7 RECOMMENDATIONS AND FUTURE SUGGESTIONS

In light of the previous results of the study, and to develop the practice of cognitive behavior in the study community, some recommendations and future proposals can be put forward, which are as follows:

1) Increasing interest in cognitive behavior and raising awareness of its importance and the necessity of its practice and application by all sample members.
2) Work to enhance trust among the faculty members (the subject of the study), and develop a culture of practicing cognitive behavior because of its positive reflections on performance.
3) Pre-planning and directing the use of the latent energies within the faculty members (study community), and encouraging them to manage knowledge and adhere to its behavior, by providing the appropriate atmosphere and environment for that.
4) Conducting more training courses and scientific activities (seminars, conferences, discussion panels, and workshops) that would support the effective practice of cognitive behavior.
5) Studying and identifying the obstacles to practicing cognitive behavior that face the sample members, and working to overcome them.
6) Conducting more studies to cover the aspects not covered by this study.

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Multi-Criteria Model for the Selection of New Process Equipment in Casting Manufacturing: A Case Study

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Abstract: The decision to introduce new process equipment is always a complex and risky process. An important competitive advantage in the automotive industry is the integration of new process equipment into the production system using different decision-making models composed of measurable key indicators, scientific methods and empirical values, study defines a multi-criteria model based on various scientific sources combined with extensive manufacturing experience, which is an important tool for making quality decisions when introducing new equipment or technology. The study considers five main areas of indicators and characteristics: internal, external, financial, knowledge level, and other important indicators. By applying the Delphi method, the importance of the indicators is defined by multidisciplinary experts and the order of each characteristic is determined, which is then prioritized using MCDM methods to select the final solution. The paper presents the model definition and a practical application of the model to the castings manufacturing in the automotive industry.

Keywords: AHP; MCDM; new process equipment; strategic decision; TOPSIS

1 INTRODUCTION

Due to the current intense changes in the automotive market, whether due to a global pandemic or environmental requirements, the key competitive advantage lies in the introduction of new technologies or more productive and flexible equipment into the manufacturing process. Many different requirements are forcing many companies to accelerate their transformation processes through organizational changes and rapid changes in the manufacturing process. In these processes, managers and experts are confronted with many attributes such as possible solutions, deviations, potential suppliers, KPIs (Key Process Indicators), alternatives ... in order to choose the best solution for a company. The selection of the attributes to be evaluated is very important for the final decision outcome. Identifying the relevant attributes can be done in many ways. One of the common methods is to interview focus groups in combination with a protocol procedure. A very effective method for selecting attributes is to involve managers and experts based on their knowledge and experience. They are familiar with the critical requirements of a process they are working with. The managers of the case study company of Chau et al. [1] recommended the following attributes: Lead Time, Operator Qualification and Training, Flexibility, Setup Time, Equipment Availability, Equipment Maintenance and Service Support, Capability, Product Quality, Reliability, and Technology Leadership.

According to several studies, it is recommended to limit the number of KPIs to a number between four and twelve KPIs for the entire company [2]. Marek et al. [3] conducted a systematic literature review of 180 papers to identify frequently considered KPIs. The final synthesis shows eleven company relevant autonomous and redundancy-free KPIs: delivery dates, lead time, return on capital employed, unit cost, overall equipment effectiveness, product portfolio extensibility, production schedule flexibility, product volume variability, customer satisfaction, product quality, and scrap rate. These are just a few examples of reference attributes in the manufacturing industry that are closely related to the production area, market, business strategies, etc. The multi-criteria decision making (MCDM) method [4] is a discipline for evaluating conflicting criteria in the process of decision making. The key to a successful decision lies in the quality of the input data of MCDM methods. For this study, the Analytic Hierarchy Process (AHP) method [5] was used to determine the weights of each criterion, and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method [6] was used to evaluate the criteria. The objectivity of the MCDC methods was ensured by using the Delphi method [7].

The aim of this study is to define key indicators and a model to determine the best solution for the introduction of new equipment in a given company.

1.1 Problem Statement and Literature Review

The decision to introduce new process equipment is usually the responsibility of top management after analysing all relevant factors for the company's ability to implement a new technology [8]. The next step is to identify and select the best possible solution that is suitable for a particular company or process. Usually, experts from the technical department play the main role in analysing all possible solutions and submitting proposals for a final solution to the top management. Often, top management makes the final decision based on the data provided by the technical department and the purchasing department. This approach can lead to indifference between experts and operators in the phase of new equipment introduction and also in serial production. To avoid such scenarios and achieve the synergistic effect of all parties involved in the introduction of new equipment processes, it is necessary to involve representative experts from the different business areas in the decision-making process. The present study was conducted to define a model for the best solution in the introduction of

new equipment suppliers by including all relevant factors in the decision-making process using MCDM methods.

Many authors have studied different methods of decision making based on a multi-criteria approach to finding the best solution. Alvarez et al. [9] made a systematic review of MCDM sorting methods, covering 30 years of research in this field. The analysis shows that the development of MCDM methods is still in a growth phase and highlights the trends of applied methods. Bertolini et al. [10] compared seven different MCDM methods in their study to evaluate the selection of new manufacturing technologies. They found that TOPSIS is one of the optimal methods for new technology selection. In a systematic literature review of decision models for supplier selection in the era of Industry 4.0, Resende et al. [11] found that 64% of the studies combined two or more techniques in the decision models. Depczynski [12] used AHP for supplier evaluation in a case study of a steel industry company. Acar et al. [13] used a combination of AHP and TOPSIS methods to evaluate production performance. Battistoni et al. [14] found the AHP method very useful for the new product development process. Khaira et al. [15] used a two-step decision making approach to identify critical equipment using the modified AHP method along with PROMETHEE methods to validate the AHP results. The validation of this innovative methodology and the corresponding equations for normalization in the AHP was performed using the PROMETHEE method and the results obtained were the same as those of the modified AHP. Rouyendegh et al. [16] used the hybrid method AHP-TOPSIS to select sectors for ERP (Enterprise Resource Planning) implementation. Nouri et al. [17] studied the prioritization of factors affecting technology selection in petrochemical companies using a hybrid approach of TOPSIS and Shanon entropy. They concluded that the technology productivity factor has the highest priority. Using TOPSIS and entropy MCDM techniques, Choda et al. [18] defined a model for industrial arc welding robot selection. An integrated three-stage Delphi MCDM Bayesian Network was identified by Dohale et al. [19] in a study of manufacturing system selection. The applicability of MCDM methods in supplier selection was shown by Agarwal et al. [20] in their study on multi-criteria decision making methods for supplier evaluation using sixty-eight research articles on the application of AHP in supplier selection [21]. Dweiri et al. [22] proposed a decision support model for supplier selection based on AHP using a case from the automotive industry. In a selection of construction equipment tasks, Temiz et al. [23] compared the MCDM methods via a case study. They concluded that the methods are consistent with each other as well as the decision makers' initial assessments of the alternatives.

The literature review shows that MCDM techniques are also successfully used in the manufacturing industry for many selection purposes. The companies' requirements in terms of strategy, functionality, and operational capability are critical for evaluating suppliers and determining the criteria using the most appropriate methods. Some methods may be advantageous for certain companies, so it is important to evaluate suppliers according to the companies' requirements. [20]. During the literature review, it was found that there are no available decision models and predefined indicators for our case study, which considers a specific area of the automotive industry and the specific task of selecting new equipment based on combined indicators. In view of a current case study and future similar decision processes, it was decided to define a hybrid model of MCDM methods and to select our list of most suitable indicators.

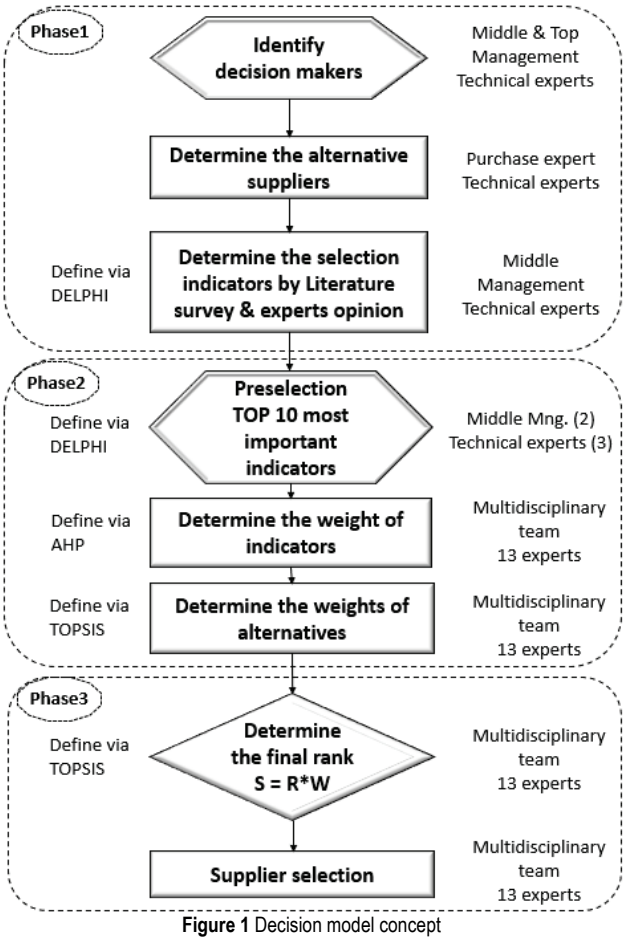

Figure 1 Decision model concept

1.2 Research Approach

The study is conducted to define a model for decision making in three phases: Phase 1 – a preparation phase with the identification of decision makers and data collection on indicators and alternative suppliers, Phase 2 - the pre-selection of indicators with the determination of the weighting of indicators and alternatives, and Phase 3 - a ranking of alternatives and the final selection of the supplier. Based on the conclusions of the literature review on the main selection indicators, the study used a hybrid application of MCDM methods combined with the experience of experts in the manufacturing company. The accepted concept of the decision process is shown in Fig. 1. Before the data were delivered to the team, the technical experts from the engineering department performed an initial analysis and excluded all indicators and suppliers that did not provide consistent results or for which relevant data were not

available. The data consisted of the final 15 indicators and 7 potential new equipment suppliers. Next, experts from middle management and technical experts from the engineering department used the Delphi method to pre-select indicators for the introduction of new process equipment.

This team consisted of two members of middle management and three technical experts. Next, the multifunctional team analysed the data provided by the technical experts and middle management on the machining area of medium-sized castings. The 13 members of the multifunctional team were from different departments of the company: Middle and Upper Management, Engineering, Quality, Maintenance, Purchasing, Planning & Controlling, and Production with more than 15 years of experience in a specific field. The AHP method was used to determine the weighting factors for each indicator and finally, the TOPSIS method was used to rank each indicator with possible alternatives and make the final solution selection.

2 DATA ANALYSIS

2.1 Phase 1 – Preparation Activities

In order to obtain reliable results of the study, one of the most important activities is the quality preparation phase with several important activities: defining the structure of the team members, predefining the key indicators, collecting objective input data for each alternative, and clearly defining and instructing all study members how to conduct the study.

Defining the team members is a very important task because it is not aimed to make a team with the loudest experts ones but with the most competent experts, that will participate in the study. Occasionally, there are many competent experts in the field with poor presentation skills who make a questionable contribution to the teamwork tasks. The Delphi method approach is a good tool to leverage expert knowledge, regardless of poor presentation skills or a public action problem. Since this is the first time the company has used MCDM methods for strategic decision making, several training workshops were set up. Based on the current corporate strategy, customer expectations, and the results of the literature review, the fifteen most important indicators for data collection were determined. The decision to reject the indicators was due to the lack of reliable data or the absence of data, as well as the priorities of the company based on the strategy in the analysed period.

2.2 Phase 2 – Preselection TOP10 Indicators with Delphi Method

The fifteen indicators were reviewed by middle management and technical experts using the Delphi method to exclude less important indicators and to simplify and accelerate the study and final decision on the introduction of new process equipment. In this study, a Likert scale from 1 (least important) to 5 (most important) was used to rate the indicators. The mean value of each indicator 4,0 is used as the criterion for acceptability. If the mean of the indicator is 4,0 and above, the indicator is accepted for further study, otherwise, it is rejected. 5 indicators were rejected and the top 10 indicators were accepted (Tab. 1). In general, due to the different opinions of the experts based on their experience and background, it is good to recalculate these values using the Shannon entropy method, but in this analysis, it was not reasonable due to the quality of the input data or the lack of data.

Table 1 Delphi method preselection results

	Indicators	Mean	MM1	MM2	Te1	Te2	Te3	Status
1	Cost/pcs	5	5	5	5	5	5	Accept
2	Flexibility	4,4	5	5	4	4	4	Accept
3	Total investment	4,4	5	5	4	4	4	Accept
4	Clamping polyvalence	4,2	3	4	4	5	5	Accept
5	Reference	4,2	4	4	4	4	5	Accept
6	Set-up	4,2	4	3	5	4	5	Accept
7	Maintenance	4,2	4	4	5	4	4	Accept
8	Nb. of clamping devices	4	4	3	4	5	4	Accept
9	Operator number	4	4	3	5	4	4	Accept
10	Automatization	4	4	4	4	3	5	Accept
11	Load	3,8	4	4	4	3	4	Reject
12	Delivery time	3,8	4	5	3	4	3	Reject
13	Payment condition	3,6	4	4	4	3	3	Reject
14	OEE	3	3	4	3	2	3	Reject
15	Layout space	3	3	3	3	3	3	Reject

MM1-MM2: Middle management experts
Te1-Te3: Technical expert from the engineering department

The study continued with 10 accepted key indicators: Cost/unit - production cost per single product, Flexibility - flexibility of process equipment to produce similar products in the future after the EOP (end of production) of the current product, Total investment - total investment depending on the number of production, measuring and logistic equipment to be installed, Clamping polyvalence - the capability of cutting tools and clamping devices, that can be used on alternative machines, Reference - supplier references in similar manufacturing processes, Setup - complexity level and number, depending on the number of fixtures, process capability and operator skill level, Maintenance - complexity of maintenance activity and machine capability Cpm (Taguchi capability index), Nb. of fixtures - number of fixtures depends on process capability, process adjustments and maintenance costs, Number of operators - impact on production quality, productivity and costs, Automation - possibility of automation (loading/unloading) of certain machines with the environment.

The weights and ratings are usually difficult to define precisely because they are subject to uncertainties that can be dealt with using linguistic terms instead of numerical values [24].

2.3 Phase 2 – Weight of Indicator Determination with AHP Method

The AHP proposed by Saaty is one of the most popular methods in the decision-making process for solving complex decision problems because it captures both subjective and objective evaluation measures. Based on pairwise comparisons, weights are calculated by finding the dominant right eigenvector (EV) of the positive reciprocal decision matrix. This qualitative pairwise comparison follows the importance scale proposed by Saaty, as shown in Tab. 2. The

pairwise comparison is also used to determine the relative importance of the alternatives for each of the criteria. The sum of the priorities for all alternatives must equal 1. The pairwise comparison is performed in matrix form to check the consistency of the judgment [22].

Table 2 Saaty AHP scale [5]

Importance intensity	Definition	Description
1	Very bad	Equal importance
3	Bad	Moderate importance of one over another
5	Medium best	Strong importance of one over another
7	Good	Very strong importance of one over another
9	Very good	The extreme importance of one over another

Table 3 Pairwise comparison matrix

Indicators	1	2	3	4	5	6	7	8	9	10
1	1	7	1	7	3	5	1	3	3	3
2	1/7	1	1/3	1	1	1/3	1/3	1	1/3	1/3
3	1	3	1	3	1	1/3	1/	1	1	1
4	1/7	1	1/3	1	1/3	1/5	1/7	1/3	1/3	1
5	1/3	1	1	3	1	1	1	3	1	1
6	1/5	3	3	5	1	1	1/5	1	3	1/3
7	1	3	5	7	1	5	1	5	5	5
8	1/3	1	1	3	1/3	1	1/5	1	1	1/3
9	1/3	3	1	3	1	1/3	1/5	1	1	1/3
10	1/3	3	1	1	1	3	1/5	3	3	1

The weighting of the indicators in the study was determined using the AHP method in the Excel template [25] with additional adaptation for our study. The decision to work with an Excel template was made for several reasons: It was the first time the company come into contact with MCDM decision-making methods, so the investment in AHP software can be avoided, the template is easy to use, user-friendly, each questionnaire should fit on one page for printing, and the filling is done manually. Thirteen experts received an AHP template with 10 indicators to set the weights, completely independent with clear instructions and a moderator from the team available for detailed explanations. They scored the indicators according to the AHP rules and parameters to make recommendations corresponding to $CR < 10\%$ (consistency ratio). The templates can handle 8 different rating scales. Saaty's basic linear scale was chosen for the study because the simulation performed with different scales showed no significant difference in the results when the other conditions of the method were met. The result of the pairwise evaluation is shown in Tab. 3. An important step in the AHP method is to check the consistency of the decision results. A higher value of *CR* means that the decision maker is less consistent and vice versa, a lower value of *CR* means high consistency. The decision team used a standard scale with nine levels, which is shown in Tab. 2. Two consistency indices were calculated: the consistency ratio (*CR*) and the geometric consistency index (*GCI*). *CR* is the ratio between the consistency index (*CI*) and the random consistency index (*RI*) and can be expressed by Eq. (1).

$$CR = \frac{CI}{RI}, \text{ and } CI = \frac{\lambda_{\max} - n}{(n-1)} \quad (1)$$

λ_{max} - Principal Eigenvalue is a result of the summation of products between each element for Eigenvector and the sum of columns of the reciprocal matrix.

The Excel AHP template, like many other AHP programs, has a "consistency" navigator - the highlighted extreme scoring results for re-scoring to reach the *CR* limit. The results of the row geometric mean method (RGMM) used to calculate the priorities could be found in Tab. 4.

Table 4 Consolidated weighted geometric mean off participants

Indicators	1	2	3	4	5	6	7	8	9	10
1	1	2,26	1,14	1,29	2,14	1,36	0,72	1,43	1,65	2,32
2	0,44	1	0,41	0,5	0,58	0,49	0,26	0,6	0,48	0,5
3	0,88	2,46	1	1,18	1,17	1,18	0,5	1,12	1,18	1,25
4	0,78	2,01	0,85	1	1,07	1,62	0,32	0,81	1,01	1,5
5	0,47	1,72	0,86	0,93	1	1,32	0,55	0,94	1,07	1,13
6	0,74	2,03	0,85	0,62	0,76	1	0,43	0,65	1,0	0,91
7	1,39	3,87	2,01	3,1	1,83	2,32	1	3,06	2,13	3,23
8	0,7	1,67	0,9	1,23	1,07	1,55	0,33	1	1,12	1,49
9	0,61	2,1	0,85	0,99	0,93	1,0	0,47	0,9	1	1,07
10	0,43	2,02	0,8	0,67	0,88	1,09	0,31	0,67	0,94	1

The criteria of weight distribution among the different experts were analysed using Shannon entropy and its division into independent components (α- and β-entropy) to derive an AHP consensus indicator. The result of the Shannon entropy α is 7,604622, for the Shannon entropy β is 1,23003. The calculation of the final priority values (Tab. 5) is based on the eigenvector method (EVM) with a fixed number of 12 iterations.

Table 5 Consensus Indicator based on RGGM results

DM	1	2	3	4	5	6	7	8	9	10	∑
1	0,21	0,03	0,16	0,07	0,05	0,09	0,23	0,09	0,02	0,05	1,0
2	0,14	0,07	0,06	0,05	0,19	0,02	0,28	0,05	0,03	0,10	1,0
3	0,26	0,02	0,03	0,14	0,08	0,03	0,20	0,14	0,03	0,08	1,0
4	0,05	0,03	0,16	0,11	0,05	0,01	0,31	0,03	0,22	0,02	1,0
5	0,25	0,13	0,06	0,05	0,23	0,02	0,14	0,03	0,03	0,07	1,0
6	0,21	0,09	0,03	0,03	0,21	0,21	0,04	0,03	0,07	0,09	1,0
7	0,03	0,03	0,17	0,06	0,02	0,14	0,07	0,25	0,18	0,06	1,0
8	0,05	0,02	0,15	0,12	0,04	0,05	0,21	0,07	0,24	0,05	1,0
9	0,06	0,02	0,08	0,17	0,03	0,06	0,29	0,19	0,05	0,04	1,0
10	0,09	0,02	0,08	0,21	0,02	0,19	0,10	0,18	0,08	0,03	1,0
11	0,03	0,04	0,05	0,15	0,03	0,17	0,17	0,19	0,10	0,06	1,0
12	0,23	0,04	0,13	0,02	0,25	0,04	0,13	0,02	0,06	0,08	1,0
13	0,22	0,04	0,08	0,03	0,09	0,09	0,25	0,06	0,06	0,10	1,0

The final result of the AHP method is attribute weights shown in Tab. 7. The overall consistency ratio *CR* reached in the study is 9,9 %, the simulation performed with different rating scales showed even better results *CR* (from 1,3% to 6,1%). Differences between individual RGGM and the *CR* results from each team member are shown in Tab. 6. All decision makers reach *CR* limit value. The *CR* result shows that the AHP method was properly done and the result is confident.

Table 6 Individual Indicator based on RGGM results

DM	1	2	3	4	5	6	7	8	9	10	*CR*
1	0,2235	0,0282	0,1522	0,0673	0,0539	0,0888	0,2223	0,0928	0,0187	0,0522	9%
2	0,1373	0,0693	0,0626	0,0497	0,1830	0,0273	0,2851	0,0517	0,0347	0,0994	10%
3	0,2699	0,0190	0,0309	0,1296	0,0794	0,0291	0,2064	0,1296	0,0298	0,0762	9%
4	0,0433	0,0291	0,1563	0,1133	0,0494	0,0145	0,3255	0,0312	0,2162	0,0211	9%
5	0,2536	0,1229	0,0681	0,0445	0,2190	0,0196	0,1379	0,0285	0,0343	0,0717	9%
6	0,2134	0,0905	0,0257	0,0242	0,1929	0,2191	0,0460	0,0287	0,0667	0,0929	8%
7	0,0262	0,0270	0,1668	0,0640	0,0225	0,1396	0,0767	0,2457	0,1730	0,0584	9%
8	0,0542	0,0233	0,1591	0,1248	0,0389	0,0469	0,2030	0,0754	0,2287	0,0455	8%
9	0,0643	0,0193	0,0833	0,1675	0,0338	0,0572	0,2984	0,1905	0,0453	0,0404	7%
10	0,0955	0,0275	0,0774	0,2078	0,0236	0,2032	0,0914	0,1696	0,0767	0,0274	8%
11	0,0345	0,0347	0,0573	0,1538	0,0313	0,1741	0,1780	0,1715	0,1029	0,0620	9%
12	0,2269	0,0406	0,1286	0,0247	0,2366	0,0388	0,1418	0,0228	0,0636	0,0755	8%
13	0,2108	0,0380	0,0778	0,0296	0,0897	0,0923	0,2476	0,0525	0,0598	0,1018	9%

2.4 Phase 2 – Weight of Alternatives Determination with TOPSIS Method

TOPSIS is one of the numerous MCDM methods for solving multiple criteria.

Table 7 Attribute weights final results

	Indicator	Weights
C1	Cost/pcs	0,211
C2	Flexibility	0,038
C3	Total investment	0,091
C4	Clamping polyvalence	0,078
C5	Reference	0,247
C6	Set-up	0,053
C7	Maintenance	0,059
C8	Nb. of clamping devices	0,031
C9	Operator number	0,092
C10	Automation	0,101

The concept of this method is to select the best alternatives that have the shortest distance to positive solutions and the farthest distance to negative solutions. These hypothetical solutions correspond to the maximum and minimum attribute values in the database that contain satisfactory solutions. The closest hypothetical best solution and the farthest hypothetical worst solution are used to obtain the best solutions [26]. The target and the important evaluation attributes are determined. For this study, cost/unit count is considered as a non-beneficial attribute (a lower value is better) and others are considered as beneficial attributes (a higher value is better). The input value for the cost/unit count attribute is numerical, and for all other attributes, it is the mean of the team experts' ratings to increase the objectivity of the study due to a mixed influence of two or more factors on the advantageous status. A Likert scale of 1 to 5 was also used in this case. In conducting the TOPSIS analysis, the team followed standard analysis steps.

Step 1: The expert team first evaluated each alternative based on the individual criteria. The information is presented in the form of the TOPSIS decision matrix in Tab. 8.

Step 2: Calculated normalized decision matrix using Eq. (2).

$$\bar{X}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{2}$$

Table 8 Decision matrix results

		A1	A2	A3	A4	A5	A6	A7
Cost/pcs	C1	2,63	2,34	3,52	1,70	1,90	5,04	1,89
Flexibility	C2	3,2	3,1	4,1	2,3	2,4	4,8	2,8
Total investment	C3	4,8	4,9	4,9	4,8	1,2	5,0	1,3
Clamping polyvalence	C4	3,3	4,9	1,2	4,2	4,9	2,8	2,3
Reference	C5	4,4	4,3	1,4	4,8	1,3	4,8	2,8
Set-up	C6	4,5	4,8	1,2	4,7	4,8	2,3	3,2
Maintenance	C7	4,1	4,5	5,0	1,3	5,0	5,0	1,3
Nb. of clamping devices	C8	2,8	5,0	2,9	1,3	4,7	3,5	2,5
Operator number	C9	2,8	3,1	4,4	1,3	4,2	4,8	1,3
Automation	C10	3,8	4,8	3,2	1,8	4,8	3,5	2,1

To allow comparison between attributes, the calculation of the normalized decision values is required, since all attributes are now in a non-dimensional form. The results of the normalized decision matrix can be found in Tab. 9.

Table 9 Normalized decision matrix results

	A1	A2	A3	A4	A5	A6	A7
C1	0,3388	0,3014	0,4535	0,2190	0,2448	0,6493	0,2435
C2	0,3441	0,3441	0,4588	0,2294	0,2294	0,5735	0,3441
C3	0,4437	0,4437	0,4437	0,4437	0,0887	0,4437	0,0887
C4	0,3180	0,5300	0,1060	0,4240	0,5300	0,3180	0,2120
C5	0,4148	0,4148	0,1037	0,5185	0,1037	0,5185	0,3111
C6	0,3904	0,4880	0,0976	0,4880	0,4880	0,1952	0,2928
C7	0,3831	0,3831	0,4789	0,0958	0,4789	0,4789	0,0958
C8	0,3216	0,5361	0,3216	0,1072	0,5361	0,3216	0,3216
C9	0,3419	0,3419	0,4558	0,1140	0,4558	0,5698	0,1140
C10	0,3254	0,5423	0,3254	0,2169	0,5423	0,3254	0,2169

Step 3: Calculate weighted normalized decision matrix.

$$V_{ij} = \bar{X}_{ij} \times W_j \tag{3}$$

The weighted normalized values (V_{ij}) of each indicator can be calculated by multiplying the normalized results of each indicator by its determined weight using Eq. (3) where $\bar{X}_{ij}$ is a normalized matrix and W_j is the weighting criterion determined by the AHP method. Tab. 10 shows the weighted normalized value.

Step 4: Identify the ideal best and ideal worst value.

Since C1 is a non-benefit attribute, the chosen value is a minimum value, and all others are beneficial attributes, so the chosen values are maximum values. The solutions were defined as in Tab. 11.

Table 10 Weighted normalized decision matrix results

	A1	A2	A3	A4	A5	A6	A7
C1	0,0715	0,0636	0,0957	0,0462	0,0517	0,1370	0,0514
C2	0,0132	0,0132	0,0176	0,0088	0,0088	0,0220	0,0132
C3	0,0345	0,0345	0,0345	0,0345	0,0069	0,0345	0,0069
C4	0,0098	0,0163	0,0033	0,0130	0,0163	0,0098	0,0065
C5	0,0376	0,0376	0,0094	0,0470	0,0094	0,0470	0,0282
C6	0,0359	0,0448	0,0090	0,0448	0,0448	0,0179	0,0269
C7	0,0945	0,0945	0,1181	0,0236	0,1181	0,1181	0,0236
C8	0,0169	0,0282	0,0169	0,0056	0,0282	0,0169	0,0169
C9	0,0203	0,0203	0,0270	0,0068	0,0270	0,0338	0,0068
C10	0,0329	0,0549	0,0329	0,0220	0,0549	0,0329	0,0220

Table 11 Ideal best and ideal worst results

	V+	V–
C1	0,04622	0,13702
C2	0,02202	0,00881
C3	0,03447	0,00689
C4	0,01627	0,00325
C5	0,04698	0,00940
C6	0,04482	0,00896
C7	0,11809	0,02362
C8	0,02820	0,00564
C9	0,03379	0,00676
C10	0,05491	0,02196

The separation measures of each alternative were calculated with Eq. (4) from the positive ideal and with Eq. (5) for the negative ideal. Tab. 12 shows the values of the separation measures for the 7 alternatives.

Table 12 Separation measures values

	S_i^+	S_i^-
A1	0,040	0,107
A2	0,025	0,123
A3	0,071	0,102
A4	0,097	0,105
A5	0,044	0,132
A6	0,095	0,101
A7	0,101	0,089

Step 5: Calculate the Euclidean distance from the ideal best.

$$S_i^+ = \left[\sum_{j=1}^{m}(V_{ij} - V_j^+)^2\right]^{0.5} \quad (4)$$

Step 6: Calculate the Euclidean distance from the ideal worst.

$$S_i^- = \left[\sum_{j=1}^{m}(V_{ij} - V_j^-)^2\right]^{0.5} \quad (5)$$

2.5 Phase 3 – Determine the Final Rank and Alternative Selection

Step 7: Calculate Performance Score and rank the results.

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (6)$$

Relative proximity is calculated using Eq. (6). The higher the P_i value is, the better the performance of the alternatives. The final results of the ranking, shown in Tab. 13, indicate that the best option for the introduction of new process equipment is Alternative2.

Table 13 Performance score and final rank results

	P_i	Rank
A1	0,727	3
A2	0,829	1
A3	0,589	4
A4	0,521	5
A5	0,751	2
A6	0,515	6
A7	0,469	7

Nevertheless, alternative A5 has the best result on the most important criterion (highest weighting value) and almost the best result on the second most important criterion, although the value of the other criterion was decisive for it to be "only" second. This fact is strong proof of the performance of the MCDM methods, if the input data are properly defined and the requirements for the procedure are strictly followed. In Fig. 2 are the result of weighted normalized decision matrix results for Top3 alternatives. This view clearly shows the power of TOPSIS analyse even for decision making with a similar input value of indicators.

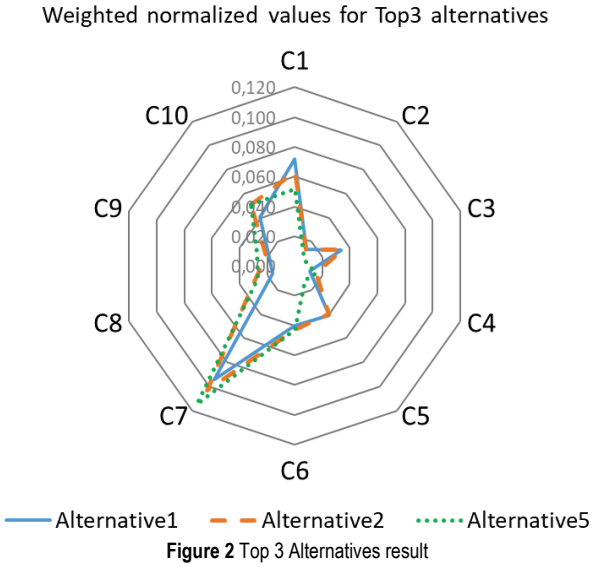

Figure 2 Top 3 Alternatives result

3 CONCLUSION

In the automotive industry, managers are faced with the decision making process more than ever in many areas due to often market changes because of the electrification era, pandemic issues or lack of raw material or components. One of the most important and risky decision area is introducing new equipment or technology into the manufacturing process to increase competitiveness in the market. For the decision makers is important to have standardized procedures or methods for fast and reliable decision making.

The aim of this paper was to define a simple and user-friendly tool for decision makers in the automotive industry. The novel approach is the decentralization of the decision-making process from managers to multidisciplinary teams

composed of experienced experts from various fields related to the decision making scope. The key point is to include all relevant factors from the manufacturing process in the decision making process about the introduction of a new manufacturing process to become familiar with new equipment at a very early stage of process implementation. This approach will greatly improve the relationship between all process factors and accelerate the implementation and optimization phases of the process. Seven final alternatives were used for decision making, considering ten attributes/criteria instead of the original fifteen attributes, which were reduced using the Delphi method. This step is very important due to the simplification and acceleration next steps in the decision model. The objective weights of importance of the attributes/criteria are assigned using the AHP method. According to the obtained results, among the 10 indicators, the Reference has the highest degree of importance due to the reason for introducing new equipment into running high runner SOP production process. This means there is no space for the generation of any delivery delays, so risk minimization is a mandatory task in all decision steps. We need to choose a reliable equipment supplier with excellent references and overall maintenance support. The TOPSIS analyse is used to select the best alternative, alternative 2 is the best and the first choice identified using the TOPSIS analyse. Due to the prior Delphi attributes reduction process in an early stage of the research process, the performing of TOPSIS analyse was fast and effective. The final result of this study is a standardization of the presented Decision model based on Delphi, AHP and TOPSIS MCDM methods, in standard company procedure.

The advantage of this study is the applicability of this hybrid decision model to different manufacturing areas with intelligent adjustment of input indicators. The decision making process is relatively fast because of the evaluation and reduction number of important indicators in the early stage of the research process. This is not a copy-paste tool for decision makers, but the result of the study approach and the application of MCDM methods combined with respectable knowledge and experience in the field of automotive manufacturing considering the company specifications. This decision model concept can be used for future research implementation into other manufacturing processes.

The model presented in this study can also be used in other industries where the input parameters need to be redefined due to the different characteristics of the industry.

Notice

The paper will be presented at MOTSP 2022 – 13th International Conference Management of Technology – Step to Sustainable Production, which will take place in Primošten/Dalmatia (Croatia) on June 8–10, 2022. The paper will not be published anywhere else.

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Application of Intersection Method for Multi-Objective Optimization in Optimal Test with Desirable Response Variable

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Abstract: This paper aims to conduct applications of intersection method for multi-objective optimization in optimal test design with desirable response variable. The partial favourable probability of the desirable response variable of the test is evaluated according to the type of "one side desirability problem" or "one range desirability problem" and the requirements of desirable response first; then the evaluation of total favourable probability P_t of the multi-objective optimization test design is conducted according to the common procedure of the "intersection" method for multi-object optimization of performance indicators of the test. Finally, regression analysis is performed for the total favourable probability and response variables to get maximum total favourable probability and optimal configuration of the optimal test with desirable response variable. As application examples of the intersection method for the test designs of maximizing yield with constraints of viscosity and molecular weight and the maximizing conversion rate with constraints of desirable thermal activity are given in detail, satisfied results are obtained.

Keywords: desirable response variable; intersection method; multi-objective optimization; optimal test design; partial favourable probability

1 INTRODUCTION

Optimization is an eternal topic in the world, including industrial production, transportation, architecture building, chemical reaction, banking, and social activities. They are likely involving several attributes or performances that must be considered in the analysis. An alternative is recommended to be an optimal one that needs to meet some requirements of response variables (performances), they are even conflicting each other. The proper approach to address this issue is to consider all responses comprehensively and simultaneously. Various techniques have been proposed, including technique for order preference by similarity to ideal solution (TOPSIS), Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR), multi attribute decision making (MADM), Analytical Hierarchy Process (AHP) and Multi-Objective Optimization on the basis of Ratio Analysis (MOORA), etc. [1].

Recently, a new approach named "intersection" method for multi-object optimization was proposed in the viewpoints of set theory and probability theory [1], which attempts to solve the inherent problems of personal and subjective factors in the above multi-object optimizations. The novel concept of favourable probability was developed to reflect the favourable degree of the candidate in the optimization, all performance utility indicators of candidates are divided into beneficial or unbeneficial types to the selection. Each performance utility indicator of the candidate is correlated to a partial favourable probability quantitatively, and the total favourable probability of a candidate is the product of all partial favourable probabilities in the viewpoints of probability theory and "intersection" of set theory, which is the overall and sole decisive index in the competitive selection process. The new multi-object optimization method was also extended in application of multi-objective orthogonal test design method (OTDM) and uniform test design method (UTDM) as well; appropriate achievements have been obtained [1].

In practical engineering fields, besides the beneficial or unbeneficial types of performance utility indicators of candidates, which have the features of the higher the better or the lower the better, there exists third type of performance indicators of candidates, which have the feature of the desired target being the best [2]. In order to address this problem, Derringer and Suich once implemented a multi-response optimization technique with a desirability function [3], which is with the weighting exponent to be assigned instead of favourable probability.

As a further development to the newly proposed "intersection" method for multi-object optimization, here in this paper, applications of intersection method for multi-objective optimization in optimal test design with desirable response are studied.

2 EVALUATIONS OF PARTIAL AND TOTAL FAVOURABLE PROBABILITIES OF DESIRABLE RESPONSE IN THE "INTERSECTION" METHOD FOR MULTI-OBJECTIVE OPTIMIZATION

2.1 One Range Desirability Problem

Under condition of one range desirability, the response variable Y_{ij} has a desirable response range, i.e., within range of $[a, b]$. In this case, the partial favourable probability P_{ij} of response variable Y_{ij} will have certain value α_j within range of $[a, b]$, and the partial favourable probability P_{ij} of response variable Y_{ij} will be zero outside range of $[a, b]$, i.e.,

$$P_{ij} = \begin{cases} \alpha_j, \ Y_{ij} \in [a, b]; \\ 0, \ Y_{ij} \notin [a, b]; \end{cases} \quad i = 1, 2, \cdots, n; j = 1, 2, \cdots, m. \qquad (1)$$

Y_{ij} represents the j^{th} performance indicator of the i^{th} candidate; P_{ij} is the partial favorable probability of the one range desirable response variable Y_{ij}; n is the total number of candidates in the candidate group involved; m is the total number of performance indicators of each candidate in the group; α_j is value of the partial favourable probability P_{ij} of the j^{th} response variable Y_{ij}.

According to the general principle of probability theory [4], the summation of each P_{ij} for the index i in j^{th} performance factor is normalized and equal to 1, i.e., $\sum_{i=1}^{n} P_{ij} = 1$, thus, it obtains naturally

$$\sum_{i=1}^{n} \alpha_j = 1,\ \alpha_j = \frac{1}{l}, \tag{2}$$

l is the number of the value of the response variable Y_{ij} falling within range of the $[a, b]$.

2.2 One Side Desirability Problem

In condition of one side desirability, the response variable Y_{ij} has a desirable response limit, e.g., within range of $[a, \infty]$, which can be taken as a special case of one side desirable condition by setting $b = \infty$. In this case, the partial favourable probability P_{ij} of response variable Y_{ij} will have certain value β_j within range of $[a, \infty]$, and the partial favourable probability P_{ij} of response variable Y_{ij} will be zero outside range of $[a, \infty]$, i.e.,

$$P_{ij} = \begin{cases} \beta_j,\ Y_{ij} \in [a, \infty]; \\ 0,\ Y_{ij} \notin [a, \infty]; \end{cases} \quad i = 1, 2, \cdots, n; j = 1, 2, \cdots, m. \tag{3}$$

Similarly, according to the general principle of probability theory [4], the summation of each P_{ij} for the index i in j^{th} performance factor is normalized and equal to 1, i.e., $\sum_{i=1}^{n} P_{ij} = 1$, thus, it obtains naturally

$$\sum_{i=1}^{n} \beta_j = 1,\ \beta_j = \frac{1}{k} \tag{4}$$

k is the number of the value of the response variable Y_{ij} falling within range of the $[a, \infty]$.

The treatment for the situation for one side desirability within range of $[0, b]$ is similar to above procedure.

As the partial favourable probability P_{ij} of response variable Y_{ij} is obtained, the evaluations of total probability P_t of candidate and the ranking of the multi-objective optimization can be conducted according to the common procedure of the "intersection" method for multi-object optimization [1].

3 APPLICATIONS OF THE "INTERSECTION" METHOD FOR MULTI-OBJECTIVE OPTIMIZATION IN CASES OF DESIRABLE RESPONSE

3.1 Maximizing Yield with Constraints of Viscosity and Molecular Weight

Montgomery et al showed a maximizing yield optimization with constraints of viscosity and molecular weight problem two input variables reaction time x_1 and temperature x_2 [5], and three responses variables, i.e., the yield y_1 (%), the viscosity y_2 (cSt) and the molecular weight y_3 (Mr.) of the product, which is cited and displayed in Tab. 1. The optimization of this problem is to get maximum yield y_1 with the constraints of viscosity y_2 and molecular weight y_3 by $62 \le y_2 \le 68$ cSt and $y_3 \le 3400$ Mr. In this second phase of the study, two additional responses were of special interest: the viscosity y_2 and the molecular weight y_3 of the product in addition to yield y_1, which are responses with desirable values. The experimenter called it as a central composite design (or CCD).

In this problem, it involves complex optimization for yield y_1 as a beneficial performance index, viscosity y_2 and molecular weight y_3 as desirable response indexes. Therefore, the partial favourable probability for yield y_1 could be evaluated by the assessment for beneficial type variable proposed in [1], and partial favourable probabilities for the viscosity y_2 and molecular weight y_3 should be evaluated by the assessment methods developed in the last section for both one side desirability and one range desirability problems, respectively. The evaluated results of partial and total favourable probabilities P_{y1}, P_{y2}, P_{y3} and P_t of this product experiment are shown in Tab. 2. Tab. 2 shows that the test No. 1 exhibits the maximum total favourable probability at first glance, so the optimal configuration could be around test No. 1.

Table 1 Experimental results of maximizing yield with constraints of viscosity and molecular weight

No.	Reaction time, x_1 / min	Temperature, x_2 / °C	Yield, y_1 / %	Viscosity, y_2 / cSt	Molecular weight, y_3 / Mr.
1	80	76.67	76.5	62	2940
2	80	82.22	77	60	3470
3	90	76.67	78	66	3680
4	90	82.22	79.5	59	3890
5	85	79.44	79.9	72	3480
6	85	79.44	80.3	69	3200
7	85	79.44	80	68	3410
8	85	79.44	79.7	70	3290
9	85	79.44	79.8	71	3500
10	92.07	79.44	78.4	68	3360
11	77.93	79.44	75.6	71	3020
12	85	83.37	78.5	58	3630
13	85	75.52	77	57	3150

Table 2 The evaluated results of partial and total favourable probabilities for the chemical experiment

	Response Variables			Favourable Probability			
No.	y_1/%	y_2/cSt	y_3/Mr	P_{y1}	P_{y2}	P_{y3}	$P_t \times 10^3$
1	76.5	62	2940	0.0750	0.1997	0.0869	2.2437
2	77	60	3470	0.0755	1.46E-05	0.0751	0
3	78	66	3680	0.0765	0.3995	0.0704	0.1163
4	79.5	59	3890	0.0779	3.81E-07	0.0657	0
5	79.9	72	3480	0.0783	1.75E-08	0.0748	0
6	80.3	69	3200	0.0787	0.0013	0.0811	0.0142
7	80	68	3410	0.0784	0.1997	0.0764	1.0902
8	79.7	70	3290	0.0781	1.46E-05	0.0791	0.0001
9	79.8	71	3500	0.0782	3.81E-07	0.0744	0
10	78.4	68	3360	0.0768	0.1997	0.0775	1.4744
11	75.6	71	3020	0.0741	3.81E-07	0.0851	0
12	78.5	58	3630	0.0769	1.75E-08	0.0715	0
13	77	57	3150	0.0755	1.21E-09	0.0822	0

In order to get an accurate optimization, the data in Tab. 2 is regressed. The fitted result for the total favourable probability is

$$P_t \times 10^3 = -210149.5010 - 2424.3807x_1 + 520.1057x_2 + \\ +0.0383x_1x_2 + 13.1983x_1^2 - 6.5788x_2^2 + \\ +73485.15 \cdot \ln(x_1) - 0.0317x_1^3 + 0.0275x_2^3, \\ R^2 = 0.8554. \quad (5)$$

P_t gets its maximum value $P_{tmax} \times 10^3 = 2.2750$ at $x_1 = 80.39$ minutes, and $x_2 = 76.91$°C.

While, the fitted result for the yield y_1 is

$$y_1 = -326843.3710 - 4410.0970x_1 + 48.0746x_2 + \\ +0.0180x_1x_2 + 25.9987x_1^2 - 0.4803x_2^2 + \\ +124747.8522 \cdot \ln(x_1) + 0.0682x_1^3 + 0.0014x_2^3, \\ R^2 = 0.9926. \quad (6)$$

The yield y_1 gets its optimal value $y_{1opt} = 76.979$ % at $x_1 = 80.39$ minutes, and $x_2 = 76.91$°C.

The fitted result for viscosity y_2 is

$$y_2 = 1454310.2050 + 20242.9592x_1 + 2436.0490x_2 - \\ -0.0900x_1x_2 + 117.4347x_1^2 - 29.7790x_2^2 - \\ -580304.3480 \cdot \ln(x_1) + 0.3025x_1^3 + 0.1215x_2^3, \\ R^2 = 0.9723. \quad (7)$$

The desirable variable viscosity y_2 gets it optimal value $y_{2opt} = 63.351$ cSt at $x_1 = 80.39$ minutes, and $x_2 = 76.91$°C.

The fitted result for molecular weight y_3 is

$$y_3 = -176217474.0000 - 2438309.5500x_1 - \\ -13078.9964x_2 - 5.7600x_1x_2 + 14549.0282x_1^2 + \\ +170.7936x_2^2 + 68063495.1500 \cdot \ln(x_1) - 38.5337 - \\ -0.7128x_2^3, \\ R^2 = 0.9238. \quad (8)$$

The desirable variable molecular weight y_2 gets it optimal value $y_{3Opt} = 2972.375$ Mr. at $x_1 = 80.39$ minutes, and $x_2 = 76.91$°C.

Above optimal results meet the requirements of the original idea of the problem, which shows that all the optimized responses are better than those of test No. 1 of Tab. 1 in overall view and the optimal configuration is close to test No. 1.

3.2 Maximizing Conversion Rate with Constraints of Desirable Thermal Activity

Myers raised a problem of maximizing conversion rate with constraints of desirable thermal activity [6]. The experiment considers three input variables, i.e., reaction time x_1, temperature x_2 and percentage of catalyst x_3, and two response variables, conversion rate y_1 (%) and thermal activity y_2 (W·s$^{0.5}$/(m^2·K)) using a central composite design with six central runs. The data are cited and shown in Tab. 3.

Table 3 Experimental results of maximizing conversion rate with constraints of desirable thermal activity

No.	Input Variables			Response Variables	
	Reaction time x_1 / min.	Temperature x_2 / °C	Catalyst x_3 / %	Conversion rate y_1 / %	Thermal activity y_2 / W·s$^{0.5}$/(m^2·K)
1	45	48	0.682	74	53.2
2	55	48	0.682	51	62.9
3	45	58	0.682	88	53.4
4	55	58	0.682	70	62.6
5	45	48	2.682	71	57.3
6	55	48	2.682	90	67.9
7	45	58	2.682	66	59.8
8	55	58	2.682	97	67.8
9	41.59	53	1.682	76	59.1
10	58.41	53	1.682	79	65.9
11	50	44.59	1.682	85	60
12	50	61.41	1.682	97	60.7
13	50	53	0	55	57.4
14	50	53	3.364	81	63.2
15	50	53	1.682	81	59.2
16	50	53	1.682	75	60.4
17	50	53	1.682	76	59.1
18	50	53	1.682	83	60.6
19	50	53	1.682	80	60.8
20	50	53	1.682	91	58.9

Table 4 The evaluated results of partial and total favourable probabilities for the maximizing conversion rate with constraints of desirable thermal activity

	Response variables		Favourable probability		
No.	y_1	y_2	P_{y1}	P_{y2}	$P_t \times 10^3$
1	74	53.2	0.0473	0.0585	2.7648
2	51	62.9	0.0326	0.0584	1.9028
3	88	53.4	0.0562	0.0585	3.2879
4	70	62.6	0.0447	0.0585	2.6142
5	71	57.3	0.0453	0.0585	2.6527
6	90	67.9	0.0575	8.4559E-05	0.0049
7	66	59.8	0.0421	0.0585	2.4659
8	97	67.8	0.0619	0.0001	0.0064
9	76	59.1	0.0485	0.0585	2.8396
10	79	65.9	0.0504	0.0055	0.2772
11	85	60	0.0543	0.0585	3.1758
12	97	60.7	0.0619	0.0585	3.6242
13	55	57.4	0.0351	0.0585	2.0549
14	81	63.2	0.0517	0.0583	3.0139
15	81	59.2	0.0517	0.0585	3.0264
16	75	60.4	0.0479	0.0585	2.8022
17	76	59.1	0.0486	0.0585	2.8396
18	83	60.6	0.0531	0.0585	3.1011
19	80	60.8	0.0511	0.0585	2.9890
20	91	58.9	0.0581	0.0585	3.4000

As to this problem, it involves complex optimization for conversion rate y_1 (%) as a beneficial performance index, and the thermal activity y_2 as desirable response index by $50 \le y_2 \le 65$ W·s$^{0.5}$/(m^2·K) and as close to 57.5 W·s$^{0.5}$/(m^2·K) as possible. Therefore, the partial favourable probability for conversion rate y_1 could be evaluated by the assessment for beneficial type variable proposed in [1], and partial favourable probability for the thermal activity y_2 should be evaluated by the assessment methods developed in the last section for one range desirability problem. The evaluated results of partial and total favourable probabilities P_{y1}, P_{y2}

and P_t of this product experiment are shown in Tab. 4. Tab. 4 shows that the test No. 12 exhibits the maximum total favourable probability at first glance, so the optimal configuration might be around test No. 12.

The data in Tab. 4 is regressed, the fitted result for the total favourable probability is

$$\begin{aligned} &P_t \times 10^3 = -55.9337 + 2.3901x_1 - 0.1179x_2 + 7.0079x_3 - \\ &-0.0250x_1^2 + 0.0010x_2^2 - 0.2800x_3^2 + 0.0019x_1x_2 - \\ &-0.0355x_2x_3 - 0.0893x_3x_1, \\ &R^2 = 0.8166. \end{aligned} \quad (9)$$

P_t gets its maximum value $P_{tmax} \times 10^3 = 3.657$ at $x_1 = 48.525$ min., and $x_2 = 61.41$ °C, and $x_3 = 2.473\%$.

While, the fitted result for the conversion rate y_1 is

$$\begin{aligned} &y_1 = 497.1314 - 0.7916x_1 - 14.5965x_2 - 49.0071x_3 - \\ &0.0733x_1^2 + 0.1175x_2^2 - 5.1915x_3^2 + 0.0850x_1x_2 - \\ &-0.7750x_2x_3 + 2.2750x_3x_1, \\ &R^2 = 0.9199. \end{aligned} \quad (10)$$

The conversion rate y_1 gets its optimal value $y_{1opt} = 94.337$ % at $x_1 = 48.525$ min., and $x_2 = 61.41$ °C, and $x_3 = 2.473\%$.

The fitted result for the desirable thermal activity y_2 is

$$\begin{aligned} &y_2 = 73.4856 - 1.7884x_1 + 0.4035x_2 - 0.9000x_3 + \\ &+0.0334x_1^2 + 0.0030x_2^2 + 0.05716x_3^2 - 0.0155x_1x_2 + \\ &+0.0625x_2x_3 - 0.0075x_3x_1, \\ &R^2 = 0.8918. \end{aligned} \quad (11)$$

The desirable thermal activity y_2 gets it optimal value $y_{2Opt} = 57.545$ W·s$^{0.5}$/(m^2·K) at $x_1 = 48.525$ min., and $x_2 = 61.41$ °C, and $x_3 = 2.473\%$.

Above optimal results meet the requirements of the original intention of the problem, which shows that all the optimized responses are more proper than those of test No. 12 of Tab. 3 comprehensively and the optimal configuration is not far from test No. 12.

4 CONCLUSION

From above discussion, the partial favourable probability of the desirable response variable of the test is evaluated, according to the type of "one side desirability problem" or "one range desirability problem" and the requirements of desirable response properly. The regression analysis for the total favourable probability and response variables provide the optimal configuration of the optimal test with desirable response variable, which corresponds to the maximum of the total favourable probability. The application examples of the intersection method for multi-objective optimization in optimal test designs of maximizing yield with constraints of viscosity and molecular weight and the maximizing conversion rate with constraints of desirable thermal activity present satisfied results, which indicate the validity of the assessment.

Conflict Statement

There is no conflict of interest.

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Big Data Analytics Changes in Health Care Industry

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Abstract: The present research is to find out the information, which are related with big data analytics in health care industry. It enhances the electronic health and electronic medical records in hospitals. Many medical services are experiencing a drastic change in maintaining the medical records in health care industry. Big data analytics is the primary factor that combines many bits of information together to focus on maintaining medical records in a systematic manner. A proper practice of documentation helps and assists the medical procedure easier. There is always a life cycle in maintaining medical records in the health care industry. The study covers the changes that are been implemented and changed the methods of maintain health care records in the private hospitals. Big data analytics is facing many challenges in enhancing the utilization of big information in a simple manner. The investigation contributes on advanced wellbeing rehearses by investigating the appropriate adaption of scientific instruments to EHRs to shape the significant utilization of large information examination with EHRs. The majority of hospitals suffer from inefficient service of big data analytics with electronic health records (EHRs) to develop high-quality understandings for their clinical preparations. Marking on the knowledge-based perspective and massive data lifecycle, this article attempt to explore how the three knowledge modes are able to attain consequential usage of huge data analytics with EHRs. To experiment with the offered model, we analyzed five hundred and eighty Chinese nurses of a big hospital over the year 2019. Structural equation modeling was utilized to investigate connections between the meaningful use of EHRs and the knowledge mode of EHRs. The study's outcomes reveal that know-what regarding EHRs use, know-how EHRs storage and utilization, and know-why storage and utilization is able to enhance nurses' meaningful use of big data analytics with EHRs.

Keywords: Big Data Analytics; Health Care Industry; Health Records; Hospitals

1 INTRODUCTION

Even as the possible for giant data analytics in medical care has been all around recorded in innumerable examinations, the potential dangers that might emerge out of making use of these contraptions have gotten the same quantity of consideration. Big information analytics innovations have shown their warranty in upgrading specific areas of care [1]. Those estimations are able to increase the proficiency of care conveyance, shrink authoritative weights, and velocity up illness discovering. Whatever the multitude of good these devices would really attain, the mischief these calculations could result in is practically as exceptional, concerns concerning data entry and assortment, verifiable and unequivocal predisposition, and concerns with sufferer and provider religion in analytics improvements have hinder the use of those tools in standard medical care conveyance. Clinical offerings experts and supplier associations endeavour to become aware of solutions for these disorders, working with the utilization of enormous information analytics in scientific consideration for healthier excellence and outcome. As hospital treatment associations become steadily elegant on analytics calculations to aid them choose care alternatives, it is most important that these apparatuses be liberated from precise or unequivocal inclination that would additionally power wellness imbalances.

"We are not elevating the best way to regulate precision versus segregation. We are no longer announcing what the proper meanings of affordable or risk-free are. We will likely let the person that could be an expert in that area select [1]". Tremendous data in hospital treatment and remedy alludes to that unique significant and multifaceted knowledge, which they are hard to investigate and care for conventional programming or gear. Colossal data analytics shelters incorporation of various knowledge, knowledge best manage, investigation, displaying, translation and approval. Use of big knowledge analytics offers exhaustive knowledge finding from the available massive measure of information. Particularly, tremendous knowledge analytics in medicine and medical care empowers examination of the giant datasets from a big number of sufferers, determining bunches and connection between datasets, simply as growing prescient units exploiting data mining approaches. Huge data analytics in remedy and medical offerings coordinates investigation of some logical territories, for instance, bioinformatics, medicinal imagination, device informatics, clinical informatics and health informatics. An overview of enormous data gears in medical and hospital treatment foundations/associations is yielded.

2 FIVE WAYS BIG DATA IS CHANGING THE HEALTHCARE INDUSTRY

The Medical care area is blasting at a quicker rate and the need to oversee patient mind and enhance medications has expanded interchangeably. With the ascent in such necessities, more up to date advances are being received in the business. One such significant change that may occur later on is the utilization of tremendous information and Analytics within the scientific care area. As indicated by a Worldwide Data Enterprise (IDC) report supported via Seagate Innovation, it is tracked down that big data is projected to fill quicker in medical care than in areas like assembling, monetary administrations or media. It is assessed that the medical services data will encounter an accumulate yearly development rate (CAGR) of 36% through 2025. Here are 5 manners by which Big Data can help and change the whole situation of the Medical care area.

2.1 Health Tracking

Tremendous information and Analytics alongside the Internet of Things (IoT), is altering the manner in which one can follow different client insights and vitals. Aside from the

essential wearables that can distinguish the patient's rest, pulse, work out, distance strolled, and so forth there are new medical advancements that can screen the patient's circulatory strain, beat Oximeters, glucose screens, and that is just the beginning. The consistent observing of the body vitals alongside the sensor data assortment will permit medical care associations to keep individuals out of the clinic since they can distinguish potential medical problem and give care before the circumstance goes more regrettable.

2.2 Reducing Cost

Big Data can be an incredible method to save costs for emergency clinics that either finished or under book staff individuals. Prescient examination can help settle this issue by anticipating the confirmation rates and help with staff allotment. This will diminish the Pace of Speculation brought about by medical clinics and indeed help use their venture as far as possible. The protection business can set aside cash by sponsorship wearables and wellbeing trackers to guarantee that patients do not invest energy in the clinic. It can save hang tight occasions for patients, since the clinic will have sufficient staff and beds accessible according to the investigation constantly. Prescient analytics additionally helps cut expenses by lessening the pace of emergency clinic readmissions.

2.3 Assisting High-Risk Patients

On the off chance that all the medical clinic records are digitized, it will be the ideal data that can be gotten to comprehend the example of numerous patients. It can recognize the patients moving toward the emergency clinic more than once and distinguish their persistent issues. Such agreement will help in giving such patients better mind and give a knowledge into restorative measures to decrease their continuous visits. It is an incredible method to keep a rundown and beware of high-hazard patients and offer them tweaked care.

3 PREVENTING HUMAN ERRORS

A ton ordinarily it has been noticed that the experts will in general either endorse an off-base medication or dispatch an alternate medicine unintentionally. Such blunders, when all is said in done, can be decreased since Big Data can be utilized to investigate client data and the recommended drug. It can validate the data and banner potential strange remedy to diminish missteps and save lives. Such programming can be an incredible instrument for doctors who oblige numerous patients in a day.

4 ADVANCEMENT IN HEALTHCARE SECTOR

Aside from the current situation, Big Data can be an extraordinary advantage for progression in science and innovation. For Medical services, Man-made consciousness, for example, IBM's Watson can be utilized to surf through various data inside the space of seconds to discover answers for different sicknesses. Such headway is as of now in progress and will keep on developing with the measure of exploration gathered by Big Data. It will not just give exact arrangements, yet additionally offer redid answers for remarkable issues. The accessibility of prescient examination will help patients making a trip to a specific geological area by contemplating comparable patients around there.

5 BIG DATA ANALYTICS FOR HEALTHCARE

5.1 Electronic Health Records

Electronic wellbeing records are considered as the cutting edge and the advanced adaptation of the wellbeing data framework, which gives data on sicknesses, past meetings and test results, the EHR permits patients and medical care experts to store, interaction and offer electronically medical data for the coordination of care. Through EHR frameworks, patient data is all the more effectively open to the various branches of medical services offices for different essential medical services frameworks [1]. From fundamental meetings to tests, diagnostics, inevitable subsequent assessments and treatment, medical services suppliers can rapidly have the correct data in the event of crisis. The blood classification, hypersensitivities, sicknesses, potential drugs or some other indispensable signs estimations, everything is concentrated and accessible initially.

5.2 Analytics for Healthcare

Consistently, many terabytes of data are created and amassed from different sources, e.g., web perusing, interpersonal organizations, versatile exchanges, web-based shopping and numerous others. In reality, the big data worldview has taken a used shape, and the plenitude of such organized and unstructured data has made it conceivable to be available to new points of view. These new wellsprings of data increment the odds of understanding one's conduct and inspirations, recognizing moment signals and triggers for somebody's advantage in a particular offer or item [5]. Getting significant bits of knowledge from voluminous and differed measures of data assists with comprehension and concentrate covered up data, which can be utilized and misused for the legitimate improvement of the clients' encounters. Heap field of studies are concerned and the medical care area is no exemption. Undoubtedly, the examination of wellbeing data can help the improvement of the nature of care for an entire populace, anticipate new pestilences and guarantee equivalent admittance to really focus on everybody. While wellbeing analytics is addressed as perhaps the main advances in e-wellbeing, their legitimate arrangement and joining to EHRs is not just about as straightforward as it appears.

5.3 Evaluating the Industry’s Integration of Analytics within EHRs

The way toward executing an EHR framework is not, at this point a test for wellbeing professionals however much it

is the situation for improving analytics and acquiring significant bits of knowledge [1]. To open the estimation of analytics over EHRs, we need to reveal insight exactly on the difficulties and issues that confine their appropriate selection.

5.4 Different Solutions, Supplementary Tasks?

The computerization of wellbeing data frameworks has brought a gigantic advancement for various partners, from essential EMRs, EHRs to big data analytics, the wellbeing area has developed immensely. However, at present, we note that the presence of a huge number of arrangements that reacts to the need of big data in the wellbeing area has additionally produced a significant issue [5]. In other words, the reconciliation of these arrangements into medical bodies pushes doctors to zero in more on their collaboration with machines instead of with their patients. Alongside that, having the information and an opportunity to produce medical notes, dissect history reports and adding additional movements, can here and there be tedious particularly if the considered EHR and its additional items are muddled and not natural. Hence, this makes it hard to embrace new arrangements by doctors and to connect more endeavours in each new item.

5.5 Priorities Engagement toward Analytics

The understanding of big wellbeing data is not restricted to a solitary methodology or model. In the event that illustrative analytics might be valuable now and again, in others, prescient analytics will be more helpful. For medical clinics, centres or other wellbeing organizations, the danger can be available, in the event that they centre around independent applications all along, when truth be told they need to embrace an earlier vision of what may come straightaway. Various kinds of logical devices can be utilized relying upon the unique circumstance and the business challenges [1]. In this vein, needs commitment ought to be resolved shrewdly to execute an interoperable stage, which can get various arrangements as, required [4]. It ought to be noticed that big wellbeing data analytics frequently have a prescient reason: as it were, the utilization of significant prescient insightful devices makes it conceivable to discover the fix before individuals are influenced by a particular sickness. In this sense, prescient analytics critically affect patients' life. In this way, starting operational activities, by giving top to bottom information on the design and nature of the connections among people and cycles, finally by proposing models that produce client characterized results.

5.6 Paid, Free or Open-Source Vendors?

Carrying out an EHR or EMR framework can be extremely exhausting. Truth be told, various boundaries and determinations ought to be intervened to convey a clinical electronic system ready to store, measure and break down data in a powerful way. Perhaps the most depleting choices to make is, regardless of whether the medical services association is prepared to contribute significant expenses for paid EHRs or just thinking about free and open-source arrangements. In the present circumstance, research contemplates are led to list all current open source EHRs [5]. The point is to give the attributes of every stage and raise the fundamental difficulties that make a hindrance to their inescapable appropriation. For the most part, the issues experienced in these frameworks is identified with the steady need of programming designers or experts, who will help in adjusting the EHR to the concerned wellbeing foundation. Besides, most of them cannot offer interoperability and adaptability, because of a late coordination of the big data innovations to their inheritance models [4].

Concerning paid stages, they can be interesting to pick, considering the training size and workers' executions, a few associations have effectively pushed toward cloud-based frameworks. Free EMRs are additionally thought to be in certain circumstances for little practices, which give just hardly any intuitive wellbeing modules. Picking between free, open source or paid EHR frameworks significantly affects the advancement interaction of any medical association [5]. The time of big data is pushing specialists to think and decide on a wide vision confronting what has to come. Monitoring what these kinds of stages can give, in a global idea, will assist with having an advancing framework that can reacts to the necessities of analytics.

6 TENDER OF FOG COMPUTING IN MEDICAL DATA ANALYSIS

With the nonstop development of medical business, extending the dimensions of clinical information and the expanding esteem, the concept of medical colossal data has developed the target of numerous experts and researchers. however, the sheer dimension of clinical enormous data, the normal stockpiling design are not able to deal with the issues, and the upward thrust of distributed computing gives a best reply for the scientific healing of huge data stockpiling and get in touch with [2].

By using various capacities, scientific mist stage is isolated into 5 sections: dispensed storage data obtaining layer, knowledge stockpiling layer, knowledge mining layer, endeavour database, and utility layer. Each element can form a free kid cloud. Knowledge mining coating and utility coating share utilizing data stockpiling coating [4].

All of the ingredients of the medical cloud platform are particular as follows:

Data acquisition layer: The capacity configuration of medical enormous data is assorted, including the organized and shapeless or semi-organized data. Therefore, data procurement layer needs to gather data in an assortment of arrangements. Additionally, medical cloud stage and different medical frameworks are required for cropping and perusing data from the comparing interface. Because of the recent social programming and organization quick turn of events, consolidating medical and informal communication is the pattern of things to come. Thus, it is fundamental for gather these data. At last, data securing layer will receive sets of various configurations of data handling, to zero in on capacity [5].

Data storage layer: the data-stockpiling layer provisions all knowledge of the scientific cloud stage belongings. Distributed storage coating data will embrace

stage mannequin for engineering and union the data gathered from information procurement layer and square for potential.

Data mining layer: information mining is the major piece of medical cloud stage, which complete the information mining and examination work over the laptop bunch engineering. Utilizing the evaluating knowledge mining calculations, data mining layer discovers knowledge from the info in information stockpiling layer and venture database and retailer the outcome in data stockpiling layer. Knowledge mining layer can likewise have an impact on claim layer using its burrowing rubrics and expertise through approaches for illustration.

Enterprise database: Clinical foundations require precious, tremendous limit of disbursed storage yet moreover excessive ongoing and excessive secrecy to local ability of information. These would require the enterprise database. endeavour database wants collaboration with data allotted storage layer and the data mining layer in knowledge, and it'll give the info to the appliance layer for show

Application layer: The soft layer is in particular organized to the requisites of customers and highlights information either specified or determined by means of data mining.

7 SUGGESTIONS

Here, we present a summed-up part of suggestions for the two analysts and clinicians, to drive the great selection and mix of analytics to EMRs [5]:

- Drive research towards the proposition of interoperable arrangements, in light of medical services principles e.g., Open EMR, HIPAA and Wellbeing Level.
- Depending on normalized arrangements as Open EMR permits having a division between the reference model and the prime example information.
- Propose new logical arrangements, in view of big data stages and environments, which are broadly received as Hadoop and Sparkle.
- The abilities of a Clinical Choice Emotionally supportive network cannot be achieved if the CDSS is not as expected related to an Electronic Wellbeing Record framework.
- There is no need of proposing excess prescient models. The point is to incorporate the current investigations into medical bodies to test their proficiency and present their joining interaction technique.
- Since analysts should react to unequivocal necessities of logical frameworks to improve their appropriations, clinicians likewise have a portion of duty in this matter. Indeed, they should aid right off the bat bringing extreme difficulties faced up in the wellbeing industry, and besides giving to the examination writing insights concerning all the clinical information, which will be misused to help the medical services local area.

The various difficulties experienced during the execution of the EHRs just as their relationship to wellbeing scientific frameworks. In this sense, we followed an execution of an Open EMR based EHR to characterize decisively the mediator modules that require exceptional core interest [2]. In other words, EHRs dependent on worldwide principles, are bound to be received broadly because of their interoperable abilities. Specialists likewise need to consider the appropriation of a structure dependent on big data stockpiling and handling advancements to achieve elite potential. Whenever this is regarded, distinct, prescient or prescriptive analytics can be consolidated effectively to get substantial huge bits of knowledge from the EHRs data.

8 CONCLUSION

"There exist several barriers that seemingly ban complete automation in Medical record settings, such as obstacles of accountability and trust." "We are hoping that the presented technique can encourage machine learning practitioners to become extra innovative in incorporate real-time human being expertise into their algorithms [2]." With healthcare businesses continuously leveraging large skills analytics instruments for more desirable perspectives and streamlined care approaches, surmounting disorders of privacy, bias, and protection, and user consider probably primary for the confident use of those models in medical care. As be taught carries on to transform round AI, computer discovering out, and other analytics algorithms, the industry maintains refining those instruments for accelerated sufferer care [4].

"Conventional techniques of machine learning need a centralized database where patient data is instantly accessed for preparing a machine learning model [5]." "those strategies are affected by practical cases, including information security, data ownership, patient privacy, and the load on hospitals which should develop and sustain those centralized databases." The reward healthcare hindrance has additionally caused healthcare leaders to increase satisfactory, delicate datasets for algorithm growth [2]. In March, the White residence workplace of Science and science protection issued a call to action for professionals to construct AI tools that may be utilized to a brand new COVID-19 dataset.

9 FUTURE PROSPECTS

The joining of computational frameworks for signal managing from both rehearsing and exploration medical experts has undergone improvements. Consequently, building up a point-by-point model of a human body by consolidating physiological data and "omics" procedures can be the following big objective [2]. This one-of-a-kind thought can improve our insight into illness conditions and perhaps help in the advancement of novel demonstrative instruments. The constant rise in attainable genomic data, such as innate concealed blunders from explore and logical practices need extra contemplation [4].

High volume of medical data assemble through heterogeneous stages has place a test to data researchers for cautious reconciliation and execution. As a result, it is suggested that transformation in medical care is increasingly anticipated to gather bioinformatics, wellbeing informatics and analytics to progress therapies that are more successful. Moreover, new systems and innovations ought to be created to comprehend the nature (organized, semi-organized, unstructured), intricacy (measurements and traits) and

volume of the data to infer significant data. The best resource of big data lies in its boundless prospects [2]. The birth and joining of big data inside the previous few years has acquired generous progressions the medical care area going from medical data the executives to tranquilize revelation programs for complex human illnesses including disease and neurodegenerative issues.

To cite a straightforward model supporting the expressed thought, since the last part of the 2000′s the medical care market has seen progressions in the EMR framework concerning data assortment, the executives and ease of use. We accept that big data will add-on and reinforce the current pipeline of medical services progresses as opposed to supplanting talented labour, subject information specialists and learned people, an idea contended by many [4]. One can plainly see the changes of medical services market from a more extensive volume base to customized or singular explicit area [2]. Hence, it appears vital for experts and technologists to grasp this developing condition.

This would mean forecast of modern results in a person's wellbeing state dependent on current or existing data, (for example, EMR-based) [4]. Likewise, it can likewise be assumed that organized data got from a specific geology may prompt age of populace wellbeing data. Taken together, big data will encourage medical services by presenting expectation of pestilences (corresponding to populace wellbeing), giving early admonitions of infection conditions, and aiding in the revelation of novel biomarkers and insightful remedial mediation systems for an improved personal satisfaction.

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Factors Affecting Knowledge Sharing in the Administrative Work Environment

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Abstract: The study aims at contributing in identifying the factors affecting the sharing of knowledge in the administrative work environment, starting from realizing the concept of knowledge sharing among administrators in the various administrative sectors of the university, identifying their opinions, attitudes, behaviors and practices towards sharing knowledge in the work environment, and depicting the expected benefits of sharing knowledge at the university. It relied on the descriptive approach using the survey method, where an electronic questionnaire was distributed to a random sample of administrators within the University. The study concluded that the most influential demographic data on Knowledge sharing is the employee's years of experience, the more the experience increases, the more knowledge sharing will be. The study attributes this result to trust and its impact on work practice. The cognitive type of knowledge that administrators share most is modern information, administrative processes and procedures, and social activities. The study also revealed that sharing knowledge pushes them towards positive relationships that bind the employee with other administrators working at the university and finding strong relationships with employees who have common jobs and relationships depending on trusting others led to increased knowledge sharing. Moreover, sharing administrative knowledge increases productivity within the university, supports innovation among administrators, helps develop university work procedures, and increases the efficiency of employee's cooperation, and helps colleagues within the university work to find solutions to problems and that the university's organizational culture promotes knowledge sharing among administrators, and a culture of teamwork. The study indicated that the most relevant applications that help administrators share knowledge are specialized training programs, work teams and groups of practice in the same profession.

Keywords: administrative staff; knowledge management; knowledge sharing; organizational culture; practice groups

1 INTRODUCTION

Knowledge sharing is one of the challenges facing organizations as its application leads to accelerating the learning process at the individual and institutional levels, increasing innovation and developing individual and institutional performance. From this standpoint, organizations seek to share knowledge and urge employees to share their experiences and skills.

Since universities are a dynamic repository of human knowledge and work to generate new knowledge, transfer it to society, and have a key role in generating economic development, they need to manage their knowledge assets. The International Conference on Administrative Development held in Riyadh in 2009 entitled "Towards a Distinguished Performance of the Governmental Sector" affirmed the necessity of transforming organizations into knowledge-based organizations in light of the absence of a clear methodology and insufficient attention to knowledge management. In light of these changes, it was necessary for universities to meet these challenges to search for modern management methods that would enable them to maintain continuity and increase their ability to achieve their goals efficiently. Thus, emerged the concept of knowledge management that is concerned with valuable information and constitutes a necessary resource for the sustainability of the organization and the development of its performance.

Indeed, one of the most important methods of applying knowledge management in organizations is the process of sharing knowledge, which enables employees to transfer their knowledge and experiences between each other. Moreover, and through the review of the literature and previous studies on the topic, the researcher noticed that the studies focusing on studying the concept of knowledge sharing and the opinions of administrative staff and their attitudes towards it at King Abdulaziz University are limited and insufficient. Henceforth, and proceeding from the importance of sharing knowledge among administrators, which is one of the most important priorities that should be taken into consideration in the application of knowledge management among employees to raise their performance levels at work and increase their effectiveness and sometimes achieve renewed innovations, the importance of the study came from the importance of applying knowledge management in the university. This application seeks, in light of rapid developments in the knowledge and technical aspects, to make the most of its internal capabilities and obtain competitive advantages through university administrators. Also, the importance of studying knowledge sharing lies in how employees can produce their knowledge and ideas and put them into practice, or work to improve and develop their attitudes and opinions towards knowledge sharing and help decision makers to design knowledge management systems based on the employment of positive factors in knowledge sharing. Accordingly, the study dealt with the concept of knowledge management and sharing among administrators in the various administrative sectors of the university at the level of operational management. The objectives are to identify their opinions, attitudes, behaviors, and the expected benefits of sharing knowledge among them in the university as well as the impact of joint administrative tasks and organizational culture on knowledge sharing and the influence of institutional affiliation and practical practices among administrators that helps to share knowledge. This prompted the researcher to address this problem and search for the factors affecting knowledge management and sharing as a contemporary concept in enhancing administrative tasks in King Abdulaziz University in Jeddah.

2 STUDY METHODOLOGY AND DATA COLLECTION TOOLS

The study procedures were as following:

- The study relied on the descriptive approach using the survey method which field nature helps to explain the phenomenon in its reality and is useful for collecting different impressions about the sharing of knowledge in the work environment for all male and female administrative employees in the two campuses. The size of the retrieved random sample was 262 employees, consisting of 199 female employees and 62 employees. The study relied on the questionnaire as a tool for collecting its necessary data. The study seeks to obtain information related to the reality of knowledge sharing among administrators through a set of questions directed to the sample members to answer, analyze and come up with the results of the study.
- The data was unloaded using descriptive statistics and inferential statistics through the SPSS program for questions related to the study axes by using the chi-square test. This test aims at finding out whether there is a relationship between the scientific specialization and the questions related to the study axes. Spearman's correlation coefficient was also used for the questions related to the axes of the study, the aim of which is to find out whether there is a relationship between years of experience in the administrative field and questions related to the axes of the study, and the use of statistical analysis in order to answer the questions of the study.

3 PREVIOUS STUDIES

After reviewing the intellectual production, some studies related to the study were selected. The researcher will review some related studies as follows:

The study of Harb, Y., Zahrawi, A., Shehabat, I. and Zhang, Z. (J). 2012 [11] entitled "Managing knowledge workers in healthcare context: role of individual and knowledge characteristics in physicians' knowledge sharing", aims at revealing physicians' knowledge sharing in hospitals that is critical to providing better healthcare services. Despite the importance of knowledge sharing in the healthcare environment the authors drew on theories of personality traits and knowledge characteristics to develop a theoretical model for examining the influence of individual characteristics and knowledge characteristics on the knowledge-sharing behavior of clinicians. The study relied on a sample of 215 doctors from 20 hospitals in Jordan. The study revealed that personality traits (extroversion, neuroticism, agreeableness, and conscientiousness) significantly influence a clinician's intention to share knowledge. The knowledge property of balancing was also found to influence the intent to share knowledge. The study contributes to the relevant literature by empirically investigating how individual characteristics and knowledge characteristics influence the knowledge-sharing behavior of clinicians. The findings add to an understanding of the role of personality traits and characteristics of knowledge in clinicians' intention to share knowledge and give important insights to practice and theory.

The study of Yao, Crupi, Di Minin, and Zhang, X. (2020) [13], entitled "Knowledge sharing and technological innovation capabilities of Chinese software SMEs", which was based on theories related to knowledge management, technology of information and communication (TIC), Software Engineering and Open Innovation, built a research model that includes factors affecting knowledge sharing and TIC, then test the model quantitatively. The study focuses on SSMEs in China where 457 electronic questionnaires were collected.The results show that knowledge sharing culture, organizational structure, middle-level leadership and management system have significant positive effects on tacit knowledge sharing. The management system and IT support have significant positive effects on explicit knowledge sharing. Both explicit and tacit knowledge sharing have significant positive effects on TIC. However, it does not take into account the factors that influence knowledge sharing at the non-organizational level or the interaction between explicit and tacit knowledge sharing.

The study of Zebardast, Farahmand, Mehrdad, Hossein, & Jalili, Razieh (2020) [14] entitled "Detecting Factors Effective in Knowledge Sharing Model Among Educational Staff" showed that the Ministry of Education is one of the effective agencies in implementing economic, social and cultural development policies in every country, as it trains specialized and experienced manpower as a basis for the comprehensive development of countries, producing knowledge and research knowledge, and providing specialized services by universities and higher education centers. Accordingly, it facilitates the exchange of knowledge and the identification of factors affecting it in the educational institution, especially among the employees of any organization because it can create an atmosphere full of trust and interaction. The study aimed to identify the factors that influence the knowledge exchange model in the individual, organizational and external environmental dimensions among faculty members. The descriptive analytical approach was used, and the study revealed that the main individual dimension includes enjoyment of knowledge sharing, organizational commitment, specific organizational knowledge, trust, motivation, value of knowledge, and individual and group interactions. The organizational dimension also includes organizational culture, document development, internal planning, and organizational rewards. The environmental dimension includes technical knowledge, information technology context, upgrading of cognitive memory, and economic and social factors.

The study of Ahmed and Karim (2019) [9] entitled "Impacts of knowledge sharing: a review and directions for future research" aimed at summarizing the results of previous research on the reflections of knowledge sharing in organizations and to suggest promising directions for future research. It was based on a systematic review of the literature. The substantive analysis of 61 studies led to the development of a framework outlining the effects of knowledge sharing as well as future guidelines of research. The study concluded that the research examined the results of knowledge

exchange at the three levels of the individual, the team, and the organization. The specific effects of each level are summarized. The most commonly studied factors influencing knowledge sharing are creativity, learning, and performance. It also found that knowledge sharing has some effects beyond the work tradition, such as that affecting team climate and employee life satisfaction. The study showed the dominance of quantitative studies over research on the results of knowledge exchange. It suggested conducting more research and studies on the disparate, psychological and negative effects, as well as the interactive and methodological aspects of knowledge sharing.

The study of Yahya, 2018 [8] came to show the characteristics of a culture of knowledge sharing in organizations and how it can be built and developed to enhance knowledge management. It revealed that the internal culture that is resistant to sharing knowledge represents the strongest obstacles to be overcome when applying knowledge management. Changing this culture into a knowledge-sharing culture requires years of effort directed to the organizational, social, administrative and technical elements of behavior. It is a multi-stage change process that begins with focusing on key employees who possess the information and communications necessary for their jobs and encouraging interaction, communication and feedback among team members as well as the organization's realization that knowledge sharing behavior is necessary through training, incentives, usability, and focus on value-added activities. Indeed, when knowledge becomes an effective element of efficiency, the organization will focus on its sharing in all areas of the organization's work, and thus the organization promises that it has a culture of conscious knowledge dissemination.

The study of Andam, & Rezaian (2017) [10] entitled "The impact of Knowledge Management Pillars on Knowledge Sharing" revealed the relationship between the pillars of knowledge management and knowledge sharing among the employees of the Ministry of Cooperatives, Labor and Social Welfare in order to identify the elements of the pillars that have the greatest impact on knowledge sharing. The data was collected from 258 cooperative ministries through a questionnaire, and the workplace and social welfare experts were explored. One of the most important results is the improvement of knowledge exchange between human resources in order to maintain sustainable development in addition to building the nucleus of the knowledge management system from the elements that were classified under four pillars, noting the main elements of the knowledge management system. The study showed that the respondents' gender, age, position, education and experience had no significant effect on their knowledge sharing. The pillars of knowledge management include leadership, organization, learning and technology that have a meaningful and positive impact on knowledge sharing. Among the 18 components of these pillars, the six elements of "a place in an office with colleagues", "based on a relationship of trust", "informal relationship", "a knowledge-sharing reward system", "availability of organizational knowledge bases" and "ease of use of knowledge sharing techniques" had the greatest impact on knowledge sharing.

4 DISCUSSION

The study presents a description and analysis of data using statistical methods that help to interpret the results in a scientific way and take appropriate decisions based on the statistical indications that were extracted from the questionnaire distributed to the study sample.

Demographic data: Frequencies and percentages of the gender variable were calculated as shown in Tab. 1.

- Distribution of answers according to the gender variable:

Table 1 The study sample Gender distribution

Gender	Number	Percentage
Male	63	24.05%
Female	199	75.95%
Total	262	100%

It is evident from Tab. 1 that the total number of female employees reached 199, representing 75.95% of the total study sample, in contrast to the number of 63 employees, at a rate of 24.05%, showing that the percentage of female employees is higher than males.

- Distribution of answers according to the variable of scientific specialization:

Table 2 Distribution of the study sample according to the variable of scientific specialization

Scientific specialization	Number	Percentage
Management and economy	73	28.24%
Arts and Humanities	67	25.57%
Sciences	49	18.71%
Information technology	33	12.59%
Human sciences and designs	11	4.19%
High school	9	3.43%
Medical sciences	7	2.67%
College of Communication and Media	2	0.76%
Building	2	0.76%
Geology	2	0.76%
Laboratory	2	0.76%
Middle	2	0.76%
Fitness	1	0.38%
Engineering	1	0.38%
Natural therapy	1	0.38%
Total:	262	100%

It is clear from Tab. 2 that most of the administrative staff included in the study sample had their scientific specializations in management and economics with a rate of 28.24% and their number was 73, while the number of arts and humanities was 25.57% and their number was 67, and the least response was for those who are specialized in communication and media with a percentage of 0 .76% and their number was 2, then come other specialties in varying proportions, as is clear in the table.

- Distribution of answers according to years of experience in the administrative field:

It is clear from the Pie chart Fig. 1 that one third of the study sample has years of experience in the administrative field between 11 to 15 years, at a rate of 33.59%, and their number was 88, followed by those who had between 6 to 10 years at a rate of 20.99%, and their number was 55. Then come those who have more than twenty years at a rate of 19.85% and their number was 52, then from 16-20 years at a rate of 18.70% and their number was 49, then less than 2-5 years at a rate of 6.49% and their number was 17, then a year with a rate of 0.38 % which represents one person.

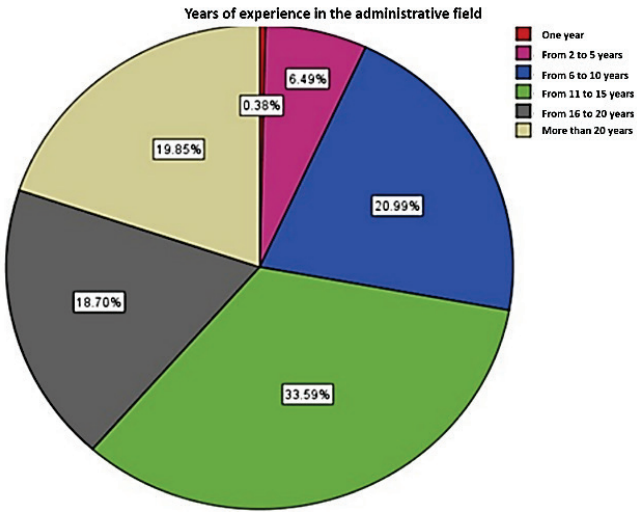

Figure 1 Distribution of the study sample according to years of experience in the administrative field

- Distribution of answers according to the titles of administrative jobs:

Table 3 Titles of Administrative Jobs

Job Title	Employees' Number	Percentage
Administrative assistant	86	32.82%
laboratory technician	33	12.60%
IT employee	28	10.69%
management specialist	15	5.73%
Head of Administration	12	4.58%
admin assistant supervisor	12	4.58%
Head of unit	12	4.58%
Accountant	10	3.82%
Scientific statistics researcher	10	3.82%
Typist	7	2.67%
Housing Supervisor	7	2.67%
Office Director	6	2.29%
Warehouse guard	6	2.29%
Systems Analyst	6	2.29%
Psychologist	5	1.91%
Admission and registration coordinator	4	1.53%
Security surveillance	3	1.15%
Total:	**262**	**100.00%**

We notice from Tab. 3 the diversity of job titles for the study sample, where the administrative assistant represents 33.0% and represents 86 employees, followed by laboratory technicians with 12.60%, then 28 information technology employees with a rate of 10.69%.

- Distribution of answers according to the perception of the concept of knowledge management and sharing by administrators:

From Tab. 4, it is clear that the concept of administrators for knowledge management and sharing in general is high. For them, this means to exchange knowledge and experiences with others, where the percentage of approval of the concept was 96.2%, and also that their participation in knowledge means for them an interactive process of transferring knowledge among participants to sort new knowledge coming with a rate of 95.8%, and it also means for the majority that it is the acquisition and sharing of collective experiences by 91%, followed by the fact that knowledge is the acquisition of information through experiences and expertise by 87%, and the lowest approval rate came by 55% that knowledge is power and strength in light of the current development. This shows the awareness and clarity of the concept of knowledge and its participation among the study sample.

Table 4 Distribution of answers according to the perception of the concept of knowledge management and sharing by administrators

	Scale	Disagree	Neutral	Agree
Knowledge is the acquisition of information through experiences and expertise.	Frequency	10	24	228
	Percentage	3.8%	9.2%	87.0%
Sharing knowledge means exchanging knowledge and experiences with others.	Frequency	4	6	252
	Percentage	1.5%	2.3%	96.2%
Knowledge is power and strength in the current development.	Frequency	67	51	144
	Percentage	25.6%	19.5%	55.0%
Knowledge management is the acquisition and sharing of collective experiences	Frequency	5	20	237
	Percentage	1.9%	7.6%	90.5%
Knowledge sharing means an interactive process of transferring knowledge between participants to sort out new knowledge	Frequency	2	9	251
	Percentage	0.8%	3.4%	95.8%

- Distribution of answers according to the types of knowledge shared by university administrators:

Tab. 5 shows the nature of knowledge shared by university administrators. 223 employees from the study sample expressed their involvement in sharing knowledge in modern information at a rate of 85.1%, which is the highest percentage of the types of knowledge sharing, while 219 administrative employees share their knowledge of administrative processes and procedures by 83.6%.

Table 5 Distribution of answers according to the types of knowledge shared by university administrators

	Scale	Disagree	Neutral	Agree
up-to-date information	Frequency	11	28	223
	Percentage	4.2%	10.7%	85.1%
Administrative processes and procedures	Frequency	14	29	219
	Percentage	5.3%	11.1%	83.6%
Social activities	Frequency	13	39	210
	Percentage	5.0%	14.9%	80.2%
Courses (for enrolled students)	Frequency	26	87	149
	Percentage	9.9%	33.2%	56.9%
Postgraduate research activities	Frequency	33	87	42
	Percentage	12.6%	33.2%	54.2%

As for knowledge sharing among administrators in the field of social activities, it numbered 210 administrative employees, at a rate of 80.2%. The sharing of knowledge among administrators about academic courses (for those enrolled in the study), the percentages ranged between supportive by 57% and neutral by 33.2%, and in the last place came knowledge sharing among administrators in the field of research activities related to postgraduate studies as the number of administrators who support sharing their knowledge reached 142 employees by 54.2%.

- Distribution of answers according to the attitude and behavior of administrators towards knowledge sharing:

Table 6 Distribution of answers according to the attitude and behavior of administrators towards knowledge sharing

	Scale	Disagree	Neutral	Agree
I spent a lot of time and effort learning what I know and would not share it with others.	Frequency	213	19	30
	Percentage	81.3%	7.3%	11.5%
Sharing knowledge with others helps to grow and share experiences.	Frequency	1	9	252
	Percentage	0.4%	3.4%	96.2%
I do not trust others and therefore I will not share what I know with them.	Frequency	69	67	126
	Percentage	26.3%	25.6%	48.1%
Sharing knowledge with others fills the gaps in my knowledge and makes me an expert	Frequency	7	36	219
	Percentage	2.7%	13.7%	83.6%
I want to share knowledge at all levels of the university	Frequency	3	17	242
	Percentage	1.1%	6.5%	92.4%

Tab. 6 shows the attitude of administrators and their behavior towards knowledge sharing at the university. 213 employees who were included in the study indicated that they do not agree with the phrase "I spent a lot of time and effort learning what I know and will not share it with others" with a percentage of 81.3%, while 30 employees agreed with it by 11.5%. About 252 employees, or 96.2%, considered that sharing knowledge with others helps growth and exchange of experiences. 242 employees also stated their desire to share knowledge at all levels at the university, at a rate of 92.4%. The majority of the study sample also agreed that "sharing knowledge with others fills the gaps in my knowledge and makes me an expert" with 219 employees, at a rate of approximately 84%, while 36 of them were neutral by 14%. The study sample showed a difference in their attitudes about "I do not trust others and therefore I will not share what I know with them", as 126 employees(male/female) agreed with it at a rate of 48.1%, while 67 of them were neutral at a rate of 26%, and the same number of them did not agree.

Knowledge-sharing behaviors are influenced by two main elements: The first is the employees' attitudes based on tendencies towards knowledge sharing, and the second is personal standards of employees' perception of the way others respond in response to knowledge-sharing behavior. The degree of influence of trends in the process of knowledge sharing outweighs the degree of their influence on the process of knowledge gathering, and this shows the different trends at the different levels of knowledge sharing. Muhammad (2015). Often a positive environment supports knowledge sharing and vice versa, if it is negative, it will lead to stagnation and conflicts between administrators.

- Distribution of answers according to the opinions of administrators towards the advantages of sharing knowledge:

Table 7 Distribution of answers according to the opinions of administrators towards the advantages of sharing knowledge

	Scale	Disagree	Neutral	Agree
Sharing knowledge supports the relationships I have with other university administrators.	Frequency	2	16	244
	Percentage	0.8%	6.1%	93.1%
Sharing knowledge contributes to creating strong relationships with administrators who have common jobs at the university	Frequency	2	17	243
	Percentage	0.8%	6.5%	92.7%
Sharing knowledge supports my sense of merit and my sense of managerial superiority.	Frequency	3	23	236
	Percentage	1.1%	8.8%	90.1%
Sharing knowledge contributes to my chances of working in higher positions.	Frequency	11	39	212
	Percentage	4.2%	14.9%	80.9%
Sharing knowledge multiplies the opportunities for promotions I look forward to.	Frequency	37	62	163
	Percentage	14.1%	23.7%	62.2%

Tab. 7 reveals the views of the administrators at King Abdulaziz University towards the advantages of knowledge sharing. Their opinions came as follows: 244 administrators, with a percentage of 93.1%, believe that knowledge sharing is the relationship that binds them with other administrators working at the university, and then came those who see that sharing knowledge contributes to creating strong relationships with administrators who have common jobs at the university, their number reached 243 administrators, or 93%. Then came those who think that sharing knowledge pervades a sense of aptitude and a sense of administrative superiority, and their number reached 263 administrators, at a rate of 90.1%. Then came those who believed that sharing knowledge doubled their chances of working in higher positions, and their number reached 212 at a rate of 81.0%, while 39 of them or 15.0%, were neutral. Finally, the administrators came with varying degrees of opinions about "the sharing of knowledge doubles the chances of promotions that S/he aspires to obtain." The number of those who agreed was 163 administrators, at 62.2%, the number of neutrals was 62 employees, at a rate of 24.0%, and the number of those who did not agree was 37 employees by 14.1%.

- Distribution of answers according to the opinions of administrators about the expected benefits of sharing knowledge at the university:

Table 8 Distribution of answers according to the opinions of administrators about the expected benefits of sharing knowledge at the university

	Scale	Disagree	Neutral	Agree
Sharing managerial knowledge with other colleagues within the university helps in working to find solutions to problems.	Frequency	2	15	245
	Percentage	0.8%	5.7%	93.5%
Employees become more and better able to cooperate with each other.	Frequency	1	13	248
	Percentage	0.4%	5.0%	94.7%
Knowledge sharing helps to develop the university's work procedures.	Frequency	1	13	248
	Percentage	0.4%	5.0%	94.7%
Sharing managerial knowledge increases productivity within the university.	Frequency	1	11	250
	Percentage	0.4%	4.2%	95.4%
Knowledge sharing supports innovation and creativity among administrators	Frequency	1	13	248
	Percentage	0.4%	5.0%	94.7%

From the above table, it is clear that sharing knowledge for university administrators has benefits, and there are many achievements and benefits that they believe resulting from activating the knowledge sharing process. The number of those who believe that sharing administrative knowledge with other colleagues within the university helps in working to find solutions to problems reached 245 employees/by 94%. In addition, the number of those who believe that sharing knowledge makes employees more able to cooperate with each other in a better way reached 248 employees, by 95%. While 248 employees or 95% approved that sharing, knowledge helps develop work procedures at the university. As for those who believe that sharing administrative knowledge increases productivity within the university, their number reached 250 employees, at a rate of 96%. Finally, 248 employees, at a rate of 95%, believe that sharing knowledge supports innovation and creativity among administrators.

- Distribution of answers according to the organizational culture at the university and the extent to which it enhances knowledge sharing among administrators:

Table 9 Distribution of answers according to the organizational culture at the university and the extent to which it enhances knowledge sharing among administrators

	Scale	Disagree	Neutral	Agree
The administrative unit environment promotes a culture of teamwork more than individual work.	Frequency	14	31	217
	Percentage	5.3%	11.8%	82.8%
The university undertakes measures that contribute to facilitating the exchange and sharing of knowledge between departments and administrative units between different sectors.	Frequency	33	59	170
	Percentage	12.6%	22.5%	64.9%
University governance regulations support knowledge sharing.	Frequency	7	93	162
	Percentage	2.7%	35.5%	61.8%
The university promotes a policy of knowledge sharing between departments and administrative units among various sectors.	Frequency	31	70	161
	Percentage	11.8%	26.7%	61.5%
The university helps administrators to trace knowledge wherever it is found without being bound by the barriers of organizational structures.	Frequency	55	76	131
	Percentage	21.0%	29.0%	50.0%

Tab. 9 reveals the university's organizational culture and the extent to which it enhances knowledge sharing among

administrators, as 217 employees, or 82.8%, believe that knowledge sharing enhances the administrative unit environment, a culture of teamwork more than individual work. While 170 employees (or 65%) agreed that the university is taking measures that contribute to facilitating the exchange and sharing of knowledge between departments and administrative units between various sectors. While the responses of administrators about supporting the university's governance regulations came with the approval of 162 employees, with a percentage of 62.0%. As for the phrase "the university promotes the policy of sharing knowledge between departments and administrative units between different sectors", the approval responses came from 161 employees, at a rate of 62.0%. The responses about "the university helps administrators to track knowledge wherever it is found without being bound by the barriers of organizational structures" came with the approval of 131 employees (by 50%), which requires the university to work to spread the organizational culture among administrators.

- Distribution of answers according to the institutional affiliation of administrators and its impact on knowledge sharing:

Table 10 Distribution of answers according to the institutional affiliation of administrators and its impact on knowledge sharing

	Scale	Disagree	Neutral	Agree
Sharing knowledge leads to an increase in the excellence and competitive value of the university.	Frequency	2	15	245
	Percentage	0.8%	5.7%	93.5%
Employee productivity increases as they share knowledge.	Frequency	2	16	244
	Percentage	0.8%	6.1%	93.1%
The participation of employees in setting the overall goals leads to motivating them and increasing their participation in knowledge.	Frequency	3	20	239
	Percentage	1.1%	7.6%	91.2%
Sharing knowledge contributes to fulfilling responsibilities, resolving disputes and enhancing a sense of institutional belonging.	Frequency	2	22	238
	Percentage	0.8%	8.4%	90.8%
My feeling of belonging to the university leads to increased knowledge sharing	Frequency	3	26	233
	Percentage	1.1%	9.9%	88.9%

The values that the employee adheres to affect his/her attitudes and opinions and thus determine his/her behavior. Hence, the various organizations are interested and seriously seek to instill positive values in the hearts of their employees in a way that helps in achieving their goals and accomplishing the tasks assigned to them efficiently and enhancing their feelings of belonging and loyalty to the organization and working in the spirit of one team and other sought positive behavior patterns at work. (Hareem, 2020, p. 96). Through Tab. 10 above that, the majority of employees agree with 94% that sharing knowledge leads to an increase in the excellence and competitive value of the university. Followed by the phrase of increasing employee production rates as their knowledge participation increases by 93%, then the phrase of employees' participation in setting the university goals leads to motivating them and increasing their participation in knowledge by 91% of approval. Then the phrase of sharing knowledge contributes to fulfilling responsibilities, resolving disputes and enhancing the sense of institutional belonging among administrators, with 91% agreeing, and then the last phrase of feeling belonging to the university leads to an increase in knowledge sharing by 89% agreeing. In fact, employees in organizations with a strong culture are characterized by a high degree of commitment and belonging to the organization. The broad consensus on the central values and beliefs increases the loyalty, faith and adherence of the employees to the organization, and this represents an important competitive advantage for the organization with positive results. Hareem (2020), p. 321.

- Distribution of answers according to belonging to the common administrative tasks of administrators, and its impact on knowledge sharing:

Table 11 Belonging to the common administrative tasks of administrators, and its impact on knowledge sharing

	Scale	Disagree	Neutral	Agree
I share my opinion on administrative knowledge constantly due to its importance to me.	Frequency	2	19	241
	Percentage	0.8%	7.3%	92.0%
Providing means of communication within the unit that facilitates employee communication and increases opportunities to benefit from sharing administrative knowledge.	Frequency	9	21	232
	Percentage	3.4%	8.0%	88.5%
Employees who practice the same managerial tasks work to formally-share knowledge while building and maintaining a network of managerial relationships for common tasks.	Frequency	15	57	190
	Percentage	5.7%	21.8%	72.5%
The majority of employees who exercise the same managerial functions share knowledge tacitly in informal working relationships.	Frequency	19	69	174
	Percentage	7.3%	26.3%	66.4%

Employees who practice the same administrative tasks consider that building and maintaining a network of administrative relationships for common tasks is not critical.	Frequency	68	54	140
	Percentage	26.0%	20.6%	53.4%

It is clear from Tab. 11 that the extent to which administrators belong to common administrative tasks affects their sharing of knowledge, and the answer that obtained the most approval is the continuous participation of other colleagues in administrative knowledge due to its importance for the employee, at a rate of 92.0% with the number of 241 employees. Followed by the provision of means of communication within the unit that facilitates employee's communication and increases the chances of benefiting from sharing administrative knowledge for 232 employees by 89%. Next, came employees who practice the same administrative tasks work to share knowledge formally through building and maintaining a network of administrative relations for common tasks with the approval of 190 employees by 73%. 57 employees are neutral at 22%. Those who disagree came by about 6%, then the rest of the statements follow in varying proportions between approval and rejection.

- Distribution of answers according to applications that help administrators to share knowledge:

Table 12 Distribution of answers according to applications that help administrators to share knowledge

	Scale	Disagree	Neutral	Agree
Specialized training programs enable me to share knowledge.	Frequency	3	18	241
	Percentage	1.1%	6.9%	92.0%
Work teams and groups of practice for the same profession increase knowledge sharing	Frequency	3	18	241
	Percentage	1.1%	6.9%	92.0%
Personal means of communication allow for the exchange and sharing of knowledge	Frequency	4	23	235
	Percentage	1.5%	8.8%	89.7%
Navigating more than one job within the workplace allows knowledge sharing	Frequency	13	25	224
	Percentage	5.0%	9.5%	85.5%
The information technologies used at the university connect all practitioners with the same tasks in all sectors	Frequency	21	45	196
	Percentage	8.0%	17.2%	74.8%

From the above Tab. 12 it is clear to us that the most applications that help administrators to share knowledge, which obtained a collective approval of 241 employees, are specialized training programs, work teams and groups of practice for the same profession with a rate of 92.0%, followed by the personal means of communication for 235 employees, at a rate of approximately 90%, and then came movement in more than one job within the workplace (job turnover) with an approval rate of 86%, a neutral response with approximately 10%, while those who rejected the statement represented 5.0%.

The variables were analyzed and a relationship was found between the demographic data and the factors influencing the concept of knowledge management and its sharing. The statistical results that have statistically significant relationships between them are presented below.

- The relationship between scientific specialization and the types of knowledge shared by university administrators:

Table 13 The relationship between scientific specialization and knowledge patterns shared by university administrators

#	Expressions	Significance Level
5	Courses (for enrolled students)	0.006

From the above table, it is clear that there is a relationship between the scientific specialization and "curricula" (for those enrolled in the course), and this indicates that the student employees enrolled in the course share knowledge patterns. It indicates that scientific specialization has no effect on knowledge sharing.

- The relationship between years of experience and knowledge patterns shared by university administrators:

Table 14 The relationship between years of experience and knowledge patterns shared by university administrators

#	Expressions	Correlation coefficient	Statistical significance
1	up-to-date information	0.058	0.352
2	Administrative processes and procedures	*0.126	0.042
3	Social activities	*-0.134	0.030
4	Postgraduate research activities	-0.042	0.497
5	Courses (for enrolled students)	-0.022	0.721
The relationship between years of experience and patterns of knowledge shared by university administrators in general		0.033	0.594

From the above table, it is clear that there is a direct statistically significant relationship between the years of experience and the types of knowledge shared by university administrators in relation to "administrative processes and procedures", where the statistical significance is less than the level of significance (0.05). This indicates that the more years of experience are, the higher the sharing percentage of knowledge patterns in administrative processes and

procedures are. However, there is an inverse relationship with a statistical significance between the years of experience and the patterns of knowledge shared by university administrators in relation to "social activities" where the statistical significance is less than the level of (0.05). This indicates that the more experience decreased the less participation of knowledge patterns in social activities is and vice versa. There is also a weak direct relationship between years of experience and patterns of knowledge shared by university administrators in relation to "modern information", and there is a weak inverse relationship between years of experience and patterns of knowledge shared by university administrators in relation to "research activities related to postgraduate studies" and "curricula (for those enrolled in a course)", where the statistical significance was greater than the level of (0.05). This indicates that the fewer years of experience are, the higher the knowledge sharing patterns for "research activities related to postgraduate studies" and "curricula (for those enrolled in a course)". In general, administrative staff share knowledge of administrative processes and procedures.

- The relationship between scientific specialization and organizational culture at the university and the extent to which it enhances knowledge sharing among administrators:

Table 15 The relationship between scientific specialization and organizational culture at the university and the extent to which it enhances knowledge sharing among administrators

#	Expressions	Significance Level
1	The administrative unit environment promotes a culture of teamwork more than individual work.	0.002
4	The university promotes a policy of knowledge sharing between departments and administrative units among various sectors.	0.041

From the above table, it is clear that there is a statistical relationship because the significance level is less than the chosen level of (0.05) between the scientific specialization and "the administrative unit environment promotes a culture of teamwork more than individual work" and "the university promotes the policy of sharing knowledge between departments and management units between different sectors".

5 RESULTS

The study revealed that the administrators' concept of knowledge management and its sharing in general is high, which indicates their awareness of the importance of the practice of knowledge sharing. The most commonly used cognitive pattern among university administrators is modern information, administrative processes and procedures, and social activities. It revealed the approval of the fact that the behavior of administrators towards knowledge sharing with others helps growth and exchange of experiences and the approval for the sharing of knowledge at all levels of the university as well as that knowledge sharing pushes them towards positive relationships that bind the employee (male/female) with other university administrators support knowledge sharing and create strong relationships with employees who have common jobs at the university that contribute to knowledge sharing. Sharing knowledge supports the employee's sense of merit and managerial superiority. Relationships that depend on trust with others lead to increased knowledge sharing. In addition, the benefits of sharing knowledge for administrators are increasing administrative productivity at the university and support innovation and creativity among administrators. It also helps develop university work procedures. Employees become more able to cooperate with each other in a better way. Sharing with other colleagues helps work to find solutions to problems. The university's organizational culture enhances the sharing of knowledge among administrators, and the culture of teamwork. It is clear that there are cooperative working groups within the university, who have informal channels of communication that help in carrying out administrative tasks. In addition, the institutional affiliation of administrators affects the sharing of knowledge and leads to an increase in the excellence and competitive value of the university. Most of the applications that help administrators to share knowledge are specialized training programs, work teams, and groups of practice for the same profession.

6 RECOMMENDATIONS

The study came up with some recommendations that help improving and developing the knowledge-sharing process with:

- Activate a formal, operational plan within the strategic planning to spread the culture of knowledge sharing among the administrative sectors. Those in supervisory positions should create a positive stimulating environment to support knowledge sharing and the creation of new knowledge.
- Conduct specialized training programs and activate groups to practice teamwork to spread the culture of sharing knowledge and exchanging experiences.
- Create an official electronic application to monitor and share the sharing of administrative knowledge among the administrative staff.
- The necessity of adopting technical programs that contribute to the preservation and sharing of knowledge to generate new knowledge for its investment.
- Establish financial incentives to encourage innovative knowledge sharing initiatives.
- Hold workshops between administrators with common interests to exchange knowledge and share it in the field of administrative operations and procedures.

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Big Data Major Security Issues: Challenges and Defense Strategies

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Abstract: Big data has unlocked the door to significant advances in a wide range of scientific fields, and it has emerged as a highly attractive subject both in the world of academia and in business as a result. It has also made significant contributions to innovation, productivity gains, and competitiveness enhancements. However, there are many difficulties associated with data collecting, storage, usage, analysis, privacy, and trust that must be addressed at this time. In addition, inaccurate or misleading big data may lead to an incorrect or invalid interpretation of findings, which can negatively impact the consumers' experiences. This article examines the challenges related to implementing big data security and some important solutions for addressing these problems. So, a total of 12 papers have been extracted and analyzed to add to the corpus of literature by concentrating on several critical issues in the big data analytics sector as well as shedding light on how these challenges influence many domains such as healthcare, education, and business intelligence, among others. While studies have proven that big data poses issues, their approaches to overcoming these obstacles vary. The most frequently mentioned challenges were data, process, privacy, and management. To address these issues, this paper included previously discovered solutions.

Keywords: Big Data; Challenges; Defense; Security; Strategies

1 INTRODUCTION AND LITERATURE REVIEW

In today's society, many individuals use the internet to communicate their social information and behaviors, which has resulted in an explosion of data produced [7]. The constant advancement of technology has resulted in an "explosive" increase in the amount of data generated by various sources, including social networks, mobile devices, sensors, X-ray machines, telescopes, space probes, application logs, climate predictions, and geo-positioning systems, to name a few [21]. Big Data is a term that refers to a huge volume of unstructured, semi-structured, and structured data that is generated at an alarming rate and is often utilized by businesses to gather information for timely actionable decision making [4]. In today's digital world, data creation and gathering are outpacing the ability of the system to keep up [17].

According to various surveyed studies, the quantity of data produced worldwide over the last three years has surpassed the preceding 400 years. This data includes documents, images, videos, web pages, e-mail, and microblogging, among other kinds. Unstructured data is more prevalent than structured data [11]. Additionally, using big data may enable the development of a variety of new kinds of sophisticated services that have been launched lately or will be released in the near future that can be used to improve people's quality of life and assist mitigate dangers and hazards [14]. However, the sheer scale of such data sets creates significant technical difficulties in terms of storage capacity and administration, as well as organization, processing, and analysis, among other things [14]. As with all contemporary information systems, big data includes security concerns throughout the storage, processing, and transmission phases, and similarly requires data and privacy protection [7].

Despite these challenges, if we can manage big data well, it may help you generate money, improve executive efficiency, make strategic choices, offer better services, define requirements, discover new trends, and create new products, all of which are covered by data science [5]. Aside from parallel and distributed processing, data science researches methods for similarity search and graph analysis and clustering and stream processing [12]. Big data problems come in a variety of forms and sizes across all businesses and areas in life. Large-scale data (big data) sets provide a variety of challenges, such as distributed and non-relational computing, cryptography, data provenance; validation; and filtering; safe data storage; and real-time monitoring [6]. Big data will be used more efficiently if the causes of challenges can be identified and addressed [17]. There is no consensus among studies discussing the issues associated with big data security. The majority of them focused on the data itself, its processing, and analysis [4, 9, 15], while ignoring additional issues that could affect big data analytics and decision-makers when dealing with big data. These additional issues may include leadership, company culture, and specialization, among others. To fill this gap, this article, as a consequence, highlights the most significant big data problems encountered by nearly all disciplines while also presenting some defense strategies that have been suggested in other academic research papers. Unlike previous studies that focused on a single issue and a single solution, this research focuses on the most significant challenges and how they may be resolved most effectively.

Based on the preceding, and given the importance of big data and the benefits it possesses, the idea of preparing this scientific study arose, the importance of which lies in attempting to enrich intellectual production in the field of big data and its applications as well as assisting decision-makers in the organization based on right and correct information that rely on extensive data analysis. The study's goal is to identify the most significant security challenges that may impede the use of this data and then determine how these threats may be mitigated.

So, the research problem of this article can be stated as follows question: What are the significant data security challenges and their corresponding solutions? The documentary analytical descriptive strategy will be used in

this study, which refers to documents and literature such as research, articles, books, and the like, and addressing them in the study with description and analysis to extract the results and indications. To address the study's topic, this study will evaluate and criticize existing papers on security problems in the big data analytics environment using the following research tools: databases available through the Saudi Digital Library and worldwide search engines. A total of 12 papers have been extracted and analyzed.

This study relies on a qualitative method because it is primarily concerned with describing the phenomenon under investigation. According to Saunders et al. (2003) [16], a quantitative approach discusses what occurs during a phenomenon, whereas a qualitative approach explains why this occurs. This study relies on a descriptive analytical method to conduct the research. Descriptive assessments rely on firsthand observation of behavior and events occurring in an individual's natural surroundings and place a greater emphasis on environmental variables [3]. Descriptive analyses may help us better understand how reinforcement works in the natural world [3].

2 ARTICLE BODY

The researcher will discuss extracted papers related to big data challenges in this section. A total of twelve papers will be presented, ranging from the oldest to the most recent.

Al-Abassi et al. (2020) [1] study titled "Industrial Big Data Analytics: Challenges and Opportunities": This review study focused on industrial big data analytics as well as the evolution of the sector over the years. Big data has been discussed in terms of its characteristics, sources, applications, concerns, and challenges, among other things. The following are some of the challenges associated with large data:

- Lack of Large-scale Spatiotemporal Database Representation: Each device's time stamp is acquired and examined statistically. Manufacturing generates huge amounts of data but lacks the infrastructure needed to analyze, integrate, and fuse it. Finding a less priced approximation will be difficult.
- Lack of Effective and Efficient Online Machine Learning Algorithms: Rapid response is necessary in industrial organizations to detect machine irregularities and check production quality, and adding equipment results in ineffective and inefficient preventative measures. Boosting big data analytics with online large-scale machine learning algorithms is already happening.
- Lack of Whole Processes Lifecycle Data Management Systems: Due to restricted storage management capabilities, data quality assurance approaches should be employed to distinguish vital and irrelevant data.
- Lack of Data Visualization Systems: Large amounts of raw data can be turned into graphical displays that help make judgments and disclose intuitive knowledge rapidly. Data visualization illustrates patterns, trends, anomalies, consistent and fluctuating data that text and tables cannot.
- Lack in Data Confidentiality Mechanisms: For financial reasons, small organizations cannot study big data exchange among geographically distributed web sources. Other organizations and web tools must examine their data, potentially compromising security. Small businesses should be cautious when dealing with third parties and preserve their sensitive data.

Hamad et al. (2020) [8] study titled "Big Data Opportunities and Challenges for Analytics Strategies in Jordanian Academic Libraries": The purpose of this study was to examine the idea of big data from the perspective of information technology workers at three large Jordanian university libraries. This study sought to elucidate the use of big data, analytics, and problems in Jordan's university libraries. We conducted a study of the research on big data in libraries and offered an overview of the applications and research objectives in this subject. The status of big data in Jordanian libraries was discussed, as well as the issues related with it. It is a qualitative research study used interviews with 23 librarians working in IT department. The findings revealed the following challenges:

- Staff competency: Participants agreed that libraries must carefully plan to overcome a variety of hurdles when incorporating big data. Staff experience in new technologies like analytics, visualization, and data curation is one of these impediments.
- Infrastructure: Another issue is a lack of infrastructure in terms of hardware and software. The three universities reported having appropriate infrastructure to enable big data usage and analysis, but this infrastructure needed to be upgraded to keep up with technological advances and optimise big data consumption and analysis.
- Financial support: The lack of financial backing for building library infrastructure and educating library staff to manage large data were the main obstacles.
- Privacy and information security: Academic libraries confront additional privacy and security challenges, and staff expressed a wish to update library rules, indicating the necessity for an information security specialist. Academic libraries are most concerned about this because most big data comes from library users and their interactions with library services.

Al-Sai et al. (2019) [2] study titled "Big Data Impacts and Challenges: A Review": Big Data was reviewed for three purposes in this paper: first, to highlight the definitions and characteristics of Big Data and summarize the most common definitions of existing works; second, to identify the impacts and opportunities for the Big Data; third, to identify the main critical challenges associated with Big Data and classify these challenges as (People, Technology, Organizations, Processes, and Data Management) challenges. This paper used a descriptive analytical review. It classified the various challenges as follow:

- People Challenges: The main issue most firms will have when attempting to adopt Big Data is preparing for

implementation and finding engineers with Big Data knowledge.
- Technology Challenges: Big Data analytics requires new methodologies, skills, and capacities for gathering, storing, and analyzing data using Big Data technologies like Hadoop, Spark, and others.
- Organization Challenges: There are several organizational hurdles that must be overcome before Big Data can be successfully deployed.
- Process Challenges: Many businesses are challenged with processing ever-increasing amounts of data. Firms will have to choose between maintaining all data and storing only the most valuable data to handle this issue. Firms must develop ways for determining the most business value from Big Data.
- Data Management Challenges: Organizations faced challenges in capturing, managing, and administering Big Data Achieving real-time data management is difficult. Data warehouses record financial transactions, insurance claims, medical procedures, personal data, diagnosis codes, etc.

Wani & Jabin (2018) [20] study titled "Big Data: Issues, Challenges, and Techniques in Business Intelligence": Using the descriptive analytical method, the purpose of this study is to identify the most critical concerns and challenges associated with big data and to provide a complete evaluation of alternative strategies for dealing with big data problems. This study discussed two facets of big data: the issues surrounding big data and the challenges associated with big data. Issues include management, storage, and processing, while challenges include the following:
- Lack of big data professionals: Firms need highly skilled employees to handle and exploit these high-performance, complex technology for big data processing.
- Interactiveness (or Designing): Interactivity refers to a data mining system's ability to encourage user feedback, support, and ideas.
- Loading and Synchronization: To load data from several sources into a single repository, one must first load the data from each source, and then synchronize it with the common repository.
- Visualization: Data visualization is the practice of visualizing knowledge to aid decision-making.

Vassakis et al. (2018) [18] study titled "Big Data Analytics: Applications, Prospects and Challenges": Using the descriptive analytical method, this study focused exclusively on big data analytics. Big data analytics has great potential and the benefits to data-driven enterprises are critical determinants of competitiveness and innovative performance. However, there are many barriers to implementing a data-driven approach and obtaining important knowledge from big data. As a result, this study concentrated on big data analytics, focusing on the uses, opportunities, and challenges associated with it. What distinguishes this study from others is its emphasis on big data analytics challenges rather than on big data challenges in general. Here are big data analytics challenges:
- Leadership: Big data's power cannot be completely fulfilled without vision or human knowledge. Business leaders who can see future trends and opportunities will be able to motivate their teams to work efficiently and achieve their goals.
- Talent Management: Many data scientists lack both analytical and subject knowledge skills. A data scientist must be able to perform statistical analysis, big data mining, visualization, and machine learning.
- Decision making procedure: Decision-makers struggle with huge data sets. As a result, decision-makers must be able to solve problems using the correct facts or interact with others.
- Decision making Quality: Quality decision making is linked to data, big data analytics, staff, and decision makers.
- Data-driven culture: Enterprise culture also hinders data-driven decision-making. A data-driven culture requires quick summarization, evaluation, and delivery of essential business information to decision makers.
- Data privacy: Businesses must take efforts to protect their consumers' data. Data policies like as privacy, security, intellectual property, and responsibility should be addressed to maximize the benefits of big data.

Mishra et al. (2017) [13] study titled "A bibliographic study on big data: concepts, trends and challenges": Citation and co-citation analyses were conducted using bibliographic and network approaches. This analysis included a review of 57 publications published in ten selected journals over a five-year period (2011–2015). The findings indicate that the number of publications devoted to the study of "big data" has expanded significantly during the last several years. Additionally, the analysis highlights several of the most prominent articles in this field. Finally, the study analyses emerging trends and the corresponding issues with big data. Regarding big data challenges, this paper concluded that challenges could be one or some of the following:
- The real challenge "was to deal with a diversity of data kinds (variety), time-sensitive response needs (velocity), and data inaccuracies (veracity)".
- Applications must also deal with semi-structured and unstructured data, such as text, images, video, and speech.
- Another concern is late responses. This could be due to a lack of resources to collect, store, and analyze massive amounts of data quickly.
- Determining legitimate from invalid data is tough because even the finest data cleaning processes cannot remove inherent ambiguity.
- Even the best data cleansing procedures cannot eradicate data's intrinsic volatility, according to IBM.

Lee (2017) [11] study titled "Big data: Dimensions, evolution, impacts, and challenges": This review study underlined the necessity of data analytics in processing

various organized and unstructured data. Data analytics for merchant reviews was proven in this paper. 400 reviews were analyzed using multiple regressions. A multivariate regression model found the characteristics substantially associated with usefulness votes. The influence of big data on key business metrics is next investigated. Six technical and managerial challenges are then discussed as follow:

- Data quality: The quality of data tends to decline as it grows more unstructured and comes from diverse sources. This might cause serious harm to patients if a medical monitoring system sensor delivers inaccurate data. Quality measures must be developed, data must be assessed, errors must be corrected and the cost-benefit ratio must be evaluated.
- Data security: Implementing comprehensive security management protocols and solutions like as intrusion prevention and detection systems, encryption, and firewalls can help secure big data.
- Privacy: Sensors, including smart health devices and smart car emergency services, can collect data on a person's travels, health, and purchasing habits. Many people fear about their privacy. To improve service quality and save expenses, big data is needed. Businesses and customers must find a way to combine personal data consumption for services with privacy concerns.
- Investment justification: Despite the vaunted benefits of big data, businesses are struggling to justify their investments. Many big data projects have vague problem definitions and rely on emerging technologies, raising the risk of project failure and irreversibility.
- Data management: Edge computing and Hadoop could help firms handle data better. Hadoop is used for large-scale data processing and calculations in distributed computing.
- Shortage of qualified data scientists: The need to analyze unstructured data like text, video, and images is expanding. If the scarcity persists, organizations may have to construct data analytics training programmers to prepare internal staff to meet demand.

Khan et al. (2017) [10] study titled "Big data challenges and opportunities in the hype of Industry 4.0": In this study, the difficulties and prospects of industrial big data are discussed in the context of Industry 4.0, although from a different point of view than previously. When it comes to building big data algorithms and methodologies, the current study assisted researchers in determining the thresholds of these latest Industry 4.0 systems. Big data presents a variety of issues across a variety of systems, but the current study focuses on the challenges and potential associated with Industry 4.0. These challenges are as following:-

- Acquisition of Automation Data: It is challenging to collect data in Industry 4.0 due to the proliferation of technologies and communication networks. Sensors, actuators, and PLCs generate data in the automotive sector. The sensor detects physical activity and sends it to the PLC for processing. Big Data Digitization Modern factory automation is required to preserve price stability and increase production.
- Data Transformation: To draw conclusions or forecast machine failure using archival big data, heterogeneous data must be translated into an interoperable format. Using smart technology in Industry 4.0 involves converting data into smart device-friendly formats.
- Data Integration and Modeling: Bringing together disparate data kinds for rapid production is difficult. Controlling, automating processes, and calculating product costs require industrial big data integration and modeling.
- Real-time access: Cyber-physical systems with sensors, actuators, and other devices require real-time access. As all actuators run sequentially with predetermined time slices, any delay in remote controlling physical devices affects following physical devices. Numerous agents are installed in industrial control engines of automobiles, triggering instructions based on big data storage.
- Security and Privacy: As Industry 4.0 expands, the volume of heterogeneous data increases, as does the move to the cloud. Because everything in Industry 4.0 is administered remotely via a web interface, a hacker may potentially take control of the physical machinery.
- Data Analytics: Incomplete data hinders real-time data analytics, needing pre-processing before analysis. Scalability of analysis is also an issue when output data volume grows.
- Data presentation: Industrial big data is needed for mining and knowledge extraction. Business CEOs need several reports. Before buying something, customers want to know everything about it. As a result, Industry 4.0 has a tough time providing data in several formats to multiple users. The LexisNexis HPCC systems distributed data intensive computation platform is significant because it can encapsulate data and write code for data reading in multiple activities concurrently.

Behera et al. (2017) [4] titled "Big Data Analytics in Real Time – Technical Challenges and its Solutions": The purpose of this article was to demonstrate an open-source solution for analyzing large amounts of data and presenting real-time information on trends and patterns, as well as alerting users in the event of a business emergency. Additionally, the article discusses hardware topology using an open-stack solution. This article focused on three technical challenges: real-time data collecting, real-time data processing, and real-time data visualization, and presented ways for overcoming them. To address these issues, they implemented open-stack technology and a parallel and distributed strategy. Here are steps of this approach:

- Data Sources which contains structured, unstructured, and semi-structured data.
- Data Collection: Data is extracted from a number of sources, data bazaars, and data stockrooms. Hadoop is a distributed and parallel computing system for large datasets. It's an Apache-sponsored open source project.

- Data Processing and Data Storage: Spark is an Apache Software Foundation tool for speeding up Hadoop data processing. Because Spark uses in-memory computation, it can process data faster by caching data and turning it to real-time. Tolerant Distributed Dataset (RDD) saves data in memory transparently and persists to disc only when needed.
- Data Consumption: Data visualization and analysis employing approaches like business intelligence and big data analysis. Business intelligence (BI) tools let business/operations professionals visualize data to aid/improve business/operations. The tool's goal is to find patterns, trends, and other information in the data sea.
- Data Monitoring: Monitoring is a major bottleneck due to the solution's enormous machine count. Ganglia is a great tool for cluster-based monitoring and data processing.
- Data Security: The goal of big data security is to protect an organization's internal data and its customers' data in real-time or near-real-time. Techniques like strong authentication, regular audits, and mandatory access control may be used to protect personal and sensitive data on the cluster of machines.

Wang et al. (2016) [19] study titled "Towards felicitous decision making: An overview on challenges and trends of Big Data": Bibliometric analysis of 2924 articles published between 2000 and 2016 were used to conduct this study. On the basis of four issues, this paper provided an overview of Big Data, which included: (I) Big Data concepts, characteristics, and processing paradigms; (II) the most up to date techniques for decision making in Big Data; (III) successful decision making applications of Big Data in social science; and (IV) the current challenges of Big Data, as well as potential future directions. Focusing on the goal of this study, this paper stated that most big data challenges are:

- Challenges in Data Capture/Storage and Curation: Solid-state drives, phase-change memory, and data access optimization may help solve this problem. Data security is a concern during these periods. Prior to deciding on information exchange strategies and protocols like certification, access control, and anonymization, privacy should be considered. Anonymization techniques may hinder data analysis by raising data uncertainty.
- Challenges in Data Analysis and Visualization: Data analysis is tough because of data and computing complexity. A decision-making dilemma comprising diverse sources, enormous quantities, and quickly changing datasets cannot be addressed with ordinary computer technologies. Thus, new approaches should be proposed to re-examine Big Data's computability (and then computational complexity). Insufficient sample sizes, confusing data linkages, and unbalanced (or even uncertain) value density distributions must be thoroughly evaluated.
- Systematic Challenges: Building suitable system architecture is crucial to supporting decision-makers in managing complex data and executing complex computations on Big Data. One option is to use cluster computers connected to an HPC platform. However, this stresses both hardware and software system architectures. Their final answers will help create system designs.
- Non-Technical Challenges: Rather than technological challenges related with Big Data processing, this refers to management issues faced by service providers and users. Big Data should help them communicate with users better.

Nasser & Tariq (2015) [15] study titled "Big Data Challenges": This narrative and descriptive study examined Big Data problems in three categories: data, process, and management. Data difficulties are a subset of challenges linked to data quality. The process category includes all challenges encountered while processing Big Data, from data acquisition to product presentation to clients. The management group addresses data access legal and ethical issues. The "big data technologies stack" is a layered design guide for theoretical Big Data challenges. Each layer will provide technologies to address specific issues, but together they will provide the entire solution. Starting with data issues, this study discussed volume, variety, velocity, veracity, volatility, quality, discovery, and dogmatism. The second issue is (Tab. 1). Privacy, Security, and Governance are all management issues.

Table 1 Challenges according to process stages

The process	Challenges
Data Acquisition and Recording	- Smart filters - Data reduction - Automatic meta-data generation - Data fidelity
Information Extraction and Cleaning	- Transforming structure less data to analytics friendly format - Extraction right information - Adequate error models
Data Integration and Aggregation	- Heterogeneity of data - Effective DB design for big data - Automating integration and aggregation
Analysis and Modeling	- Noisy, untrustworthy and heterogeneous data - Dynamics and inter-related data - Scaling queries - Integrating DB systems and analytics tools - Analytics-on-the-fly
Interpretation	- Making assumptions available to users - Wrong modeling - Erroneous data used - Application bugs

To solve these challenges, the paper introduced a layered architecture reference known as the "big data technology stack" which consisting of seven layers. These layers are:

- Layer 1 - Redundant physical infrastructure (Data challenges): Data properties such as high-volume, high-variety, and high-velocity offer issues for the construction of new technical infrastructure.
- Layer 2 - Security infrastructure (Management challenges): Encryption is the major way for protecting data. Before saving data records, any personally identifiable information must be erased. Before saving the data records, anonymize them and remove all personal sensitive info.
- Layer 3 - Operational databases (Process challenges): The database must support the ACID transactional behavior, which stands for Atomicity, Consistency, Isolation, and Durability.
- Layer 4 - Organizing data services and tools (Data & process challenges): Simply put, the programmer can't

turn 0s and 1s into valuable insights. Big Data services and technologies collect, validate, and organise it. Apache Hadoop is an open source software system designed to handle massive volumes of data in real time.

- Layer 5 - Analytical data warehouses (Process challenges): Data warehouses and Big Data are a hybrid framework. Traditional data warehouses manage highly ordered data while Hadoop manages widely scattered and dynamic data.
- Layer 6 - Big Data analytics (Process challenges): Reporting and dashboards, visualization, and analytics and advanced analytics are the three main categories of analytics technologies that organizations can use individually or together to gain business value.
- Layer 7 - Big Data applications (Process challenges): A well-defined API interface allows developers to access the functionality exposed by each tier via those interfaces.

Jin et al. (2015) [9] titled "Significance and Challenges of Big Data Research": The concept of big data is briefly addressed in this narrative and descriptive paper. Onto the significance and promise of Big Data. The video then showed real-world big data projects from throughout the world. Finally, it identified the primary obstacles (such as data, computational, and system complexity) and recommended solutions. Like the previous study [15], this investigation confirmed that some of the difficulties stem from big data characteristics, some from current analytical models and methodologies, and yet others from current data processing technologies. Authors in this paper categorized challenges as the following:

- **Data complexity:** Identifying and quantifying significant features is tough when dealing with large data sets. To do so, we'll require data dispersion theories and models for various contacts. We'll also need to understand the relationship between computational and data complexity.
- **Computational complexity:** Stating the obvious, we should look at the weak CAP network shared-data system model and its algebraic computational theory. Then we'll need to enhance networking, storage, and processing for big data. Existing reduction-based computing technologies must also be studied.
- System complexity: Consider current workloads and resource distribution. Application development requires study in performance evaluation, distributed system architecture, streaming computing, and online data processing. Benchmarks are useful for predicting and validating system performance.

3 DISCUSSION

While studies have confirmed that big data presents challenges, they differ in their approach to these challenges. Some research has concluded that challenges can be separated into three categories: data, process, and system or management (see, for example, [4, 9, 15], whereas Mishra et al. (2017) [13] have added a fourth area, which he refers to as data quality. According to Wang et al. (2016) [19], the prior issues have been reinforced by the addition of systemic challenges, which refer to developing a functionally adequate system design.

With the addition of the following difficulties, Khan et al. (2017) [10] brought categorization to a whole new level: acquisition of automation data; data transformation; data integration and modeling; real-time access; security and privacy; data analytics; and data presentation, among others. Rather than focusing solely on data, process, and visualization, Vassakis et al. (2018) [18] added the following: Leadership, Talent Management, Decision Making Procedure, Decision Making Quality, and Data-Driven Culture to his list of priorities. Apart from the lack of professionals and visualization, Wani & Jabin (2018) [20] emphasized the importance of interactiveness (or design), which refers to the capacity of a system to facilitate user interaction, such as feedback, assistance, and ideas, and loading. They also introduced synchronization, which refers to the act of transferring data from multiple heterogeneous data sources to a single data repository, as well as the process of ensuring data consistency across time between different data sources and shared storage. Al-Sai et al. (2019) [2] categorize big data difficulties into broad categories: People Challenges, Technology Challenges, Organization Challenges, Process Challenges, and Data Management Challenges, among others. Finally, Hamad et al. (2020) [8] added infrastructure and financial support to the list of earlier obstacles that previous investigations had identified.

Regarding solutions, Nasser & Tariq (2015) [15] introduced a layered architecture framework dubbed the "big data technology stack" that consists of seven layers beginning with redundant physical infrastructure, security infrastructure, operational databases, organizing data services and tools, analytic data warehouses, and big data analytics. According to Jin et al. (2015) [9], the following solutions are recommended to overcome the computational complexity associated with big data applications:

1) Move away from traditional computing paradigms and investigate the weak CAP network shared-data system model and its algebraic computational theory.
2) Develop algorithms for distributed and streaming computing and a framework for big data computing that integrates and optimizes communication, storage, and processing.
3) Investigate the non-deterministic algorithmic theory that does not assume independent and identical distributions.
4) Investigate existing reduction-basis techniques.

Apart from deconstructing the relationship between the complexity, computability, and efficiency of big data applications, we'll also need to quantify a variety of energy efficiency factors, such as system throughput, parallel processing capability, job calculation accuracy, and energy consumption per unit [9]. While access to Big Data is constrained by the system imbalance created by CPU-intensive yet I/O-deficient systems, several related technologies such as solid-state drives, phase-change memory, and data access optimization may help [19]. A decision-making dilemma comprising diverse sources, enormous quantities, and quickly changing datasets cannot

be addressed by ordinary computer technologies. So, new approaches should be proposed to re-examine Big Data's computability (and then computational complexity). Insufficient sample sizes, confusing data linkages, and unbalanced (or even indeterminate) value density distributions must all be thoroughly investigated [19]. To address challenges relating to real-time data collecting, real-time data processing, and real-time data visualization, Behera et al. (2017) [4] implemented open-stack technology and a parallel and distributed strategy shown in Fig 1.

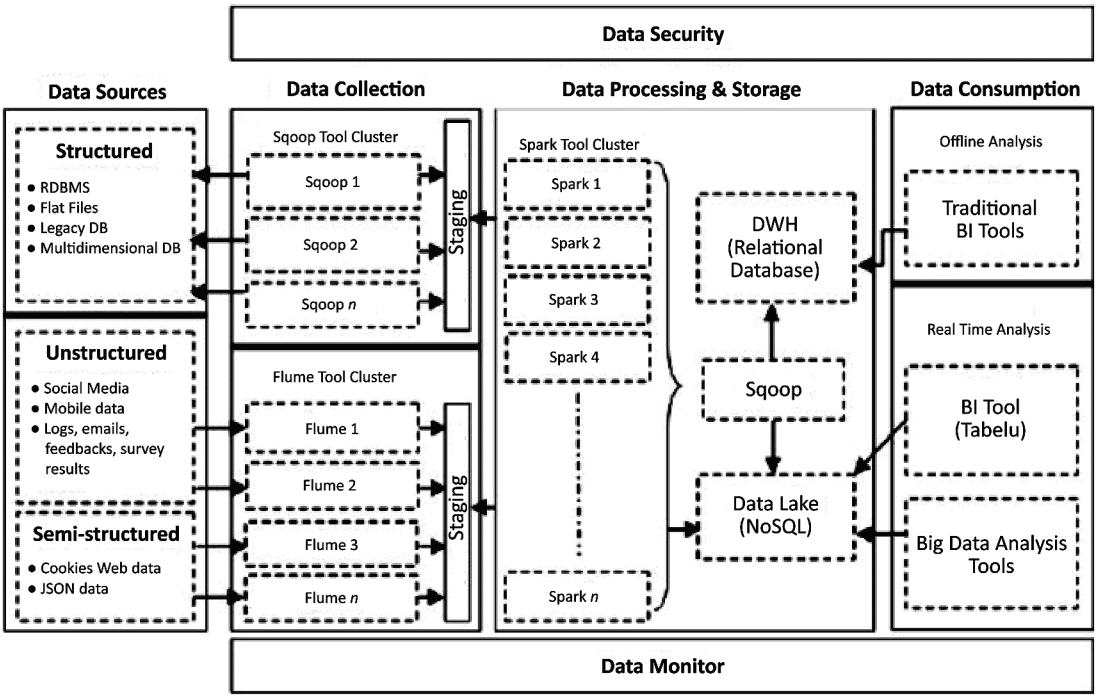

Figure 1 Open-stack technology [4]

4 CONCLUSION AND FUTURE WORKS

Enormous possibilities have arisen as a result of the advent of the Big Data age. In addition to influencing everyone's social and economic conduct, big data has also affected their way of life and thought. Big data is a valuable tool for solving various challenges; yet, it has also introduced a slew of security concerns. This paper examines multiple security features and problems in the big data environment from the perspectives of privacy protection, trust, analysis, technique, and access control. These include technical challenges, security, user privacy protection challenges, and safe storage of massive data, analysis challenges, and trust security issues. It also discusses preventive solutions for these issues. These study contributions appear theoretically and practically. Theoretically, despite the fact that studies have demonstrated that big data presents challenges, the ways taken to overcome these challenges differ. Data, procedure, privacy, and management were the four most often reported difficulties in the survey. This study includes previously identified solutions to these problems in order to solve them. Practically, these solutions would be useful to decision-makers in a wide range of industries, including healthcare, industry, education, marketing, and others. Although there has been some progress, there is still more work to be done to protect big data security and privacy. To effectively address big data security problems, it is necessary to integrate technological solutions with appropriate laws and legislation.

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Major Security Issue That Facing Social Networks with Its Main Defense Strategies

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Abstract: The Social Network Service "SNS" has enabled significant advancements in a wide variety of scientific fields, and as a result, it has become an extremely popular subject in both academia and business. SNSs can be extremely beneficial to users because they eliminate economic and geographical barriers and can be used for job searching, entertainment and education. Regardless of the economic and social benefits, protecting businesses and users' security and privacy remains a critical issue that must be addressed. It is critical to address and evaluate social network service challenges, as they vary according to the variety of SNS sites. Thus, by discussing SNS challenges alongside available and potential solutions, users, developers, and businesses can identify relevant and timely responses to specific threats, resulting in the best SNS-based services possible. The objective of this article is to discuss the inherent challenges of social networking sites and some critical solutions for resolving them. We extracted and analyzed seminal papers to add to the corpus of literature by focusing on several critical challenges in the social network service domain and shedding light on how these challenges affect a variety of domains, including users, sites, and business. The most frequently mentioned difficulties concerned privacy risks, anonymity risks, malware, spam, identity theft, phishing, business data, social content, technical issues, and psychological difficulties. By incorporating previously discovered solutions, this paper addressed these issues. The implications for both researchers and practitioners have been discussed.

Keywords: SNS; Social Network; Social Network Challenges; Strategies and Defense

1 INTRODUCTION AND LITERATURE REVIEW

A **S**ocial **N**etwork **S**ervice (SNS) has recently gained a lot of attention due to a variety of features. SNS enables users to make new friends and expand their social circle. Another critical feature of SNS is the ability for users to share their interests, videos, photos, and activities. In today's world, social networks are extremely popular. SNSs can be extremely beneficial to users because they reduce economic and geographical barriers and can be used to accomplish goals such as job searching, entertainment, and education [16].

By definition, social networking is about fostering and reflecting personal and social ties among people who have similar values, aspirations, or interests [1]. The massive amount of data shared and disseminated on social media platforms includes users' personal information, location, address, email, usernames, and interests. Additionally, users provide updates in the form of status information, which includes their thoughts or contributions to an online discussion [3].

In a bounded system, social network sites (SNS) enable users to build an open or semi-public profile, to identify other users with whom they share a connection and to view and navigate their own list of connections as well as those made by others [1]. However, issues regarding the privacy and security of a user's information can arise, particularly when the user's uploaded content is multimedia in nature, such as photos, videos, and audios [16].

Numerous security researchers have examined and discussed security issues in social networking sites. According to Gao et al. (2011) [7], major security issues in SNSs are classified into four categories: (a) privacy concerns, (b) viral marketing, (c) network structural-based attacks, and (d) malware attacks. Their research included a detailed examination of each issue and its associated defense mechanisms. Novak & Li (2012) [14] conducted a survey of the major security and privacy concerns associated with SNSs. They discussed current techniques for protecting SNS users from a variety of entities, including SNS providers, third-party application developers, advertisers, and other users. Additionally, they provided a concise overview of link prediction, location hubs, and user attributes in SNS inference.

Jin et al. (2013) [8] examined four aspects of user behavior in SNSs: (a) malicious behavior, (b) mobile social behavior, (c) traffic activity, and (d) connection and interaction. With the proliferation of traditional threats and challenges posed by multimedia data on social networking sites, numerous researchers and security firms have proposed a variety of solutions to mitigate these threats. Watermarking [20], steganalysis [12], and digital oblivion [19] are all examples of solutions for protecting SNS users from threats posed by multimedia data. On the other hand, various solutions have been proposed to mitigate traditional threats, such as spam detection [13] and phishing detection [11].

Despite the aforementioned efforts, the gap appears in how these threats and solutions can be handled in Arabic countries. In recent years, Facebook, Twitter, YouTube, LinkedIn, Skype, 9jabook, and Logbook, among other social networking sites, have cemented their place at the center of many users' daily internet activities, becoming a primary target for hackers and vehicles for political revolutions in some countries (examples are Tunisia, Egypt, Libya, and Saudi Arabia) [1]. As a result, social network challenges must be addressed and introduced cautiously in Arabic-speaking countries, as they require a more holistic approach in these countries. The study's objective is to identify the most serious security threats that could jeopardize social network service and then determine how to manage these threats. Thus, the research questions for the article could be phrased as follow: ***What are the most significant challenges facing social network services and how are they being addressed?*** The documentary analytical descriptive strategy

will be used in this study, which entails referring to documents and literature such as research, articles, and books and addressing them in the study through description and analysis in order to elicit results and indications. To address the study's subject, this study will evaluate and critique existing literature on security issues in an internet of things environment. It will accomplish this through the use of the following research tools: databases made available via the Saudi Digital Library and international search engines. Several seminal publications have been extracted and analyzed in their entirety.

To accomplish the study's objective, a qualitative approach is taken in order to adequately describe the phenomenon under investigation. According to Saunders et al. (2003) [17], a quantitative approach examines what occurs during a phenomenon, whereas a qualitative approach sheds light on why it occurs. The descriptive analytical method is used in this study to conduct the research. Descriptive assessments place a greater emphasis on environmental variables and are based on direct observation of an individual's behavior and events occurring in his or her natural environment [4]. Descriptive research may help us better understand how reinforcement works in nature [4]. This article begins with article body section, then the discussion section, before it ends with conclusion.

2 ARTICLE BODY

The researcher will discuss extracted papers related to social network challenges: in this section. A total of ten papers will be presented, ranging from the most recent.

Al-Obeidat et al. (2020) [3] study titled "The Socio-economic Impacts of Social Media Privacy and Security Challenges": This article examined and analysed the socioeconomic impacts of social media challenges. A framework for defining the scope of the research findings allowed for the identification of appropriate measures to address challenges and mitigate socioeconomic impacts. The findings also highlighted the importance of solutions that go beyond technology, such as social science solutions that address behavioural issues and how to address them. This study identified the following social media privacy and security issues:

- **Privacy challenges:** The threats to privacy are multi-media, traditional, and social. Content exposure and transparency are harmful aspects of multimedia content. Personal and corporate reputations can be damaged by bullying, espionage, stalking, and other privacy violations such as data leakage, and profiling.
- **Security Challenges:** There are two types of security threats: classic threats that social media inherited from the web, and modern threats that are specific to social media. Both challenges are presented in Tab. 1.

Al-Obeidat et al. (2020) [3] discussed the socioeconomic consequences of social media challenges and categorized them into the following:

- Financial Crimes: Social media crimes generate an estimated $3.25 billion annually in global cybercrime. Card fraud and data hacking/selling. Hire a botnet or booter for $10/month or $25/life.
- Cyber Threats: Social media users face virtual cyber-threats. Cyber-bullying is online intimidation. Threats to cyber security, digital autonomy, and privacy are common.
- Physical Threats: Social media threats can cause property damage or death. Violence in society is one example. Social media allows virtual information exchange.
- Other Social Vices: Privacy and security issues in social media Politicians and gangsters are two examples. Social media manipulation has shaped democracy.
- Health Issues: Concerns about social media privacy and security also affect health. There's also death and depression. Financial loss and cyber-threats are typical.

Table 1 Classic and Modern Threats

Classic Threats	**Malware** is malicious software designed to steal personal data from users. Due to the nature of social media and high user interaction, malware attacks are easier on social media than other platforms.
	Phishing is another well-known threat in which cybercriminals obtain user data by impersonating legitimate third parties and using a false identity.
	Spam is unsolicited mail. Social media spam is more dangerous than email spam because users spend more time there. Spam usually contains ads or malicious links that lead to malware or phishing sites.
	Cross-site scripting is a serious security issue affecting web applications. Cross-site scripting allows cybercriminals to run malicious code on targeted users' web browsers, compromising their data or stealing cookies or other confidential data.
Modern Threats	**Sybil attacks:** Creating multiple fake identities to send messages to legitimate users and collect private data only friends can see.
	User profiling: Social media platforms analyze routine user activity, which can be accessed by cybercriminals.
	Social engineering: Using social devices and mechanisms to deceive users into disclosing confidential data.
	Identity theft: Attempts to collect personal data to benefit or harm users. They can occur when users share account details, download malicious apps, or have low privacy settings.
	Clickjacking: Tricking users into clicking on links they didn't intend to click.
	Compromised accounts: Malicious users hijacking accounts and gaining access to users' social media data.
	Inference attacks: Using data mining to collect sensitive information by analyzing available and authorized data and drawing conclusions.
	De-anonymization attacks: It's a type of inference attack where users' identities are inferred from their mobility traces.

Kožuh & Debevc (2018) [10] study titled "Challenges in Social Media Use among Deaf and Hard of Hearing People": This study examined the deaf and hard of hearing community's use of social media, including the benefits and challenges. Existing recommendations for overcoming obstacles were reviewed, and approaches for designing and

using social media efficiently were proposed. Inclusion advisors, educators, and policymakers may find the findings useful in determining how to best use social media as an inclusive tool for social participation. Based on the selected studies, this study defined three major issues facing the deaf and hard of hearing when using social media. Among the challenges are:

- **Technical issues:** There are issues with accessibility, privacy and security as well as disorganised layouts. Users are frequently digitally illiterate. Also, the social media gaffe Captions/subtitles for deaf people are rare on social media (e.g. searching jobs).
- **Psychological issues:** When users encounter privacy issues and share their passwords with peers, they risk becoming a bully or a victim of cyber bullying.
- **Social issues:** Individuals may overlook their social networks, eroding their social capital.

The study of (Kožuh & Debevc, 2018) [10] proposed recommendations for overcoming barriers to social media use among the deaf and hard of hearing. These recommendations are explained in terms of the constituent groups they serve. The following stakeholders are targeted by the recommendations found in the selected studies:

- **Social media developers and producers:** Deaf users' needs were emphasized. Communication will improve. Extend and caption web page elements to improve privacy and security.
- **Education, health and business sectors:** However, the majority of deaf and hard-of-hearing people do not own a computer. Social media educators can teach readers and writers.
- **Policy makers and other stakeholders:** Creators and developers of online content should consult disabled users. Use social media to post official alerts and track community traffic.

Rathore et al. (2017) [16] study titled "Social network security: Issues, challenges, threats, and solutions". This article examined the various security and privacy risks that every social networking user faces. It also addressed the threats posed by sharing multimedia content on social networking sites. It also discussed current state-of-the-art defense solutions for protecting social media users. Then, a future direction was discussed, along with some simple response techniques, to create a trustworthy and secure social network ecosystem. Fig. 1 depicts the paper's social network service threats.

As Rathore et al. (2017) [16] classified social network threats as multimedia, traditional, and social, they proposed solutions for establishing a more trustworthy, secure, and privacy-conscious SNS ecosystem. These solutions are described in Tab. 2.

Shaw et al. (2016) [12] study titled "Social Network Forensics: Survey and Challenges". This article discussed the forensic issues that arise in numerous social networking sites like Facebook, MySpace, LinkedIn, and Twitter. A social network is made up of nodes, or officialdoms. These nodes are linked by acquaintances, likes, and relationships. These nodes handle a lot of data. Social network forensics is the study, protection, and extraction of data using various network forensic tools. A few threats to social networking sites are listed in Tab. 3.

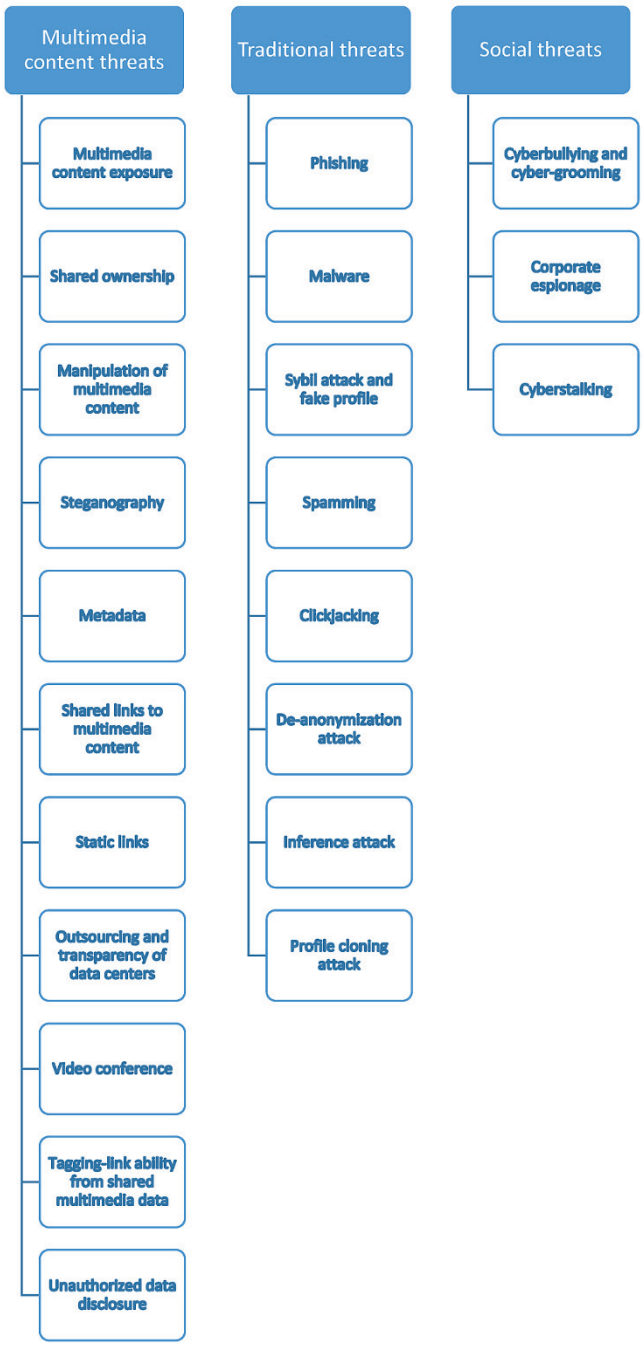

Figure 1 Classification of SNSs security threats

Chaudhary & Kumar (2015) [5] study titled "Challenges in protecting personnel information in social network space". This paper discussed a variety of cyber-related topics, including cyber-bullying, Internet banging, and cyber-attacks. The various techniques employed by the attackers have been discussed. It included a review of the privacy issues that arise as a result of the actors in the social network

graph's lack of privacy knowledge and skills or their ignorance. Finally, this paper discusses possible solutions to privacy attacks. The authors introduced privacy issue and challenges regarding social network service as follow:

- There may be little or no protection for privacy in connection with activities that involve third parties or are conducted in public. The same is true for activities that are regulated by the government.
- With the subject's permission, activity data can be used, collected, and monitored.
- When a person saves their home address as the source GPS address, one of the privacy concerns arises.
- Identity theft, personalized spam, and digital stalking are all threats on social media. Users' data can be used to train predictive models. These can be used to deduce user behavior and information.

Table 2 Solutions for social network service threats

Solution	Description
Watermarking	It embeds data into media to prove ownership. Hidden or visible watermarking An image's visible watermarking usually contains text or a logo identifying the owner. This type of watermarking is difficult to remove.
Co-ownership	Multiple users can apply their privacy settings to co-owned videos and images using the co-ownership model.
Steganalysis	Finding malicious data in multimedia files requires steganalytic software. Many traditional steganalysis methods exist. For these methods, a large dataset of images is used to train a general model that is then used to classify new images.
Digital oblivion	Digital data is given expiration date so that no one can access it after that. Thus, digital oblivion can protect large amounts of data.
Storage encryption	Encryption protects user data from malicious providers or other organizations. In SNSs, users can securely store and retrieve data without exposing it to a third-party service provider, such as a cloud-based service provider.
Metadata removal and security	Remove metadata and protect privacy in SNSs using many methods. For example, storing multimedia metadata encrypted in a file. A user may also request to edit file metadata and re-create it.
Malware detection	One proposed system detects malware. As an example, an SNS malware detection system that takes advantage of topology and malware propagation. The system adds decoy friends to a group of legitimate SNS users to monitor communication.
Sybil defense and fake profile detection	SybilDefender, for example, defends against Sybil attacks using network topology. For large SNSs, it relies on a small number of arbitrary walks within social graphs.
Phishing detection	Anti-phishing techniques are numerous. In real-time, phishAri detects phishing on Twitter That is, it can differentiate between phishing and legitimate tweets with URLs.
Spammer detection	Spam detection and SNS protection have taken time. Researchers have developed graph and content-based features, a novel social honeypot-based approach, and a data-mining technique to detect spam in SNSs.
Commercial solutions	Several security firms have developed SNS security solutions to combat evolving threats. Like FB Phishing Protector, Check Point Software developed SocialGuard Privacy Scan for Facebook.
Built-in SNS security solutions	Features like user privacy, authorization, and reporting abusive content are built into SNS. SNSs provide authentication mechanisms to ensure users are genuine (socialbot). Nowadays, CAPTCHA and MFA are used.

Table 3 Threats that social networking websites face

Facebook	**Most Hilarious Video Attack:** When the operator clicks on the video link, he or she is directed to a bogus Facebook login page. This allows the invader to steal the operator's login credentials.
	Like Jacking: Like Jacking is an attack that tricks the operator into liking a link that is potentially harmful. These worms use catchy messages to attract other users.
	Phishing Attack: Sending a unique subject email to catch the operator's eye. By clicking on this link, the user is taken to a fake Facebook page.
	Worm Based Virus: "Know who viewed your profile" entices. An extension is required to use this link. The extension installs a malware function.
MySpace	**Koobface Attack:** This attack downloads a malicious code into a user's MySpace account, turning their computers into botnets. This worm sends spam messages to operators on the acquaintance list.
	Image Attack: Fake MySpace cover pages redirect users to fake MySpace login pages. The attacker gains access to the operator's login information.
Twitter	**Denial of Service Attack:** MySpace detected a DoS attack by "Cyxymu". Tweeting the worm caused massive network traffic. Cybercriminals use SEO to lure victims to malicious websites.
	Worm Infects Twitter: The worm attacked Twitter in four stages, each increasing the worm's ability to spread and steal personal information from Twitter accounts.
	Phishing: Attackers create malicious links that redirect users to the Twitter login page and ask for login credentials.
Orkut	**XSS:** Recently, Orkut users received a message from friends containing malicious code. The attack used cross-site scripting to redirect Orkut users to a fake page. A malicious computer program is automatically installed on the victim's computer.
	Spam Phishing Attack: An operator is redirected to a fake home page in Orkut Spam Phishing. If the operator enters its login credentials, the attacker will gain access to the operator's credentials.
	Spoofed Email Attack: In a spoofed email attack, Orkut users are informed that their accounts will be terminated if the link in the message is not visited. When you click the link, a Trojan downloads other malicious files. The file monitors browser activity to steal user credentials.

Chaudhary & Kumar (2015) [5] proposed solutions for privacy breach in social network. These solutions include:

- Sanitization techniques can help protect privacy. Removing all details and friendship links from the graph reduces the classifier's accuracy.
- To maintain privacy, data mining algorithms can be developed that make use of sensitive actor information.
- Consideration can be given to policy formulation in order to protect the privacy of social networking site users.

- More privacy protection on social media. Unified access control is suggested. Control behavior is an attribute or a session. It should include: Need long-term privacy and security policies User and resource policies.
- Implement a distributed system's privacy policy. Consist of privacy metadata tables for external recipients and authorized users.
- Social media privacy is protected in two ways. Query answering can obtain insensitive information about social network actors. Attackers can re-identify actors' data. Actor identifiers are also public.

Abdulhamid et al. (2014) [1] study titled "Privacy and national security issues in social networks: the challenges". This article examined the structure and components of a member profile, as well as the privacy concerns that individuals and governments who engage in social networking face. It also examined how it can be used to distort national security, how social media platforms have evolved into new weapons of mass mobilization, and how social media platforms have evolved into rallying forces for revolutions and social justice. The following are some of the most serious threats to social networking sites.

- **Viruses:** Due to their popularity, social networking sites are frequently attacked. Infecting millions of computers by embedding a virus in a website or third-party application is simple.
- **Tools:** Hacking user accounts is very common. It can then access personal information and contacts. They can post malware as them.
- **Social Engineering Attacks:** Attackers may send phony emails or posts. Email virus or personal data request. This compromises data security and system security.
- **Identity Theft:** On-line thieves can steal your or a friend's identity. A data hacker can guess your security questions and passwords.
- **Third-party Applications:** Online games and quizzes are available. These apps may gain access to your profile data without your permission. Ads could be targeted, spam sent, or contacts accessed.
- **Business Data:** Putting company data on social media can backfire. Any information about the business could lead to liability, bad publicity, or even help competitors.
- **Professional Reputation:** Unsafe content can jeopardize a user's Colleges can be found online. Pre-interview searches are common. Respect and integrity can hurt an application.
- **Personal Relationships:** Any internet-connected computer or smartphone can post comments. Even retraction can harm. One cannot control who saves it online.
- **Personal Safety:** Not all information posted online is safe. Declaring an absence increases the risk of a break-in, especially if your address is public.

Obiniyi et al. (2014) [15] study titled "Social Network and Security Issues: Mitigating Threat through Reliable Security Model". This paper focused on educating social network users about some of the unique security issues associated with social media. It proposed an algorithm and a model for evading security threats classified as user authentication, data confidentiality, and data integrity. This paper concentrated on the following social network security issues:

- **Malware:** Tweet Worm and Koobface VIDEOMESSAGE WORMS Twitter prank attack Profile Spy is a third-party app that collects personal data and sends spam to the victims' followers.
- **Digital Dossier of Personal Information:** An attacker collects victim profiles and uses them to harm them. It's possible to harm a profile's image on most social media sites.
- **Spam:** Unsolicited email or social media messages are known as spam. Some have tried to advertise with it, but most are malicious.
- **Cross-Site Request Forgery and Cross-Site Scripting:** Unsafe websites or programs are opened on computers, and then used to attack legitimate websites (possibly submitted by the legitimate user).
- **SQL Injections:** SQL injection is a database hacking technique. Hackers can use SQL queries to target vulnerable social media apps.
- **Identity Theft:** Social media identity theft is rampant. This Facebook user attack is ongoing.
- **Phishing:** Websites pretend to be passwords to trick users. Phishing was a common problem in 2012. It's not a retreat, but a shift to social media.
- **Stalking and Cooperate Espionage:** Data leaks cost money and reputation. Employees' use of social media is unabated. Some of this data is shared blindly.
- **De-Anonymization Attack:** De-anonymization attack is another way attackers bypass user privacy settings on social networks.
- **Awareness:** What users see and share on social networking sites may be a way for attackers to gain access. Be wary of fancy stories, images, and URLs.

The approach developed by Obiniyi et al. (2014) [15] emphasizes the confidentiality, integrity, and authentication of information/data. Confidentiality is the assurance given to an entity (data or information) that it will not be read or accessed by anyone other than the recipient specified by the sender. The integrity of an entity (data or information) entails the assurance that it has not been altered, either intentionally or unintentionally. Finally, authentication provides an entity (system, data, or information) with the assurance that another entity (which could be a user or agent) is who it claims to be. Cryptography is critical for maintaining the confidentiality and integrity of data. Fig. 2 shows user-to-user encrypted post model for confidential and Integrity of user post.

Ajami et al. (2011) [2] study titled "Security Challenges and Approaches in Online Social Networks: A Survey". This article discussed various methods and approaches for ensuring social network security for both providers and users (SNs). This article discussed several examples of this type of research. While all models surveyed prioritized user privacy,

they ignored other critical issues. These areas offer numerous opportunities for new or existing mechanisms to investigate and design mechanisms that do not require (or at least minimize) trade-offs in terms of user privacy, data security and performance. Social network security poses the following technical challenges:

- **Privacy risks:** Data sharing risks must be disclosed to users. Also, the SN privacy tools are hard to use and lack customization. Personal information like photos and friends is also uncontrollable.
- **Security risks:** Passwords are reset using fake social media accounts or emails. Cybercriminals can use SN sites to steal users' data.
- **Anonymity risks:** Users' identities and privacy are stolen. A mobile device connecting to an SN site exposes users' personal information and location.
- **Other risks:** Other risks on SN may compromise the user or the SN providers. Some are physical, but most are logical. Some examples:
  - Connecting home devices to an SN site may reveal more about the users. Unprotected devices may compromise other devices on the home network.
  - The SN and its users are exposed to SN site operators and possibly their partners. Large-scale SN privacy breaches may compromise user data. Intentional or accidental data disclosure violates privacy.
  - Furthermore, many SN sites are free, and providers may disappear at any time, denying users access to their data. Using a false identity or group collusion may allow access to personal data.
  - The lack of user-provider trust jeopardizes the success of SN sites. Users must trust each other, service providers, and in many cases, partners. It's difficult to build or maintain trust.

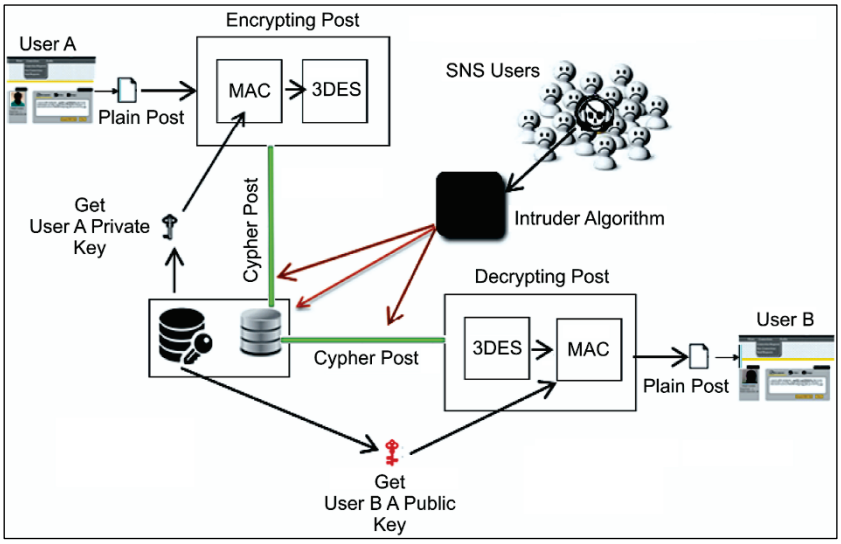

Figure 2 User-to-User Encrypted post model

Table 4 Advices for companies deciding to use Social Media

Five points about using media	Choose carefully: The best medium for any purpose depends on the target audience and the message.
	Pick the application, or make your own: In some cases, it may be better to simply join an established Social Media application and leverage its popularity and user base.
	Ensure activity alignment: It is critical to coordinate all of your Social Media activities.
	Media plan integration: The same holds true for the relationship between Social Media and traditional media: Igniting is key While you may think these two areas are distinct, your customers see them as part of the same entity: your corporate image.
	Access for all: After the company has decided to use Social Media applications, it is important to ensure that all employees can access them.
Five points about being social	Be active: Social media is all about sharing and interacting so keep your content fresh and engage with your customers.
	Be interesting: As a result, if you want your customers to engage with you, you need to give them more than just the best airline or the best kitchen blender.
	Be humble: Before entering any application, learn about its history and basic rules. Start participating only after you have gained the necessary understanding.
	Be unprofessional: People on social media, like you, recognize that life is not always easy. A nice person may even offer free advice on how to improve your performance next time.
	Be honest: Because you're dealing with some of the most technologically advanced people on the planet, don't expect other participants to remain anonymous.

Kaplan & Haenlein (2010) [9] study titled "Users of the world, unite! The challenges and opportunities of Social Media". This study began by defining Social Media and comparing it to related concepts like Web 2.0 and User Generated Content. Based on this definition, it classified Social Media into more specific categories by characteristic:

collaborative projects, blogs, content communities, social networking sites, virtual game worlds, and virtual social worlds. Finally, it offered ten suggestions for businesses using social media.

Kaplan & Haenlein (2010) [9] proposed ten pieces of advice for companies deciding to use Social Media. Tab. 4 summarizes these advices.

3 DISCUSSION

The study emphasized in this section how each study included in the review addressed social network challenges from a unique perspective.

Concentrating on the socioeconomic consequences of social media challenges, Al-Obeidat et al. (2020) [3] discussed the socioeconomic consequences of social media challenges and categorized them into financial Crimes, cyber Threats, physical Threats, other Social Vices, health Issues, and reputational Damage. Concentrating on the people suffering from deaf and hard of hearing, Kožuh & Debevc (2018) [10] proposed recommendations for overcoming barriers to social media use among the deaf and hard of hearing focusing on stakeholders such as social media developers and producers, education, health and business sectors, and policy makers and other stakeholders. As Rathore et al. (2017) [16] classified social network threats as multimedia, traditional, and social, they proposed solutions for establishing a more trustworthy, secure, and privacy-conscious SNS ecosystem. This ecosystem include Watermarking, Co-ownership, Steganalysis, Digital oblivion, Storage encryption, Metadata removal and security, Malware detection, Sybil defense and fake profile detection, Phishing detection, Spammer detection, Commercial solutions, and Built-in SNS security solutions. To handle social network challenges, a security enforcement algorithm and model for a social networking site have been proposed by Obiniyi et al. (2014) [14]. This approach emphasizes the confidentiality, integrity, and authentication of information/data. Fig. 3 shows user-to-user encrypted post model for confidential and Integrity of user post. Similarly, Ajami et al. (2011) [2] proposed fourteen distinct security strategies for SNs.

Regarding privacy defenses and awareness, Chewae et al. (2015) [6] recommended strategies such as a privacy awareness campaign can help users understand their rights, the role of schools and institutes in educating students, and stronger authentication and access control to prevent the threats. Chaudhary & Kumar (2015) [5] proposed solutions for privacy breach in social network. These solutions include sanitization techniques, data mining algorithms, policy formulation, user-centered approach to access control, and system's privacy policy.

More generally with concentrating on companies, Kaplan & Haenlein (2010) [9] proposed ten pieces of advice which divided into company level and personal level for companies deciding to use Social Media. Company level includes choosing the medium carefully, ensuring activity alignment, integrating media plan and access for all employees. While on the other hand, personal level includes active, interesting, humble, unprofessional, and honest.

On the other hand, Shaw et al. (2016) [16] introduced a process model (Fig. 2) and tools for each stage of network forensic analysis (Table 4) in order to investigate the point of vulnerability of social networking sites in order to gain a better understanding of the challenges these sites face.

4 CONCLUSION AND FUTURE WORKS

As a result of the social network service challenges, enormous opportunities have opened up. Along with influencing everyone's social and economic behavior, the social networking service has had an impact on their way of life and thought. While social networking sites have improved economic and social outcomes, they have also introduced a slew of security risks. This article discusses a variety of security features and issues in the social network service environment, including privacy risks, anonymity risks, malware, spam, identity theft, phishing, business data, professional reputation, and personal relationships.

Additionally, it encompasses difficulties associated with multimedia content, social content, technical issues, psychological issues, and the majority of threats directed at Facebook, MySpace, Twitter, and Orkut. Additionally, it discusses preventative measures for these issues. These contributions to research can be found on both a theoretical and practical level. Theoretically, this study focuses on the most prevalent challenges in a variety of fields, which can aid scholars in developing a holistic understanding of these issues and validating the methods used to address them. To address these issues, this study incorporates previously identified solutions. In practice, these solutions would benefit organizations and individuals who interact with these social media platforms. While some progress has been made, much more work remains to be done to safeguard social network service and privacy. To address social network service security concerns effectively, technological solutions must be combined with appropriate laws and regulations.

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Social Media Security Awareness in Saudi Arabia

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Abstract: With the daily use of social media, the cybersecurity and privacy are challenging for most communities. This research is aimed to explore and evaluate the awareness of cybersecurity in Saudi Arabia. It is also designed to discover how the ordinary users performances in using internet security while using social media. This research employed mixed methods. The researcher sent the online questionnaire to random people who used the social media to participate in this study. At the end of the online survey, one more question was attached to ask participants to involve in the second round of data collection (interview). This research found that social media users' awareness about internet security is different from users based on their gender. In addition, the ways of contact were affecting the reaction of users to share their information with others. The results also indicated that when the level of awareness is high the way of dealing with others is different. This study also confirmed the users' belief in internet security and most of them knew the strengths of internet security enabled them to protect their devices and personal information from outside intruders. Moreover, the findings of this study showed that the users of social media need to give more attention to all types of security threats. The findings of this paper can be used theoretically and practically by identifying the level of security awareness based on social media usage and the purpose of use.

Keywords: awareness; Saudi Arabia; security; social media

1 INTRODUCTION

Today, ensuring the privacy of your confidential information online is quite a challenge. The line between what is safe and what is not is quite thin these days. We have to take caution over the growing number of threats in the online space, from trojan horses to worms to viruses to spam even cyberstalkers. This study focused on three cyber threats which are widespread currently [14, 1]. Based on a research conducted in June 2012 by Mcafee.com the total number of malicious websites/bad URLs was more than 36 million. Moreover, the number of new bad URLs in a month was at over 2.7 million. The malicious websites are developed to infect your device with Trojan horses or and keystroke loggers. These malware are designed to collect critical personal information for example, credit card details and bank details [4]. If you do not take caution, these cyber criminals will get away with everything you possess [15]. Moreover, email security awareness is something crucial [27]. According to k-state.edu, this is another area that attackers use to launch cyber attacks. Some of the potential malware entry points when using E-mail include: adware, scams, attachments, spyware, bad URLs and viruses [11]. Prevention is better than cure, do not share personal information with anyone online. If you receive email messages from senders you cannot verify, do not open them. Owing to the ever-increasing complexity of cyberattacks, email scams can even collect your private and confidential data [18].

Today the easiness of networking socially is higher than before. However, this increased easiness comes with corresponding increased security risks [26]. Social networking platforms have continually shaped the behaviour of human beings [28]. Over the years, the amount of personal information that is shared online has been on the rise [9]. A common tendency in people is to share more personal information on the various social media platforms than with our families and friends [25]. Cyber criminals are taking note of this tendency in people and are continually taking advantage of this. Such personal information that is shared online can be used to social engineer the said people [11]. Avoid oversharing online, it is more dangerous than confiding in family and friends. The same risk of having your personal information stolen is as prevalent on these sites as anywhere else [3]. The possibility of cyber stalkers breaking into your homes or of pedophiles stalking your children cannot be ignored [10]. With this in mind, social network platforms may be regarded as the worst threats in IT world [1]. According to a prediction by Canada, in coming years Facebook will be the biggest threat to cybersecurity [24, 23]. IT World magazine did a SWOT analysis as well on the evaluation of security needs [20]. Here are some of the highlights below.

The security strengths of the organization include? In the case of organizations that are small, their strength can be deemed to be the fact they are small, therefore easier to secure compared to the larger companies. The presence of an existing security culture embedded in the companies systems is another strength [1]. It is easier to strengthen an organization with an already existing security infrastructure than one without. On the other hand, Lack of a culture that fosters security awareness or a program that does the same is regarded as a weakness [1]. For example, the lack of a well-defined patch management program is a sure shortcoming. However, companies that lack this have a huge opportunity to make amends and improve on this. In some instances, some organizations have been attacked due to existing minor vulnerabilities that would not have been exploited if there was a robust patch management system [2]. Bringing to reality a patch management program may be costly. However, this amount compared to the damage cost due to the existence of the vulnerability cannot be compared. Some weaknesses may be more technical than others [11]. The absence of a proper logging framework in place is a weakness that is easy to fix. Lack of funds is another prevalent weakness. Without funds, some weaknesses are hard to sort

out. In some cases, some organizations are put out of business following security breaches.

The security and protection of the Internet represents a great responsibility on the user to save his data, and this topic is related to our lessons in college in terms of the possibilities of networks and ways of connecting and securing. From our sense of the problem of safety on the internet we did this research to answer some of the questions which are:

1. What internet security characteristics are commonly published in social media discussions?
2. What are the similarities in the strategies of discipline in the sites of the wall on the social communication security methods?
3. What are the variations in disciplinary techniques in the social media's wall publications by internet security?

The aim of undertaking this study is:

1. Determine the security characteristics that are commonly published in social media
2. Investigation the similarities in the strategies of discipline in the sites of the wall on the social communication security methods
3. Discuss variations in disciplinary techniques in the social media's wall publications by internet security

The scope of this research was on the study of safety factors used by users on social networks. Moreover, this research was limited to the topic of internet security in social networking sites and did not address various internet sites, especially electronic payment methods, and this is under the ban on citizens due to the Corona virus with the frequent use of buying and selling through different internet sites.

2 MATERIAL AND METHODS

The presence of internet security in social media and how to develop this behaviour: this statement formed the basis of this study intending to examine the magnitude and nature of internet security use by human (even male or female) in social media. This study comes in handy for every researcher interested in people's internet security behaviour over social media and who are developing these behaviors of security. Denzin [8] state that the research design of a study refers to a set of guidelines linking theoretical models to practical methods of inquiry in addition to strategies for gathering empirical material; these guidelines can be adapted. So as to enable the collection of more complex data [17] suggests that the methodological system of the research be more qualitative. The underlying defense for this framework is the fact that the research tries to comprehend the cultural responses as well as the social semiotics internet security in social media. Hence, the current research adopts a qualitative approach, which means evaluating the answers of the respondents elicited through the interviews and focus groups, and making conclusions based on the subjective evaluation in addition to the analysis of the internet security in social media materials [12].

The aim of this research was to understand and evaluate the use of internet security in social media. Moreover, how their performances in using internet security at social media conversations? The researcher selected the sample by sending an online questioner to the most human that used social media (such as: Facebook, Twitter, Second Life, What's App), to answer if they use disciplinary in chatting with friends or formal chatting, and decided if they want to participate in the research. In the end of online survey (questionnaire), one more question is attached to ask participants for continuing the following interview protocol.

This study consists of two instruments and two stages:

1. Online survey of to see how they use internet security in conversations.
2. Online interview for discover how they evaluate the kind of internet security disciplinary they use on conversation (friendly or formal).

The researcher gathered spontaneous and unguided emerging information that was needful in coming up with subject matters for the facts. The goal of the researcher was to study the various degrees of internet security measures employed in social media. This was carried out with a goal to get insights on the role played by gender in internet security techniques. The researcher took up the role of a passive observer through out the interaction. This meant that the researcher could not get involved in any of the forums. However, he looked at the chosen social media platforms (Facebook page, Twitter, Second Life as well as What's App). While on the various platforms he was able to monitor the internet security patterns and the role of gender with regards to internet security techniques while using social media platforms.

The data collected, such as communication data, was subjected to close analysis at some point to notice internet security patterns during the commentary. With this in place, the researcher could have a more well defined view of the existing patterns as well as correlations between employed internet security techniques and gender on social media platforms. Later, this records become coded into a desk in step with Brown's and Levinson's (2005) internet security classes to get a more concise and more vast comprehension of internet security patterns. Moreover, the internet security measures to be applied based on social media usage will be more clear [22].

In the first stage (online survey), the participants will be of mixed gender (male and female) and will be approximately 40 participants (n = 40). The researcher will select the samples using convenient sample, by sending an online questionnaire in electronic versions with the informed consent letter and information statement simultaneously. Along with invitation participation to decide if they are willing to participate in the research. If participants complete the online questionnaire, one more question will be attached to ask them for continuing the following interview protocol. In the second stage (online interview), an online interview protocol will be used to collect data of participants to see how they evaluate the kind of internet security that they used. The interview protocol will be developed using the responses from the trends of online survey questionnaire. Analysis of the collected data was done using the following methods:

information records coding and categorizing. The statistics that were gathered were noted penned down in English. Next, the statistics was coded and categorized consistent with the types of internet security. Moreover, the language patterns from both male and girl contributors had been analyzed based totally on [14] concept. The system was able to successfully notice convergent as well as divergent patterns in the internet security practices of various genders. The system was able to construct tables that showed the correlation between the tendency of a given style of language and the employment of various internet security measures in the selected people's social media communications.

Tabs. 1-7 have been designed to show the frequency of language styles as well as the use of internet security schemes inside the social media forums of the chosen individuals. In the technique of coding, the transcribed discourse changed into segmented and categorized, consistent with Brown's and Levinson's (2005) theory of internet security techniques. Eventually, at the final degree of analyzing, this statistics were analyzed as a good way to pick out the goal of the communicators. Using coding manner was to generate an outline of categories of issues for analysis [7].

a) Statistical method

The study shall utilize several statistical methods, including standard deviation, mean as well as skewness and kurtosis(measures of normality), to obtain study results.

i) The Mean Eq. (1)

To obtain the mean, you divide the sum total of a given set of numbers by the size of the set. Most times, when people occasionally make mention of average, they are usually referring to mean. Calculations of mean come in handy in our daily lives. Using mean, you can find how long it takes you to get a job daily as well as find your average monthly expenditure.

$$M = \frac{1}{N}\sum_{i=1}^{N} a_i = \frac{1}{N}(a_1 + a_2 + \ldots + a_n). \quad (1)$$

ii) Standard Deviation Eq. (2)

The formula for finding the standard deviation is similar to the formula for finding the variance. It is the standard deviation formula is similar to the variance formula.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x})^2}. \quad (2)$$

Where: σ - standard deviation, x_i - each value of the dataset, $\overline{x}$ - the arithmetic mean of the data, N - the total number of data points, $\sum(x_i - \overline{x})^2$ - the sum of $(x_i - \overline{x})^2$ for all data points.

iii) Skewness Eq. (3)

Skewness is defined as a probability distribution measure of a random variable that is real-valued. Skewness assumes three possible types of values: negative, positive, undefined. A positive value of skewness means that the right side tail is longer than the left side tail and most of the values in the set occur to the left of the mean value. On the other hand, a negative skew means that the left side tail is longer than the one on the right. Moreover, a notable subset of the set occurs on the left side of the mean. A zero value means that there is a relatively constant distribution of the values on both ends of the mean value. However, this does not mean it's asymmetric distribution.

$$Skewness = \frac{\sum(M - a_n)}{\sigma}. \quad (3)$$

Where: M - the mean, a_n - sample number, σ - Standard deviation.

iv) Kurtosis (Eq. (4)

Using kurtosis, you get to know your graph's peak, that is, how high the graph is around the mean. This is regarded as the fourth moment in statistics. There are two possible values in this case: positive values and a negative value. If you obtain a positive value, it means you have little on your tails. If you obtain negative values, it means you have a lot of data on your tail. Lightness or heaviness of the tails depicts how peaked your data is, that is, more peaked for heavy and less peaked for light.

$$K = \frac{n(n+1)(n-1)\sum_{i=1}^{n}(x_i - M)}{(n-2)(n-3)\left(\sum_{i=1}^{n}(x_i - M)^2\right)^2}. \quad (4)$$

The quantitative survey data will inform the qualitative interviews, and this will lead to interpretation and help to shape the interview questions. Nvivo used to analyze the qualitative data.

3 RESULTS AND DISCUSSION

The extremely trendy social media application that the participants visit regularly shown in Tab. 1. About 50.00 % of the total participants agreed that they use all of the social media sites regularly. Only 15 people (37.50 %) mentioned that they utilize Facebook for general social media purposes. This study points out the widespread use of various social media platforms among the population for a number of varied reasons. This indicates the prevalence of communication sites among the majority of society.

The main purpose for regular browsing that the participants visit regularly shown in Tab. 2.

While replaying this item, 37 participants answered that they use chatting sites such as Facebook, Twitter, Second

Life, and What's App only for communication and chatting. The rest of the elements appear to be compatible with ratios in terms of study, games, and none with 1 for each category. Chung [6] and Cavalli [5] also mentioned that a great number of people access social media with the aim of chatting and communicating only. The useful tool for internet security among social media are shown in Tab. 3.

Table 1 Social Media Application

Type	Participants	Percentage, %
Facebook	15	37.50
Twitter	1	2.50
Second Life	2	5.00
What's App	2	5.00
All of them	20	50.00

Table 2 Purpose of Social Media Usage

Type	Participants	Percentage, %
Chatting	15	92.50
Study	1	2.50
Fun & Games	2	2.50
None	2	2.50

Table 3 Language Acquisition

Type	Participants	Percentage, %
Strong Agree	5	12.50
Agree	30	75.00
Disagree	5	12.50
Strong Disagree	0	0.00

Among all, 30 participants agreed that social media sites were useful for internet security, where 5 participants believed they strongly agreed. Five of them disagreed with this since this had never come to their knowledge. Consequently, a large number of participants supposed that social media could be valuable and safe by using internet security. McBride [16] points out the role played by various social media platforms to recreate changes in internet security. Tab. 4 shows the preferred mode of communication among social media users while on social media platforms.

Table 4 Communication Application

Type	Participants	Percentage, %
Chatting	32	80.00
Video Calling	4	10.00
Posting	4	10.00
Blogging	0	0.00

Thirty-two of the selected participants preferred communicating on social media platforms via chat. Four of these in the set said they prefer video calls as a mode of communication. In another case, 4 said they preferred to communicate with one another through posts, that is, by coming up with posts as well as commenting on other people's posts. Blogging as a mode of communication, in this case, did not interest anyone. Tab. 5 shows the user responses to the question, "Has usage of internet security in blogging or chatting affected the way your write academic papers or exam script?"

Table 5 Internet Security Programs

Type	Participants	Percentage, %
Yes	3	7.50
Often	15	37.50
No	15	37.50
Never	6	15.00

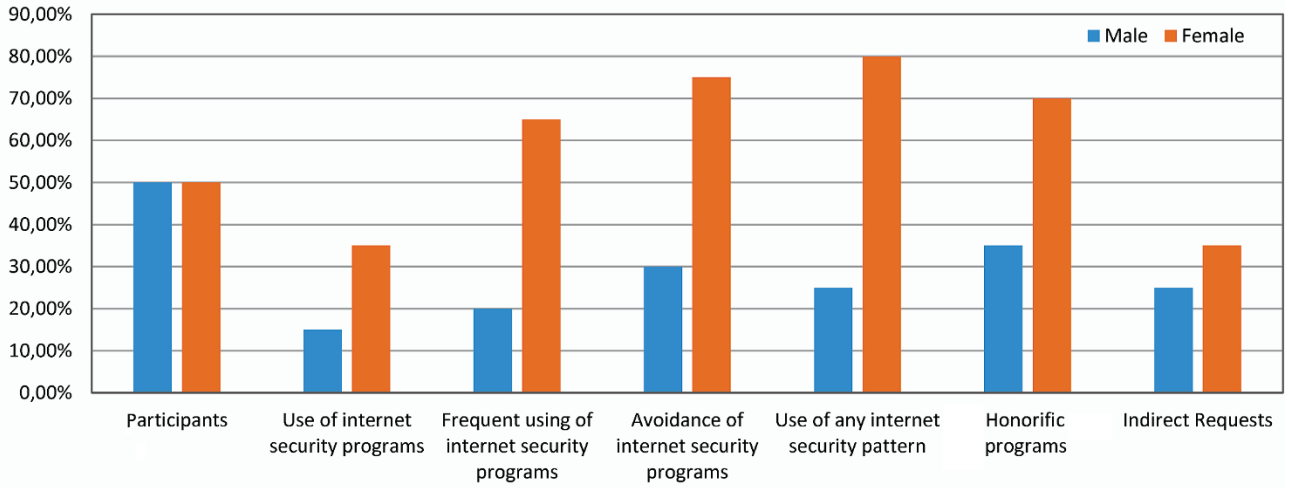

Figure 1 Internet Security Patterns

Including all 18 participants (7.15 % + 37.50 %) said that they got adopted by social media through using internet security programs in the practical life, where the other half (37.50 % + 15.00 %) said they avoid that condition regularly. Once over, these results encouragement the division between the conclusions of [21, 5]. This also provisions the indication of where the instigators stated that investigates had variations in results for having variability in reason, members, satisfied and background [19]. The regularity amount on the internet security programs patterns in social media's conversations of certain participants was shown in Tab. 6 and in Fig. 1.

The evaluation indicates that out of 20 male individuals, handiest three or 15.00 % of them tend to use extremely internet security of their social media's conversations. 4 or 20.00 % of male participants generally tend to internet security frequently, six of the male contributors (30.00 %) keep away from the use of internet security and use the

honorific program in their social media's conversations to reveal internet security. The Simplest 5 or 25.00 % of male individuals use tag questions, and some other 5 who represent 25.00 % of male participants generally tend to make requests from their pals circuitously in their social media conversations. Otherwise, out of 20 female individuals, 7 or 35.00 % of them use the extremely good-well-mannered shape of internet security and indirect requests in their social media safety programs. 14 or 70.00 % of those female participants use honorific programs, and 13 female with 65.00 % use safety and security also are discovered to have the tendency to more internet security via social media. A majority of 15 or 75.00% of the lady members keep away from the usage of any program for security at the same time as 16 female or 80.00 % of those female contributors use tag hack programs in their social media's security.

Table 6 Language Patterns

	Frequency of Usage		Percentage of usage (%)	
	Male	Female	Male	Female
Participants	20	20	50.00	50.00
Use of internet security programs	3	7	15.00	35.00
Frequent using of internet security programs	4	13	20.00	65.00
Avoidance of internet security programs	6	15	30.00	75.00
Use of any internet security pattern	5	16	25.00	80.00
Use of Honorific programs	7	14	35.00	70.00
Indirect Requests (Hack program)	5	7	25.00	35.00

The regularity amount on the use of internet security in social media's conversations of certain participants shown in Tab. 7 and in Fig. 2.

Table 7 Level of Internet Security

Internet Security Strategies	Frequency of Usage		Percentage of usage (%)	
	Male	Female	Male	Female
Programs	18	17	90.00	85.00
Online Software	8	13	40.00	65.00
Hack Programs	7	15	35.00	75.00
IP change	5	9	25.00	45.00

Internet security from different cultural histories might also define security in a distinctive way that is suitable to their context and settings [2]. In keeping with [13], Internet security is developed by using protocols and codes so as to reduce friction in private communications (1992) says politeness is the set of social values that communicators don't forget each different by way of gratifying shared expectancies. Consequently, it can be visible that humans exercise Internet security because there are desires for one to recollect their feelings, set up a given standard of mutual consolation as well as foster rapport.

The information evaluation has recognized numerous internet security patterns that are utilized by contributors in the various social media forums irrespective of gender. The accumulated information has been categorized based on Lakoff's (1975), Bonvillain's (2002), and Beeching's (2012) principle of internet security and gender, which encompass: using internet security form of safety, frequent using of internet security programs, internet security programs, use of any internet security pattern, use of honor program and indirect requests / hack program [10].

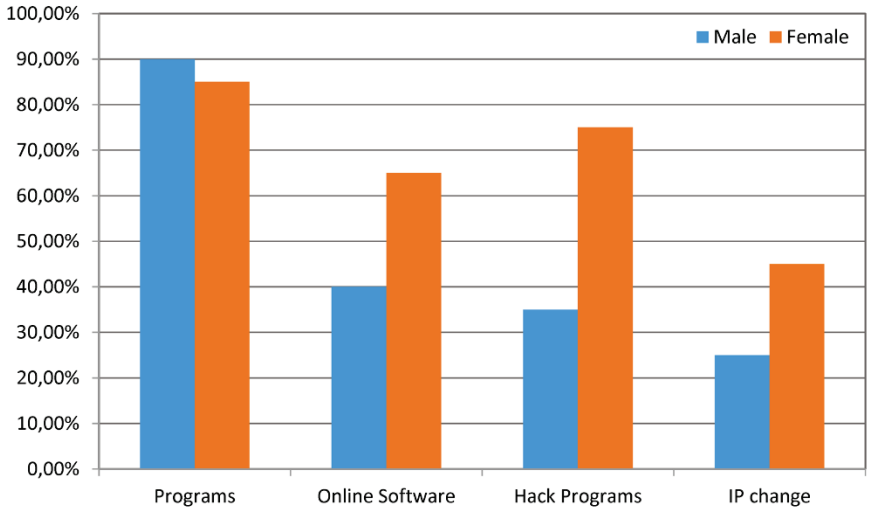

Figure 1 Level of Internet Security

Including all 18 participants (7.15 % + 37.50 %) said that they got adopted by social media by using internet security programs in practical life, where the other half (37.50 % + 15.00 %) said they regularly avoid that condition. Once over, these results encouragement the division between the conclusions of [21, 5]. This also indicates [19] where the instigators stated that investigates had variations in results for variability in reason, members, satisfied and background.

Except for the application of internet security techniques, male and woman also are determined to be exclusive in phrases of internet security sample. Lakoff [13] idea on female's language observed that girls are extra internet security than guys of their speech. Lakoff [13] proposed that ladies' language may be differentiated from men's through looking into some components along with using internet security, the avoidance of internet security thru first rate-

well-mannered shape consisting of they are using these programs and so on. Additionally, they express regret to a higher level as well as take pleasure in utilizing indirect request(s) while inquiring for assistance.

4 CONCLUSION

This study is helping in understanding the level of security awareness during the usage of social media in Saudi Arabia. The results indicated that there was no clear picture of information security in the minds of social media users. It is also indicated the level of awareness is varied from male to female about the term of "information security". The study contributed in two ways, theoretically and practically. From a theoretical point of view, this study would bridge the gap in the lack of literature within Saudi Arabia regarding security awareness in the usage of social media. From a practical point of view, this recommends the necessity to raise awareness of the importance of information security and safety.

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Predicting of Roll Surface Re-Machining Using Artificial Neural Network

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Abstract: The paper presents a model for predicting the roll wear in the hot rolling process. It includes all indicators from the entire continuous rolling line that best predict the roll wear in the hot rolling process. Data for model development were obtained from annual production on the first rolling stand of the continuous roll mill. The main goal of the research was to determine significant parameters that affect the wear of the roll in the process of hot rolling. It has been found that the amount of rolled material before the re-machining of the roll surface has the greatest impact on the life of the roll contour. Therefore, the amount of material rolled before re-machining of the roll was used to estimate the wear of the roll. An artificial neural network was used to predict this amount of rolled material and was validated using data from one-year production.

Keywords: artificial neural network; hot rolling; linear regression; prediction; roll wear

1 INTRODUCTION

In hot rolling, the dimensions of the long bars vary according to the groves of the rolls. The surface of the cooled roll wears out due to the constant contact with the hot-rolled bars. Surface cracks also occur on the surface of the roll due to temperature gradients. The reason for the formation of temperature gradients is the constantly changing thermo-mechanical tribological rolling conditions, which depend on the rolled material and the roll, the temperature of the coolant and the rolling speed.

In addition to the above, it is necessary to know the effects that rollers have on the surface defects of rolled bars. There is a lot of research in this field [1-5].

Understanding roll wear and the ability to accurately predict the wear is essential for the steelmaking industry. Practical guidelines for reducing roll wear during hot rolling are given in the literature. Practical instructions can be divided into 5 sets.

The first set combines guidelines for extending the life of rolls by modifying existing roll material [6].

The second set includes approaches to reduce roll wear by applying additional surface coatings to the rolls [1, 3].

The third set combines instructions for the use of lubricants [2, 7, 8, 4].

The fourth set contains instructions for changing the geometry of the groves of rolls [9-12] and the last set provides instructions for reducing roll wear by changing the rolling conditions (e.g. rolling load, rolling temperature) [2, 13-16].

Some excellent mathematical models for predicting roll wear have been published in the literature. The best-known researchers who have studied this topic are Archard, Yasada, Lim and Ashby, Sibakin, Oike, Somers, Tong and Chakko [1, 3]. However, none of these models can be practically applied in industrial environments, where the specifics of different types of steels appear, where different rolling regimes are used and where delivery deadlines need to be met.

In a one-year period, the 7 influencing parameters on the wear of the roll of the first rolling stand of the continuous roll mill for long round bars were investigated. In our very flexible environment, the diameter of the roll, geometry of groves, its surface, contact time, carbon equivalent of rolled material, rolling temperature and amount of the rolled material were analysed. It should be noted that the survey included data for more than 220 serial-produced steels. The bars were rolled to a diameter range of ∅20 mm to ∅58 mm.

In this study, the effects of the entire hot rolling process of round bars on the wear of the rolls were identified and analysed. The first part of the paper presents the experimental setup, including the industrial environment and description of collected parameters. The following chapter presents a model for predicting roll wear based on artificial neural networks and linear regression. In developed models, roll wear is defined as the amount of rolled material before re-machining the rolls. The developed models were validated using the data from one-year production. The last chapter provides conclusions and plans for future work.

2 STEEL ROLLING PROCESS, MATERIALS AND METHODOLOGY

The small and flexible steelworks Štore steel Ltd. produces over 200 types of steel with various chemical compositions. Steel production begins with the melting of scrap steel in an electric arc furnace. After melting, tapping and ladle treatment is performed, after which the melt is continuously cast into billets of dimensions 180 × 180 mm. A two-strand continuous caster performs this procedure.

To further roll the billets in the rolling mill, the billets are heated to 1250 °C. The heated material is led to a descaling device and through a duo reversible rolling stand. The billets are made in 7 passages over a stand with rollers of 800 mm diameter. The billets are rolled into bars with a circular cross-section to a final diameter of between 90 mm and 110 mm.

The bars are then transported on a duo reversible rolling stand with 650 mm diameter rolls. After four passes and the last cooling by-pass, the material cools down to the rolling temperature and exits the rolling stand.

An infrared pyrometer is used to control the rolling temperature.

Table 1 The chemical composition of the outer working layer of the roll

C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cr (%)	Ni (%)	Mo (%)
3.1-3.9	1.1-1.9	0.4-0.9	<0.059	<0.019	0.6-1.3	0.9-2.9	0.2-0.6

The material is then transported to the final continuous rolling line with rollers of 460 mm diameter and length of 700 mm (Fig. 1).

The following number of passes on a continuous rolling line is required to make the desired cross-sections of the bars:

- 9 passes for making a bar with a diameter between 20 mm and 38 mm.
- 7 passes for making a bar with a diameter between 38 mm and 49 mm.
- 5 passes for making a bar with a diameter between 50 mm and 59 mm.

The continuous rolling line is made of 14 devices. The first device is a descaling device, followed by six horizontal and four vertical rolling mills. For hot cutting both ends of the rolled bar, two shears are integrated on the line and additional ones for cutting the bar to the final dimension before it enters the cooling bed.

The rollers of the continuous rolling mill consist of two layers (according to Inspection certificate provided by the roll producer). The outer working layer is made of steel and the core is made of nodular cast iron. The working layer of the roll consists of perlite and bainite. The ratio depends on the required hardness. The thickness of the working layer of the roll is determined by adding approx. 35 mm to the geometry of the groove. The core of the roll is made of perlite, which contains free cementite and spherical pearlite.

After the appearance of roll wear and fatigue cracks, the rollers are re-machined with the turning process. The re-machining process is carried out at the Štore steel Ltd. steel plant. The re-machining process is repeated until all the working layer of the roller is removed and the core layer of cast iron is displayed. Then the rollers must be discarded.

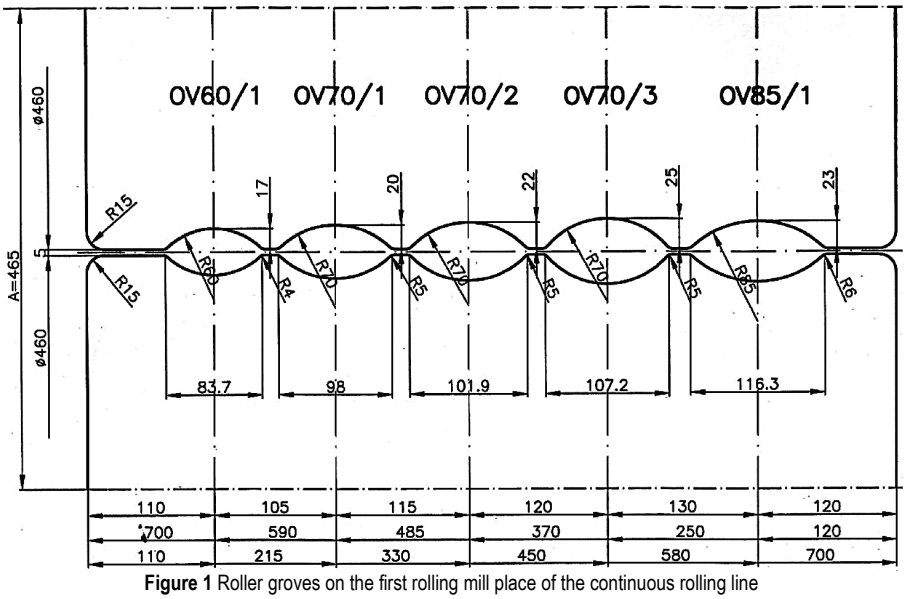

Figure 1 Roller groves on the first rolling mill place of the continuous rolling line

In the test year, the lifespan of rolls was analysed on the first roll stand of the continuous roll mill, where long round bars with diameters from ∅20 mm to ∅58 mm are rolled.

In a one-year experiment, the groove surface after machining *GS* (mm^2), the rolls diameter after re-machining *RD* (mm), the contact time *CT* (s), the average carbon equivalent *CE* (%), the average rolling temperature before entering first rolling mill place *RT* (°C) and amount of rolled material before machine operation *Q′* (kg) were monitored.

In the case of worn rollers, a cutting process must remove the affected part of the surface.

Based on available data from the steel plant, it is possible to conclude that there is no information on the primary cause of the re-machining of the rolls.

The reduction of the roll diameter *RD* and the groves surface *GS* on the first rolling mill place of the continuous rolling line throughout the roll life cycle is shown in Tab. 2.

The time between entry and exit of the rolled piece from the deformation zone is defined as contact time *CT*. It is calculated by the Eq. (1).

$$CT = \frac{l}{v}, \tag{1}$$

l is the contact length (mm) and is determined by the Eq. (2):

$$l = \sqrt{\frac{RD}{2} \cdot \Delta h}, \tag{2}$$

$$\Delta h = h_0 - h_1, \tag{3}$$

where h_0 and h_1 are the effective heights of the input and output workpiece,

$$v = \frac{v_r}{\prod_i^n R\_f_i}, \tag{4}$$

where v is roll circumferential speed. v_r is rolling speed and R_f_i are reduction factors for calculation of rolling speed at i–1 stand.

Table 2 Change in cylinder diameter and surface area of individual groves during the entire life cycle of the roll

Roll diameter *RD* (mm)	OV60/1 (mm²)	OV70/1 (mm²)	OV70/2 (mm²)	OV70/3 (mm²)	OV85/1 (mm²)
420	122848	142254	148634	157547	166361
419	111317	128774	134461	142381	150445
417.2	111036	128445	134115	142011	150057
415	110474	127788	133424	141271	149282
413.5	109855	127065	132663	140457	148428
411.2	109433	126572	132144	139903	147846
408	108786	125816	131349	139052	146953
406.4	108027	124928	130416	138054	145905
404.2	107436	124238	129690	137277	145089
401	106817	123514	128929	136463	144235
420.3	106114	122692	128065	135538	143265

Tab. 3 shows the reduction factors for rolling round bars with a diameter of 21 mm on the continuous rolling line in the Štore steel plant.

Table 3 Reduction factors for rolling round bars with a diameter of 21 mm on the continuous rolling line in the Štore steel plant

Roll mill place	Reduction factor
1H	1.188
2H	1.143
3V	1.285
4H	1.190
5V	1.147
6H	1.000
7V	1.000
8H	1.000
9V	1.000

A one-digit number representing the influential alloying chemical elements represents carbon equivalent *CE*. In the research, it was determined by the Eq. (5).

$$CE = \mathrm{C}(\%) + \frac{\mathrm{Mn}(\%)}{6} + \frac{\mathrm{Si}(\%)}{6} + \frac{\mathrm{Cr}(\%)}{5} + \frac{\mathrm{Mo}(\%)}{5} + \\ + \frac{\mathrm{V}(\%)}{5} + \frac{\mathrm{Cu}(\%)}{15} + \frac{\mathrm{Ni}(\%)}{15}. \tag{5}$$

Tab. 3 shows some of the most important parameters selected from year-round production (2014).

3 MODELS FOR PREDICTING ROLL WEAR

This research aims to design and test the methodology for predicting the roll wear in the Štore steel plant.

With linear regression and artificial neural networks, two models were developed to predict the amount of rolled material before re-machining the rolls.

The data from Tab. 4 are used for modelling.

The average deviation between the predicted and experimental data is selected for the Fitness function, which is calculated according to the equation:

$$\Delta = \frac{\sum_{i=1}^{n} \frac{(Q_i - Q'_i)}{Q'_i}}{n}, \tag{6}$$

where n is the size of the acquisition data and Q'_i and Q_i are the actual and the predicted amount of rolled material before re-machining of the roll.

3.1 Linear Regression Model

The results of the linear regression obtained by ANOVA show that the model does not predict in a significant way the amount of rolled material before the re-machining of rolls ($p > 0.05$).

The results also show that only 18.34 % of total variances can be explained by independent variables variances (R-square).

The results also show that the surface of the individual grove is the only significant parameter ($p < 0.05$).

A linear regression model for predicting the amount of rolled material before re-machining the rolls is given by:

$$Q = 30 \cdot (-1.045 \cdot GS + 912.6 \cdot RD + 629703.9 \cdot CT + \\ + 38012.9 \cdot CE - 107.7 \cdot TR + 169073.9). \tag{7}$$

The relative deviation of the regression model from the experimental data is 70.9 %.

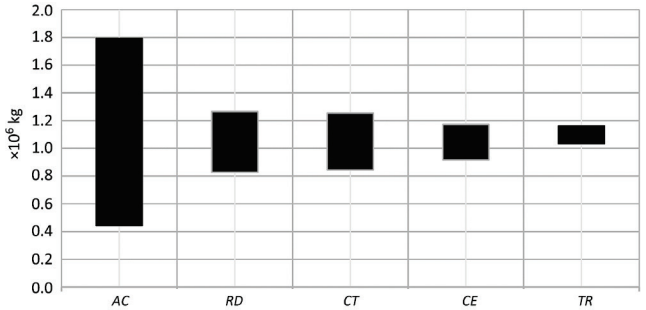

Figure 2 Calculated effects of parameters on the amount of rolled material before re-machining of rolls

Fig. 2 shows the effects of individual parameters (individual variables) on the amount of rolled material before re-machining the rolls.

The results in Fig. 2 show that the surface area of an individual groove is the most significant parameter in predicting the amount of rolled material before the re-machining of rolls.

Table 4 Parameters from year-round production included in the survey

Roll diameter after re-machining *RD* (mm)	Groove surface after re-machining *GS* (mm^2)	Amount of rolled material before re-machining *Q′* (kg)	The temperature of rolled material in front of the first rolling mill place *TR* (°C)	Contact time *CT* (s)	Carbon equivalent *CE* (%)
420	111317	776655	925	0.0503	0.6976
420	134461	1199692	925	0.0593	0.7375
420	128774	2325086	925	0.0588	0.8234
420	142381	738174	925	0.0696	0.7615
420	134461	356011	925	0.0558	0.7874
420	150445	535935	925	0.0623	0.7136
419	111036	1153021	925	0.0480	0.6796
419	134115	2145107	925	0.0597	0.6966
419	128445	1514654	925	0.0574	0.8283
419	142011	678049	925	0.0661	0.8513
419	150057	456329	925	0.0602	0.7036
415	109855	1369647	925	0.0502	0.6647
415	132663	2210526	925	0.0585	0.7505
415	148428	143922	925	0.0561	0.7076
415	139976	745241	925	0.0696	0.8114
413.5	126638	2496935	925	0.0579	0.8164
413.5	139976	232599	925	0.0576	0.6707
413.5	132213	744329	925	0.0587	0.8234
413.5	147923	619444	925	0.0640	0.7605
413.5	109489	1208941	925	0.0495	0.6727
413.5	132213	1217757	925	0.0599	0.7365
411.2	108786	1366408	925	0.0577	0.7764
411.2	139052	716366	925	0.0668	0.7954
411.2	131349	645335	925	0.0605	0.8363
411.2	146953	159756	925	0.0554	0.6307
411.2	108786	1136483	925	0.0490	0.6816
411.2	131349	3848595	925	0.0594	0.7335
408.5	124928	1134203	925	0.0577	0.7794
408.5	138054	594424	925	0.0694	0.8204
408.5	130416	363868	925	0.0607	0.7695
408.5	145905	103325	925	0.0682	0.6367
408.5	108027	1419997	925	0.0492	0.6327
408.5	130416	2005371	925	0.0584	0.7226
406.4	124238	1333465	885	0.0565	0.7964
406.4	137277	804124	885	0.0672	0.8413
406.4	129690	544296	885	0.0579	0.7635
406.4	145089	603241	885	0.0613	0.6916
406.4	107436	1127698	885	0.0508	0.6527
406.4	129690	1956519	885	0.0588	0.7265
404.2	123514	1637308	925	0.0572	0.8563
404.2	136463	370057	925	0.0637	0.8543
404.2	128929	253466	925	0.0543	0.7964
404.2	144235	179304	925	0.0594	0.7395

3.2 Artificial Neural Network Model

In this chapter, the adaptation of the artificial neural network (ANN) architecture to the problem of predicting the amount of rolled material before re-machining of rolls is presented in detail.

To perform modelling of the amount of rolled material before re-machining of rolls, the popular three-layer neural network architecture was used. A standard backpropagation learning algorithm was selected. The network architecture with 5 input neurons is selected. The optimal number of hidden layers, the number of neurons in each hidden layer, the training parameters, and the optimal type of activation function were determined by systematically changing the parameters in the simulations. The optimal ANN architecture containing 4, 6 and 3 neurons in each level is determined by simulations [17-19]. The only output of ANN is the amount of rolled material before re-machining of rolls; therefore, only one output neuron is needed.

Signals are transmitted at synapses between neurons, where they are processed by Dot product input and output Sigmoid-bi activation function [20, 21]. Fig. 3 shows the detailed architecture of the developed neural model for predicting the amount of rolled material before re-machining of rolls.

Four steps are required to construct a neural prediction model of the amount of rolled material before re-machining of rolls [22, 23].

In step 1, experimentally obtained training and testing data were delivered to the neural network [24].

1200 data points were dedicated to train 120 ANN. Additional 600 data points were used to test and validate the developed ANN. The generalization capability of ANN and the accuracy of the predicted results was determined by the testing process.

The optimal ANN architecture and learning parameters were determined in Step 2. In this step, the optimal number of hidden layers, the number of hidden neurons in each level, the momentum rate (β), the learning speed (α), the total network error, and the maximum number of iterations were searched with simulation.

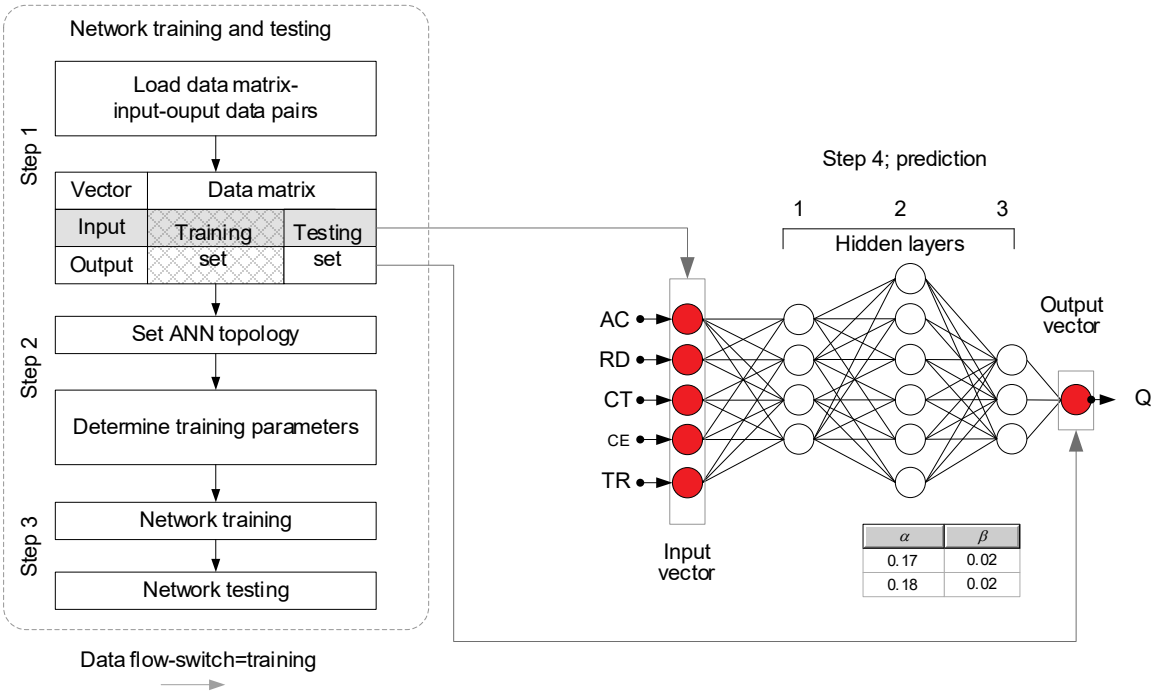

Figure 3 Block diagram of training and using the ANN model for predicting the amount of rolled material before re-machining of rolls with its detailed structure

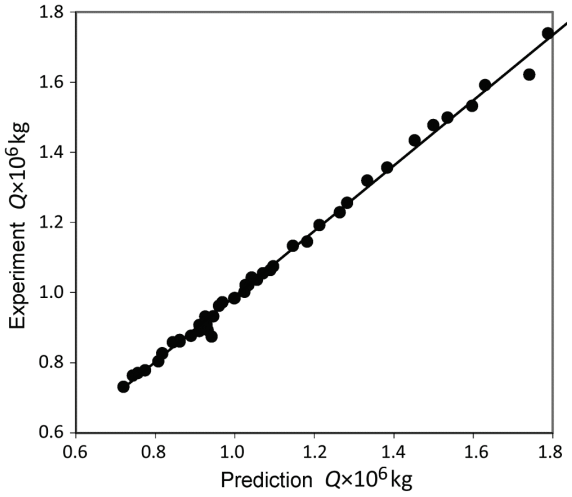

Figure 4 Scatter diagram of predicted and experimentally obtained Q for testing data set

Performances of 49 neural networks were evaluated with fitness function and the number of training repetitions.

The simulations results of 49 different neural networks showed that the most suitable for predicting the amount of rolled material before re-machining of rolls was a neural network with 13 neurons in three hidden layers, where the learning rate α must be less than 0.2 and the momentum rate β must be between 0.005 and 0.02.

The process of training and testing the artificial neural network is performed in step 3.

During training, ANN adjusts the weights on the synapses, thus adjusting its internal structure to correctly predict the te amount of rolled material before re-machining of rolls according to the input parameters.

1200 sets of experimental data were used for the training process.

The training process ended after 910 iterations of training when the prediction model error fell below a predefined lower error limit. The test error for 600 data points was found to be close to 4%. Fig. 4 shows a scatter diagram of the predicted values and experimentally obtained values of the amount of rolled material before re-machining of rolls for the test data set. After 910 iterations of training, the model is built and ready for use.

The model is then tested with additional pairs of input-output data that were not included in the training process.

The predicted values were compared with the actual amount of rolled material before re-machining of rolls after which the prediction errors were calculated.

Finally, in the last step, a trained ANN is used to predict the amount of rolled material before re-machining of rolls.

Fig. 3 shows a block diagram of ANN fabrication and testing for predicting the amount of rolled material before re-The relative deviation of the artificial neural network model from the experimental data is 41% which is 1.72-times better than the linear regression model.

Fig. 5 shows the effects of individual parameters on the amount of rolled material before re-machining the rolls. The results in Fig. 5 show that the roll diameter is the most

significant parameter in predicting the amount of rolled material before the re-machining of rolls.

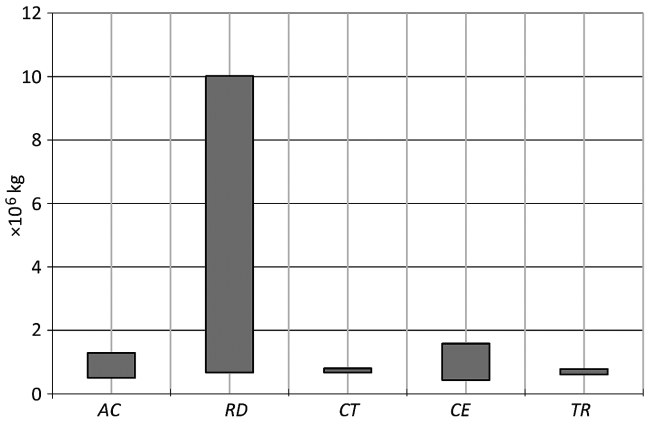

Figure 5 By ANN obtained effects of parameters on the amount of rolled material before re-machining of rolls

4 MODELS VALIDATION

Based on the analysis of the results of the neural network model and the linear regression model, it was determined:

- Both models have relatively low performance.
- Surface of each groove after re-machining and roller diameter after re-machining are the most significant parameters.

However, these two parameters are highly dependent on the machining of the rollers, so it is necessary to include accurate additional data and information on the main reason for the decision to re-machining.

For this purpose, an experiment was carried out throughout 2015. The additional data obtained are presented in Tab. 5. The decision to re-machining was made in all cases only based on detected rollers wear. Throughout the year of the experiment, no fatigue cracks were detected on the rollers, so this was never a reason for re-machining.

The relative deviation of the artificial neural network model from the experimental data is 32.8 %. The relative deviation of the linear regression model from the experimental data is 57.2 %.

The improved performance of both models in terms of the amount of rolled material before rolls re-machining can be attributed to the fact that fatigue cracks as the main reason for re-machining were excluded from the data obtained in 2015.

Only tool wear is considered as the only reason for re-machining.

Table 5 Parameters included in the survey collected during 2015 annual production

Roll diameter after re-machining *RD* (mm)	Groove surface after re-machining *GS* (mm^2)	Amount of rolled material before re-machining *Q′* (kg)	The temperature of rolled material in front of the first rolling mill place *TR* (°C)	Contact time *CT* (s)	Carbon equivalent *CE* (%)
460.0	142255	945915	925	0.0609	0.8079
460.0	122848	1196252	925	0.0535	0.6836
460.0	148634	2146607	925	0.0629	0.7373
458.6	141334	33192382	925	0.0614	0.8487
458.6	165275	6042556	925	0.0610	0.6477
458.6	147666	23033377	925	0.0630	0.7413
456.0	121330	14101331	925	0.0513	0.6786
456.0	146768	17867192	925	0.0625	0.7214
456.0	140479	30322521	925	0.0618	0.7632
456.0	146768	9038047	925	0.0616	0.7512
456.0	164265	6610225	925	0.0674	0.6249
453.4	139624	16724445	925	0.0610	0.8079
453.4	120598	12175954	925	0.0514	0.6269
453.4	145869	29559639	925	0.0620	0.7632
450.6	138737	11690848	925	0.0606	0.8348
450.6	144935	20958064	925	0.0621	0.7831

5 CONCLUSIONS

In the one-year experiment, the groove surface after machining (mm^2), the diameter of the roll after re-machining [mm], the contact time (s), the average carbon equivalent (%), the average rolling temperature before entering the first rolling mill place (°C) and amount of rolled material before machine operation *Q′* (kg) were monitored.

With linear regression and artificial neural networks, two models were developed to predict the amount of rolled material before re-machining the rolls.

The average relative deviation between predicted and experimental data was chosen for the fitness function.

The relative deviation of the artificial neural network model from the experimental data is 41.0%. The relative deviation of the linear regression model from the experimental data is 70.9%. The results of the neural network model were 1.72 times better than the results of the linear regression model.

Both models have relatively low performance.

To validate and improve both models, additional data were collected in an experiment conducted throughout 2015. Fatigue cracks as a main reason for re-machining were excluded from the entire database obtained. Both models have developed once again, accordingly.

The relative deviation of the newly developed artificial neural network model from the experimental data is 32.8%.

The relative deviation of the new linear regression model from the experimental data is 57.2%.

Distinctive improved performance of both models in terms of the amount of rolled material before rolls re-machining can be attributed to the fact that fatigue cracks as the main reason for re-machining were excluded from the data obtained in 2015. Only tool wear is considered as the only reason for re-machining. Future research will focus more on collecting data related to rolls wear. As a result, it will be possible to predict the wear of the rolls and the maintenance of the rolls relatively accurately according to the rolling quantities in the timetable. It should also be noted that a customized methodology could be used in different rolling mill environments (e.g. rolling stands, different pass designs, and different rolls).

Notice

The paper will be presented at MOTSP 2022 – 13th International Conference Management of Technology – Step to Sustainable Production, which will take place in Primošten/Dalmatia (Croatia) on June 8–10, 2022. The paper will not be published anywhere else.

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Influence of the Process Input Parameters on the Cross-Wire Weld Breaking Force

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Abstract: Cross-wire welding is a type of electric resistance welding called projection welding that is used in the production of a variety of products. This paper deals with the case where steel wires of equal radii are joined together to form a reinforced steel mesh. The objective of the study is to determine the correlation between the welding parameters and the breaking force of the weld. Each weld is cut out from the given wire mesh and tested separately by destructive testing on the universal testing machine. A modular testing fixture was constructed for the tests. Although the tests are still in the initial stage, the results already give a good insight into the influence of the process input parameters on the breaking strength of the weld.

Keywords: breaking force; cross-wire welding; destructive testing; electric resistance welding; projection welding; welding

1 INTRODUCTION

Electric resistance welding (ERW) is the welding process that involves passing of an electric current through the components. Heat generated from the electric current joins the components at the interface with no filler material being used [1]. Most common use of this type of welding can be found in the automotive industry. This article however is focused on a different type of resistance welding called cross-wire welding.

Cross-wire welding is the type of the projection welding. Two steel wires of the same radii are joined together to form reinforcing wire mesh. Bushell [2] and Jordan [3] have described mesh production, where multiple welds are being produced at the same time. This paper focuses on this type of production process called, indirect [4] cross-wire welding, with three welds per current flow being made.

Desired setdown between the two steel wires is obtained through variation of the welding parameters. In this case the welding parameters are weld current strength and weld time. As the article by Nielsen et al. [5] states, setdown can be related to the weld strength and is direct measure of compression. Results in [5] are given for the large diameter wire mesh used in reinforcing concrete. This article however analyzes wires of the smaller radii used in production of mass produced products that need to be coated to prevent corrosion.

Every projection welding creates expulsion [4]. Too much expulsion however creates a challenge in the field of corrosion resistance. Welds with small amounts of expulsion are desired if the goal is to achieve required corrosion resistance with the powder coating corrosion protection method.

If the amount of expulsion can be controlled, satisfactory weld appearance can be achieved on every single weld. Satisfactory weld appearance means that the powder coating is easier to apply. This directly reduces the amount of electrostatic powder coating [5] needed to achieve longer corrosion resistance, thus reducing the overall production cost. However, because weld appearance is not the only requirement, expulsion must be controlled without sacrifices being made to the weld strength.

Electric resistance welding on the microscale, as described in [6] is in general the same process as the large-scale resistance welding, but due to the size of the testing sample and dominant stresses that are acting on the sample testing method is different. Experimental research on the micro scale resistance welded joints were mainly focused on the optimizing weld schedules with respect to weld strength and setdown. [5]

Destructive testing method in this case is used to completely break down the weld to determine its breaking force. This is carried out with the specific fixture designed specifically for this test, a sensor that records the force data and the universal testing machine that acts as a press.

Aim of this paper is to define correlation between the variations in the welding parameters and the weld breaking force for obtaining the strongest weld possible with the satisfactory appearance.

2 WELD STRENGTH TEST

2.1 Testing Equipment

According to the Resistance Welding Manual [8] the proper way of testing the strength of the cross-wire weld is with the use of simple fixture and pusher bar. Aim of the project is to determine the strength of the cross-wire welds with the different wire diameters. With this goal in mind, the testing fixture is constructed in a way that it can be quickly adjusted for various wire diameters. Force value at weld breaking point is obtained through the force sensor connected to the PC while the pressure force is introduced with the use of the universal testing machine. Equipement used for the force measurement is Burster 8524 load cell [9] with DigiVision [10] software used to track and store test results. Wire material is specified to be S235 steel and the wire diameter is 4 mm for all tested samples.

Cross-wire weld strength test setup is shown in Fig. 1.

2.2 Pre Test Operations

Before testing, each individual sample is cut from the wire mesh. Then, each weld is photographed with telecentric camera. Although the setdown is predetermined, it is also

measured for verification. Storing of the weld images is required for monitoring the influence of the ERW parameters on the amount of expulsion and weld appearance. While this data is also used and monitored in this project, focus of this paper is only on the weld strength testing. Fig. 2 shows an example of the image taken during the setdown measuring phase of the testing.

Figure 1 Cross-wire weld test setup

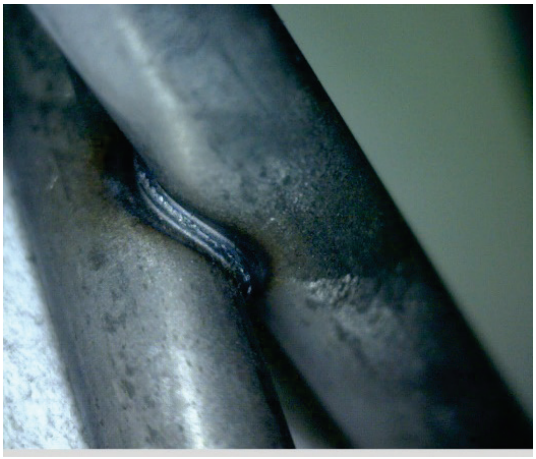

Figure 2 Weld close-up image taken by the microscope

According to the Resistance Welding Manual percent setdown (%) is calculated as:

$$P_s = \frac{A - B}{A} \cdot 100\ \%, \qquad (1)$$

where A is the same diameter as C or smaller as shown in Fig. 3.

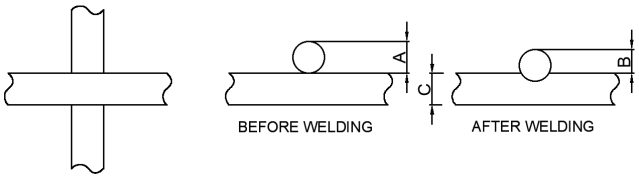

Figure 3 Wire diameters before and after welding

Because of the large amount of testing samples on one testing specimen, wire mesh is divided into the zones, where each zone contains nine samples. Zones and mesh division is shown in the Fig. 4.

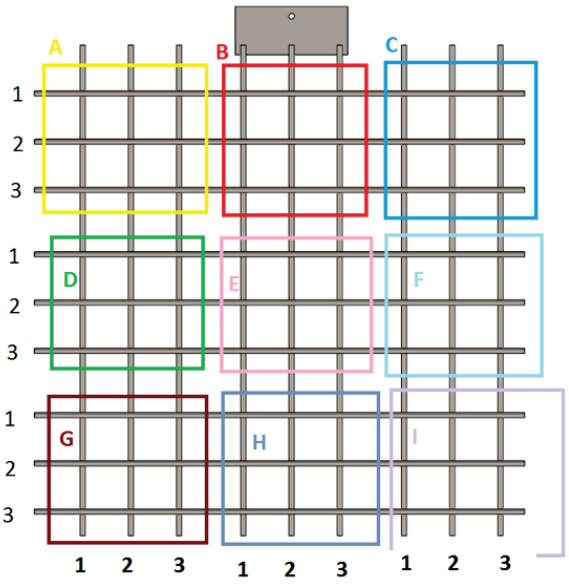

Figure 4 Wire mesh division and zone names shown on the wire mesh sample

After the test is conducted, load cell records the force value, while the sample is destroyed. Example of the destroyed sample is shown in Fig. 5.

Figure 5 Sample after testing

3 RESULTS

This section of the paper shows results of the tests carried out on the seven wire meshes with different parameters. Parameters that were varied for these tests are weld current strength (A) and weld time (t). Due to the nature of this stage of the project only relative values were given, while the absolute values remain disclosed. Since S235 steel is a low carbon steel, according to [11] for low carbon steels, mechanical properties of the material should be almost identical to the mechanical properties of the weld.

Tab. 1 shows the variations in the parameters for each given wire mesh.

Table 1 Welding parameters variations on the given samples

Mesh sample	Weld current strength variation (%)	Weld time variation (%)
Optimal sample 1	0	0
Optimal sample 2	0	0
Test sample 1	+25	0
Test sample 2	–20	0
Test sample 3	+30	0
Test sample 4	0	–20
Test sample 5	+20	+20

From Tab. 1 we can see that we have two "optimal" samples and five samples with varied parameters. Samples are considered optimal relatively to the weld appearance. On the test samples 1, 2 and 3 there is a variation in the weld current strength. On sample 4, weld time is 20% lower than on the optimal sample, while on the sample 5 the weld current and time are 20% higher regarding optimal samples.

As mentioned before each weld is cut out of the wire mesh and separately tested as described in previous chapter. Each mesh has 81 sample, which adds up to 567 separate test that were conducted and included in presented results.

Fig. 6 shows the average breaking force value for each tested wire mesh.

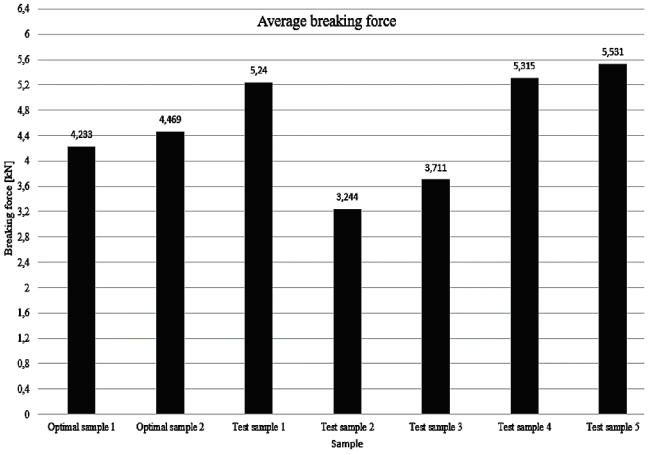

Figure 6 Average values of the weld breaking force

Fig. 7 shows the same results, but presented in a boxplot diagram. This is shown because of the significant deviation in the obtained results on the same mesh sample. Reason for this deviation now is uncertain that it can come from many contributing factors such as; impurities in the material and on the material surface, process stability, welding electrode misalignment, fact that electrode welds three welds simultaneously, etc.

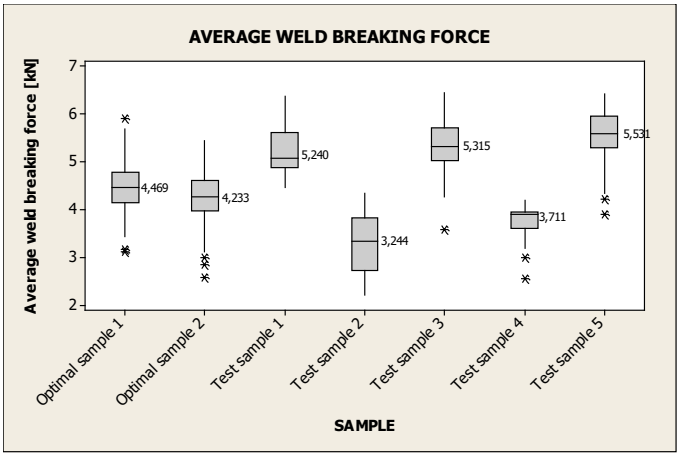

Figure 7 Boxplot of the test results

Despite shown deviations, we can see the trend of the results. Average value of the weld breaking force increases significantly with the increase of the welding current strength, while reducing the weld time has smaller impact on the breaking force. This conclusion is drawn relatively to optimal samples. Reducing the weld current strength, results in the drastic drop of the weld breaking force.

Sample with both welding current strength and the weld time increased by 20% showed the highest average breaking force value.

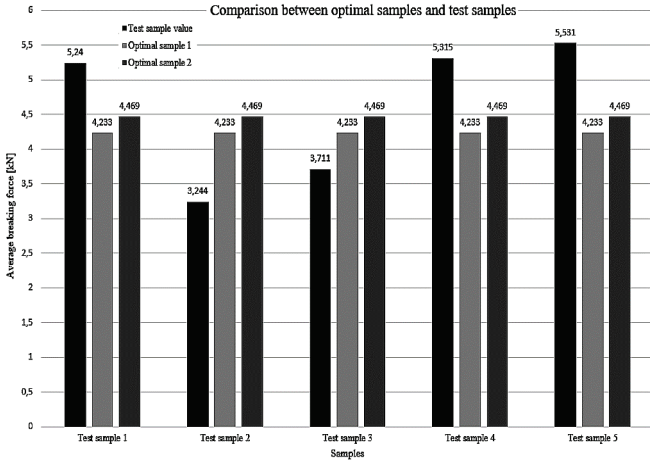

Figure 8 Comparison of average breaking force values between optimal and test samples

4 CONCLUSION

From the tests conducted on the seven-welded wire, meshes with the variations in the parameters can be concluded that parameters of the welding process have significant impact on the weld breaking force.

Samples with increased current strength have shown significant increase in the average breaking force and the increase in both time and current strength resulted in the

highest average breaking force value. Reducing the weld current strength resulted in significant drop of average weld breaking force.

Relatively to the optimal samples, sample with decreased weld time has shown no significant decrease in the average breaking force value. From this, it can be concluded that the weld current strength is more significant ERW parameter when it comes to increasing breaking force of the weld.

Problems with the increase of the weld current strength is that it causes bad weld appearance. By bad is meant that the ERW process creates too much expulsion for the electrostatic powder coat to be applied evenly and in small layers.

This paper showed the influence of the ERW parameters on the weld breaking force. Research is in its initial phase but from the given results, weld current strength is successfully identified as the dominant parameter. Taking into consideration that highest breaking force possible is not the ultimate goal of this research some adjustments are needed.

Future work on this research should include more experimental testing with the parameters variation in the smaller increments. Goal of this research would be the control and prediction of the amount of expulsion for creating the process, which will result in strongest weld with satisfactory appearance every time. Additional research must be done to increase process stability thus reducing the deviation in the data. Results given in this paper are expected to be confirmed with additional testing.

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Notice

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Influence of Programming Language on the Execution Time of Ant Colony Optimization Algorithm

Luka Olivari*, Luca Olivari

Abstract: Supply chains can be accelerated by route optimization, a computationally intensive process for a large number of instances. Traveling Salesmen Problem, as the representative example of routing problems, is NP-hard combinatorial problem. It means that the time needed for solving the problem with exact methods increases exponentially with the increased dataset. Using metaheuristic methods, like Ant Colony Optimization, reduces the time needed for solving the problem drastically but finding a solution still takes a considerable amount of time for large datasets. In today's dynamic environment finding the solution as fast as possible is important as finding a quality solution. The programming language used for finding the solution also influences execution time. In this paper, the execution time of Ant Colony Optimization to solve Traveling Salesman Problems of different sizes was measured. The algorithm was programmed in several programming languages, execution time was measured to rank programming languages.

Keywords: ACO; Ant Colony Optimization; execution time; programming language; Traveling Salesmen Problem; TSP

1 INTRODUCTION

In order to reduce inefficiencies and considerable economic waste, any company with a distribution network needs to accelerate their supply chains. One aspect of supply chain optimization is finding the route with minimal cost. For a large number of instances, route optimization is a computationally very intensive process. For some time now, due to the dynamic and ever-changing environment, requirements for route optimizers have not just been finding the quality solution but finding it as fast as possible. [1] Although there is a metaphorical deluge of heuristic and metaheuristic solvers for route optimization in the scientific literature [2], Ant Colony Optimization (ACO) algorithm is chosen because it has proven to be an efficient and reliable algorithm time and time again over many years. Also, ACO has been historically often used as a solver for a variety of supply chain and vehicle routing problems. [1] Regarding computational intensity, it can represent lots of other algorithms such as Particle Swarm Optimization, Firefly, Bee Colony, Artificial Bee Colony, etc., as they are very similar in implementation to the ACO.

For those interested in creating software applications for solving route optimization problems, an important decision is which programming language to use, as it may considerably impact computational time. The purpose of this paper is to give an answer to the question of which are the fastest and slowest programming languages for this purpose. Python, C, C#, R, and MATLAB as some of the most popular programming languages in science and the industry, have been compared and ranked according to the execution time of the ACO algorithm.

Traveling Salesman Problem (TSP) is chosen to represent routing problems as one of the simplest among them, and yet very complex to solve. TSP is considered the simpler version of the Vehicle Routing Problem (VRP). While VRP looks for the shortest path for m vehicles, visiting n customers, TSP is reduced to one vehicle. A solution to TSP is the shortest Hamiltonian cycle in a complete graph.

Both problems are well known to the scientific community, with TSP being introduced in 1930, [3] and VRP being introduced in 1959. [4] Both problems have their dynamic variant, where information, such as customer location, is subject to change after the vehicle has already started the route. Such variants of problems are named Dynamic Traveling Salesman Problem (DTSP), and Dynamic Vehicle Routing Problem (DVRP). In those dynamic variants of the problems, it is especially important to make quick decisions, as they are made as vehicles are already on the route. Making quick decisions often compromises with decision quality. That means, that more time is used for calculating better solutions, reactiveness to the dynamic changes is decreased.

TSP is an NP-hard computational class of problem, which means that optimum cannot be found by exact algorithms in a time suitable for practical use. Computational problems are divided into complexity classes which determine how much resources are needed to solve a given problem, and how needed resources scale with an increased size of the problem. The computational complexity of a problem is denoted as O and it refers to the worst-case scenario. The size of the problem is denoted as n and it refers to the number of nodes in a graph. Some of the complexity classes are P class, NP class, NP-complete class, and NP-hard class. Solution to the P class of problems can be found in polynomial time $O(n^2)$. For the NP class of problems, solution can be found in nondeterministic polynomial time $O(2^n)$. It is obvious that the computational time of NP problems increases significantly faster with size than the computational time of P problems. NP-complete problems are the hardest problems in NP class, and NP-hard class problems are at minimum as hard as NP-complete problems. [5]

The maximum number of possible tours in symmetric TSP is $(n - 1)!/2$. [6] Brute force algorithms take factorial time $O(n!)$ to solve TSP, which is the worst possible computational complexity class (excluding the theoretical infinite computational complexity class). With dynamic programming, by using the Held-Karp algorithm in this case, the computational complexity of the problem is reduced to exponential time $O(n^2 2^n)$ [7] which means that calculation for large-scale problems takes too much time for practical use.

That is the main reason why heuristics and metaheuristics are often used for finding a near-optimal solution.

Ant Colony Optimization (ACO) algorithm is a metaheuristic method used for solving complex combinatorial problems. ACO is biologically inspired algorithm. It mimics behaviour of ant colonies in search of food. The first ACO algorithm, called Ant System (AS) was created by M. Dorigo in 1996, [8] it was applied to the classical Traveling Salesman Problem. ACO mimics a pheromone trail which real ants use as a communication method while searching for food. High-quality solutions to the complex combinatorial problems can be obtained with ACO algorithm. [9]

To the authors' knowledge, no such comparison of programming language influence on the execution time of the ACO algorithm has been made. Although, other programming language comparisons exist.

In [10] authors compare the execution time of the same algorithm programmed in different programming languages on Windows and Mac operating systems. Chosen programming languages are often used for numerical analysis in macroeconomics. The authors confirmed that compiled programming languages are considerably faster than scripted programming languages.

In [11] authors compare syntax, Lines of Code, Machine Dependency, Compilation Time, and Execution Time of most common high-level programming languages. The authors concluded that there isn't the best overall programming language for all-purpose. Each programming language has its own strengths and weaknesses which potential programmer needs to evaluate according to their own requirements.

In [12] authors compare execution time, memory consumption, and energy efficiency of 27 programming languages. The authors concluded that even though there is a connection between performance and energy consumption, more time-efficient languages are not always ones that consume the least amount of energy. Also, the authors state that it is possible to find the best programming language for execution speed and energy consumption, but it is not the case if memory usage is also taken into consideration.

In [13] authors compare Julia programming language execution speed with several other popular programming languages. Authors increase the complexity of algorithms and measure execution time in comparison with problem size. Julia performed well compared with other languages.

In chapter 2 of this paper Traveling Salesman Problem and Ant Colony Optimization algorithm are explained in detail. Chapter 3 describes the experiment, and a discussion about results is presented in chapter 4.

2 TRAVELING SALESMAN PROBLEM AND ANT COLONY OPTIMIZATION ALGORITHM

2.1 Traveling Salesman Problem

Traveling Salesman Problem (TSP) looks for the shortest path in a complete graph between a given set of nodes, which are often called locations, cities, or customers, that goes through every existing node exactly once and returns to the origin. Only the first/last node is visited twice to close the path. The number of nodes in the problem is denoted with n. If i and j are nodes of a graph, and node i is adjacent to node j, which means that two nodes are connected with an edge ij, Solution to TSP is the shortest Hamiltonian cycle in a complete graph with weighted edges. All graphs can be assumed to be complete by assigning positive infinity (or very large constant) weight to the non-existing edges. [14]

If the cost of traveling between node i and node j is the same as traveling in another direction, from node j to node i, the problem may be represented with an undirected graph. In this case, the problem is called *Symmetric TSP*. If traveling cost is different when traveling from node i and node j than traveling from node j to node i, then is called *Asymmetric TSP*. [15]

The mathematical structure of TSP is a complete weighted graph, where each city salesmen need to visit is represented as a node in the graph, roads between cities are represented with weighted edges between nodes, while edge weight value represents distance or cost of traveling between two cities.

The distance from node i to node j is denoted d_{ij}, where $i, j = 1,\ldots, n$. As a convention, the value of d_{ii} is set to positive infinity to disallow connecting the node to itself. Variable x_{ij} is needed to formulate asymmetric TSP.

$$x_{ij} = \begin{cases} 1, & \text{if node } j \text{ is reach from node } i \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Variable $x_{i,j}$ is a binary variable, and equal to 1 if node i is reached from node j, and otherwise it is 0 (zero). As stated above in the text, the total number of cities or nodes is denoted n.

Traveling salesman problem can be formulated as:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_{ij} \tag{2}$$

The length of the tour is defined as the sum of edge weights of all the edges included in the tour. To select all edge weights included in the tour, their edge weight is multiplied by $x_{ij} = 1$, to exclude edges that are not part of the solution, their edge weight is multiplied by $x_{ij} = 0$.

Constraints in the TSP are that all nodes in the tour must have exactly one edge pointing to the node, and one edge pointing away from it. As there can be only one node from which node j is visited, called entry node, and entry node can be any node except node j, the constraint can be formulated as:

$$\sum_{\substack{i=1 \\ i \neq j}}^{n} x_{ij} = 1 \quad \forall j = 1, 2, ..., n \tag{3}$$

Also, there can be only one node that is visited after node i, called *exit node*, and that node can be any node except node i, the constraint can be formulated as:

$$\sum_{\substack{j=1 \\ j\neq i}}^{n} x_{ij} = 1 \quad \forall i = 1, 2, ..., n \tag{4}$$

Binary restrictions for x_{ij} can be written as:

$$x_{ij} \in \{0,1\} \quad \forall i = 1, 2, ..., n \quad \forall j = 1, 2, ..., n \tag{5}$$

With this formulation, it is possible that the solution is an unconnected graph, where every connected component is considered subtour. Those solutions may be optimal, but not feasible, as the tour is not closed. To exclude subtours i.e., tours that are not connecting all the cities, additional subtour braking constraints are needed. If S is set of all edges in subtour, the constraint can be written as:

$$\sum_{(i,j)\in S} x_{ij} \leq |S| - 1 \tag{6}$$

This reads as, if subtour exists, not all edges in that subtour can be selected, or from all edges in subtour, at least 1 edge needs to be removed. [15]

Traveling Salesman Problem is represented in the computer as $n \times n$ square matrix, called adjacency matrix where n represents the number of nodes. Value of cell a_{ij} represents the distance between node i and node j. There are no loops in the graph, as it makes no sense that the node connects to itself, so diagonal values of the matrix are always 0.

2.2 Ant Colony Optimization Algorithm

Ant Colony Optimization (ACO) was created in 1996. by M. Dorigo [8]. At the time it was called Ant System (AS). It is a metaheuristic inspired by the stigmergy of the ant colonies. Stigmergy is the mechanism of interaction and coordination between agents. In this case, ants, modify the environment. Agents can be entirely unaware of each other, there is no hierarchy, and there is no direct communication between them. This type of self-organization can produce seemingly intelligent solutions, without any planning or management, by simple agents who are not even aware of each other and have no memory. [16] Ants modify their environment by laying pheromone trails for other ants to "read". Pheromone is a chemical left on the ground by ants for various purposes, upon death ant will release warning pheromone, when searching for food and will lay pheromone to mark its path to find a way back, when an ant finds a food source it will release pheromone for other ants to follow, and when the food source is depleted, it will release yet another kind of pheromone to inform other ants that the food is gone.

Ant Colony Optimization algorithm uses only one kind of artificial pheromone, inspired by the one that ants leave on the ground when they find a source of food. When a single ant finds the food source, it will mark its way back to the colony. The goal of an ant colony is to collect the maximum amount of food by spending the minimum amount of energy. In order to do so, they need to find the shortest path from the colony to the food source. Often there are multiple ways to reach the food. At first, ants will randomly choose a path to reach the food, but in time all ants will travel the shortest one.

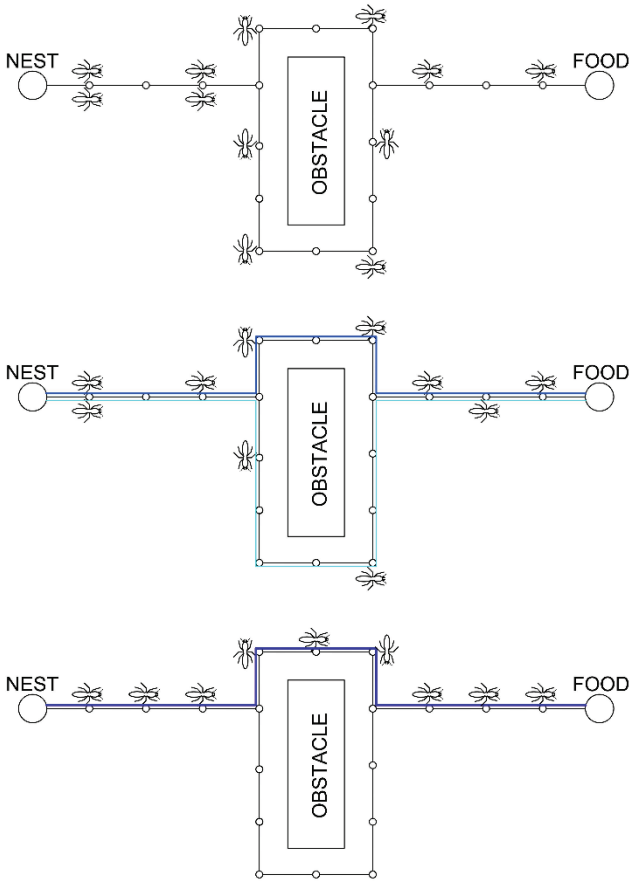

Figure 1 Ant searching for food [authors]

If there are two possible paths to reach the food source, ants have a 50% chance to choose either of them. Those ants that travel shorter path will reach food source faster as is shown in the top picture in Fig. 1. On the way back, all ants leave the same amount of pheromone on each trail, but on the longer trails, a pheromone has more time to evaporate until the next ant is confronted with the choice of path. Now ants have a higher chance to choose the shorter path because it has a stronger pheromone trail. As it is shown in the middle picture in Fig. 1, more ants will travel the shorter path, leaving an even stronger pheromone trail, while pheromone on a longer trail evaporates.

Eventually, as it is shown in the bottom picture in Fig. 1, all the ants will use the shorter path, as pheromone on the longer path is completely evaporated. [17]

Mathematical models of ACO algorithms may slightly variate, like in the case of different methods of laying pheromone. The algorithm can be modeled to release the same amount of the pheromone on the path regardless of path quality or to release a higher amount of the pheromone on paths with higher quality. Or pheromone evaporation may occur before or after laying new pheromone levels in each iteration.

2.2.1 ACO Mathematical Model

There are three important concepts to be modeled, laying pheromone trail, pheromone evaporation, and decision-making. A mathematical model for depositing a higher amount of pheromone on a better-quality path will be used, and it can be formulated as:

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{1}{L_k}, & k^{\text{th}} \text{ ant travels on the edge } ij \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

Where $\Delta\tau_{ij}^{k}$ is the quantity of pheromone deposited by k^{th} ant when traveling from node i to node j; L_k is the path length. The longer the path length, the less pheromone is deposited on every edge that makes that path. If ant did not travel over the edge, it leaves 0 (zero) amount of pheromone on that edge. After every ant has deposited the pheromone, pheromone levels on each edge need to be calculated by summation of all pheromones laid by every ant, which can be formulated as:

$$\tau_{ij}^{k} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \tag{8}$$

Where m is the total number of ants. This mathematical expression simulates pheromone deposition without evaporation. If evaporation needs to be modeled, expression is formulated like this:

$$\tau_{ij}^{k} = (1-\rho)\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \tag{9}$$

Where ρ is the evaporation rate and can be any number between 0 and 1. If the evaporation rate ρ is set to 1, all previous pheromone levels will be evaporated, and expression will be the same as one above. If the evaporation rate ρ is set to zero, no evaporation occurs. If the evaporation rate ρ is set to, let's say 0,4 it means that 40% of previous pheromone levels will evaporate, or more accurately 60% of previous pheromone levels will remain and new pheromone levels will be added. A higher evaporation rate will lead to higher randomization of the new solution.

To use pheromone levels to influence the decision-making of an artificial ant, the probabilities equation will be used:

$$P_{ij} = \frac{(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}}{\sum\left[(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}\right]} \tag{10}$$

Where P_{ij} is a probability that an ant will choose a certain path. Quality of edge ij is indicated by η_{ij}, and is calculated as:

$$\eta_{ij} = \frac{1}{L_{ij}} \tag{11}$$

where L_{ij} is the length of the edge ij.

Parameters α and β are used to increase the impact of τ or η on path choosing process of artificial ant. If β is set to 0 (zero) quality of edge ij is not considered in the decision-making process. If α is set to 0 (zero) then the pheromone level of edge ij is not considered in the decision-making process, but that beats the purpose of the Ant Colony Algorithm.

2.2.2 ACO Pseudocode and Initial Parameters

Traveling Salesman Problem will be solved by using Ant Colony Optimization algorithm programmed in several programming languages. ACO algorithm code is based on [18] and [19].

Pseudo code for ACO:

procedure *ACO algorithm for TSP*
    Initialize ACO parameters, initialize pheromone trails
    while (stopping condition not met) **do**
        Construct solutions
        Update pheromone levels
    end
    Display results
end [18]

After initializing the parameters of the ACO algorithm, each ant is placed on a random node. Each ant randomly creates a path in the graph according to the probability rules of an algorithm. After each ant has exhausted all unvisited nodes, it returns to the initial node. The last visited node must be one step away from the initial node. All path lengths are calculated, and the best solution is stored. Pheromones for each path are updated according to path fitness. After the pheromone matrix is updated, evaporation occurs. The algorithm loops until the stopping criteria is met, in this case, the maximum number of iterations. The final step is to display the best path and total path length.

The Ant Colony Optimization algorithm's initial parameters include the maximum number of iterations, number of ants, initial pheromone level, the desirability of an edge, alpha and beta parameters.

The maximum number of iterations determines how many times ACO will run in order to find the solution. The more time algorithm runs the higher chance of finding a better solution, but it takes more time to run the algorithm. In simple problems, solutions may be found in a low number of iterations so there is no need for the algorithm to run any longer as an optimal solution is already found.

The number of ants determines how many artificial ants will be looking for the solution in each iteration i.e., how many solutions will be in each iteration. Again, the higher the number of ants higher the chance of finding a better solution but the algorithm takes more computational resources.

The initial pheromone level is the amount of pheromone on each edge before the first iteration. The initial pheromone level is inversely proportional to an average distance of all the edges multiplied by the number of nodes.

The desirability of an edge is value inversely proportional to edge length, the shorter the edge the more desirable it is for artificial ants to use.

The evaporation rate is set to a constant value, it determines the percentage of pheromone that will evaporate at end of each iteration. The higher the evaporation rate, the more randomized solutions will be.

α and β parameters increase or decrease the influence of pheromone level and path desirability when randomly choosing a path.

Parameter values are shown in table 1.

Table 1 ACO parameters

Parameter	Value
Maximum number of iterations	50
Number of ants	10
Pheromone evaporation rate	80%
α	1
β	2

3 EXPERIMENT

The goal of this experiment is to measure the Execution time of five popular programming languages when solving the Traveling Salesman Problem with the Ant Colony Optimisation algorithm. **Execution time** is "wall-clock time" needed to run the program i.e., processing input given by the user, in this case, node coordinates, and generate a solution, in this case, shortest path on a graph. It should be noted that compiling time is not included in Execution time.

Chosen programming languages are Python, C, C#, R, and MATLAB. These programming languages are very popular in science and industry. According to https://www.tiobe.com/tiobe-index/, all programming languages are ranked in the top 15 most popular programming languages in February 2022. Phyton being ranked no.1, C being ranked no.2, C# being ranked no.5, R being ranked no.13, and MATLAB being ranked no.14. Another important factor for choosing these languages is the authors' familiarity with them.

Python is an open-source, object-oriented interpreted scripting language, used mostly for system administration, CGI programming, and other small computing tasks. It is available for most computing platforms. [20] Visual Studio with Python extension and Python version 3.9.5 was used. Execution time was measured using the *time* module.

C is a flexible, general-purpose programming language, it was initially designed in 1972 for system programming, but it can be used in a wide range of application areas. C gained in popularity in the 1980s because the widely used UNIX operating system provided a compiler for it on different computers. [20] Visual Studio with C/C++ extension and gcc version 11.2.0 was used. Execution time with *clock* function from library *time*.

C# is the simple object-oriented programming language for general purposes. The main concepts of C# are borrowed from Java and C++. [20] Visual Studio with C# extension v1.24.0 and .NET SDK 6.0.102 was used. Execution time was measured using *watch* class.

R programming language was primarily conceived to be used for statistical computing. In the 90s almost hundreds of computer scientists and mathematicians were improving, at that time, very popular programming language. The main goals were to offer free, easy, and versatile programming language. [13] R v4.1.2 version was used in the experiment. R Studio with and R version v4.1.2 was used. Execution time was measured using the *system.time* function. *Elapsed time* was measured and reported because it refers to elapsed wall-clock time.

MATLAB, short for Matrix Laboratory, is a programming platform often used for numeric and scientific computation. MATLAB is a scripted programming language. MATLAB R2015a was used, and Execution time was measured using *tic* and *toc* functions.

The Execution time of the ACO algorithm in each programming language was measured as the number of nodes in TSP was incrementally increased. Execution time was measured for each data set i.e., number of nodes *n.* Problems were divided into two groups. In the first group problems scale form size $n = 20$ to $n = 200$ with an increment of 20. This means that execution time was measured for problem sizes $n = 20, 40, 60, \ldots, 200$. In the second group problems scale from $n=200$ to $n=2000$ with an increment of 200. This means that execution time was measured for problem sizes $n = 200, 400, 600, \ldots, 2000$. Nodes were randomly generated, but the time needed for random number generation was not measured. It should be noted that the quality of the solution was not considered, only the Execution time for a limited number of iterations. Although a very important characteristic of any solver, convergence rate was not measured for two reasons. First, it is considered that, if the algorithm were to run enough times in any programming language, statistically, the convergence rate should be the same in all cases because they all run the same algorithm with the same parameters. Another reason why convergence rate was not considered is that benchmark datasets consist of irregular increases between them. For example, as found on TSPLIB (http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/) instances sizes are $n = 14, 29, 52, 58, 130, 150, \ldots, 1000, 1291, 1577$, etc. For our purpose, we wanted a regular increase in instance size, so we used randomly generated coordinates for each instance. Because node coordinates were randomly generated, optimal solutions were not available, and convergence rate was not possible to determine. Also worth mentioning is that coordinates of the nodes do not influence execution time at all.

Original code was created in MATLAB, and then "translated" into other programming languages. In C, C# and R used arrays were static. In Python, even though lists were used their size wasn't changed during the execution of the algorithm. In MATLAB new elements were added to the list. ACO algorithm was created to be time-efficient, but authors cannot guarantee that the algorithm in all languages was made as time-efficient as possible. Experienced

programmers in optimization problems and languages used would most likely find room for improvement. One of the possible improvements would be to preallocate memory i.e., that a program allocates all the required memory blocks once after start-up, rather than allocate memory multiple times during execution and leave a memory that is no longer needed for the garbage collector to free.

The experiment was conducted on Windows 10 Enterprise operating system. Computer configuration is Intel(R) Core™ i7-8750H CPU 2.20 GHz, Installed RAM 16 GB, 64-bit operating system, x64-based processor. Source code used in the experiment can be found on the GitHub repository available at https://github.com/l-olivari/influence-of-programing-language-on-the-execution-time-of-ant-colony-optimization-algorithm.git.

As stated in Tab. 1, the algorithm stopping criteria was 50 iterations, and 10 ants were used in each iteration. If execution time was less than 20 seconds, the algorithm was run 5 times and results were averaged to reduce the influence of background processes of the operating system. Similarly, if execution time was between 20 and 60 seconds, the algorithm was run 3 times and the result was averaged. If execution time was above 60 seconds, the algorithm was run only once as time variations for multiple runs were insignificant relative to total time.

Results of absolute Execution time for problems size n = 20 - 200 are shown in Tab. 2. As it can be seen, the fastest results are obtained with the C programming language.

Table 2 Absolute Execution time in seconds for problems size n = 20 - 200

n	Python	C	C#	R	MATLAB
20	0,194	0,007	0,018	0,111	0,229
40	0,560	0,030	0,058	0,256	0,437
60	1,079	0,068	0,122	0,426	0,654
80	1,795	0,121	0,211	0,661	0,871
100	2,672	0,190	0,326	0,907	1,106
120	3,676	0,273	0,462	1,255	1,325
140	4,926	0,372	0,626	1,517	1,579
160	6,350	0,484	0,809	1,921	1,821
180	7,989	0,615	1,022	2,425	2,051
200	9,624	0,758	1,253	2,862	2,324

In Tab. 3 relative time is shown. The fastest performing programming language is given value 1,0. Other values are calculated by dividing their respective absolute Execution time by the fastest absolute Execution time for each problem size. The table gives a clear indication of how many times other languages are slower than a best-performing programming language.

Table 3 Relative Execution time for problems size n = 20 - 200

n	Python	C	C#	R	MATLAB
20	27,0	1,0	2,5	15,5	31,8
40	18,8	1,0	1,9	8,6	14,7
60	16,0	1,0	1,8	6,3	9,7
80	14,9	1,0	1,7	5,5	7,2
100	14,1	1,0	1,7	4,8	5,8
120	13,5	1,0	1,7	4,6	4,9
140	13,2	1,0	1,7	4,1	4,2
160	13,1	1,0	1,7	4,0	3,8
180	13,0	1,0	1,7	3,9	3,3
200	12,7	1,0	1,7	3,8	3,1

Graphical representation of data from Tab. 2 i.e., the absolute execution time for problem sizes n = 20 - 200 is shown in Fig. 1.

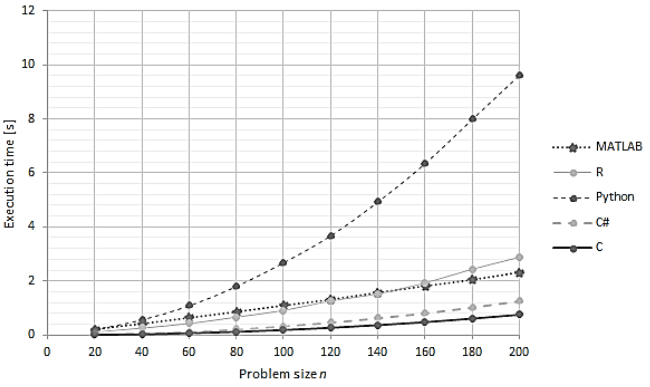

Figure 2 Absolute Execution time (n = 20 – 200) [authors]

As absolute Execution time for the Python programming language is much larger compared to other programming languages, it was excluded from graphical representation in Fig. 2 to offer a clearer comparison between other programming languages.

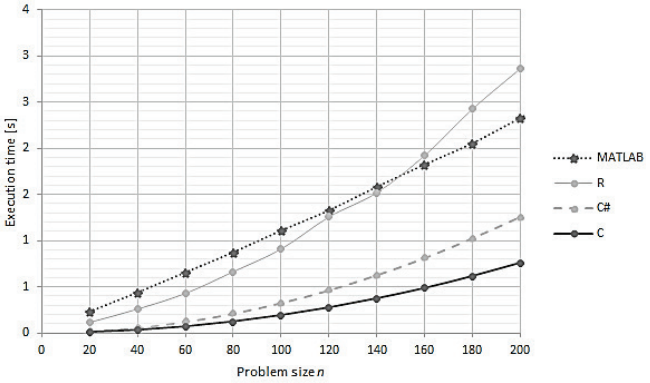

Figure 3 Absolute Execution time (n = 20 – 200) without Python [authors]

Results of absolute Execution time for problems size n = 200 - 2000 are shown in Tab. 4. As it can be seen, the fastest results are again obtained by the C programming language, while Python has the worst results.

Table 4 Absolute Execution time in seconds for problems size n = 200 - 2000

n	Python	C	C#	R	MATLAB
200	9,62	0,758	1,25	2,86	2,32
400	36,87	3,034	5,01	9,81	5,35
600	80,93	6,809	11,13	23,36	10,12
800	147,42	12,162	19,70	39,95	16,76
1000	223,36	18,928	30,61	62,40	24,00
1200	335,51	27,048	44,26	91,78	34,40
1400	452,51	37,031	59,64	124,15	44,96
1600	605,57	48,349	77,46	160,44	55,40
1800	797,30	62,341	98,03	204,53	69,02
2000	919,46	76,958	120,03	253,70	82,98

In Tab. 5 relative time is shown. The fastest performing programming language is given a value of 1,0. As in Tab. 3, other values are calculated by dividing their respective absolute Execution time by the fastest absolute Execution

time. The table gives a clear indication of how many times other languages are slower than a best-performing programming language.

Table 5 Relative Execution time for problems size n = 200 - 2000

n	Python	C	C#	R	MATLAB
200	12,7	1	1,7	3,8	3,1
400	12,2	1	1,6	3,2	1,8
600	11,9	1	1,6	3,4	1,5
800	12,1	1	1,6	3,3	1,4
1000	11,8	1	1,6	3,3	1,3
1200	12,4	1	1,6	3,4	1,3
1400	12,2	1	1,6	3,4	1,2
1600	12,5	1	1,6	3,3	1,1
1800	12,8	1	1,6	3,3	1,1
2000	11,9	1	1,6	3,3	1,1

Graphical representation of data from Tab. 4 is shown in Fig. 3 i.e., the absolute execution time for problem sizes n = 200 - 2000.

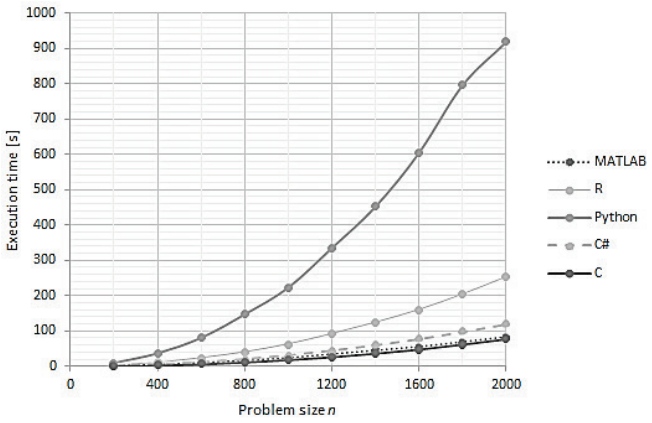

Figure 4 Absolute Execution time (n = 20 – 200) [authors]

As was the case with Fig. 2, results obtained by Python programming language were excluded from graphical representation in Fig. 4 to offer a clearer comparison between other programming languages.

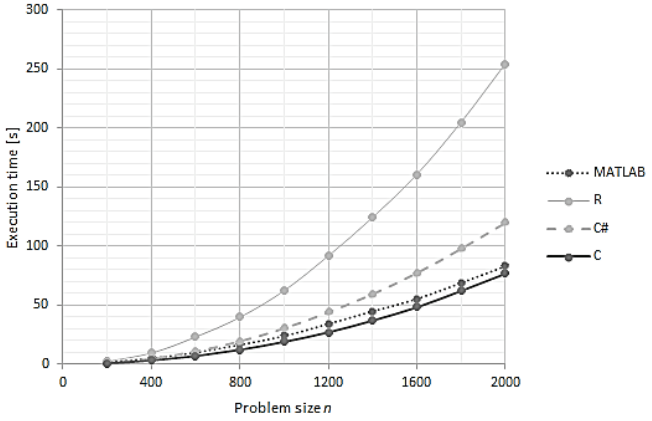

Figure 5 Absolute Execution time (n = 200 – 2000) without Python [authors]

4 DISCUSSION

For problem sizes n = 20 - 200 fastest programming language turns out to be C, closely followed by C#. Relative differences in Execution time between programming languages are higher the smaller problem it is. For example, MATLAB is almost 32 times slower than C for problem size n = 20, but only 3,1 times slower for problems size n = 200. Similarly, R is 15,5 times slower than C for problem size n = 20, to be only 3,8 times slower than C for problem size n = 200. For problem sizes n = 20, programming languages ranked from fastest to the slowest are:

1. C
2. C#
3. R
4. Python
5. MATLAB

For problems sizes n = 40 - 140 situation is different as Python falls to the last place, and languages are ranked:

1. C
2. C#
3. R
4. MATLAB
5. Python

For problems size n = 160 - 200, programming languages are ranked:

1. C
2. C#
3. MATLAB
4. R
5. Python

For problem sizes n = 200 - 2000, C is again being fastest, with C# in the second place up to the problem size n = *400*, but then is taken over by MATLAB. Python remained the slowest one. So, for problems size n = 200 - 400 ranking is not changed.

Finally, for problems size n = 400 - 2000, programming languages are ranked:

1. C
2. MATLAB
3. C#
4. R
5. Python

C programming language is undisputed winner of this race, which is not surprising because it is "lowest" of "high" programming languages, also it is compiled language, while others, on this list, except C#, are scripted languages. C has proven to be the fastest programming language for both, small and large problem sizes.

C# is somewhat slower than C, but it performs consistently just above 1,5 times slower than C except for small problem sizes (n = 20 and 40). C# hold second place for all problem sizes up to n = 400.

MATLAB Execution time was very interesting to follow, as it started as the slowest programming language, to overtake Python at problem size n = 40, and R at problem size n = 160, only to end up in the second place at problem size n = 600. It turns out to be just 1,1 times slower than C for problem size n = 2000, while C# was 1,6 times slower for the same problem size. Authors tested will MATLAB overtake C for even larger problem sizes, but as it is not the case, results are not reported in the tables.

Python is convincingly the slowest programming language overall. It was slower than other candidates to such an extent it had to be removed from graphical representations to allow a clearer representation of other programming languages. The biggest relative difference from C was 27 times slower at problem size n = 20, and the smallest relative difference from C is 11,9 times slower at problem size n = 2000. As results were unexpected, to make sure that mistake isn't made on our part and syntax is correct, we used an independent algorithm (which can be found on: https://pypi.org/project/ACO-Pants/) and compared results. Results from our code and independent code can be found side-by-side in Tab. 6.

Table 6 Relative Execution time for two different algorithms in Python

n	Our code	Independent code	n	Our code	Independent code
20	0,194	0,193	200	9,624	9,398
40	0,560	0,699	400	36,869	37,984
60	1,079	0,880	600	80,933	85,574
80	1,795	1,499	800	147,421	158,731
100	2,672	2,283	1000	223,356	247,655
120	3,676	3,240	1200	335,513	355,658
140	4,926	4,560	1400	452,507	491,909
160	6,350	5,949	1600	605,573	653,725
180	7,989	7,562	1800	797,296	808,770
200	9,624	9,398	2000	919,456	1017,300

As it can be seen, the results are roughly the same. Our algorithm was somewhat slower for smaller instances (n = 20 - 200) but was somewhat faster for large instances (n = 200 - 2000).

R is performing consistently well, as with the other programming languages, the relative difference is reducing with the size of the problem, to be about 4 times slower than C for problem sizes n = 140 – 200, and about 3,3 times slower than C for problem sizes above n = 400.

5 CONCLUSION

The fastest programming language for solving Traveling Salesman Problem with Ant Colony Optimization algorithm, unsurprisingly, turns out to be C, closely followed by C# for problem sizes less than n = 400, at which point it is overtaken by MATLAB. Python turns out to be the slowest programming language for solving this kind of problem for all problem sizes, except for n = 20, in which case MATLAB is to be the slowest one.

It was interesting to see MATLAB, which was the slowest programming language for problem size n = 20, taking third place for problem size n = 160 - 200, and then climbing to second place for problem sizes n = 400 - 2000.

A possible explanation why MATLAB was the slowest programming language in the beginning and got at the second place, in the end, is because original code was created in MATLAB and then "translated" into other programming languages. As stated above in the text, code is based on [19], whose author is internationally recognized for his innovations in optimization algorithms. It is possible that small in-language optimization techniques add up for large instances in the case of complex algorithms such as Ant Colony Optimization and result in lower Execution time.

Although relative differences for small problem sizes are largest, the programming language does not make a considerable difference as results are calculated within a fraction of the second. For large problem sizes, Python should be avoided, while C, C#, and MATLAB are all good choices.

In future research, it would be important to find out what makes Python, in this group, the slowest programming language for large instances, and can something be done to alleviate slow execution times. Also, it would be interesting to see how the Execution time of the ACO algorithm scales when it is used for solving VRP and DVRP problems and to include even more programming languages such as C++, Java, JavaScript, Julia, and others. Future analysis can be expanded to include other metrics such as lines of code, memory management, and energy consumption.

Notice

The paper will be presented at MOTSP 2022 – 13th International Conference Management of Technology – Step to Sustainable Production, which will take place in Primošten/Dalmatia (Croatia) on June 8–10, 2022. The paper will not be published anywhere else.

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Analysis of the Cross-Wire Welding Process Stability

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Abstract: The research paper was prepared within the framework of a project whose aim is to improve the durability of the corrosion protection properties of the product by regulating the input parameters of the cross-wire welding process. Cross-wire welding is a subtype of electric resistance welding. Products made by the cross-wire welding process are widely used in everyday life and can be found in the form of grids, gratings, fencing systems, baskets, guards, etc. The subject of the research work is a preliminary analysis of the stability of the cross-wire welding process. The results of the performed analysis will serve as a starting point for the second phase of the project. Since the recorded values of the set down output parameter differ significantly from the expected values, this parameter is considered as an indicator of the process stability. From the specific trend of the results in the performed analysis, it was concluded that the position of the electrode has a significant influence on the result, which was confirmed by comparing the test results before and after the preliminary tests.

Keywords: cross-wire welding; electric resistance welding; process stability; welding process

1 INTRODUCTION

This research is being conducted for the purpose of working on the European regional development fund project. It is expected that causal relationships and empirical modelling of the process will be established through this and future research to gain insight into the behaviour and stability of the resistance welding process.

Resistance welding is a highly efficient production method, most commonly used in mass and automated production, but also suitable for small batch production due to its flexibility and simplicity [1, 2]. The weld is formed by contact of the parts with electrodes through which electric current is passed, heating them until they melt and bond at the point of contact. The current and pressure are then turned off and the weld is cooled, creating a strong metal bond between the two parts [1]. In the project and the research conducted, the subtype of resistance welding used is cross-wire welding.

Cross-wire welding is a form of projection welding in which local welding current and force are used to weld at the contact point of two perpendicular wires [3]. In electronics, various components such as resistors, capacitors, diodes, and transistors are usually welded using this method [4]. In this paper, a wire mesh is used on which three welds are welded simultaneously in one step.

Setdown as one of the output parameters of the cross-wire welding process has a significant effect on the appearance, shape, and quality of the weld. If the setdown is too low, the weld will have low strength, and interfacial failure will occur, also known as cold welding. Cold welding occurs due to insufficient welding current, welding time, or electrode wear [5]. However, if too strong a current is used or the cylinder rotates too slowly, then expulsion occurs [3]. Whether a setdown is too large or too small is determined by measurement. The measured values and pre-defined setdown range requirements are used to determine whether a process improvement is required.

The objective of this paper is to perform a stability analysis of the cross-wire welding process on a test series before moving to the next phase of the project, where detailed testing of wire meshes will be performed. By measuring and analysing the values obtained, setdown variations within the mesh were determined for the same welding parameters. The variability of the process decreased after electrode adjustment.

2 CROSS-WIRE WELDING PROCESS

In cross-wire welding, one or more rows of parallel rods or wires are welded together at right angles [6]. The material of the wire is S235 steel, which is supplied in large spools weighing up to several tons. As with any type of welding, the wire must be clean, free of dirt, paint, heavy grease, or high-strength coatings [6]. Before welding, the wires are cut to a specific length using a cutting machine. The operator then inserts them into a special fixture on the robot arm. The operator sets the input parameters (welding current, time, pressure, etc.) on the control panel and starts the program to begin the welding process. Welding begins by pressing the wires between the two electrodes. The force applied to the electrodes is transferred to the wires, whereupon current flows through the electrodes and heats the wires at the contact points. The material melts, mixing occurs, and after cooling, a strong joint is formed.

The welding force or pressure is determined by the wire diameter, setdown percentage, desired appearance, required weld strength, and the electrical and mechanical capacity of the welding machine. The welding force determines the appearance of the weld. Its value must be accurately determined to avoid the uneven appearance of the weld without increasing welding time and decreasing productivity [6]. The welding time is also determined by the diameter of the wire. According to [6], the most consistent welding results are obtained with automatic welding timers with synchronous precision.

The welding current is determined by the wire diameter, the setdown percentage, and the welding time. The current should be slightly lower than that which causes spitting or

ejection of metal to obtain a weld of good strength and pleasing appearance [6].

The electrode material is copper. The electrode acts with a concentrated force on the outer surfaces of the wires to be welded. Due to their low electrical resistance, these electrodes can achieve large currents per workpiece without significant heat loss. In addition, their high thermal visibility allows more accurate control of weld formation as well as the rate of cooling and heat dissipation from the workpiece [7]. It is specifically designed to weld three positions, Fig. 1, on the wire mesh simultaneously with one stroke of the electrode, which reduces welding time and increases productivity.

Figure 1 Upper cross-wire welding electrode

Contact locations of electrode and mesh can be easily noticed on Fig. 1. Those positions of the electrode are darker than the rest of the electrode due to the passage of weld current. Exact position identification is shown on Fig. 7. The lower cross-wire welding electrode is shown in the following Fig. 2.

Figure 2 Lower cross-wire welding electrode

Fig. 3 shows the final product obtained by welding process of wire, where electrodes shown in Fig. 1 and Fig. 2 were used.

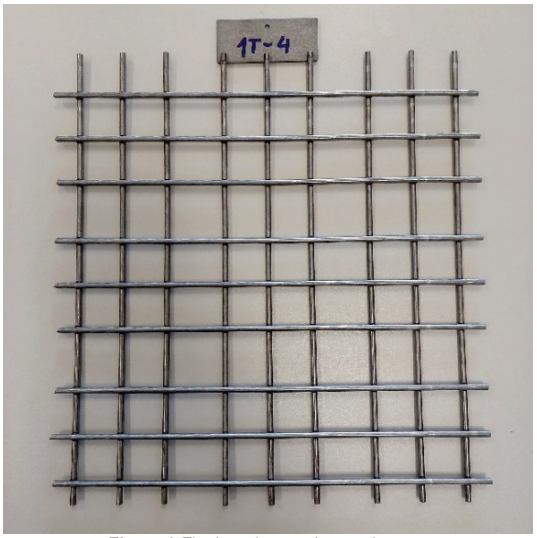

Figure 3 Final product – wire mesh

2.1 Cross-wire Welding Process Stability

The second phase of the project, will test and validate the solutions under real conditions, monitor the results obtained, and determine the necessary improvements. Before the implementation of the second phase, the stability of the cross-wire welding process must be verified on a test series of welded meshes.

The main characteristic of the quality of the production process is variability. By analysing certain product characteristics, it is possible to determine whether changes need to be made to the process. Significant variations indicate the need to redesign and improve the process. They are influenced by a variety of parameters and elements of the process; in cross-wire welding, these can be a machine, operator, material, electrode, environment, etc. If variations occur as a result of common causes, which is considered a natural phenomenon in any process, regardless of its quality, then it can be said that the process is stable or under statistical control. A stable process results from the complete elimination of variations caused by special causes.

Therefore, the main task is to use statistical "signals" to warn of the presence of variations in the process, and control charts are used for this purpose. Control charts monitor a characteristic of the product taken from the process [9]. In this paper, setdown is used as a measure of process stability. Setdown is one of the characteristics of a weld that determines its quality [5] and directly affects the strength of the welded parts [8].

An evaluation of the capability of the cross-wire welding process is also performed. The process capability indices C_p and C_{pk} are used to evaluate the process capability. The higher their value, the lower the variability of the process and the more capable the process is. The process is considered incompetent if $C_p < 1$, at the limit of acceptability for $C_p = 1$,

and capable if $C_p \geq 1{,}33$. The potential capacity of the process is measured by C_p and the actual C_{pk}. When $C_{pk} > 1$ at least 99,73% of all measurements are within the limits, and when $C_{pk} < 1$, the process should be improved because products are produced that do not meet the requirements. The tolerance field is the difference between the upper and lower limits of the requirements and can be defined by standards, regulations, and customer requirements [9]. For this project and research, the limits are defined based on practical experience. To achieve a setdown of 0,600 mm or 15%, which is the initial value in this case, the tolerance is ±10%, which means that the lower limit is 13,50% and the upper limit is 16,50%.

The first step consists in cutting samples from the mesh. The second step consists in measuring the thickness of the two welded wires. Due to the geometry of the samples, simplicity, speed, and precision, the Mahr 40 EVR digital micrometer is used. The main specifications of the micrometer are the measuring range 0-25 mm, the resolution 0,001 mm, and the measuring error of 4 µm. The outside micrometer is clamped in the stand, which facilitates the placement of the specimens between the anvil and the spindle and the reading of the values, Fig. 4.

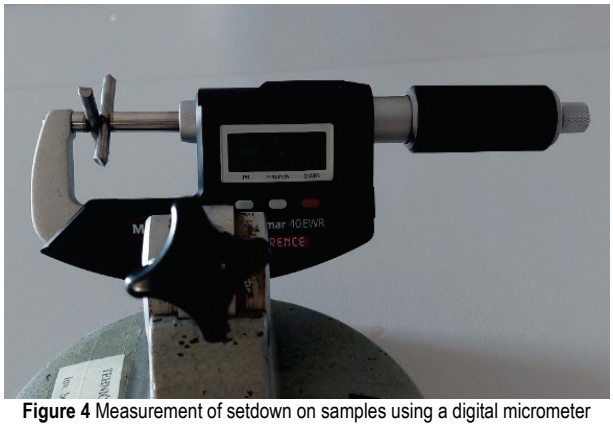

Figure 4 Measurement of setdown on samples using a digital micrometer

Another advantage is the LCD screen and the connection and transmission of readings to the computer. The wire diameter is Ø4h9 mm for all samples in the test series. The diameter of the wires was measured after cutting, the values obtained are within the tolerance limits. The percentage of setdown is calculated according to [6] as follows in Fig. 5.

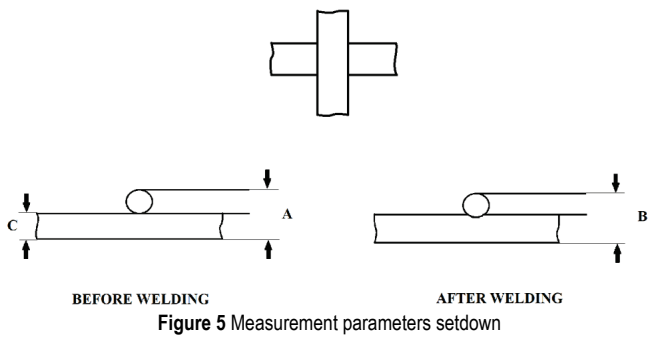

Figure 5 Measurement parameters setdown

Equation for calculation of the percent setdown:

$$PERCENT\ SETDOWN = \frac{A-B}{C} \cdot 100\ \% \quad (1)$$

where:
A - Sum of diameters of two wires before welding, mm
B - Sum of diameters of two wires after welding, mm
C - Wire diameter (diameter of one wire before and after welding is the same or approximately the same), mm

3 RESULTS

In this part of the paper, the results of the stability of the cross-wire welding process are presented. The requirement was a setdown of 0,600 mm, which corresponds to 15%. The meshes on which the tests were performed were made with the same input parameters (welding current, time, pressure) in order to compare the results obtained. Percent setdown data through time by electrode position and trajectory before and after its adjustment are shown in Tab. 1.

Table 1 Setdown data

Percent Setdown, %								
S	Position 1		S	Position 2		S	Position 3	
	B	A		B	A		B	A
1	12,51	15,21	28	17,02	15,44	55	20,43	15,39
2	13,41	15,66	29	17,29	15,66	56	19,50	15,54
3	12,66	15,34	30	17,09	15,24	57	20,03	14,91
4	12,23	15,81	31	16,59	15,54	58	19,97	15,54
5	12,51	14,81	32	16,42	14,46	59	18,67	14,19
6	12,38	14,96	33	16,09	14,71	60	19,72	14,59
7	13,68	15,61	34	18,05	15,09	61	18,92	14,79
8	12,91	14,86	35	16,54	15,39	62	18,52	15,01
9	12,76	14,89	36	16,67	14,84	63	18,30	14,56
10	13,13	15,26	37	16,97	15,09	64	18,97	14,81
11	12,88	14,84	38	16,92	14,39	65	18,62	14,19
12	12,86	15,04	39	16,44	14,66	66	18,40	14,21
13	12,71	15,29	40	16,82	15,04	67	19,32	14,69
14	12,36	14,66	41	16,64	14,81	68	18,37	14,79
15	12,26	15,04	42	16,84	14,94	69	18,85	15,11
16	12,68	15,61	43	16,97	15,46	70	19,15	15,39
17	12,26	14,41	44	16,57	14,46	71	19,00	14,54
18	12,81	14,89	45	17,09	14,99	72	19,15	14,61
19	12,31	14,76	46	17,12	15,16	73	20,05	15,29
20	12,48	14,86	47	16,92	15,16	74	18,90	14,96
21	12,11	14,91	48	16,67	14,89	75	18,80	14,91
22	18,62	15,96	49	17,27	15,44	76	13,43	15,54
23	12,86	14,16	50	16,74	14,89	77	18,80	14,81
24	14,11	14,54	51	17,29	14,74	78	17,72	14,66
25	13,41	15,14	52	17,19	15,06	79	19,45	15,16
26	12,53	14,69	53	16,87	14,84	80	18,65	14,64
27	12,78	14,79	54	16,99	14,89	81	19,15	14,79

where from the table:
S - sample
B - before electrode adjustment
A - after electrode adjustment

Fig. 6 shows a control chart for 81 samples from one mesh. The electrode welds three welds simultaneously during one working stroke. Therefore, in order to check the stability, an analysis was performed as a function of the position of the electrode, which is shown in control charts and a boxplot.

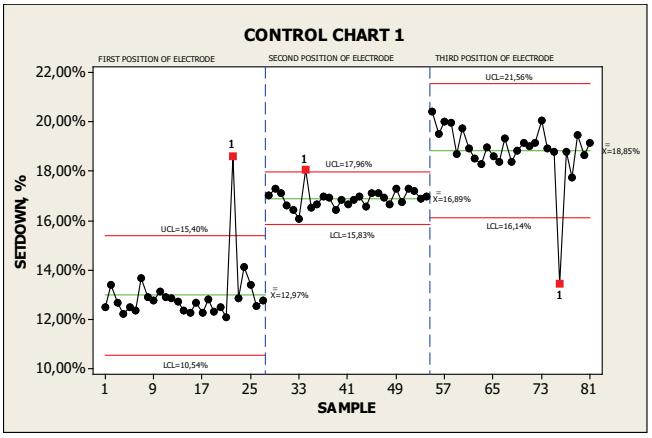

Figure 6 Control chart according to electrode position before adjustment

The ordinate of the control chart, consisting of the centre line of the process, the upper and lower control limits, takes on different values depending on the position of the electrode. It can be seen in the control chart that at each electrode position there is a point outside the control limits (UCL or LCL), which is an indication that the process is out of control. In this case, the required 15% setdown was not achieved, and the causes of the variability need to be addressed.

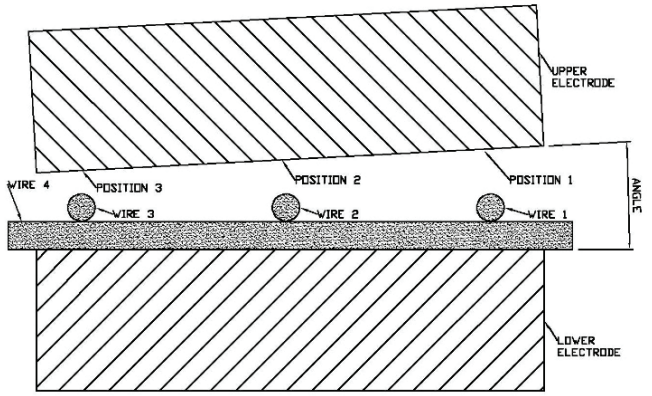

Figure 7 The angle between the electrodes

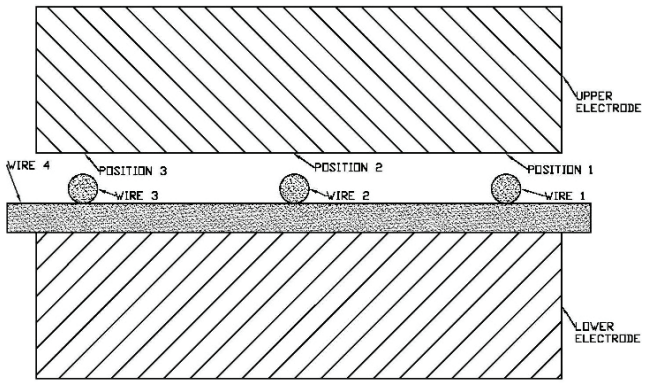

Figure 8 Electrode parallelism after angle adjustment

The electrode is considered as a possible cause, as the setdown values are different depending on the position, indicating a possible deviation of the electrode from parallelism. Electrode check was performed and as found condition is shown at Fig. 7.

In order to achieve target results electrodes must be in parallel relation. During electrode check the angle between the electrodes was detected, what led to uneven welding at all three contact positions. Therefore, precise adjustment of upper electrode position was performed to cancel out detected angle, and result can be seen in the Fig. 8.

In order to confirm that the unwanted angle has been removed and that the electrode is the cause of variability, a second series was made whose results are shown in Fig. 9.

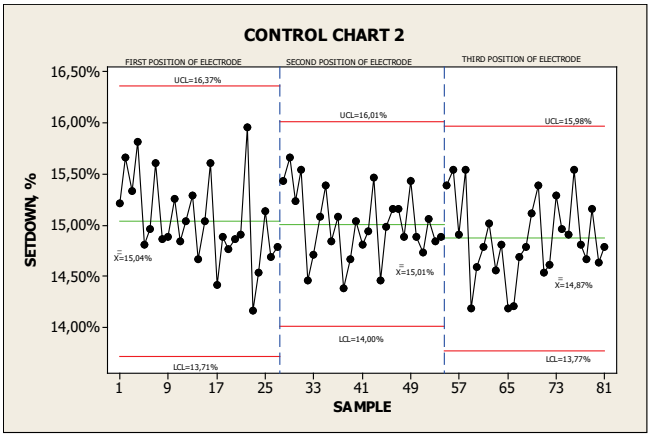

Figure 9 Control chart according to electrode position after adjustment

After the adjustment, there is an improvement in the welding process. The process is now under control and the indicators are the points that are within the control limits. The deviations from the electrode position are minimal and all measured values are now at 15%, meeting the original requirement.

Following Fig. 10 shows comparison of welding percent setdown results obtained before and after adjustment of electrode angle. The boxplot diagram shows range and average value of percent setdown by electrode position.

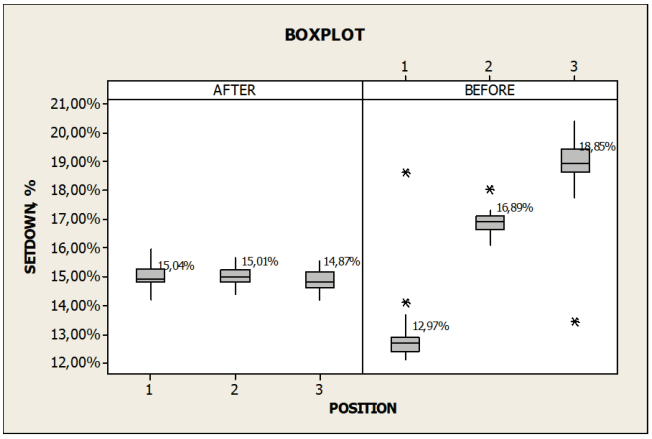

Figure 10 Comparison of results percent setdown by electrode position

Capability of the process before the adjustments of the electrode angle can be seen in the following Fig. 11.

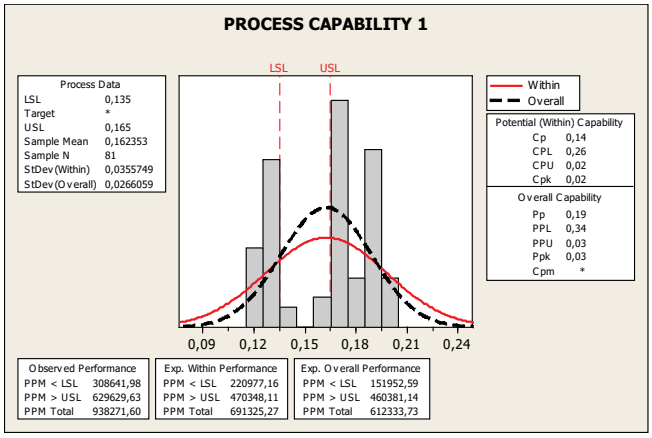

Figure 11 Process capability before electrode adjustment

It can be seen that the process indices are $C_p = 0,14$ and $C_{pk} = 0,02$, which is an indication that the process is incapable and that it is necessary to improve it. After adjusting the electrode, the process capability indices are $C_p = 1,82$ and $C_{pk} = 1,79$, which can be seen on the Fig. 12.

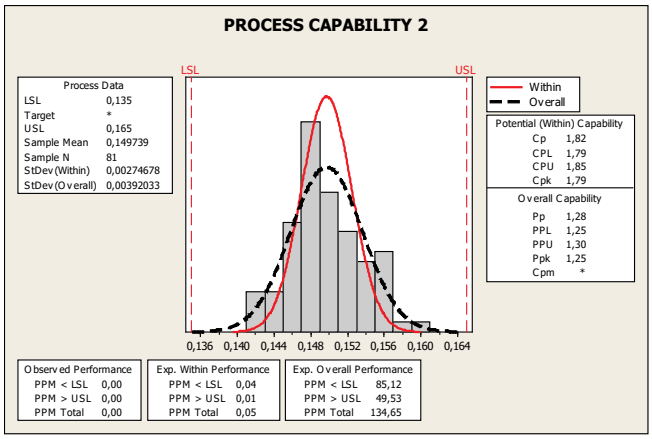

Figure 12 Process capability after electrode adjustment

4 CONCLUSION

The test meshes were tested based on the analysis of the stability of the cross-wire welding process using control charts and boxplot. The control charts determined the instability of the process and the process out of control. The cause of variability was the electrode.

Due to the deviation from parallelism, a percent setdown value of 12,97% was obtained for the first position of the electrode, while the value for the third position was 18,85%. This is an indication that the electrode was slightly raised forward (first position), which is why it had more contact with the samples in the third position, where a larger setdown value was achieved. By adjusting the angle between the electrodes, the process is under control and the range between the minimum and maximum setdown percentages is reduced from 8,32% to 1,8%. The setdown percentage is around 15% and a requirement that is now met. Welding current and pressure can also have a large influence on the welding output parameters, but they are constant throughout the process and their influence did not need to be explore separately.

The process performance indicators C_p and C_{pk} were well below acceptable limits before electrode adjustment, which was also an indication that process improvement was needed. Process capability was achieved after the adjustment, and the reported process capability indices are now above the limits to be achieved.

To ensure the existing condition of the process, it is necessary to perform continuous controls, define elements (Poka-Yoke) or mechanisms to prevent the recurrence of electrode non-parallelism.

Acknowledgement

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Notice

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Towards a Circular Product (Re)Design Methodology: Proposition of the Unlinear Method to Foster Circularity

Bixente Demarcq*, Dimitri Masson, Jérémy Legardeur, Antoine Millet

Abstract: Works on garment and shoe dismantlement and recycling have highlighted the complexity of this kind product and the difficulty to find a recycling channel for each material they are made of. The way they are designed perturbate the recycling process at products end of life. This paper examines these product complexities and proposes Unlinear methodology to help product design teams to redesign a more circular products which materials can be recovered at the end of their life. This method is based on a standardized product representation tool where each component product is made of is represented with its material and the function it ensures.

Keywords: circularity; design for recycling; material recovery; product dismantling

1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) report highlights the urgency of climate change and the need of changes in our societies to keep global warming below 4 °C [1]. This change will be imposed on all industrial practices with a view to reducing CO_2 emissions and preserving natural resources. To this end eco-design is, according to the definition given in the ISO 14062 standard, a design approach aiming to reduce the environmental impacts of products and services throughout the whole lifecycle, while assuring similar or improved services to the end customer [2].

The circular economy promotes to move from linear economy where products go from cradle to grave to cradle-to-cradle [3]. It reposes on principles of eliminating waste and pollution, circulation of products and material, and regeneration of nature [4]. It involves creating cycles, both biological where materials at the end of life of a product are returned to natural regeneration processes, and technical cycles where materials, components or whole product are reused for as long as possible.

Moving from linear economy to a circular economy requires transforming the **destroy-value** processes of the post-use of a product into **retain-value** processes as it is shown in Fig. 1 [5]. This implies reuse/redistribute, refurbish, remanufacture and recycle processes.

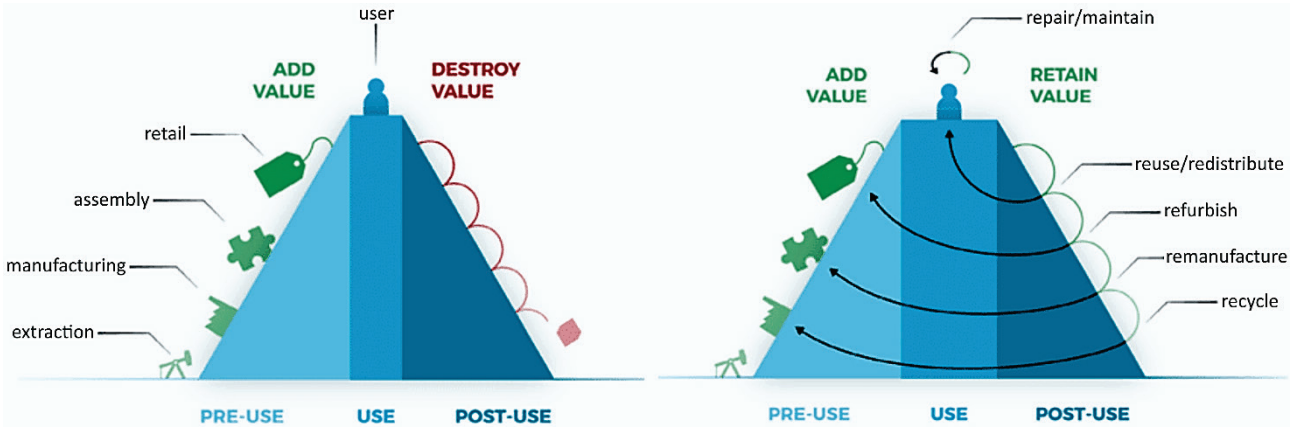

Figure 1 From destroying value in Linear Economy to retaining value in Circular Economy [5]

The current fashion industry is facing a lot of barriers and issues to reach sustainability goals [6]. Some of them are due to the **linear aspect** of the supply-chain with a take-make-dispose model. Policies are being put in place, such as in France, to prevent the destruction of unsold products and to favor circularity by encouraging the development of recycling solutions for shoes and clothing [7]. In France, 55% of the clothes collected are reused [8]. However, in 95% of the cases they are sent for export to the African or Asian continent to be reused or landfilled. Only 1% of textile fibers used to make garment are recycled into new garment [9].

This failure to manage the end of life of clothing or shoe is due to a lack of technology to achieve integral product dismantling, and separation of materials to a degree of purity that is necessary for reuse (think a plastic bottle is made only of PET and a paper label, a shirt is made often made of a mix of fiber, of different colors, assembled with different thread, added with buttons and labels).

If some "hard & traditional products" can be designed with design for X approaches: Design for recycling [10], Design for maintainability [11], Design for disassembly [12] few clothes or shoes are designed with end-of-life in mind. They cannot know a high-quality recycling process due to their complexity: materials they are made off cannot be separated properly, garment or shoe composition includes recycling perturbator, too much different material to recycle each of them on a dedicated channel. It starts form product design stage: there is a need to highlight this design choices that at products end of life prevents a qualitative recycling

This paper proposes a eco-design methodology to **Unlinear** existing products by understanding how they could be redesigned to (1) be dismantled and (2) be made with material that could be recycled, while retaining functional (e.g. Durability) and non-functional properties (e.g. Aesthetic choice). Our approach is based on a functional analysis of the structural decomposition of the existing product by a team of stakeholder in the design and production of the product from various background (e.g., designer, product engineer, and salesperson).

2 IDENTIFICATION OF FACTORS INFLUENCING PRODUCT'S CIRCULARITY

It has been noted that at present, there is few quantity of textile fibers recycled in close loop (only 1%). One of the challenges for the textile industry will therefore be to increase this ratio and to allow clothes at the end of their life to be recovered in quality.

To do this, integrating end-of-life from the (re)design phase is an important means to activate. This means providing for the recovery of materials from the initial design phases as well as the dismantling of the product.

An important product dimantling and recycling brakes is product complexity. In fact the more complex is a product, the more dismantling steps it will be. It is therefore important to be aware of these sources of complexity in order to target them during the redesign phase.

A way to help identify areas of complexity to be changed/removed from a product is to adopt functional reasoning. This allows you to target the essential functions of the product and identify the components or materials that provide them.

2.1 Identification of Product Dismantling Complexities

To be able to scope products design choices that prevent a high quality recycling of it, it is important to identify clearly, its complexity sources.

The project takes its roots in two industrial case studies where the goal was to define a dismantling process for complex products. These two studies were on shoes and complex garments. To do this, a systematic approach inspired by design thinking process with divergence and convergence phases have been used in order to analyse the product and propose a dismantling process. The different steps of the process were:

- **Understand the product:** Dismantling the product to understand the way components are assembled and the material used.
- **Prioritization of recycling challenges:** Categorization of extracted materials and classification the dismantling steps according to the difficulty of carrying them out. Extracted material categories must integrate a recycling channel and must be enough significant in volume to have an economical interest to be recycled. Otherwise, these materials will be landfilled.
- **Generating a generic dismantling process:** Summarize the observations on a standardized way to represent the dismantling process. Each stage of dismantling is illustrated with the technologies available or that can be envisaged to carry it out as well as the materials that can be recovered. The generic dismantling process is represented with high level dismantling steps in black. They correspond to product sub-assemblies. In each high-level steps, important operational dismantling steps are detailed to complete sub assembly full dismantling (see Fig. 2).

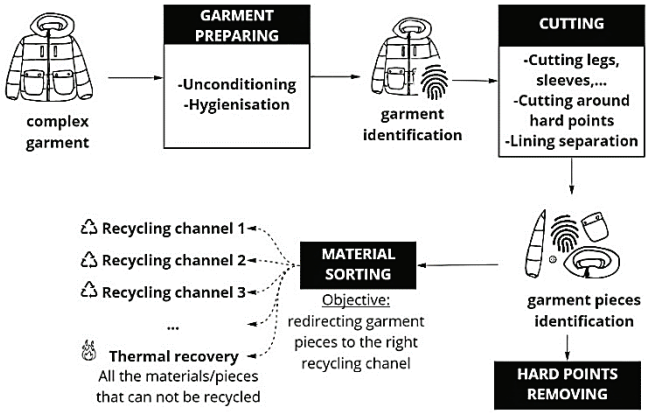

Figure 2 Complex garment simplified dismantling process

This complexity will constitute challenges to product recycling. As the Fig. 3 illustrate it, ten criteria have been proposed to define complex garments. These criteria were identified by gathering insights from product designers from brands and by a literature review [13, 14]:

	COMPLEX GARMENT		
SOURCES OF COMPLEXITY	A) MATERIALS	B) ASSEMBLIES	C) HARD POINTS
CRITERIA	• Number of fabrics (colors and materials) • Number of layers of different materials • A fabric with multiple materials • The ennoblement and treatments	• Reversibility of glued assemblies • Reversibility of stitched assemblies • Accessibility of assembly parts	• Kind of hard points • Number of hard points • Location of hard points

Figure 3 Identified sources of complexity for a garment

This set of criteria constitutes the whole elements to be considered to evaluate the complexity of a garment. It is difficult for a designer to consider all these criterias on a garment at the same moment. We propose to break down the

product as a sum of components. A component is an element of the final assembly. Each component is defined by the material is made, its function in the assembly and its own recyclability. The assemblies and the accessibility of components influence the dismantlability of the product. It justifies the necessity to have a tool that allows modelling all these information about the product in a simplified and understandable way.

Unlinear represent the product as the sum of component it is made of. It is necessary help to identify through the component representation the obstacles to the circularity of the product. It could be used in a circular product redesign process to target the components or parts hindering circularity and make changes. Component's functions or material they are made of could be useful to help product designers to take decisions.

2.2 Related Work to Functional Reasoning

It is well accepted that nowadays a product is not only an artefact but an experience providing meanings and values to user all over the product lifecycle.

With the ecological awareness, the depletion of raw resources, the revalorisation of finished products has become an industrial issue and a challenge for designers to provide meaningful products and strong values to users.

These functional and emotional values are the result of designers' choices within the design process. Selected colours, used materials, all these choices are made on one side with a functional point of view like the strength, permeability or flexibility of a material. On the other side these choices are perceived and felt by users and provide them an emotional value [15]. In order to revalue a product, it is interesting to identify the high-value technical and emotional functions of the product that can be reused.

Regarding technical functions, there are different approaches in the field of engineering to break down a product into technical functions. These include Functional Analysis and Quality Function Deployment.

The Functional Analysis is a method of structuring the functions and sub-functions of a product hierarchically down to the technical and technological solutions that provide them [16]. Applying this method and especially several tools related like Structured Analysis and Design Technic (SADT) or Function Analysis System Technic (FAST) provide designers a global representation of the product and its technical function. Despite this method allows to identify all function of a products it does not provide information about the values of these functions. The Quality Function Deployment can help in this way by associating price, esteem, or pleasure value to these functions.

About the emotional value, designers' choices concerning colours, materials and more generally product attributes, strongly determine the user's experience [17]. Each attribute is felt and perceived by users, providing them meanings, affects and emotions and thus a subjective value to the product.

During the redesign phase of a product, it will be important to consider both technical and emotional functions.

3 UNLINEAR, A METHODOLOGY TO SUPPORT CIRCULAR PRODUCT REDESIGN

3.1 Unlinear methodology description

The complexity of footwear and clothing make it difficult for a brand's teams to rethink the design of their product outside of eco-design and life cycle analysis improvement. Transitioning towards more circularity [18] implies to decouple the composition of the product from its assembled physical version. This meant allowing the designer to isolate all the components, to be able to study their interest alone and then to move on to a more global approach and to examine the product and the way it is assembled**.** The aim is to create a clear, simplified, and generic modelling of the product and its components to question the product design. Designers to propose more circular products alternatives will use this modelling.

It is for this purpose that the Unlinear method was created. It is a methodology, which aims to facilitate circular product redesign by giving designers insight about the product. This method consists of 5 steps:

1) **Product dismantling**: To enable designers to understand the product: its components, the way they interact and their assembly.
2) **Completing the Unlinear facilitation cards**: These cards are a redesign facilitation tool. Each card represents one component of the product. It is necessary to fill each card with: the material used, the name of the component it represent and the function of the component. These facilitation cards are detailed below
3) **Product mapping:** It is the moment when the redesign team go back at the product dimension. To do this, cards that have been completed are used and product assembly links are represented. These links are those identified in the first phase.
4) **Product design critical analysis:** Identification of the obstacles to product circularity by using the product mapping. Participants have to ask themselves:
- Is component's function essential? Can it be removed from the assembly?
- Is the component easily extractable?
- Is the component recyclable?
- Is it possible to replace the material of the component?
- Can the function of the component be assumed by another component?
5) **Generate product redesign proposals: B**uild on identified design obstacles in the previous phase to provide solutions. The aim is to make the product more circular and recoverable at the end of its life.

3.2 Unlinear Facilitation Cards

The role of the Unlinear facilitation cards is to allow workshop participants to identify all the product components individually without considering them as part of the product and to represent them with a standardized aspect: hexagons. In a second time, the interaction between components is studied while the product mapping phase.

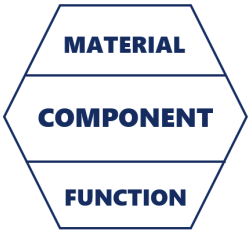

Figure 4 Unlinear facilitation card

As we can see above, these cards are filled in with 3 different information:

- **The material the component is made of:** This information enables workshop participants to know each material in the product and to target non-recyclable components in order to replace them.
- **The name of the component:** This information aims to help the redesign team to precisely identify each component.
- **The function:** This information represents the main function performed by the component. It helps in the redesign phase to prioritize the components for which modifications are required according to the importance of the function they perform and the value it gives to product. This type of functional analysis is also inspired by building and disassembly research. This research proposes to move to a model where each function/component pair is independent [16]. This independence favors the dismantlability of the product and therefore its circularity.

4 CASE STUDIES: WORKSHOPS WITH 2 FASHION INDUSTRY BRANDS

4.1 Workshops Description

To validate the methodology, two experiments took place with shoe and clothing marketers. For confidentiality issues, their name was anonymized and called brand A & brand B. The redesign workshop with brand A took place in March 2021 and the one with brand B in March 2021.

The product chosen by brand A was a high heel shoe. It was a complex shoe made of leather with a heel and a large amount of accessories. The number of components present in this shoe made it impossible to recycle it at the end of its life.

Brand B defined 4 "categories of product" of circular redesign:

- **Aquatic vision**: The team had to work on complex swimming goggles for advanced swimmers.
- **Mobility**: The team had to work on fins, children's buoy and pool shoes.
- **Swimming**: Several men's and women's swimsuits were being redesigned.
- **Wetsuits:** Participants were asked to work on a mid-range wetsuit.

The objective of these brands through these workshops was to use the methodology by taking their products and to identify solutions for improving their circular potential.

Each workshop followed Unlinear methodology:

- Presentation of Unlinear methodology
- Workshop participants were divided in groups, taking care to distribute the participants' profiles: The following profile of employees were mobilized: designer, product design engineers' production manager, seamstress, buyers, CSR department… The objective was also to see the collaboration between technical profiles and to identify their complementarity during the redesign work.
- Workshop proceedings.
- Feedbacks and analysis about the methodology interest.

Table 1 Unlinear workshop's summary

	Brand A	Brand B			
Workshop duration	3 hours	4 hours			
Attendees profile	Designer, product design engineers' production manager, seamstress, buyers, CSR department				
Number of attendees	13	31			
Number of groups	2	4			
Number of attendees per group	6-7	5-11			
Product	High heeled Shoe	Swimming goggles	Fins, Pool shoes, Children's buoy	Swimsuits	Wetsuits

Expectations through these experimentations were to:

- Validate the interest of using Unlinear methodology in a circular redesign process.
- Study how a schematic way to represent a product enables different profiles to collaborate while redesigning it.
- Study the interest and the complementarity of different profiles collaboration.

  Identify research axes to ameliorate methodology's efficiency.

4.2 Workshops' Results & Analysis

The redesign of the products presented allowed identifying 3 benefits about using Unlinear in a circular product redesign process. The use of the methodology allowed to:

- **Illustrate product complexity**

Initially, wetsuits were a product perceived as non-complex by the redesign team. As it is shown below with the Fig. 5, the Unlinear facilitation tool illustrated the complexity of this product with 31 cards used to represent the whole wetsuit. The complexity comes from the hard points, the welding and its main material: the neoprene (which actually is not recyclable in close loop).

The complexity of the high-heeled shoe was also shown. To enable respect the duration of the workshop, il was decided to divide the shoe in two sub-assemblies: the sole and the upper part. Each group was working on one part of the shoe. Finally, to represent this shoe more than 30 cards were used. It demonstrates the complexity of the shoe and the difficulty to recycle each component in the right recycling channel.

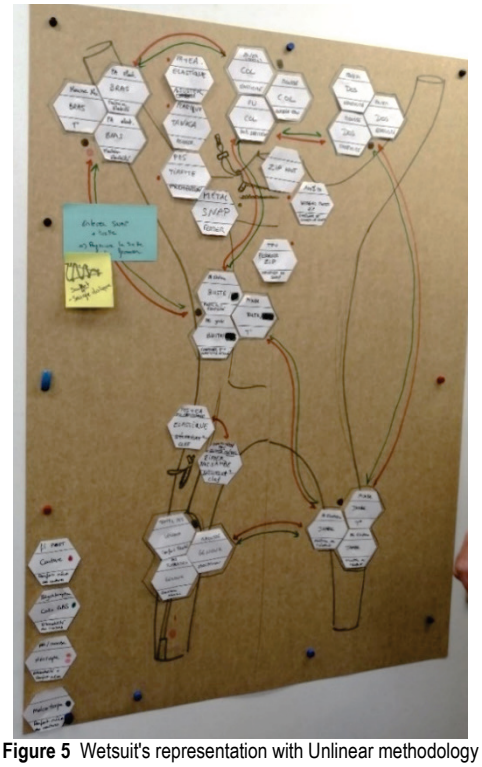

Figure 5 Wetsuit's representation with Unlinear methodology

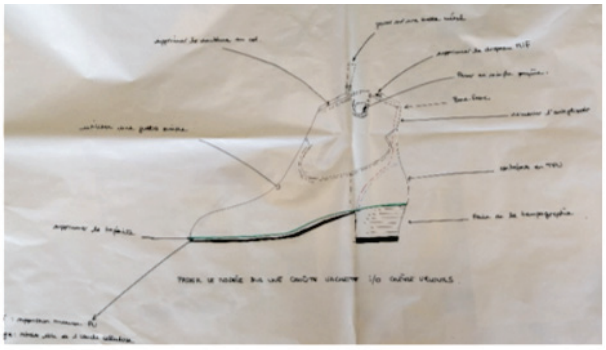

Illustration A

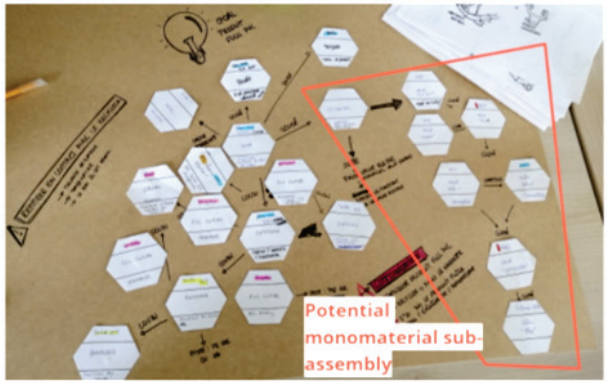

Illustration B

Figure 6 Illustration A: Circular redesigned high heeled shoe. Illustration B: Children's Buyo alternative design proposal

- **Generate more circular product alternatives:**

The methodology enabled for swimming goggles and for brand A high heeled shoes to remove from their product each component without an essential function. It led to design a clean product where each component ensures one essential function in the assembly. The Fig. 6 - Illustration A represent a circular alternative of the high-heeled shoe of brand A designed at the end of workshop.

The methodology allowed to identify product sub-assemblies which can potentially been made in the same material. It will reduce the amount of dismantling steps and generate a more circular alternative. The valve of children's buoy can potentially be made with only one material at is shown in Fig. 6 - Illustration B.

- **Highlight inconsistencies in product design**

The component-by-component study allows the workshop participants to question the presence of the different components. Thus, during the study of certain swimsuit components, reinforcement components were identified as being replaceable. Expert profiles such as seamstresses proposed alternatives to reinforcing materials by means of sewing. The Fig. 7 illustrate it with the identification of components that can be removed.

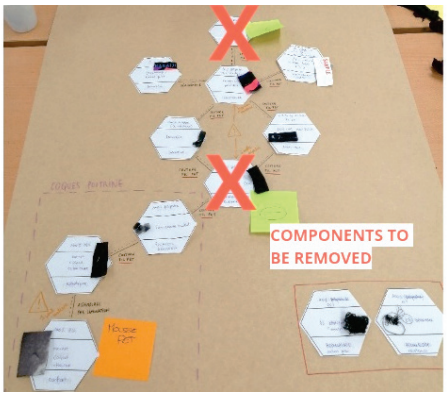

Figure 7 Swimsuit components to be potentially removed

Table 2 Product redesign observations

Benefits of Unlinear	Product	Observations
Illustrate the product complexity	Brand B - wetsuit	The complexity of materials and accessories was shown
	Brand A— - High heeled shoe	The complexity of shoe's sole and its upper part has been demonstrated
Generate circular product alternatives	Brand B - swimming goggles	Design choices: remove each component without an essential function
	Brand A - High heeled shoe	Design choices: remove the welt, remove the inner collar lining and switch to raw edges, remove the French flag or replace the leather pull tab with metal.
	Brand B - pool shoes	To design a monomaterial pool shoe
	Brand B - swimsuit	To replace flockings on swimsuits by embroideries to eliminate disruptors to fibre recycling
	Brand B - children's buoy	The valve sub-assembly of the buoy has been identified as an assembly that could become mono material. This presents a challenge for brand B considering the amount of valves present in their products
Highlight inconsistencies in product design	Brand A - High heeled shoe	The presence of a cambric in the shoe was not necessary, it could be removed
	Brand B - swimsuit	The team identified the presence of unnecessary components or seams.

Tab. 2 is listing the product redesign observations and their categorisation among the 3 identified benefits of using the method.

5 CONCLUSION

We proposed in this paper a methodology to help people to redesign product under circular perspectives. We focused our proposition on the use of a facilitation tool to represent product under a formal and standardized form that help to redesign circular product. We tested this method during two workshops where the objectives were to design circular alternatives to existing products.

As a result, we demonstrated the interest of the methodology in circular product redesign process. We have also been able to identify 3 benefits about using this methodology from our experiments. This methodology enables the collaboration and the complementarity of different profiles during the product redesign phase.

Several next steps have been identified:

- Adopt a way of systematically representing assembling elements according to the complexity of dismantling them. The objective is to allow identifying visually on the product mapping all the assemblies, which could cause problems to product total dismantling.
- Couple this methodology with quantified indicators to validate the redesign phase of the product. These could be indicators such as the environmental impact of each component, their recyclability or their durability.

Notice

The paper will be presented at MOTSP 2022 – 13th International Conference Management of Technology – Step to Sustainable Production, which will take place in Primošten/Dalmatia (Croatia) on June 8–10, 2022. The paper will not be published anywhere else.

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The Place of 3D Printing in the Manufacturing and Operational Process Based on the Industry 4.0 Structure

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Abstract: The article presents the place of 3D printing in the manufacturing and operational process. It analyzes selected incremental technologies in the product life cycle. It describes selected processes for testing the properties of materials used in 3D printing, including accelerated aging tests and simulation of operating conditions. Areas of application of 3D printing were defined, starting from design and prototype development through manufacturing of technological tools and finally finished products. Design criteria of additivelymanufactured elements in relation to the exploitation process are discussed. A methodology for the development of 3D-CAD models of manufactured elements, software processing of data and data storage format for manufacturing products and spare parts is presented. The assumptions of repair procedures based on the production of spare parts by means of 3D printing in relation to data circulation compatible with the idea of Industry 4.0 structure have been adopted.

Keywords: additive manufacturing; Industry 4.0; manufacturing process; operational process; 3D printing

1 INTRODUCTION

Additive manufacturing can occupy different places in the production process and the design of additive manufactured products should also take into account their operational process. The life cycle analysis of additive manufacturing products can be a collection of relevant information allowing the development of criteria for manufacturing products dedicated to different types of 3D printing technology [1]. These criteria should include incremental processes, tests of the properties of materials used in additive technologies, including accelerated durability tests using simulated operating conditions [2, 3]. The analysis of the research results allows to define the areas of 3D printing applications, starting from the design and prototype development, through the production of technological tools and finally finished products [4]. From the point of view of the additive process itself, the method of 3D-CAD numerical modeling of manufactured elements, program processing of data and data storage in formats intended for the production of products and spare parts using 3D printing methods is particularly important. Additive technologies are now an important element of the production system, they allow the production of functional products, components and spare parts based on data transfer in accordance with the idea of the Industry 4.0 structure [5].

2 PLACE OF 3D PRINTING IN THE INDUSTRY 4.0 STRUCTURE

3D printing technologies allow for flexible adaptation of production to the needs of the recipient using solutions of production systems based on network structures in accordance with the INDUSTRY 4.0 scheme. In this case, the integration of network tools, typical technological processes and 3D printing technology is used. In this structure, various software tools are used, starting with the design and processing of numerical models intended for the manufacturing process and quality control. This type of data is often stored in distributed systems and saved on servers in the form of a cloud. The data includes, among others source files of 3D-CAD models, construction documentation, technological documentation, documentation of the manufacturing process, e.g. 3D-STL or 3D-CAM files, layer files, measurement files and results of geometric analyzes related not only to incremental but also conventional technologies. In this structure, due to the network organization of work, data security is very important. The distributed data structure allows for parallel work in different locations of the same company as well as cooperating entities [8, 10]. Thanks to this, it is possible to remotely work or monitor the process from any place with network connections. The use of automated procedures, virtual reality industrial robots or artificial intelligence in the structure additionally increases its possibilities in terms of product quality and production speed. In such a structure, in relation to additive technologies, it is necessary to equip production devices with appropriate interfaces enabling their communication with the entire system in the Industry 4.0 structure [11].

System integration begins when the customer defines the product assumptions as product custumization (Fig. 1). At this stage, it is necessary to define the technological capabilities of the enterprise and the related process of purchasing and supplying raw materials for production. The use of 3D printing allows, in many cases, a flexible approach to the modeling and manufacturing process, and real-time data exchange enables the acceleration of processes such as ordering raw materials, product modeling, data preparation for production and quality control, which can be implemented in a parallel system. The production and finishing process as well as quality control depends on the design of the product itself, it also determines the place of 3D printing in the production system and the individual stages of sub-process and finishing.

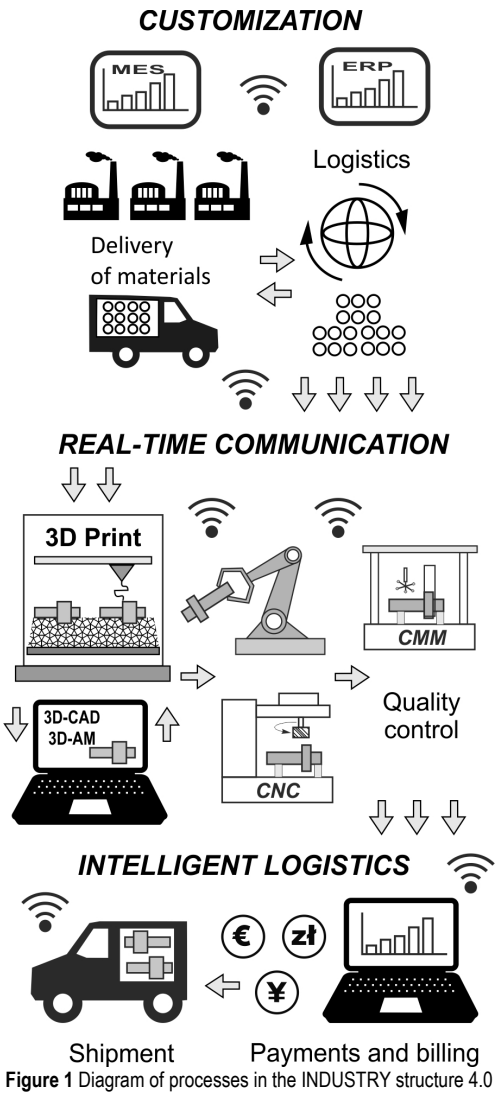

Figure 1 Diagram of processes in the INDUSTRY structure 4.0

The diagram shown in Figure 1 also lists the element of intelligent logistics, which on the one hand can be linked to the system of a given company using MES and ERP software, on the other hand. Intelligent logistics can be an element of internet portals for ordering additive manufacturing products, where it is possible for the orderer to automatically load the numerical 3D model of the product, determine its valuation for a given number of items made of a given material with the selected 3D printing technology. Systems of this type can be equipped with expert advisory modules that suggest to the client the possibilities of using given materials or additive technology.

In the process of additive manufacturing, two basic groups of factors influencing the accuracy of models can be distinguished: factors resulting from numerical processing of data and factors resulting directly from the incremental process. These factors, depending on the technology used, are directly or indirectly related to each other, they are also often related to the technological capabilities of the 3D printer and the course of the additive process itself, or the materials used. The analysis of these factors is important from the point of view of selecting a measurement method to analyze the accuracy of incrementally manufactured products. When analyzing the structure of Industry 4.0, however, it should be remembered that it is based on the efficient operation of IT systems and the supply chain with a specific scope. In this case, it is a very good tool to implement production in a planned manner, tailored to the recipient, with the possibility of saving time and minimizing the costs of production processes. The structure of Industry 4.0, however, is sensitive to disruptions in supply chains, especially in crisis situations related, for example, to a pandemic or economic sanctions. In this case, 3D printing technologies can be an important element of production support in relation to the production of products, spare parts that may be unavailable at a given moment.

3 TESTING THE PROPERTIES OF PRODUCTS MANUFACTURED BY 3D PRINTING METHODS

3.1 Strength Tests

Designing incrementally manufactured products allows for an individual approach to both the customers needs and the possibly flexible approach of the designer. Defining the essential criteria for designing and manufacturing products with the use of incremental methods, however, requires knowledge of 3D printing technology by both the designer and the recipient. This knowledge does not have to include the details of the incremental processes themselves, it may be limited to the knowledge of the basic technological parameters as well as the types and properties of materials used in 3D printing Technologies [9]. Modern computer tools allowing the use of expert systems in the selection of additive technology, and systems of this type can be included in the structure of Industry 4.0 as a tool for the initial verification of the criteria for selecting a manufacturing metod [12, 14].

Detailed guidelines for the production procedures of products manufactured with additive methods require the determination of design assumptions based on the operational requirements of the product assumed at the beginning. This entails the need to carry out strength tests of samples as well as product elements, which can be carried out on the basis of appropriate standards or on the basis of individually dedicated research plans. Additively manufactured products often have different mechanical strengths depending on the layered structure and path distribution within each layer. Taking this into account, it seems advisable to carry out strength tests both in the field of traditional static tensile strength tests as well as in the field of additional loads, e.g. torsional moment. Research of this type may also be the basis for determining the boundary conditions for computations and computer simulations using the finite element method (FEM) for samples and incrementally manufactured elements for which we do not have computational parameters in the available software databases. In addition, carrying out systematized tests may constitute the basis for the development of databases of strength parameters of products manufactured additively with the use of a specific 3D printing method and specific construction materials [13].

3.2 Static Strength Tests of Incrementally Produced Samples

Tensile strength is the basic parameter used in the calculation and design of machine elements. Strength tests for products manufactured additively should be carried out on the basis of appropriate standards for the shapes of samples with a standardized shape. The most commonly used for testing polymer materials are samples of the shape shown in Fig. 2 with the use of appropriate testing machines. Thanks to this, it is possible to determine the strength parameters for products manufactured additively with a heterogeneous internal structure (Fig. 3).

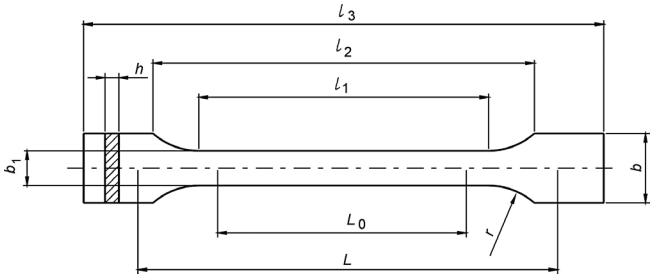

Figure 2 Sample model for strength tests (l_1 - length of the part delimited by parallel lines, l_2 - distance between wide parts, l_3 - total length, b - the width of the gripping part, b_1 - width of the measuring section, h - sample thickness, L_0 - measuring length, L - initial distance between the handles)

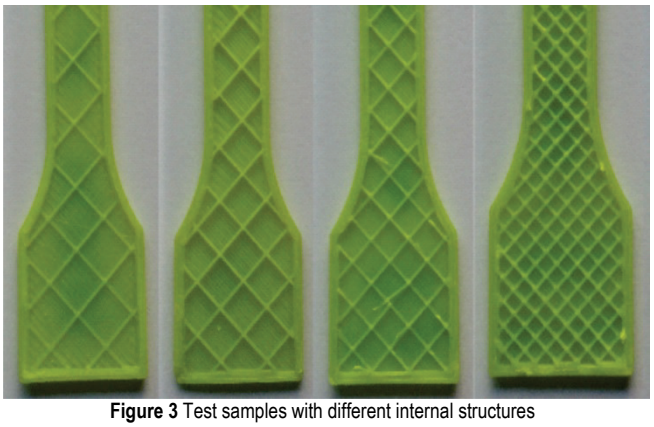

Figure 3 Test samples with different internal structures

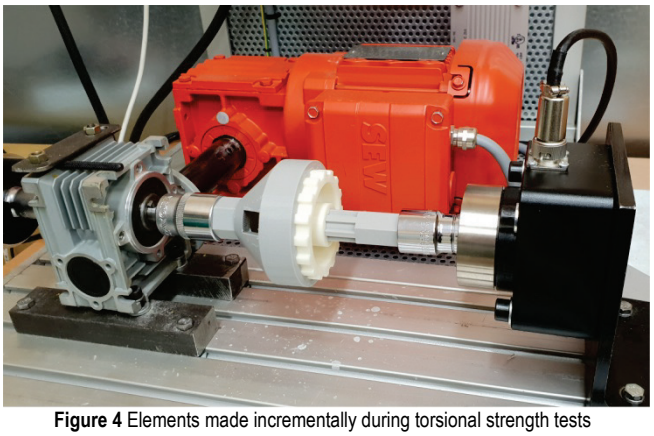

Figure 4 Elements made incrementally during torsional strength tests

The analysis of mechanical strength based on basic tests, which also includes bending strength tests and compressive strength tests, allow to determine the basic parameters of samples produced with various incremental methods in relation to their industrial applications.

The strength of additive manufacturing products can also be subjected to static torsional strength tests, which can be particularly useful for machine components used in drive transmission systems. Fig. 4 shows the stand for testing the torsional strength of incrementally produced samples. The results of this type of research can be important information in the product design process, they can also be used as data for strength calculations used in the simulation process based on the finite element method.

3.3 Durability Tests of Incrementally Produced Samples

The exploitation of products, including those manufactured additively, requires durability tests under conditions of accelerated wear. Construction of product durability test stands should take into account the possibility of load changes and simulate working conditions similar to real ones. One of the examples of such a test may be the durability tests of gear pairs carried out with the use of a special stand developed at the Department of Machine Design, Rzeszów University of Technology (Fig. 5). The stand is universal and allows for the implementation of durability tests of gears of various geometries, produced by injection and incremental methods from polymeric materials. The stand consists of the test gear, the driving system of the loading system equipped with the rotational speed and torque measurement system, which values are recorded continuously. The control system allows you to program test cycles dedicated to specific pairs of gears, allowing you to simulate various working conditions at a given load.

Figure 5 Stand for durability tests of gear pairs

4 DETERMINING THE PLACE OF 3D PRINTING IN THE PROCESS OF DESIGNING AND MANUFACTURING PRODUCTS

4.1 Place of 3D Printing in the Design Process

Additive technologies, especially in the first years of their development, were mainly used in the process of designing and prototyping products for the production of

conceptual and visual prototypes. Currently, 3D printing continues to perform these functions at the design and prototyping stage, however, it allows for the production of functional prototypes and finished products at the same time. In the case of additive technologies, an independent process approach can be distinguished, regardless of whether it is the stage of design or primary production, or the stage of preparing numerical data for the 3D printing process. These stages include the basic processes of numerical processing of the model, starting from the 3D-CAD model, through the transformation of the 3D-CAD model as a file that can be read by the software controlling the 3D printer, to transforming the model into a layered structure as numerical data readable directly by the printer's executive system. 3D. The first stage of CAD modeling is particularly important and has a fundamental impact on the geometrical parameters of the product and enables its conversion to an intermediate format suitable for 3D printing. 3D-CAD modeling programs are equipped with modules for exporting the solid model to a readable form in the subsequent stages of the incremental manufacturing process. The numerical processing of data has a significant impact on the accuracy of the product representation in relation to the 3D-CAD nominal model, therefore this process should be carried out while maintaining appropriate procedures.

4.2 The Use of 3D Printing in the Production Process of the Product

Manufacturing products using 3D printing has many advantages, including belong:

- relatively quick production of the product without the use of specialized tools typical for mass production,
- production of personalized products, production of products with complex shapes that are difficult or impossible to produce using conventional methods,
- manufacturing of products with a controllable structure and directional mechanical strength, designed with the use of topological optimization algorithms.

The mentioned advantages cause that 3D printing is more and more often used for the production of final products or for the production of semi-finished products intended for further finishing processing. At the same time, there are new challenges regarding the life cycle of such a product, the processes of supplying or manufacturing spare parts for machines and devices, and waste management. Among the trends in the exploitation area, it can be noted that manufacturers using 3D printers to produce machine components are moving away from supplying spare parts in the traditional workflow used classically. This place is taken by the delivery of additively produced spare parts documentation along with the device in the form of files with 3D-CAD models or models in intermediate formats prepared for production with the use of a 3D printer. This causes a change in the approach to the planning of operational processes in relation to both wear processes, but especially to renovation processes. It should be remembered that the documentation of the model alone is insufficient to produce a spare part that meets the assumptions of the operational process. In this case, the data should also indicate what 3D printing technology was used to produce a given element, what material was used and what were the parameters of the 3D printing process itself. This type of information is often overlooked by manufacturers of this type of product, which may cause some problems when manufacturing spare parts using additive methods. By using the elements of the Industry 4.0 structure, it is possible in the production process of products to assume what data will be provided to the recipient of the product and thus eliminate the possibility of subsequent service or post-warranty complaints.

5 METHODOLOGY FOR DESIGNING ELEMENTS MANUFACTURED BY 3D PRINTING METHODS

The methodology of designing mass-produced products is based on the traditional scheme of conduct presented in Fig. 6, which includes the following stages:

- Determining the functional and operational assumptions of the product and making preliminary design calculations,
- Preparation of designs and CAD models of the product as well as numerical simulations,
- Development and execution of research prototypes and conducting tests at research stands,
- Introducing design changes based on the performed tests,
- Preparation of technological processes and tools as well as production launch,
- Distribution, sale and exploitation of products.

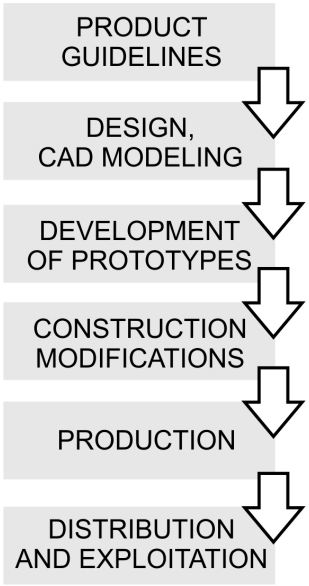

Figure 6 Classic diagram of the main stages of the production process

The presented diagram can be extended using rapid prototyping methods and 3D printing at various stages of the production and operation process, including repair and renovation tasks. By analyzing individual stages, it is possible to determine for them the possibility of applying various additive technologies, most often from the third stage. In the second stage, 3D-CAD models, virtual prototypes and data for the 3D printing process are developed, and preliminary visual models using additive

technologies can also be implemented. The third stage of the process, concerning the development and implementation of research prototypes, has a very high potential for the use of various 3D printing methods depending on the purpose of the prototype. It is possible to make visual and test prototypes as well as functional and technical prototypes from materials similar to the finished products or the same as the products are manufactured. Not all 3D printing technologies should be used at this stage, due to the purpose of the prototype, costs and time of its implementation. For this reason, 3D printing methods have been selected in the diagram shown in Figure 7 and assigned to the subsequent stages. Abbreviations for determinations of incremental methods were adopted in accordance with the standard ISO: VPP – VAT Photopolymerization, MJT – Material Jetting BJT – Binder Jetting, PBF – Powder Bed Fusion, MEX – Material Extrusion, DED – Directed Energy Deposition [6, 7].

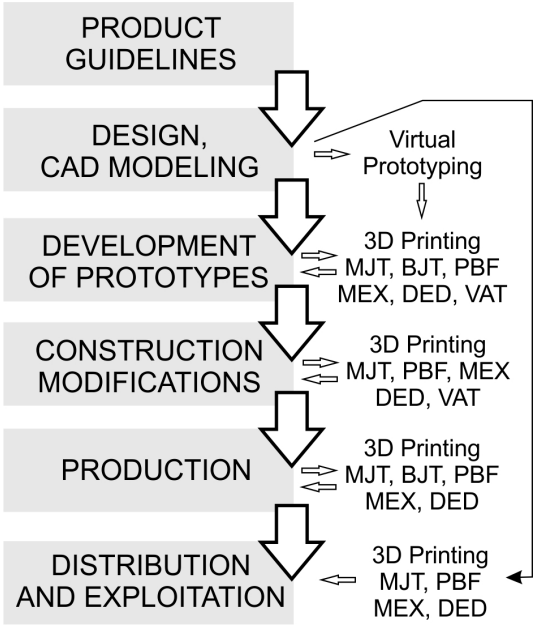

Figure 7 Diagram of the main stages of the production process using various incremental methods

Design changes can also be made with the use of additive technologies, which allow for quick testing of modifications. The production of technological tools is a stage where additive technologies can be used, especially those enabling the production of metal tools (e.g. injection molds) and tools in foundry processes (e.g. casting molds or casting models). In the last of the presented stages of the product life cycle, additive technologies can also be used. This is the case when we base the production process on the production of elements using additive processes, then the spare parts needed for operation are also produced incrementally. The second possibility of using additive technologies at the stage of operation and repair of products is the production of spare parts that are difficult to obtain for various reasons, e.g. a crisis situation or a lack of suppliers. Here, a reverse engineering process should be used, in which not only the geometry of a given element is recreated, but also the material properties are tested in order to make a replacement part, which will allow the functionality of the object to be restored and its failure-free operation within the assumed time.

6 CONCLUSIONS

The production process using incremental methods can be based on various patterns that allow for the inclusion of new technologies. This is possible thanks to the Industry 4.0 structure which, thanks to the use of IT and network tools, allows the exchange of information related to production in real time and quick response to production needs. In the simplest cases, 3D printing is used at the prototyping stage. Taking into account the development of additive technologies, these solutions can be used at most of the production stages. This also applies to the design process, which can be oriented towards the production of products or semi-finished products using 3D printing and the use of modern modeling methods based on topological optimization. This type of products can have completely new properties in relation to traditionally manufactured products. At the same time, the operational aspects that determine the design of the products as well as the renovation and repair processes should be taken into account. Taking this into account, the integration of design, production and operational processes with 3D printing in the industry 4.0 structure and using the TPM method - Total Productive Maintenance can give positive effects, the dimension of which can be an important scientific and application issue.

Acknowledgement

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Determining the Assumptions for the Selection of Measurement Methods for Products Manufactured with Incremental Methods

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Abstract: The article presents the method of determining the assumptions for the selection of measurement methods for products manufactured with the use of incremental processes. In the research area, an analysis of 3D printing methods was carried out in terms of the specificity of the additive process, the materials used, the possibility of process deformations, and the accuracy of technological machines. With regard to the measurement methods, the analysis covered the accuracy of the method, the speed of the measurements, the costs of the measurements and the applicability to additive manufactured products. As a result of the analysis, assumptions were made for the criteria for selecting measurement methods for incrementally manufactured objects. The accuracy of prototyping in incremental processes largely depends on the accuracy of their numerical models. Taking this into account, simulations and studies of program processing of data were also carried out, starting from the development of a 3D-CAD model, through the export of numerical models and the preparation of data for manufacturing and control-measurement processes.

Keywords: additive manufacturing; coordinate measurements method; data processing; quality control; 3D printing

1 INTRODUCTION

Additive technologies allow for the production of models, prototypes, semi-finished products and finished products with various geometrical accuracy, which depends on many technological factors. The geometric accuracy is influenced, among others, by program processing of data in the 3D-CAD modelling process, the process of exporting numerical models, positioning the model in relation to the 3D printer coordinate system, implementation and type of the incremental process itself and the material from which the object is produced [1, 2]. The analysis of geometric accuracy should be carried out at the key stages of the incremental process with the use of measuring devices and software for the analysis of geometric data [3, 4]. The selection of measurement methods and the method of data processing is important from the point of view of determining the quality of products [5], but also the time and costs of quality control. For this reason, it is advisable to carry out an analysis of the selection of measurement methods for additive technologies from the point of view of the intended use of products manufactured with specific 3D printing methods [6].

1.1 Analysis of 3D Printing Methods

The analysis of the accuracy of products manufactured with the use of 3D printing methods is subject to the standardization process in accordance with ISO standards [7-9]. The standards define the types of additive processes, guidelines for product design, materials used in 3D printing, numerical data processing, industrial applications and quality control. According to the information presented in the standards, as of today, there are seven basic incremental processes, which include:

- VPP – Vat Photopolymerization – a process consisting in layered photopolymerization of the resin carried out in a specific volume with the use of a concentrated beam of UV light or light emission from a UV projector, which source is located above or below the manufactured object,
- MJT – Material Jetting consists in layered printing of a liquid material in the form of a resin, from a print head, which applies successive layers of a specific thickness based on the program cross-sections of the model. The change from liquid to solid-state most often occurs because of photo-polymerization or solidification,
- BJT – Binder Jettingin volves bonding a powdered material with a liquid adhesive. In this process, the base material in the form of powder is bonded by printing the liquid adhesive from the head, which applies successive layers based on the cross-sections of the three-dimensional model,
- PBF – Powder Bed Fusion consists in selective sintering or melting of the material from the original powder form into a 3D model. In this process, concentrated thermal energy is delivered within the volume of the powder bed and binds successive layers of the model until the physical model is ready,
- MEX – Material Extrusion consists in layer extrusion of the material - the process is based on the extrusion of a thermoplastic material from the original form of fiber or granulate and layering according to given sections according to numerically defined paths,
- DED – Directed Energy Deposition consists in the targeted melting of the material, usually delivered in the form of a powder. In this process, concentrated energy melts the material in layers as it is deposited. Concentrated thermal energy can be emitted as a laser beam, an electron beam or a plasma or electric arc,
- SHL – Sheet Lamination is a process consisting in layered lamination of material sheets of a predetermined thickness. In this process, successive sections of the model are cut from the sheets of the processed material glued to each other.

2 FACTORS AFFECTING MODEL ACCURACY

In the process of additive manufacturing, two basic groups of factors influencing the accuracy of models can be distinguished: factors resulting from numerical processing of

data and factors resulting directly from the incremental process. These factors, depending on the technology used, are directly or indirectly related to each other, they are often related to the technological capabilities of the 3D printer and the course of the additive process itself, or the materials used. The analysis of these factors is important from the point of view of selecting a measurement method to analyse the accuracy of incrementally manufactured products.

2.1 Data Numerical Processing

The first steps in the additive manufacturing process include mainly numerical processes, starting from 3D-CAD modelling, through converting the CAD model to a software format dedicated to a 3D printer (e.g. STL format), up to the division of the model into layers and preparation of numerical data directly for the incremental process. The 3D-CAD modelling stage is important from the point of view of the correct solid model, which will be further processed numerically [10]. Generally, the CAD model must be a uniform solid that allows it to be converted to the intermediate 3D-AM format. One of the most common 3D-AM intermediate formats is the STL format, in which, because of the triangulation of a solid model, its representation is created in the form of a triangle mesh spanning the entire surface of the model. Most 3D-CAD modelling programs have modules for transforming a solid model into an STL model, which can be a base model for analysing the dimensional accuracy of products [11, 12]. The influence of numerical data processing on the accuracy of mapping the 3D-AM model and ultimately the product is most noticeable for objects with shapes composed of curvilinear surfaces. In the case of objects consisting of flat surfaces, in most cases the triangulation parameters do not affect the number of triangles describing the model (Fig. 1).

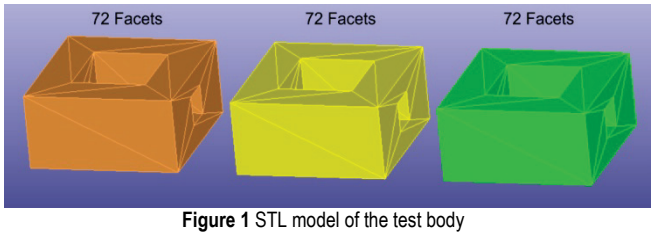

Figure 1 STL model of the test body

The model of the solid shown in Fig. 1 shows that the change of the tessellation parameters in CATIA (= 1 mm, SAG = 0.01 mm, SAG = 0.001 mm) in each case gave the number of 72 triangles describing the solid. The situation changes with the appearance of curvilinear surfaces. The model shown in Fig. 1 was rounded off all edges with a radius of 1 mm. This solid was also triangulated for which the change of the tessellation parameters in the CATIA program (SAG = 1 mm, SAG = 0.01 mm, SAG = 0.001 mm) in each case increased the number of triangles describing the solid successively from the value of 744 triangles to 3369 triangles and 22616 triangles (Fig. 2). Additionally, Fig. 2 shows a close-up of the edge rounding detail for specific mesh densities.

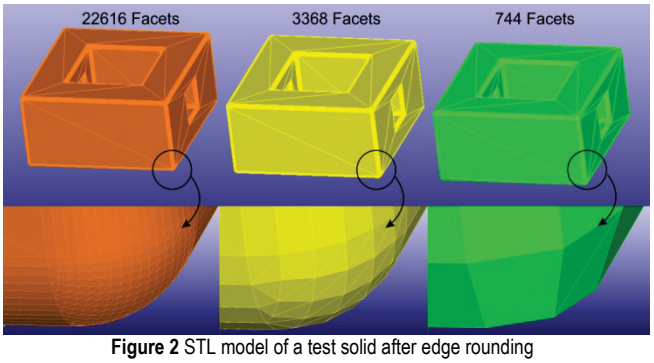

Figure 2 STL model of a test solid after edge rounding

Many coordinate measurement methods are based on the transformation of sets of points obtained because of measurements to the form of a triangle mesh saved in the STL format. This applies to both non-contact measurement methods based on laser scanning or structural light emission, where the triangle mesh is built on a set of points from the scanning of the object's surface, as well as volumetric measurement methods in which the triangle mesh is built programmatically on the basis of cross-section images as well as this is the case with computed tomography. In addition, the production of products based on the STL model can be carried out both using the STL model obtained because of the software transformation of the 3D-CAD model as well as the STL model obtained in the process of program processing of data from 3D scanning.

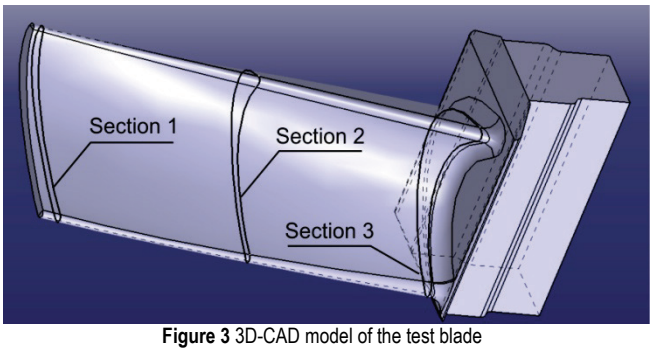

Figure 3 3D-CAD model of the test blade

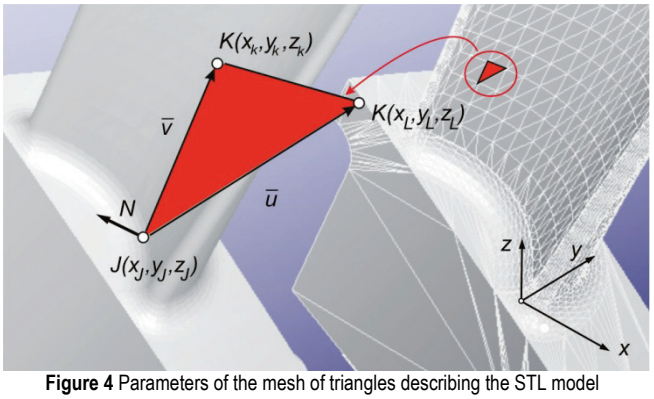

Figure 4 Parameters of the mesh of triangles describing the STL model

A good example for considering the accuracy of incremental methods and their dimensional analysis can be a blade of a fluid flow machine, with a pen described by curvilinear surfaces described in guide curves, the 3D-CAD

model of which is shown in Fig. 3. The surfaces of the paddle blade must be transformed into a solid model, which, together with the lock, forms the basis for the transformation into an STL model. The correct STL model is completely covered with a mesh of triangles with normal points outside the model (Fig. 4).

The paddle model was subjected to a tessellation process using standard software settings (Fig. 5). Trials should be carried out for various values of the mesh describing the surface in order to optimize the accuracy of the mapping, the results of the analysis are presented in Fig. 6.

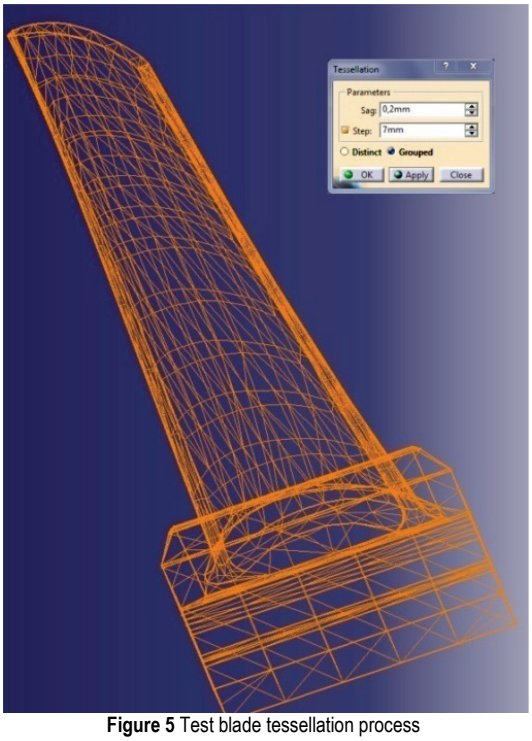

Figure 5 Test blade tessellation process

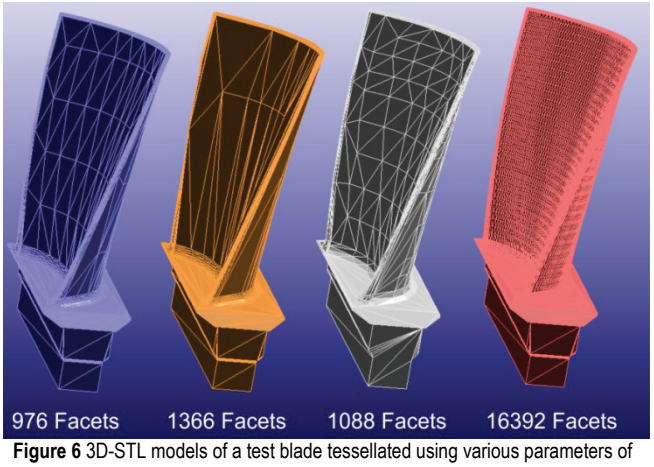

Figure 6 3D-STL models of a test blade tessellated using various parameters of the solid surface description

The 3D-STL model obtained as a result of exporting data from a 3D-CAD file should be of such accuracy that it can be used as a base model for the accuracy analysis of objects, the measurements of which will be carried out with the use of 3D scanning, as a result of which the STL model is also obtained (Fig. 7).

The software for dimensional analysis allows loading the base model and the model obtained from measurements into one file, and perform deviation analysis in the global system or in specific sections (Fig. 8).

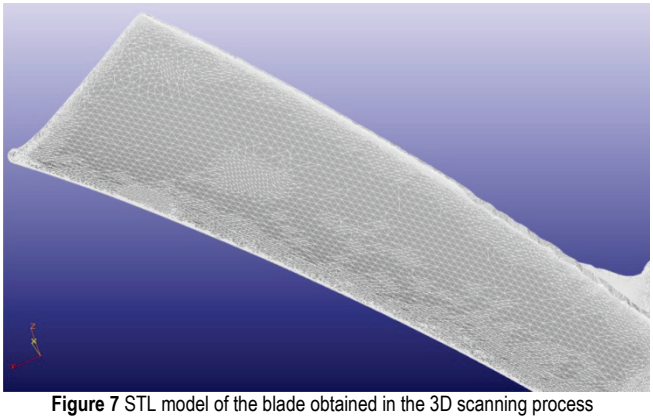

Figure 7 STL model of the blade obtained in the 3D scanning process

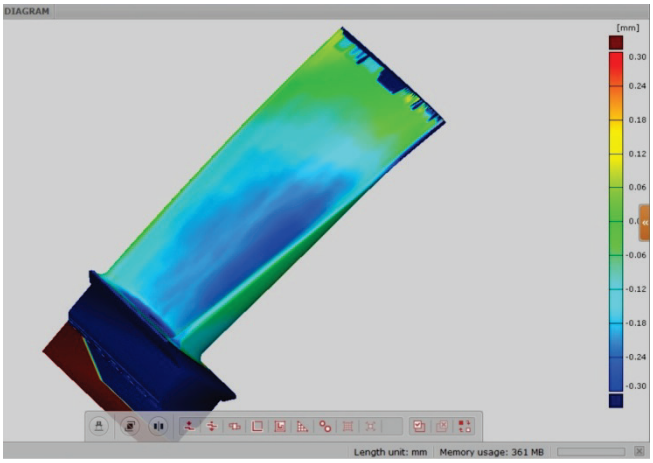

Figure 8 Analysis of accuracy of test blade

2.2 Preparation of Data for the Manufacturing Process

Preparation of data for the manufacturing process has a significant impact on the dimensional accuracy of additive manufactured products. In the first stage, the position of the model in relation to the coordinate system of the 3D printer should be determined. The next stage is the division of the model into layers of a certain thickness (Fig. 9) and preparation of possible transition paths in a given layer (if it is assumed by a given incremental process).

Algorithms controlling a 3D printer can differently determine the structure of the physical model in relation to the 3D-CAD model. For this reason, the model can be made with a negative tolerance (Fig. 10a), a mixed tolerance (Fig. 7b) and a positive tolerance (Fig. 7c). The reason for this is in most cases the inability to clearly map the model dimensions resulting from the nominal values converted to the 3D-AM format (e.g. STL) and the dimension values resulting from the division of the model into layers for a given additive technology.

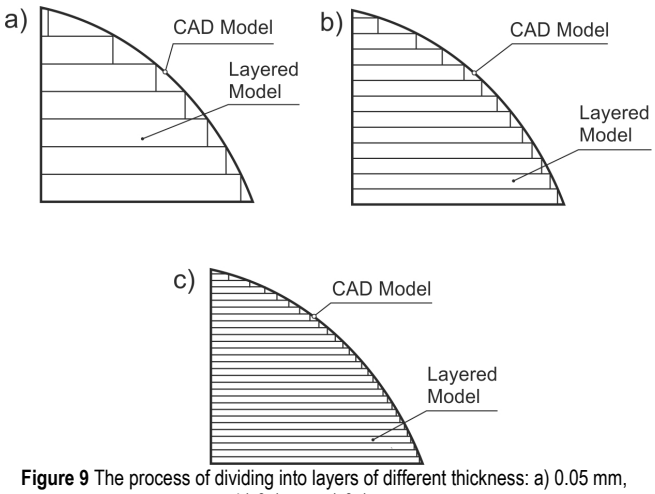

Figure 9 The process of dividing into layers of different thickness: a) 0.05 mm, b) 0.1 mm, c) 0.15 mm

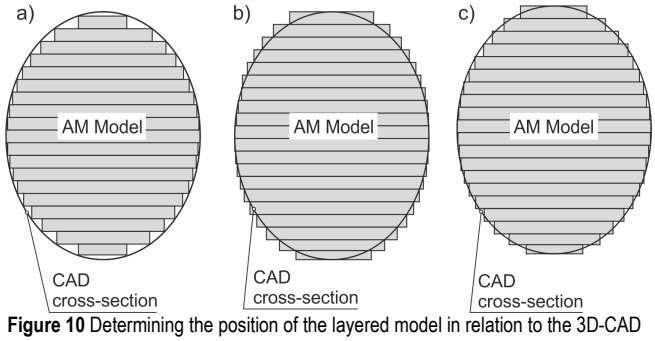

Figure 10 Determining the position of the layered model in relation to the 3D-CAD model: a) negative tolerance, b) mixed tolerance, c) positive tolerance

2.3 Incremental Manufacturing Process

The incremental manufacturing process is also a source of dimensional errors in the physical model. The accuracy of the products in this case is influenced by many factors, including they include: the progress of the incremental process, the kinematic accuracy of the mechanical system of the 3D printer, materials used for 3D printing, compensation procedures, environmental conditions, operating parameters and the condition of the devices. The issue of the accuracy of incremental processes is very broad and it should be analysed in detail for each incremental process, therefore it goes beyond the volume and content-related framework of this article.

3 MEASUREMENT METHODS USED TO ANALYSE THE ACCURACY OF PRODUCTS MANUFACTURING IN INCREMENTAL PROCESS

The accuracy of additive manufactured products can be checked using a variety of measurement methods, depending on the intended use of the product and the complexity of its shape. In the case of products with simple shapes and products with regular shapes, e.g. circular or rectilinear, where length or diameter measurements can be made, it is possible to use basic workshop tools, i.e. calliper type-measuring tools (Fig. 11). It is also possible to use gauges that allow, for example, verifying threads (Fig. 12). Products with higher accuracy can also be measured relatively quickly using micrometric measuring tools (Fig. 13).

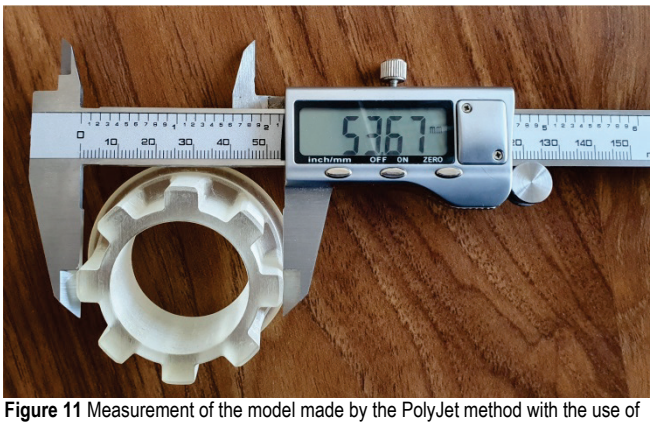

Figure 11 Measurement of the model made by the PolyJet method with the use of a calliper

Figure 12 Checking the correctness of the thread geometry of the cap model made using the PolyJet method with the use of a gauge

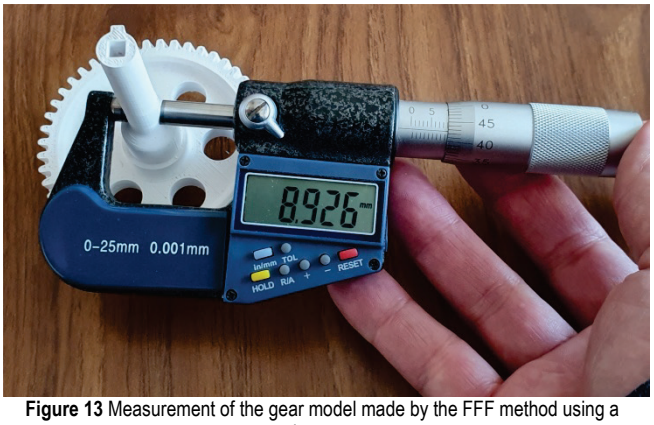

Figure 13 Measurement of the gear model made by the FFF method using a micrometer

The analysis of the dimensional and shape accuracy of products with complex shapes should be carried out using computer-aided coordinate measurement methods based on various methods of data acquisition and processing. These methods include contact coordinate measuring techniques, laser scanning with the use of scanning heads and handheld scanners, scanning with the use of structured light and computed tomography. An example of measuring a blade model using a coordinate measuring machine is shown in Fig. 14.

Models used in medical engineering are obtained based on images obtained in the process of computed tomography. An example of this is a model of the skull with a bone defect, for which a prototype of the defect restoration was

developed, and the accuracy of the fit was based on the analysis of measurements made with an optical scanner (Fig. 15) or a computed tomograph [13].

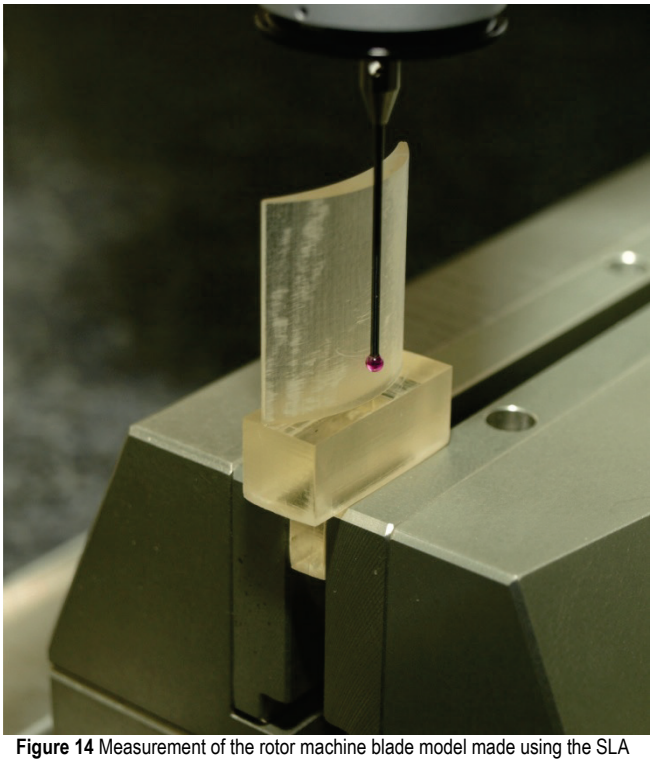

Figure 14 Measurement of the rotor machine blade model made using the SLA method with the use of a coordinate measuring machine

Figure 15 Optical measurement of the skull fragment model made with the 3DP incremental method with the bone defect

As can be seen from the analysis examples, additive manufactured products can be measured using various methods and tools. The selection of measurement methods should be dictated by both cost considerations and the time of measurements. Considering this, an attempt can be made to analyse the criteria for the application of measurement methods to assess the geometric accuracy of incrementally manufactured products, for example by adopting a three-level parameter evaluation scale: LOW – L, MEDIUM – M, HIGH – H.

Table 1 Characteristics of selected measurement methods

Characteristics	Workshop tools	Laser scanner	Optical scanner	CMM	CT
Accuracy measurement	M	M	H	H	H
Time of measurement	L	M	M	H	H
Data processing time	L	M	M	H	H
Measurement costs	L	M	M	H	H
Operator skills	L	M	M	H	H
Purchase costs	L	M	M	H	H

It should be noted, however, that the assessment included in Tab. 1 is relatively simplified and does not contain detailed data, but it gives a certain view on the possibility of using measurement methods at the initial selection stage. Product details and measurement methods can already be taken into account at a later stage. It is also possible to create a computer application that allows the selection of a measurement method for a given incrementally manufactured product, adopting specific criteria and input data. The application can function in this way both in the system of a production company, also as an application of companies offering measurement services and can be an element of a distributed system using modern network tools based on the Industry 4.0 structure.

4 CONCLUSIONS

The considerations presented in the article are preliminary with regard to the selection of measurement methods for products manufactured additively. It should be remembered that the processing of numerical data is particularly important and it should be taken into account already at the initial stage of designing the production process of a given product, for the production of which additive technologies will be used. The architecture of the quality control system in which IT tools from the Industry 4.0 area are used is also important. It is important to define access to data from measurement processes and to ensure the security of this data.

Based on the data collected in Tab. 1, it can be seen that coordinate measurement methods based on laser scanning or structured light emission work very well with the measurement of incrementally manufactured products. It is caused, among others, by in that these measuring dates are characterized by measurement accuracy higher than that of most additive technologies. These measurement methods use the same type of data as 3D printing methods, which greatly facilitates the processing of numerical data in the quality control process. In addition, the measurement time is relatively short, which is important from the point of view of the entire production process.

Coordinate measurement methods using contact measurements are rarely used for the evaluation of additive manufactured products due to the long measurement times.

Computed tomography is perfect for measuring products with complex shapes with closed spaces, as well as for

analysing the internal structure of the product produced with incremental methods.

Notice

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Smart Agriculture Development and Its Contribution to the Sustainable Digital Transformation of the Agri-Food Sector

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Abstract: This study analyses the importance of the connection between the development of smart agriculture and sustainable digital transformation (DT) of the agri-food sector. The sustainability of DT depends on a number of complex components, especially information and communication technologies (ICT), and economic systems. The increase in the number of studies in this area indicates a complex nature as well as interdependencies. Over the last few decades of innovation, ICT, artificial intelligence (AI) and the Internet of Things (IoT) have significantly affected human activities in all aspects. This includes the rapidly changing and difficult-to-predict agricultural sector in the context of global development, indicating the need to address these challenges. The global trend of DT has included all sectors, opening space for the contribution of smart agriculture to sustainable DT, but also to find appropriate "tailor-made solutions" for every challenge we face.

Keywords: Artificial Intelligence (AI); Digital Transformation (DT); Information and Communication Technologies (ICT); Internet of Things (IoT); Smart Agriculture

1 INTRODUCTION

The expansion of the Internet of Things (IoT) in all sectors, including agriculture, has led to a new concept of the Internet of Everything (IoE) [1]. Smart cities and smart villages, as a concept in development, presuppose a holistic and multidisciplinary approach to all challenges of new technologies and paradigms, including in the agricultural sector. Trends of smart urban and/or rural communities regarding the development of sustainable digital transformation (DT) indicate the importance of development, but also the impact of the connection between the system and infrastructure. Håkansson [2] points to the importance of the systematic, "tailor-made" and sustainable application of information and communication technologies (ICT) in the development of smart cities, bearing in mind the importance and expectations of all stakeholders, as well as their needs. O'Grady et al. [3] emphasized the importance of harmonizing all technological aspects, but also their further connection and appropriate application and further development. Continuously, taking into account all aspects of change management, but also the complexity of the challenge, this is focused on the contribution of innovative technologies in agriculture and DT, and showing the impact of new phenomena such as smart agriculture.

Consequently, it is necessary to take into account all trends, specifics, business and other related conditions, in order to provide an appropriate "tailor-made" solution and include all aspects and impacts [4]. Research in the conditions of "Living Laboratories" and their impact on DT confirms this [5]. The aim of this paper is to present the links and inter-impacts of smart agriculture and sustainable digital transformation.

2 DIGITAL TRANSFORMATION IN AGRICULTURE

Agriculture has a primary role in meeting global nutrition needs. During the past two decades food and agriculture sector have passed through the dramatic changes The mentioned changes ensured successful achievement in overcoming growing challenges in various areas of food and agriculture production – safety, sustainability and health. Those changes were provided by improvements in application of the non-digital technologies such as mechanization, animal and plant breeding, and environmentally friendly farming methods. Regardless of the mentioned challenges and solutions, improvements in agricultural productivity are expected to be increased in order to ensure planned development, improvements and maintenance that may cover the needs of growing world populations. Accordingly, this has to be followed in solutions and actions towards climate changes, animal welfare, recovery efficiency, food health and safety, as well as critical changes in human behaviour. As DT is taken into account in terms of technical and technological aspects, it is necessary to emphasize the importance of non-technological aspects and components at the outset. DT is defined as a profound transformation of business and organizational activities, processes, competencies and models to take full advantage of the changes and opportunities of digital technology combinations on society in a strategic and priority way [6]. The technological and especially non-technological aspect of DT needs to be considered because of the integration of DT into the life of individuals and organizations, in urban and rural environments. A review of DT through a series of case studies and studies is provided in [7, 8].

Three procedure groups stand out with the aim of ensuring a sustainable and comprehensive approach:

- Replacement (where digital technologies replace an existing function or procedure),
- Expansion (where digital technologies improve the functionality of an existing process or product),
- Transformation (where digital technologies basically redefine or create a new process or product).

In DT, organization are passing through the systematic, overall group of changes of the business system, including companies, business models, processes, relationships and

products [9]. This leads most of the cultural and organizational changes needed to use new digital technologies to enable great improvement. Some of these are better user experiences, streamlining business and innovating products or services and business models, as well as improving business performance [10]. DT is a set of changes brought about by digital technologies at the operational level through product improvements, organizational structure or through automation processes [11]. In addition, DT influences social processes through changes in strategy and transformations of business activities, processes, competencies, and overall business models [12].

The intention of agricultural and other producers has ensured a successful digital transformation in order to provide a new offer. These improve the existing offer of customers or users, and the technology itself is crucial in operational terms, but also part of the same offer. This further involves investing in technology and a business model to effectively address all customer or user requirements and expectations, at all times during the product lifecycle [13]. The IoT as an approach toned to provide the significant increase in productivity, a potential to achieve higher levels of control. Digital agriculture would therefore be a set of systems for collecting, processing and transmitting data with the aim of faster, easier and simpler management of systems in agricultural and food production. Because the impact on DT is set, significant, and growing, it takes into account and influences business processes and maintains the management and changes it manages [14]. Recent research points to the impact of DT on the industry, and numerous case studies noted a contingency approach, especially in real-life situations and consideration of the critical aspect of DT [15]. The recent work of Tomičić Furjan et al. [7] presents models and technological concepts or factors relevant to the DT initiative, as well as holders and expectations related to DT.

Considering the maturity of DT, all determinants to enhance and ensure the development and maturity of DT should be considered. The most common ones are:

- Strategic determinants,
- Customer/user focus,
- ICT and process infrastructure,
- Talent, abilities and capacity building,
- Innovation culture and organizational commitment.

Stakeholders, employees and others should "live" in this transformation, and everyone should be involved in processes and in an environment that supports innovation and change [16]. DT is challenging for both urban and rural areas, due to a range of social, political, economic and historical conditions, for example, the elderly population. Despite promising growth trends, an insufficient number of young farmers, critical infrastructure and decision-makers are not sufficient to support the change. Among the various influences on DT drivers, given the creation of a business model, there is a strong need to consider the drivers of change management in DT [17]. Not only the benefits, but also numerous challenges are related to DT and its impact on change in almost every aspect. They are identified and described as "potential problems" and can be classified as challenges, or obstacles, depending on the difficulty and time dimension, which is provided in the next steps [15]. The McKinsey Global Survey on Digital Transformation [18], showed the problems and new opportunities in digital transformation from different aspects.

3 SMART AGRICULTURE AND IoT

The architecture of food and agricultural systems based on IoT includes a number of opportunities for the development of IoT in the direction of agriculture and other industries. It is expected that the IoT could bring significant changes in food production and agriculture, with possible challenges such as overcoming difficulties such as addressing its heterogeneity. Digital Agriculture 4.0 aims to provide sustainable framework for modelling IoT systems in each industry, especially food and agricultural production [19]. The inclusion of the IoT at the macro and micro levels allows for gradual but also rapid change, depending on the goals, strategies and policies that have adopted the need for change in all sectors and activities.

The IoT in smart agriculture allows [20]:

- Monitoring and control of production and its development,
- A better analysis and improvement of the process,
- Easier interpretation and further research of all phases, processes and aspects of production,
- Easier definition and monitoring of quality standards,
- Improving quality and monitoring quantity,
- Development of consumer awareness and education at all levels.

IoT application may open various challenges, food and agriculture depend on natural conditions too often, being under the influence of weather conditions and diseases [21]. In addition, there are many different types of production, such as farming, organic farming, greenhouse farming, or animal husbandry.

Farmers have to deal with a number of interconnected facilities such as:

1) Intake and costs, seeds, fodder, fertilizers or pesticides;
2) agricultural land, barns, tractors and equipment;
3) animals, food and fresh produce;
4) Logistics, transport, packaging, containers and trucks.

In order to provide a solution for such a heterogeneity providers need to ensure interoperable nodes within a newly developed ecosystem [22, 23]. Newly built IoT systems must provide interoperable nodes within a well-coordinated software ecosystem maximizing the repeated utilization and synergy across multiple IoT systems. IoT-based systems are now integrated in a coherent way, leading to the System of Systems (SoS) [24]. In the development of IoT applications in agriculture one of the possible approaches, which provide the greatest development opportunities is the SoS [20].

4 INNOVATIONS AND TRENDS IN SMART AGRICULTURE

The rapid advance of geoinformation technologies, including novel remote sensing approaches using unmanned aerial vehicles (UAVs), allowed their integration in the decision-making processes even for small farmers [25]. This resulted in the availability of a large amount of image data at the micro-level, as well as a high degree of compatibility with IoT. A wide selection of sensors suitable for the integration with the UAVs covers the majority of the requirements for spatial data collection in agricultural production. While their cost prevented the farmers from obtaining them individually, presently RGB, multispectral, radar and LiDAR sensors are commercially available at reasonable prices. Due to the high computation requirements of aggregating these data in agricultural land management and precision agriculture, big data solutions will likely become more necessary in smart agriculture.

The emergence of the machine learning algorithms enabled a superior accuracy and computational efficiency of cropland suitability and soil parameters prediction compared to the conventional methods [26]. These methods would likely become gradually more instrumental to the efficient agricultural land management planning as a basis for smart agriculture. Moreover, the effects of climate change will eventually require the introduction of new crop rotation systems, making a suitability analysis focal point of the new land management plans. The computational efficiency of machine learning methods also opened more possibilities to additional exploitations of data sources that was previously under-utilized, such as satellite multispectral imagery [27]. These data enable efficient monitoring of large continuous areas, providing a possibility for more efficient agricultural subsidy control systems and detecting soil degradation.

The overall trends in smart agriculture will presumably be oriented towards the end-user, allowing small farmers to actively collect data regarding their farms and process them in real-time. With the availability of exponentially higher data count, new unbiased observations regarding agricultural production efficiency will be explored [28]. Ultimately, smart agriculture would be oriented to the adaptation to increasing food production by implementing state-of-the-art ICT solutions.

5 CONCLUSION

The core of DT is a deep transformation of business and organizational activities, processes, competencies and models. These components fulfil the necessity to take full advantage of the changes and opportunities of digital technology combinations. Their accelerating impact on society acts in a strategic and priority way, keeping in mind current and future shifts. Aside from the general DT, the implementation of the ICT in new agricultural projects should be further subsidized, leading to a more efficient agri-food sector. Digital agriculture could be described as a set of systems for collecting, processing and transmitting data with the aim of faster, easier and simpler management of systems in agricultural and food production. The digital transformation of agriculture, like most other activities, is based on several things on the Internet, but also the development of a set of systems, through the SoS.

The advantages brought by these new systems and changes, as well as considerable challenges, lead to an increasing need for education and the adoption of increasingly complex and diverse knowledge. This especially refers to the spatial component of smart agriculture by integrating modern geoinformation technologies into agricultural production. The farmers are referred to an increasing number of professional sources in development and production planning, which will ultimately increase the efficiency of agricultural production.

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Exploring Sentiment Analysis on Arabic Tweets about the COIVD-19 Vaccines

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Abstract: The COVID-19 pandemic has imposed a public health crisis across the world. The global efforts lead to the development and deployment of multiple vaccines. The success of ending the COVID-19 pandemic relies on the willingness of people to get the vaccines. Social media platforms prove to be a valuable source to perform experiments on sentiment and emotion towards COVID-19 vaccination in many languages, mainly focusing on English. The people express their opinions and emotion on Twitter briefly, which can have tracked almost instantaneously. This helps the governments, public health officials, and decision-makers to understand public opinions towards vaccines. The goal of this research is to investigate public sentiment on COVID-19 vaccines. Twitter social media extracted all Arabic-language tweets mentioning seven vaccines in 7 months from 1 November 2020 to 31 May 2021. A set of Arabic sentiment lexicons were prepared to perform the sentiment analysis. The tweets' monthly average sentiment were calculated from the collected dataset and evaluated comparatively for each vaccine throughout the 11 months. Out of 5.5 million tweets that have been retrieved using the most frequent keywords and hashtags during the COVID-19 pandemic, 202,427 tweets were only considered and included in the monthly sentiment analysis. We considered tweets that mentioned only one vaccine name of the text. The distribution of tweets shows that 47.5% of the considered tweets mentioned the Pfizer vaccine. It is reported that 64% of the total tweets are non-negative while 35% are negative, with a significant difference in sentiment between the months. We observed an increase of non-negative tweets in parallel with increasing negative tweets on May 2021, reflecting the public's rising confidence towards vaccines. Lexicon-based sentiment analysis is valuable and easy to implement the technique. It can be used to track the sentiment regarding COVID-19 vaccines. The analysis of social media data benefits public health authorities by monitoring public opinions, addressing the people's concerns about vaccines, and building the confidence of individuals towards vaccines.

Keywords: COVID-19; Sentiment Analysis; Social Media; Text Analysis; Twitter; Vaccine

1 INTRODUCTION

By mid-August 2021, more than 180 million global COVID-19 cases and 3.5 million deaths have been confirmed [1]. People were encouraged to stay at home, apply social distancing, and do their work remotely. This isolation led to many posts using social media to express people's opinions towards the pandemic [2].In 2020 and 2021, most of the top hashtags and posts on Twitter were related to the COVID-19. Its variations[3] not just by people but also governments and health authorities share policies and news related to the pandemic [4]. Recently and after the approval of several COVID-19 vaccines worldwide, most discussions on social media are about the wide availability, people acceptance/rejection of taking vaccines, and side effects of each vaccine [5]

Utilizing computing power in several technologies helps to study different areas of the COVID-19, its impact, and people's response to it effectively [6-8]. Many research trends argue that social media play an important role in public health [9]. Surveillance systems are one component of public health that are used to monitor, identify, and evaluate health issues [10]. Social media offers a great chance for such research. Monitoring infectious diseases [11] and disease outbreaks [12], tracking public response to health issues [13], detecting target areas for intervention efforts [14], and spreading fake news about epidemics [15, 16] are examples of public health surveillance.

As the Twitter social media platform has over 187 million active users, it serves as a powerful medium to better understand public perception about the COVID-19 vaccines. Twitter data is used in many types of research to understand public attitudes and discussions about the COVID-19 pandemic. Some researchers have investigated many topics related to COVID-19, including the qualitative content analysis to understand public communication [17], sentiment analysis and word frequency [18], misinformation detection [19], topic modeling [20-22], and social distancing measurement [23].

The key success to control the spreading of the COVID-19 pandemic is the development of vaccines [24-25], while the refusal to uptake the vaccine harms herd immunity [26]. The traditional surveys that have been conducted to understand people's opinions are more expensive because of some issues, including the time-consuming, addressing short health topics, and obtaining from small-scale data. Therefore, we need to look at the community, not just individuals. Social media, including Twitter, can be a great opportunity to infer public sentiment about the COVID-19 vaccines.

Multiple studies have discussed vaccine issues on Twitter data. Twitter is used to detect the community hesitancy regarding other vaccines such as MMR, HPV, and Rdap [26]. It was used to analyze vaccine images [27], detect sentiment about HPV [28], and understanding of vaccine debate of Russian trolls [29]. Since the starting of the COVID-19 pandemic in 2020, Twitter data has been utilized in many research to understand different issues related to pandemic vaccines, such as the detection of people opinions about vaccine hesitancy [30, 31], sentiment analysis [32], content analysis of COVID-19 tweets]33], fake news and misinformation [34-36], pro-vaccine campaign on Twitter [37], anti-vaccination tweets [38] and people emotion during the pandemic [39].

The previous studies offer valuable insights about COVID-19 vaccine problems with some limitations. First, most studies focused on the analysis of Tweets in English and some other languages. This research proposes a method that analyzes collected tweets to bridge the gap of covering some under-resourced languages such as Arabic. It identifies the content sentiment of tweets and the major discussed topics to

provide insight into the evaluation of public attitudes about the COVID-19 vaccine over time. This is the first article assessing sentiment towards seven vaccines in Arabic to the best of our knowledge.

2 METHODOLOGY

This part provides details on the method used in the paper. We propose a methodology framework containing five components, as depicted in Fig. 1.

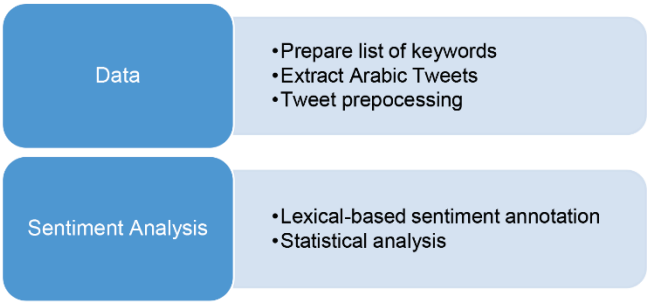

Figure 1 Research methodology

2.1 Data Collection

The Twitter streaming API (Application Programming Interface) retrieved Arabic tweets from November 1, 2020, to May 31, 2021. We used different keywords to search and retrieve relevant tweets such as, "لقاح، اللقاح، تلقيح، لقاحات" and names of each vaccine in Arabic. All Arabic tweets posted in that time were collected and filtered to be included in the sentiment analysis. Tweets that were posted from accounts related to spammer, advertising, and pornographic were excluded. Duplicated tweets from the same users and short tweets that contained less than three words were removed. This process yielded 180,000 tweets out of 5 million tweets.

2.2 Date Pre-processing

The daily tweets were measured, and completed descriptive statistics were conducted on the collected tweets. The natural language processing techniques were applied to process, analyze, and visualize the text from tweets. To preprocess the tweets, several steps are used to clean the text, such as removal of URLs, user mentions, non-Arabic words, and punctuations. All analysis was conducted using Java (Apache NetBeans IDE 12.4).

2.3 Sentiment Analysis

In our sentiment analysis, we used multiple lexicons from the www.saifmohammed.com website. The lexicons were compound and classified into negative and non-negative (positive and neutral) classes. The final lexicon contains 14,000 words. We calculated the difference between each tweet's negative and non-negative sentiment scores. If the difference was less than zero, we assign a negative class to the tweet. Otherwise, the sentiment class would be non-negative. A rule-based approach was developed to extract the sentiment polarity of each tweet in our dataset.

To evaluate the usefulness of this approach, we randomly selected a sample of 1000 tweets representing all vaccines categories. Each tweet was tagged manually by two persons to show if a tweet had a negative or non-negative sentiment. Out of the manually annotated tweets, we used 745 tweets tagged by humans with results obtained by the rule-based approach.

The comparison showed that 78% is the highest agreement between human and rule-based annotations.

2.4 Statistical Analysis

This paper conducted a statistical analysis using Tableau[1] to compare each vaccine's sentiment changes over time. It also proposes a comparative comparison between vaccines each month. As mentioned above, we classified the tweets in our dataset into negative and non-negative classes only. Figure 2 shows the distribution of tweets over time concerning the date. The tweets distribution ranges for 13 months, from May 2020 to May 2021. We notice that the increase in the number of tweets in both classes starts in November 2020, which is the starting period for the production of COVID-19 vaccines.

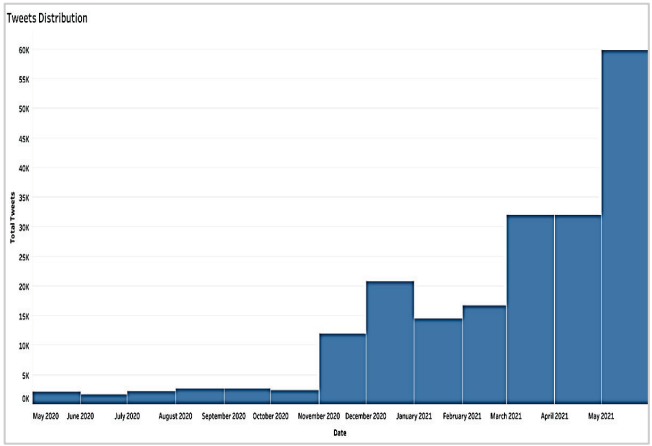

Figure 2 Distribution of tweets and sentiment classes over time

Fig. 3 shows the vaccine's tweets distribution over time. It depicted that the Pfizer vaccine has the highest number of tweets (96,156 tweets), while the Novavax has the lowest number of tweets (1,204 tweets).

In Fig. 4, the distribution of sentiment of each vaccine is shown. The total non-negative tweets (130,326 ≈ 64.4%) are higher than the negative tweets (72,101 tweets ≈ 35.6%) on each vaccine.

In Fig. 5, users mostly interact with the Pfizer vaccine's tweets (Likes = 763,230, Replies = 141,889 and Re-tweets = 257,250), as most of tweets in the dataset belongs to the Pfizer vaccine.

[1] https://www.tableau.com/

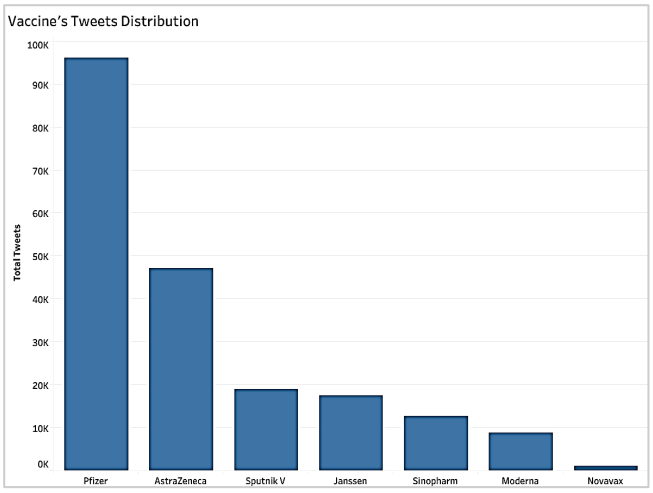

Figure 3 Vaccine's tweets distribution over time

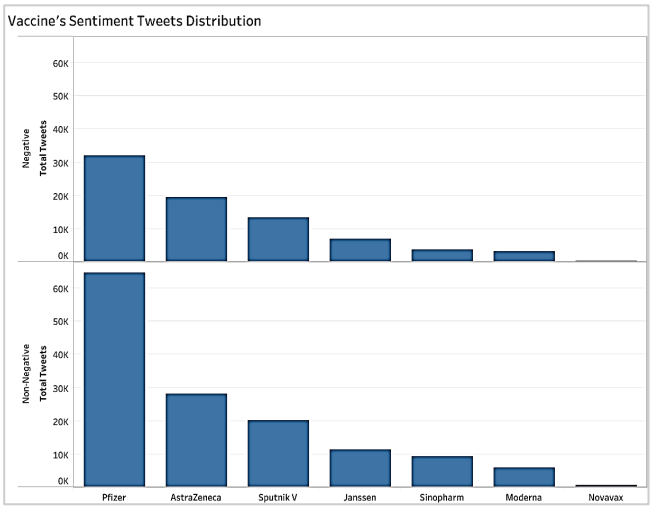

Figure 4 Vaccine's sentiment tweets distribution

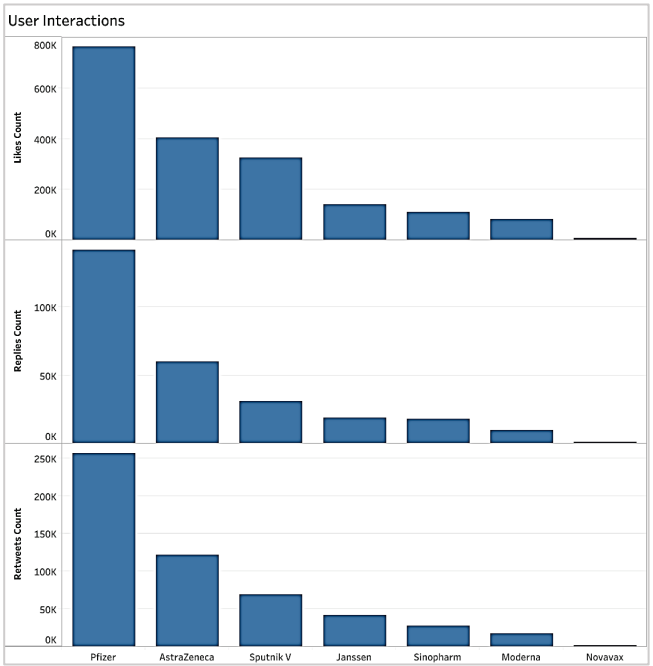

Figure 5 User interactions

3 RESULTS

A total of 202,427 tweets have been included in this study from a total of 5.5 million tweets that were retrieved. Sentiment analysis was performed and the selected tweets were annotation into two classes: negative and non-negative. The percentage of each vaccine tweets is as follow: Pfizer 47.5% (n = 96,156), AstraZeneca 23.3% (n = 47,218), Sputnik V 9.4% (n = 18,948), Janssen 8.6% (n = 17,503), Sinapharm 6.2% (n = 12,605), Moderna 4.3% (8,793) and Novavax 0.6% (1,204).

4 CONCLUSION

Lexical-based sentiment analysis is a valuable and easy way to implement. It helps to track the sentiment about COVID-19 vaccines. The results in this paper show that Twitter can help in giving suggestions about sentiment towards the COVID-19 vaccines. The methodology in this research can be applied in a similar data from other social media networks such as Facebook.

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Towards Creating a Model of IoT to be used in Library Activities for Saudi Arabia's Taibah University

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Abstract: The library must create a replacement organisation system in instruction to swap the existing system with the new one. There are several details why library operates need to adopt a new scheme, including the following: I have lost a lot of info on library books. The lack of familiarity with the literature Difficulty deciphering the fine print of library operations because of a sluggish system Difficulty in maintaining current information. Apart from orientation, the user interfaces are pleasant, and retraining was required. The researcher suggests that this approach be used on an ongoing basis to ensure the continued provision of library services. Other management responsibilities include serials and magazines, as well as reservations book, e-mail notice, and automated reminder, as well as the use of bar codes, scanners, and labels, as well as the custom of regularity identification tags to reduce book theft. Additionally, it is suggested that the library system engage in online surfing to enable users to access books and courses through the internet. The proposed research project would contribute to the development of a model IoT application for library operations at TIBA University in Saudi Arabia. The new system will manage and regulate all library information, resolving the aforementioned issues while also providing numerous advantages to staff and students.

Keywords: Internet of Things (IoT); library management; RFID; service delivery; smart libraries

1 SERVICES PROVIDED BY MODERN LIBRARIES

The library is regarded as a repository of information for students in any field of study. Following the internet's creation, it became a primary source of information for education and research. The introduction of the internet as a product of Information and Communication Technology (ICT) facilitated the advancement of the traditional educational system, which has evolved into an online omnipresent educational system. In this shifting educational landscape, the notion of traditional information resources such as instructors, books, and even libraries is evolving as well. Teachers are rebranded as Learning Enablers, books become audio/video e-books, and libraries become Learning Resource Centers. Electronic and communication technology advancements are resulting in the miniaturization of equipment and an increase in the speed of transmission involving massive amounts of data [1].

Through a variety of uses, information technology (IT) has transformed and simplified life. Users attended libraries to examine a variety of info sources based on their specific requirements. The development of Internet technology, contemporary telecommunications, and related fields such as processing, management data systems, and information retrieval systems, among others, has had a profound effect on the operation and atmosphere of libraries during the past three decades. Libraries are always changing and developing in order to survive. They lack the need to settle on, to vary and develop, but they do require survival and the ability to retain their prominent position as data and learning hubs. There are many explanations for this societal phenomenon. Every aspect of life has been transformed by technology [2].

Users' information-seeking behaviors have changed. Libraries must evolve and adapt in order to meet the users' knowledge requirements. Libraries are allegedly tasked with the responsibility of providing information to users when and in whatever format they have it. The current generation, dubbed millennials or netizens, is more at ease working in virtual settings. The users' expectations and demands have multiplied. They are dissatisfied with location-based library services and need information offerings that extend beyond the actual library's four walls. The contemporary library's aim is to assist in increasing market share by making it very simple for consumers to utilize. Computer systems are raising consumer expectations and businesses who are not computerized will inevitably lose out owing to the strong rivalry and efficiency brought about by computers. It is prudent for libraries to remodel their services in accordance with the expectations and needs of their user community. Libraries may use new technology to provide novel information services in order to maintain and attract new patrons [3].

2 IOT SERVICE DESCRIPTIONS

The Internet of Things (IoT) is a prominent trend that is being utilized to create and manage smart libraries. The Internet of Things (IoT) is a term that refers to the usage of interconnected devices and frameworks to collect data gathered by implanted sensors and other monitoring. IoT makes use of interface media like as wireless networks and bodily substances to join devices to one another and hence to the internet, with little direct human interference obligatory to bolster public services. Several of the benefits of IoT include the ability to demand access to information from anywhere on any device; enhanced device connectivity; increased time and cost efficiency; and improved service quality. There are many Internet of Things (IoT) applications in a variety of fields, as shown in Fig. 1, and as a result, interest in IoT is growing yearly across the world, with numerous major companies investing resources in the innovation process [4].

The Internet of Things has made it easier to maintain control in the retail and supply chain industries. Due to

the distant nature of agricultural operations and the large number of farmed animals that must be monitored, the network of Things has the potential to change the way agricultural processes operate and make farming simpler for farmers.

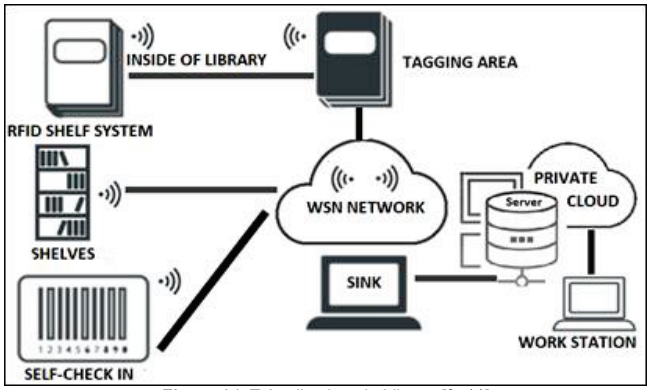

Figure 1 IoT Applications in Library [9, 11]

Issues such as disrupted shelving, library thefts, and so on are addressed by implementing an Internet of Things-based system across the library. RFID technology, scanners and monitors, as well as alarms, are widely implemented. Scholars may quickly find books by using their smart phones or library computers to search the library's Online Catalogue (OPAC) and, as a result of the automated network, they are sent straight to the shelves. Additionally, it supports user authentication and generates unique profiles for easy borrowing and return. Users are informed immediately when it is time to return given material. Additionally, the library management system supports fine computation, easing the load on personnel. By using online data storage, portable and digital libraries, you may eliminate paper-based processes and associated maintenance costs, increase efficiency, reduce activity costs, and save time. Additionally, it assists customers by giving a virtual tour of the library. As a result, much research and development effort has been directed into automating public and academic libraries during the past two decades. It facilitated enhanced management and service delivery. Numerous other technologies, like as blockchain and machine learning, are utilized to suggest books to consumers through their devices. Numerous software programs are created, with some including specific changes to improve administration in a variety of library types. Cloud storage has eliminated security risks while facilitating access. Recently, public library use has decreased as a result of a lack of current books and inadequate upkeep. The primary goal of giving students with high-quality education and training is impossible without first learning about their evaluations and needs. Thus, use statistics may assist staff in determining the users' interests. Additionally, in academic libraries, proper analysis of student use of books, periodicals, and other materials may result in increased collaboration between instructors and students throughout the learning and research process. Faculty members may see how students study and refer to write notes. Through this study, library personnel may serve as a liaison between academics and instructors, as well as update the collection with more important resources. As a result, our proposed study will focus on fully automating IoT in library administration and will use predictive analytics to help in improving the entire automation process and upgrading the library [5].

3 THE INTERNET OF THINGS IN RELATION TO COMMERCIAL SERVICES

(a) Library information literacy services

The library collection's RFID-tagged items allow the creation of a virtual representation of the items, which can be recognized by means of computers and RFID readers. By incorporating RFID tags into member cards, it is often possible to simplify the circulation of goods and fine collection. The IoT will be able to inform users of unpaid books and the amount of fine they owe the library, allowing them to reappearance late paid books and pay the fine online without having to wait at the circulation desk16. Additionally, keen numeral shelves may be prepared to push material that is backed by customers' borrowing records and online search histories. Additionally, IoT will aid in improved inventory management by making it easier to find lost books [6].

(b) Library-based IoT services

The Internet of Things might make it possible for libraries to provide location-based services to its patrons. Using an IoT-enabled mobile device, a user who creates a results have suggested in the digital library from his or her homes and offices will be able to obtain instructions to the stacks where his or her favorite novels are postponed, as well as guidance in recognizing impressive titles relevant to the topic and the position of checked out books, when that user walks into the library [7].

(c) IoT-enabled appliances and services in libraries

The Internet of Things may assist libraries and their patrons in better managing accessible equipment, thus reducing energy expenditures. While some of these measures are already in place in certain libraries, they may expand control beyond library personnel to users. Consider that a person entering a library, sitting in a cubicle or reading table, using their IoT-enabled mobile phone, might manage the lights, air conditioning, and Wi-Fi, among other things [8].

(e) IoT-enabled library services

Whenever a researcher looks for materials on a certain topic in a database, it is feasible for the database to suggest other materials which may be of interest to them. No matter how many times a user returns to the library or is on the brink of returning, IoT will be ready to inform him or her of recent comers during his or her

field of work or of the availability of a loaned book which he or she was looking for during a prior visit [9].

(f) Impact of IoT on library services

In order to enhance the value of the service and offer a great library experience for consumers, libraries will be ready to boost their worth. The Internet of Objects is all about connecting things online based on their unique identifiers, which is what it is called. Because of the use of radio frequency identification (RFID), which performs the same function of conversing with machineries, tagging and updating the library system with entries of library books to a user, librarians are already familiar with this concept. The only difference between RFID and IoT, however, is that the web is interfacing with something physical, such as a book. Libraries include books, journals, and CDs/DVDs; these, as well as many other tangible things, as well as the Internet of Things (IoT), are often a gift in disguise for addressing a variety of recurrent library problems [10].

4 TAIBAH UNIVERSITY LIBRARY DESCRIPTIONS

Research libraries are those that are solely devoted to research. Studies that analyze library websites in order to assess researchers-targeted programs are typical of this kind of study [7-11]. The assessments of the requirements of researchers presented in the former part mark the substantial importance of having broad accessibility to the latest materials, electronic as well as print. Van Zijl's investigation of the policies and procedures for research collection at two universities of technology, one in South Africa and another in New Zealand and, discovered that the institution in South African, for instance, fell short of international standards in many areas. The two recent comprehensive assessments of library research services conducted by the Research Information Network (RIN) are especially useful. Respondents were given the option of selecting from a menu of thirteen options. Academics' answers reveal seven categories of library competence that are critical duties: dataset manager, repository manager, operations manager of data management, custodian of collections, subject-based knowledge expert, technology specialist, and teacher of data managerial skills, to name a few. The answers from librarians prove those issues. Nevertheless, they include others, including intellectual property counselling, information literacy education, and metadata management, to the list of recommendations. Researchers seem to put a greater value on their roles as instructors of comprehension skills and propagandists of research findings than do researchers, according to this study. Using mostly qualitative methods, this study investigates the connection between specific library features and the academic standing of a university's research program. In addition to boosting the income of research, taking on skilled researchers, and encouraging them, eleven library characteristics have been shown to be essential. Information and organizational abilities, proactive information specialists, outstanding research collections, a strong service culture, subject expertise, and leadership in institutional repository administration are just a few of the library qualities that have been recognized as important. It is possible that the most important, and yet intangible, feature for the future of university libraries is the common idea between a research institution's faculty members that the academic library is a necessary component of their research. The creation of specialized research units aiming to "embed" the library in research operations, is one example of a library initiative that seeks to join the world of researchers proactively [11].

For instance, at Curtin University of Technology, the mission is to "proactively support research activities through offering appropriate information and resources, improving research procedure, enabling scholarly interaction, and enhancing research output" (Garner 2006) [12]. Several of the operations carried out by these units include the following:

- supervising the submission of electronic theses:
- Institutional repository management Collecting research materials Instruction in database search
- Providing reading areas for scholars apart from the undergraduate classroom. Developing connections between the research communities of institutions, for instance, among research and development offices, as well as postgraduate study committees:
- establishing communication and collaboration platforms, such as wikis, for research communities;
- placing librarian offices inside faculties to maximize interaction with researchers; students pursuing advanced degrees; and
- creating online research portals that provide great accessibility to a wide variety of electronic resources.
- Accessibility to extended and updated print and electronic collections
- Access to archives and special collections - facilitated over the last years by libraries digitalization-related projects
- Effective communication and information technologies
- Rapid document delivery services
- Assistance and advice in finding resources from experts.

5 THEORETICAL MODEL RELATED TO IoT LIBRARIES

IoT in libraries seems to be a strong industry, based on recent advances in this area. Once fully developed, the Internet of Things has the potential to fundamentally alter how libraries operate and offer services to their users. It has the potential to transform library buildings into smart buildings, where patrons may interact with different objects in the library and get practically any kind of information via communication-enabled devices. Apart from the areas of implementation mentioned previously, IoT may penetrate deeper into various areas of libraries over time, providing statistics on library resource usage, maps indicating the most heavily used areas of the library, user satisfaction levels, and when students become frustrated with library resources and resort to Google.

Libraries must examine a variety of factors before jumping on the IoT bandwagon [13]. The first concern is the privacy and security of patron data, since there is a possibility of exchanging this information with other parties, which may result in hacking. Secondly, the financial, personnel, and time costs associated with investing in IoT technology. Thirdly, staff training is necessary, and the most critical factor is the decrease in physical library usage. The library management system combined collection and acquisition, and therefore classified physical loading, cataloging, circulation, and information and retrieval for reference service series. When these computerized library services are implemented, the process is referred to as library automation. Automation and technologies that are involved with the planning & design processes, as well as systems that reduce the amount of human participation needed in their operations, are characterized as being part of the planning and development process. Library automation is a wide term that refers to the use of information and communication technologies (ICTs) to replace human library activities in a variety of settings. In light of the following considerations, is it acceptable to automate the library?

a) The growth rate of the information they offer is very fast, especially for the majority of material in libraries. It has become more difficult to manage and organize data using conventional methods [14].
b) It is difficult to update knowledge as a result of the significant rise in the number of specifications and the increase in the degree of specification concerned.
c) When it comes to sharing resources between libraries and users, automation can make things much easier. Automation provides a high speed, extra accurate, and extensive increased storage library automation, which improves the effectiveness of our work by providing uniformity and appreciation for our control. It also minimizes repetitious labor by automating it, and it makes bibliographic controls, checking, and other features possible. Computers are utilized to perform library tasks in the context of library automation [15].

Computers are increasingly being used by college students as both exercise books and textbooks. This implies that pupils who did not advocate for new technology would fall far behind, since current knowledge is often accessible simply via the usage of computers. This demonstrates unequivocally that library service administration is doomed to failure if new technologies are not used to organize these offerings. Only by digitizing and storing library material on small, accessible, and secured electronic media will future generations be able to benefit from their efforts to preserve the past. Since a result of the widespread use of computers in society and education, it is no longer necessary to visit libraries or book stores to get books, as many people increasingly rely on electronic books and other soft copies. Instead of carrying about a stack of books, a flash drive, CD, or laptop must be transported. Soft copies are less in size than textbooks and are easier to look through. Additionally, the writer observed that soft copies are more cost efficient than textbooks, and that many of us often access soft copies. Additionally, copies can do delicate animations, which are not feasible with text, and are rarely destroyed [16].

Table 1 TAIBAH University "Wish list" of library research support services

Ranking	"Wish list" of library research support services
1	Updates on new information resources are provided on an ongoing basis.
2	Keeping research repositories up to date is important.
3	Getting Started with a Database
4	offering suggestions for reading material on my subject and advising me on my literature review
5	Advice on how to properly reference a source in a bibliography
6	Suggestions for my research subject
7	Writing a study proposal: some pointers

6 IMPLEMENTATION OF IOT IN LIBRARIES

At TAIBAH University, libraries are locations where students come to access and utilize the information they libraries in order to provide information and services to patrons [17]. ICT is increasingly playing a significant role in the library environment, both in terms of delivering services need to complete their assigned duties. As an institution, the library collects both print books and publications and digital and electronic versions of many kinds of information resources. Additionally, it includes the provision of various user-oriented services that assist users in meeting their informational requirements. Librarians are also required to undertake certain administrative functions inside to customers and administering other library operations:

a) Creating master plans for collection storage;
b) Standardization of storage;
c) Organizing the purchase of storage systems and their installation;
d) Keeping an eye on collection growth in relation to available storage space and layout;
e) Arranging for collection relocations;
f) Arranging for storage equipment maintenance and replacement;
g) Managing the physical preparation of goods to ensure they will last a long time;
h) Delivering and reshelving goods ordered from storage, whether on-site or off-site, including in public places;
i) Keeping track of the position of collection objects when they are removed from and replaced on the shelf;
j) Keeping the shelf order and sequencing consistent.

Radio Frequency Identification is an acronym for Radio Frequency Identification. RFID technology makes use of wireless radio communications to create unique identifiers for people or assets. It is a technology that enables the tracking and communication of an object,

such as a library book, through radio waves. This technology is conceptually similar to a telephone. RFID is a term that refers to the combination of radio frequency and microchip. RFID technology has the potential to significantly improve library operations by enhancing the efficiency of library transactions and providing better service to library customers [18]. Libraries are benefiting from the usage of small Radio Frequency Identification (RFID) tags to monitor their assets, which aids in inventory management of hundreds of thousands of objects (Fig. 2).

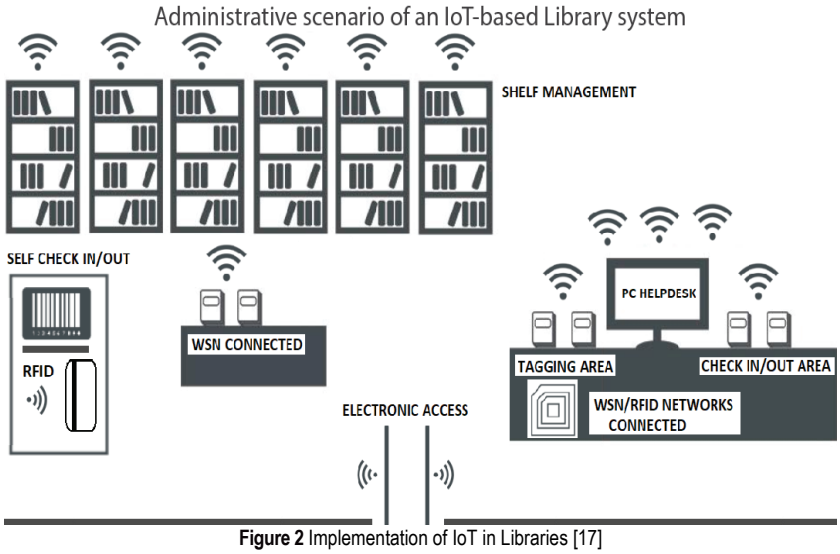

Figure 2 Implementation of IoT in Libraries [17]

This may be accomplished in a single day, rather than over the course of many months. Numerous libraries have used or are considering using RFID technology to automate circulation, inventory management, and security control. RFID technology enables automated check-out and return of library items at any time of day or night. It streamlines checkouts and maintains a more organized collection. Apart from facilitating checkouts and maintaining a more organized collection, RFID promises to improve a library's control over theft, non-returns, and incorrect filling of assets.

6.1 Radio Frequency Identification Tags

A programmable chip and an antenna are included with this tag. Each paper-thin tag is equipped with an etched antenna and a microchip with a minimum capacity of 64 bits. Three types of tags exist: "read only," "WORM," and "read/write". Tags are considered "read only" if the identifier is encoded during manufacturing and is not rewritable. The employing organization programs the Write-Once-Read-Many tags, but without the ability to modify them afterwards. The "read/write tags", which are preferred by the majority of libraries, allow for the modification or addition of data. It is typical for libraries that employ RFID to have a portion of the read/write tag protected from rewriting, such as the item's number [19, 20].

6.2 Radio Frequency Authentication

In order to communicate with one another, RFID scanners and tags need a wireless channel, which implies that the signals they send may be susceptible to listening or interception. Additionally, tags react to a reader's inquiry without their carriers being aware of what is going on around them. The use of encryption to protect the components of sent information may be an excellent method of ensuring that even if an unknown individual spills the beans on the linkage, the cipher text will not reveal critical information unless the key has also been stolen; however, encryption is not always effective. There is a requirement for a secure, safe system that will allow management to monitor the communication of their employees at all times. In this study, we utilized two different encryption techniques to protect the data stored in the system: the triple coding standards (3-DES) and the Message Digest 5 (MD5) (MD5) [20]. Throughout the authentication process, RFID tags are utilized to validate an individual's identity by scanning the tag (Fig. 3).

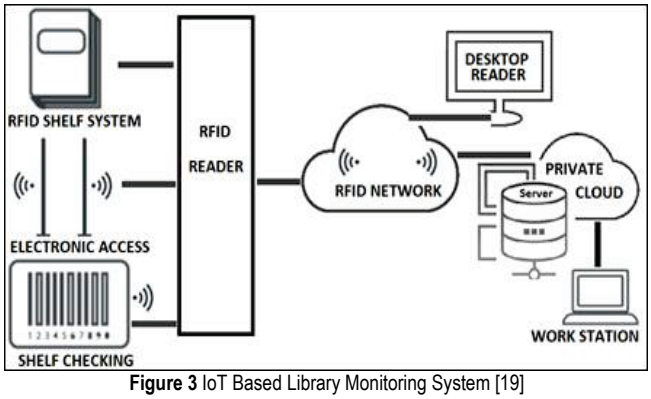

Figure 3 IoT Based Library Monitoring System [19]

(a) One of the most significant advantages of RFID technology is that it is non-contact and line-of-sight. Tags are often read through a variety of materials, including book covers, plastic products in any orientation, and other visually or environmentally challenging situations in which barcodes and other optically read technologies would be useless, such as in dangerous areas. RFID tags may also be read at rapid speeds even under challenging circumstances, with responses often taking less than 100 seconds.

(b) Reading and writing capabilities of a passive RFID system are also a significant advantage in multimedia applications such as work-in-process tracking and inventory management [21]. While RFID is costlier than barcode (in contrast to barcode), it may become indispensable for a broad range of automated data collecting and identifying purposes that would otherwise be difficult to implement without it.

(c) Libraries are being subjected to severe budget cutbacks. The reduction in financing from the state and local governments has made it difficult for libraries to keep their doors open around the clock, seven days a week. RFID is seen as a way of solving the lack of skilled workers [22].

(d) The self-service component of the RFID system enables members to check out goods without the need for assistance from staff employees. Self-service systems have the potential to become very popular with both members and staff. Members may check in or check out several books at the same time using RFID self-check systems, rather of just one book as in the past [20]. With self-check devices, there is no longer a need for people at the circulation counter.

7 CONCLUSION

Advances in information communication technology have created a fresh window of opportunity for innovation within established library paradigms. The Internet of Things offers enormous promise for libraries. If done properly, it has the potential to produce desired outcomes and add value to library resources and services. It is still in its infancy, therefore it is prudent for librarians to learn about and wait for this new technology to gain wider acceptance, adoption, and availability for better application in libraries. Simultaneously, it would be fascinating to learn from early adopters and develop more effective strategies for maximizing the benefits of IoT adoption in libraries. Because smart IoT technology in libraries is still in its infancy and is still developing, librarians must be educated in this technology until it is more widely recognized, used, and accessible. RFID technology is used to track the position of references, store data, and retrieve it quickly. RFID deployment in libraries has been explored. All operations, including issuing, reissuing, returning references, searching for references, and locating a lost reference location, may be completed efficiently using RFID in a library.

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Greenhouse Gas Emissions of Electric Cars - A Comprehensive Evaluation

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Abstract: As an important trend in the automotive industry, electrification of propulsion systems has potential to significantly reduce greenhouse gas emissions of the transportation sector. Whereas electric vehicles do not produce exhaust emissions during driving, the impact of electricity provision for charging the batteries as well as the impact of vehicle production play an essential role in a holistic consideration of the carbon footprint. The paper introduces a comprehensive evaluation of greenhouse gas emission-related factors of battery-electric cars, considering the entire product life cycle. This comprises vehicle production, including battery system, electric powertrain and other relevant components, the car's use phase under consideration of different electricity mixes, user patterns and the end-of-life phase. The results of the study can serve as a basis for comparison with the characteristics of cars driven by conventional propulsion systems and allow a detailed discussion of the different technologies, especially under consideration of future development trends.

Keywords: electric cars; greenhouse gas emissions; life cycle assessment; production technologies; technology evaluation

1 INTRODUCTION

The electrification of powertrain systems seems to be an effective method to reduce greenhouse gas emissions of the transportation sector. In this way, governments in worldwide markets introduce legislative boundary conditions to push forward a transition towards electric vehicles. Exemplarily, the European Commission released vehicle fleet-related restrictions of CO_2 exhaust emissions for new personal cars that targets to a considerable reduction of fuel consumption of cars driven by combustion engines. The mid-term fleet targets of CO_2 emission, e.g. for 2030, are on such low level, which cannot be reached by fleets consisting of cars driven by combustion engines only. In this way, manufacturers are forced to bring a certain share of electric cars into the market within a short time frame.

Electric cars to not produce tailpipe exhaust emissions, as they are limited by the above-mentioned legislations. In this way, they are very advantageous not only under environmental aspects but also from the viewpoint of car manufacturers to reach the fleet emission targets. On the other hand, the efforts for production of electric cars, especially of their battery systems, are very high. In this context, electric cars are under critics and there is an ongoing discussion about the actual total greenhouse gas impact of this technology, considering the entire life cycle.

The present work contributes to this discussion by delivering a holistic reflexion of the different influencing factors on the total carbon footprint of electric cars. The results deliver objective data to support an independent evaluation of the technologies as well as discussions and decision-making processes in governmental- and academic institutions, car manufacturer enterprises and the supplier industry. In this context, the methodology of life cycle assessment has been applied to enable a holistic and objective evaluation of the entire life cycle of electric cars, including materials provision, production, use phase and end-of-life treatment.

2 LIFE CYCLE ASSESSMENT IN THE AUTOMOTIVE INDUSTRY

Life cycle assessment (LCA) is a standardized procedure that is increasingly applied to evaluate and compare different products and their technologies, required resources and related processes of materials- and energy supply, manufacturing, logistics, the product's usage as well as the end-of-life treatment including recycling and waste management. In the automotive industry, standardized LCA is typically conducted according to the ISO 14040 and the ISO 14044 [1, 2]. In this way, the procedure of an LCA is classified into the following four main steps: *Definition of goal and scope*, *Inventory analysis*, *Impact assessment* and the *Interpretation of results* (Fig. 1).

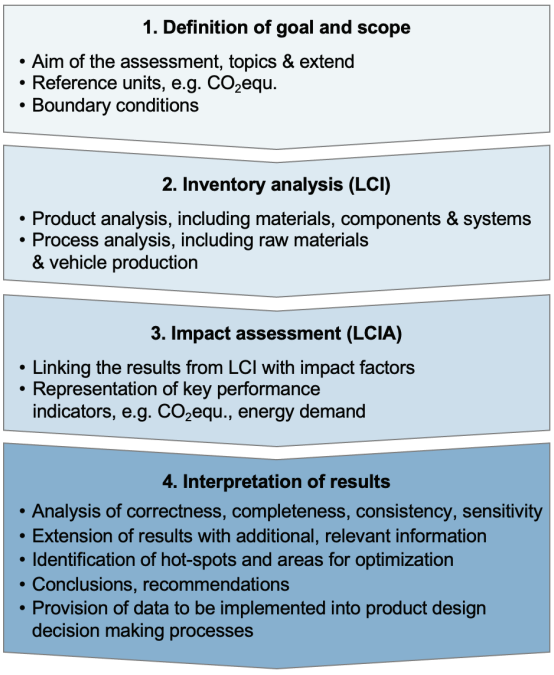

Figure 1 Phases of life cycle assessment (LCA)

2.1 Definition of Goal and Scope

The first phase, *Definition of goal and scope,* targets to a clear determination of system limits, boundary conditions, considered factors and potential limitations of the study. As an important factor, the resulting parameters have to be defined, e.g., energy demand, global warming potential, resource depletion, toxication potential, energy consumption. In the present investigation, the global warming potential is considered in form of carbon dioxide equivalent emissions (CO_2equ.). This means that all influencing factors on global warming are converted into one representative parameter. This approach became very popular in the last years because it delivers one key performance indicator that can be used for evaluation and discussion of different technologies. As one weakness of this method it has to be considered that a reduction of data to one representative key parameter does not allow reflection of all the different factors that might have impact on a holistic LCA, e.g., land use, resources demand, environmental pollution, energy storage and system efficiency, but it enables a simplified representation, comparison of technologies and discussion of affecting parameters.

2.2 Inventory Analysis

As an important section of LCA, the *Inventory analysis* focuses on a product analysis of systems, modules and components of a car and the corresponding materials. In addition, the production processes are considered, beginning from raw materials extraction and production, the creation of components and systems as well as manufacturing and assembling processes. The inventory analysis is conducted top-town and targets to a definition of main modules, sub-modules and components. As a relevant factor in the automotive industry, supply chain as well as transportation and logistics have to be considered, too. Fig. 2 shows an exemplary top-level structure of an electric car, including the main modules. Depending on car type and size, implemented technologies, powertrain system and equipment, each module influences the results of an LCA in different ways.

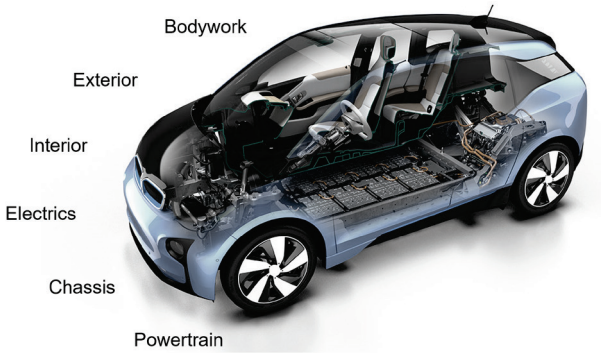

Figure 2 Main modules of an electric car, modified from [3]

In case of battery-electric vehicles (BEV), the main modules might differ significantly from those of conventional cars driven by combustion engines. The *Bodywork*, which includes vehicle body as well as doors and closures, is usually made of material combinations, whereas steel sheets and / or aluminium components represent the central structure of mass production cars. In addition, synthetic materials can be used as covers and protection elements. Carbon fibre reinforced plastics (CFRP) is not widely used in mass production, but in some specific applications, e.g., sports cars of different manufacturers and one electric compact car today [4].

Exterior components include plastic parts for bumper, styling and outer components, but also supplementary elements that complement the vehicle body. The exterior module typically has a low carbon footprint in relation to the bodywork.

Interior includes seats, inner panels, dashboard, air condition system and a number of comfort-related equipment. Besides the seats, the comfort equipment has a considerable impact on both, greenhouse gas emission impact and vehicle weight.

The *Electrics* module includes electric standard components, wiring, sensors, actuators and controllers as well as the supply of electric and electronics systems on different voltage levels. In case of battery-electric vehicles, this module represents the low-voltage system, which is connected to the high-voltage system of the powertrain including lithium-ion battery, inverter and electric motor.

The *Chassis* contains the lower vehicle structure, suspension, brakes and wheels. Electric cars often have a different vehicle architecture in comparison to conventionally powered cars, which comprises a large, flat battery below the passenger cabin.

One main component of the *Powertrain* module of battery-electric cars represents the high-voltage battery system for energy storage including a high-voltage charging system. The electric energy storage capability of the battery significantly influences the driving range. In this way, large battery systems are implemented, which has a big influence on the vehicle architecture and the other main modules. In addition, lithium-ion batteries are sensitive against various types of external influences, e.g., temperature, vibration, mechanical deformation, which requires extensive protection measures. In this way, the high-voltage battery system has the largest impact on CO_2 equivalent emissions considering materials provision and vehicle manufacturing. For today's BEV models, the battery system typically contributes with about 30 % to 50 % of the total production-related carbon footprint, whereas the actual share is influenced by the battery size, vehicle class, and the production technologies applied [5]. The batteries provide an energy storage capacity ranging from about 10 kWh in small cars up to more than 100 kWh in large luxury cars. Typical voltage levels are 400 V and 800 V, which requires extensive effort for protection [6].

In an inventory analysis of the battery system, the different materials used and the various manufacturing processes have to be investigated and analysed [7]. In general, automotive battery manufacturing can be separated into the production of cells and the production of the battery unit, including assembling of cells to modules, adding conductors, sensors and controllers, as well as integration of the entire battery with thermal system, battery management and housing. In most cases, the cells are produced at cell

supplier factories in China, South Korea or Japan and shipped to the battery system manufacturing plants located near the car manufacturer's vehicle assembly lines today. Some car manufacturers integrate the entire battery manufacturing chain in large, so-called giga-factories, e.g., [8].

Besides the battery, the electric powertrain structure consists of one or several inverter(s) that control the corresponding electric motor(s). Inverters are high performance power electronics components and electric motors are typically designed as synchronous or asynchronous motors, consisting of rotor, stator and housing [9]. Synchronous motors can be designed as permanent magnets- or externally excited synchronous machines. In case of permanent magnets, the production-related impact is considerably higher because of the extensive impact of raw materials provision [10]. The torque provided by the electric motors is transferred via a mechanical gear box - in most cases a simple, non-shiftable transmission - to the differential gear and the drive axles.

2.3 Impact Assessment

The *Impact assessment* represents the third phase of an LCA. It targets to a linkage of data and the representation of characteristic parameters, for example the resources- and energy demand and environmental pollution factors. In the present work, the carbon footprint in form of CO_2 equivalent emissions is calculated, because this parameter is increasingly used across different industries. Fig. 3 shows an overview of the main phases and influencing factors that have been considered in the study.

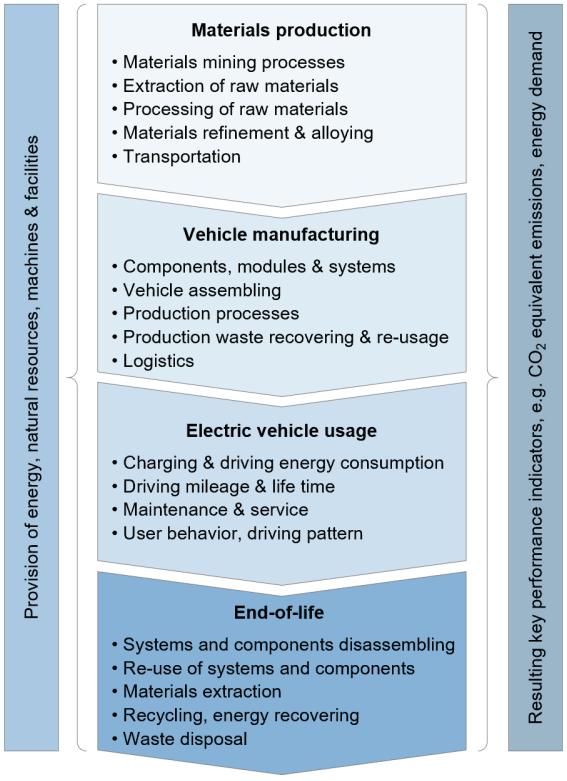

Figure 3 Main phases and influencing parameters of an automotive LCA

A holistic application of LCA represents a complex task that requires high effort and detailed investigations of the different sections in a life cycle. This includes raw materials extraction, manufacturing and assembling processes as sequences of production, aspects of the product's usage and service efforts as well as dismantling, recycling and disposal in the final life cycle phase.

The provision of energy and natural resources has an important impact on the life cycle behaviour. This includes electrical and chemical energy that is required in all sections of the life cycle, as well as air, water and of course resources for materials production and vehicle manufacturing. In this way, impacts of raw materials sourcing and processing are explicitly investigated and material-related aspects are also considered in the sections of vehicle manufacturing, car usage and end-of-life. In case of recycling, a certain share of materials can be extracted and returned to the previous sections of the vehicle life cycle to reduce the total carbon equivalent impact.

As electric energy plays a major role throughout all sections of the life cycle of electric cars, the carbon footprint of electricity provision is of high interest. This is related to the use phase of the car, where the battery is charged from the electricity grid, but also to the entire chain of manufacturing-related processes, starting with the provision of raw-materials and including the production of components, modules and systems, as well as logistics and vehicle assembling. In this context it has to be considered that delivery of materials and supplied components might be provided from various countries or regions with different carbon footprints of electric power generation.

Table 1 LCA-based CO_2 equivalent emissions of selected technologies of electric power generation [11, 12, 13, 14]

Technology of electric power generation	LCA grams CO_2 equivalents per kWh electric energy
Brown coal:	1100 g/kWh
Hard coal:	950 g/kWh
Oil:	700 g/kWh
Natural gas:	450 g/kWh
Solar cells:	50 g/kWh
Wood chips:	40 g/kWh
Bio gas:	25 g/kWh
Wind power:	25 g/kWh
Nuclear power:	25 g/kWh
Hydro power:	20 g/kWh

Tab. 1 shows the CO_2 equivalent emissions of selected technologies of electric power generation in an LCA-consideration. This includes the contributions to the total carbon footprints of building the power plants, as well as service efforts and the required resources for electricity generation. Fossil-based technologies convert chemically stored energy, e.g., in form of coal, oil or natural gas, and consequently have a high carbon footprint. So-called renewable technologies convert bio-mass, sun radiation, wind- or hydro energy to electric energy and have a significantly lower total greenhouse gas emission impact factor. Nuclear energy is not considered as renewable, but the

CO_2 footprint of electricity is very low. It has to be stated, that in the present LCA-oriented investigation, efforts for construction, service and maintenance are considered, but not those of nuclear waste deposition and risks of potential nuclear accidents.

Table 2 CO_2 equivalent emission intensity of electric power generation in selected countries [11, 12, 13, 14, 15, 16, 17]

Country	LCA grams CO_2 equivalents per kWh electric energy
Poland:	682 g/kWh
China:	600 g/kWh
Japan:	450 g/kWh
USA:	430 g/kWh
Germany:	382 g/kWh
EU 28:	296 g/kWh
United Kingdom:	278 g/kWh
France:	59 g/kWh
Sweden:	52 g/kWh
Norway:	35 g/kWh

In the present study, the carbon footprint of electric power generation in the related countries and regions is considered for the corresponding life cycle process sequence. In view of vehicle manufacturing, this includes materials provision, manufacturing of supplied components and systems, as well as vehicle assembly. In addition, recycling processes are also considered at the corresponding geographical locations, e.g., in case of battery cell recycling. In the concerned regions, different technologies of electric power generation are applied, which results in so-called electricity mixes. Based on the electricity mix, the average CO_2 equivalent emissions of electric power generation can be calculated for the regions and countries. In this context, Table 2 lists the CO_2 equivalent emission intensity of electricity production in selected countries.

2.4 Interpretation of Results

In the fourth section of LCA, the results are interpreted and put into context of the investigated product application, see Fig. 1. Considering battery-electric cars, this is applied onto two main phases, vehicle production and use phase of the cars. The effects of the end-of-life phase are considered in the vehicle production phase, as potential recycling of materials and energy recovery can be fed back to the production processes. Due to the focus on carbon footprint in the present work, other environmental impacts are not investigated in further detail here, but of course represent relevant factors, e.g., depletion of resources, air pollution and waste management.

Vehicle production includes the sections of material preparation, vehicle manufacturing and potential recovery of materials and energy the end-of-life phase. The carbon footprint of BEV production is significantly influenced by vehicle type and size, battery technology and capacity, powertrain technology as well as the vehicle's configuration and equipment. In addition, technologies of material sourcing, vehicle manufacturing and the behind lying processes of energy provision are to be considered. In this way, results published by car manufacturers, suppliers and scientific institutions, may show certain dissimilarities, e.g., [18-22]. Due to the high carbon footprint of battery system production, the total CO_2 equivalent emissions of BEV production are about 50 % to 100 % higher than those of the production of comparable cars driven by combustion engines [5].

With the target to display and discuss the manufacturing-related greenhouse gas emission characteristics of an actual case study, Figure 4 indicates a breakdown of the contributions to CO_2 equivalent emissions of an exemplary battery-electric vehicle production. The shown breakdown is calculated for a synthetic compact electric car, which represents averaged characteristics as a result of a conducted analysis in the European market. Tab. 3 gives an overview of the main technical parameters of the considered vehicle.

Table 3 Main characteristics of the investigated electric compact car

Car type:	Compact car (C-class)
Vehicle mass:	1800 kg
Propulsion:	Permanent magnets synchr. motor
Max. power:	110 kW
Battery capacity:	60 kWh
Country of battery cell production:	China
Country of vehicle manufacturing:	Germany
Car body main material:	Steel
Vehicle comfort equipment level:	Standard
Total carbon footprint of production:	14.0 tonnes CO_2 equivalents

Considering the main modules, it is visible that battery system production has the largest carbon footprint. It is influenced by the battery size, active materials of anode and especially cathode, the applied production technologies and the electricity mix that is provided in the geographical location of cell production. For the investigated car, the battery system is responsible for 50 % (7 tonnes) of the total production-related carbon footprint. *Car bodywork*, *Electric powertrain* and *Interior* come next, but at a significantly lower level with each 10 % to 14 % (1.4 t to 2.0 t).

The main module *Electrics & electronics* includes electrics low-voltage systems of the car and has a carbon impact of 8 %, respectively 1.1 tonnes. *Exterior* and *Chassis* modules play an inferior role with just 3 % and 5 % of the production-related CO_2 equivalent emissions.

Putting a focus on the influences of different applied materials it becomes visible, that the material provision for the production of *Battery cells* (here considered as one representative parameter for cell production) plays an important role, but the percentage of CO_2 equivalent emissions impact is clearly lower than those of the *Battery system* main module. Reason for this is the high relevance of electricity in battery cell production, which has a share of nearly 50 % of cell's carbon footprint. In this way, the applied electric power generation technology significantly influences the total carbon footprint of battery cell manufacturing. With 23 % and 15 % share of the total production-related carbon

footprint, the "traditional" materials *Steel* and *Aluminium* have a considerable impact on the carbon footprint. The materials-related CO_2 equivalent emission impact shown in Fig. 4 considers the *Electrics & electronics* components in a simplified representation in one block that amounts to 20 %, respectively 2.8 tonnes. This comprises all electrics and electronics components of the high-voltage system (including the battery, but excluding the cells), and of the low-voltage system, e.g., cables and wires, sensors, microcontrollers. Relatively low carbon footprint of production show *Polymers* (7 %), *other Metals* (4 %) and *other Materials* (3 %).

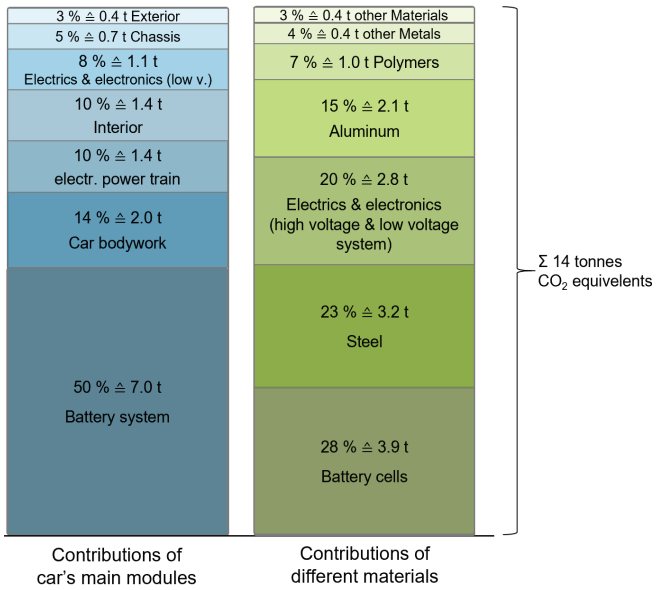

Figure 4 Contributions of main modules and different materials to CO_2 equivalent emissions of an exemplary electric vehicle production

Not explicitly shown in the diagram, but of high relevance is the electric energy consumption and the underlying carbon footprint of electric power generation of the different processes. In the present research, various CO_2 equivalent emission factors are taken under consideration according to the geographical electricity mix, respectively the specific technology of power generation (Table 1 and Table 2). For the exemplary compact car under consideration, the *Battery system* production has a high CO_2 equivalent emission level, because the cells are delivered from China with a relatively high carbon footprint of electric power generation.

A reduction of the carbon footprint is topic of extensive ongoing improvements of BEV manufacturing. In this context, an optimization of battery production plays an essential role, which includes scaling effects by increasing production volume, improvement of cell production processes, a higher integration of battery systems, recycling as well as the usage of low-carbon electricity. It is expected that design improvements and process-related optimizations have the potential to reduce the manufacturing-related carbon footprint of automotive battery systems about 50 % [23]. In addition, the application of electric energy from renewable, respectively low-carbon sources has further potential. By effective implementation of improvements, it can be estimated that the total carbon footprint of electric car production can be lowered about 30 % within the next 10 years, decreasing the production-related greenhouse gas emissions of BEV closer to a level of cars driven by combustion engines.

To reach this target, recycling plays an essential role. Considering the segmentation of main modules as introduced above, the battery system is of high importance. The other modules are also relevant of course, but have a lower share of carbon footprint and their recycling processes are well established in the industry today. This is different with the automotive battery systems. In theory, recycling and recovering of sensitive materials can be conducted, but due to complexity of batteries dismantling, safety-critical behaviour of high-voltage systems and complex processes for material extraction, automotive battery recycling is not applied on a large scale today. Research in this field covers a standardization of battery systems in combination with improved dismantling capabilities and the development of effective recycling procedures for large volumes. Due to the high importance of battery recycling in the future, legislative boundary conditions are set (e.g., in China [24]) or in preparation (e.g., in the EU [25]) to provide a fundament for the effective re-use of relevant materials on a large scale, considering the fast growth of electric car fleets.

The **car's use phase** is characterized by vehicle application-related aspects in the hand of private customers and in case of commercial use. Relevant factors for the calculation of the LCA-based carbon footprint of this phase include driving energy demand and energy consumption of auxiliaries, energy losses during charging, and also the impacts of service, maintenance, spare- and wear parts. It has to be stated, that in modern electric cars, the battery system is designed for life-time durability. Typically, car manufacturers provide warranty in the range of about 150000 to 200000 km, or 8 to 10 years, by ensuring minimum 70 % to 80 % of remaining battery capacity. In this way, a replacement of the battery system is not considered in the present investigation. In relation to the greenhouse gas emission impact of vehicle manufacturing and propulsion, the effects of service, maintenance and spare parts are relatively low.

The energy consumption of the propulsion system is influenced by vehicle driving resistances, efficiency of the powertrain and the actual operator-related driving style, respectively driving pattern. The charging losses are defined by technical characteristics of charging system and battery, but also by the user behaviour, respectively the actually applied charging power. Low power charging takes longer time, but enables high efficiency of the charging process of up to 95 %. High power charging, so-called super charging, is able to reduce the charging time considerably, but can lead to electrical losses of more than 30 %, which requires specific cooling of charging system and battery.

User behaviour-related factors are very complex to consider and topic of different investigations, e.g., [26]. In the present work, the standardized driving cycle WLTC (world harmonized light vehicles test cycle, [27]) and

averaged user patterns are taken under consideration. This includes consideration of charging losses for an assumed charging behavior of 75 % slow charging (maximum 11 kW) and 25 % high-power charging (up to 100 kW). Based on conducted measurement series, the energy consumption of the considered electric compact car (C-segment) in the standardized driving cycle has been defined with 16 kWh per 100 km and the energy demand of auxiliary systems, e.g., climate condition of the passenger cabin, lights, electronics, are taken into account with plus 10 %. Summing up charging- and driving energy as well as energy consumption of other electrical systems in the car results in total with 20 kWh per 100 km (Fig. 5).

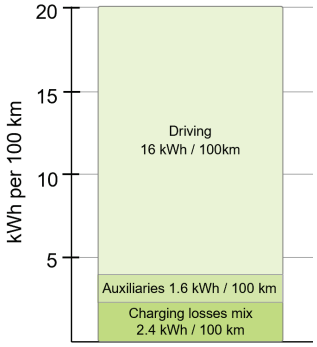

Figure 5 Energy demand distribution of an exemplary electric compact car

In a similar way as it is for the vehicle production phase, the technology of electric power generation has a large impact on the CO_2 equivalent emissions of the use phase, because it defines the carbon impact of the energy required for vehicle propulsion. In a typical consideration, the carbon footprint of propulsion is calculated as a function of the driving distance, e.g., in grams CO_2 equivalents per driven kilometre. In case of cars driven by combustion engines, this impact is composed of the so-called well-to-tank emissions, which consider the production and provision of fuel, and the so-called tank-to-wheel emissions, which consider the conversion of fuel in the engine to drive the car - thus the fuel consumption. Battery-electric cars do not produce CO_2 emissions during driving (they have no exhaust emissions). In this way, their carbon footprint of driving is exclusively defined by the electric energy demand of the car and the CO_2 equivalent emissions of the applied electric power generation technology mix.

Fig. 6 shows the total CO_2 equivalent emissions of the investigated electric compact car that is operated in selected countries with different carbon footprint of electric power generation. In countries with high share of fossil-based electricity production technologies, e.g., Poland and China, the carbon footprint when operating electric cars is very high - it is even in the range of the total carbon footprint of cars driven by modern combustion engines. In countries with low-carbon power generation, the greenhouse gas emission impact of electric car's operation is very low, nearly zero, e.g., in France, Sweden and Norway. In this way, Figure 6 points to the high relevance of the transition of the energy sector towards low-emission power generation technologies. It has to be stated that this work focusses on the carbon footprint of the different technologies and does not consider other, potentially relevant influencing factors and risks, e.g., land use, water supply, environmental impacts, as well as nuclear waste management and nuclear risks. Independent from the automotive industry, but related to that, it is important to consider these factors in a comprehensive discussion of future energy systems.

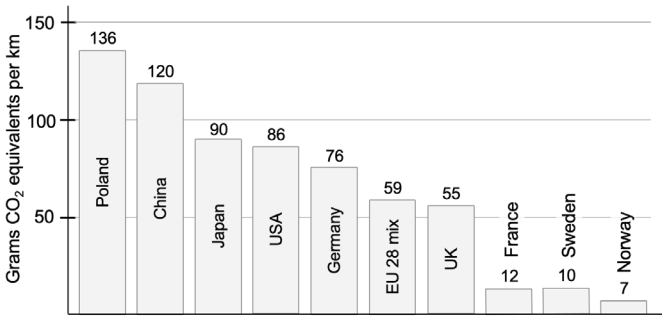

Figure 6 CO_2 equivalent emissions of an exemplary electric compact car operated in selected countries with different carbon footprint of electric power

The **total life cycle** carbon footprint of an electric car is calculated by summation of the CO_2 equivalent emissions of vehicle production and those of the car's use phase. As stated above, the influences of the end-of-life phase including recycling and materials recovering is considered in the LCA section of production in this work. Combining the carbon footprints of production and use phase, Figure 7 illustrates the life cycle CO_2 equivalent emissions of the exemplary electric compact car operated in selected countries with different carbon footprints of electric power generation and an assumed life-time usage of 200000 km.

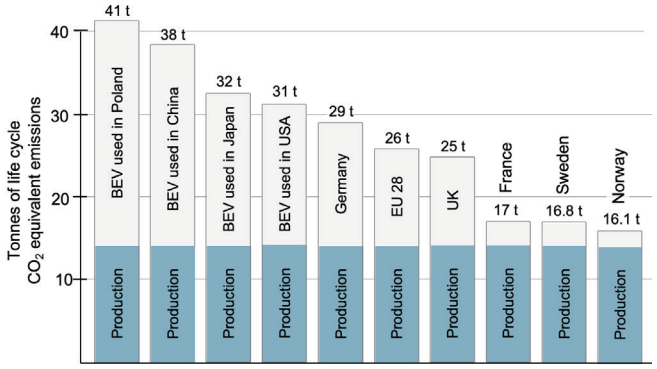

Figure 7 Life cycle CO_2 equivalent emissions of an exemplary electric compact car operated in selected countries with different carbon footprints of electric power generation and a life-time usage of 200000 km

In the present consideration, the vehicle production is defined to be in central Europe and the battery cell production in China. With 14 tonnes, the manufacturing-related CO_2 equivalent emissions represent an exemplary behaviour that might be different for other cars and in specific cases under dissimilar boundary conditions. In any case, the impact of electricity provision to the total carbon footprint is clearly visible. The high carbon footprint of BEV production is compensated relatively quickly in case that the cars are

operated in countries with low-carbon electricity production. In countries or regions with high-carbon electricity mix, the use phase represents one major contributor to the life cycle greenhouse gas emission impact, whereas in countries with a lower carbon footprint of the average electricity mix, the section of vehicle production becomes more significant, e.g., in case of the median mix of the European Union (EU 28). In this context, Fig. 7 points to the importance of a reduction of the production-related carbon footprint, e.g., by moving manufacturing of battery cells from China to European countries with low-carbon electricity, and / or the use of solar, wind- and hydro energy in specific manufacturing plants. In addition, the supply of low-carbon electric power for the operation of BEV is essential to reach the ambitious goals of the "New European Green Deal", which targets to a CO_2 – neutral continent in 2050 [28].

Not shown here, but potentially of interest is the life-cycle greenhouse gas emission impact of electric cars in comparison with cars driven by combustion engines and hybrid cars. This topic was not content of the present work, but has been investigated by the authors in other publications, e.g., [5, 29]. The process of LCA and a comparison of different automotive energy storage and propulsion systems is relatively complex, because cars driven by combustion engines have varying architectures, modules and systems than electric cars. In any case, for the considered compact car segment and cars with comparable sizes and performances, the total life cycle CO_2 equivalent emissions, including vehicle production and a usage of 200000 km amount to about 40 t for a modern car driven by gasoline engine and about 33 t for a modern full-hybrid car with gasoline engine [5]. These numbers show, that in case of operation an electric car in countries with high electricity carbon footprint, the benefits are small - or nearly zero. In comparison with modern, efficient hybrid cars, the electric vehicle might have a higher greenhouse gas impact. On the other hand, when considering low-carbon electric power generation, the life cycle related greenhouse gas emission impact of electric cars is significantly lower than those of cars driven by combustion engines, even if their footprint of vehicle production might be higher than those of conventional cars.

3 CONCLUSION

A comprehensive evaluation of battery-electric cars with focus on their impact on greenhouse gas emissions requires the application of holistic life cycle assessment. This includes a detailed analysis of the vehicle's structures, their main modules and the related manufacturing processes. In addition, the use phase of electric cars is investigated under consideration of the energy demand of operation as well as of service and maintenance-related efforts. Finally, the end-of-life phase provides a certain potential of materials recovery and energy conversion, but in case of automotive high-voltage battery systems the corresponding processes are not yet implemented on industrial scale.

The carbon footprint of electric cars production is significantly influenced by battery manufacturing, which involves both capacious demand on laborious materials and excessive consumption of electric energy. Today, main share of battery cells is produced by involvement of high-carbon electricity, consequently leading to an extensive greenhouse gas emission impact.

The results of the investigation point to the importance of electric power generation, which has a significant impact on all phases of electric cars life cycles. In this way, the carbon footprint of the provided electric energy influences vehicle production and - to an even higher extend - vehicle usage. In case of the application of low-carbon impact electricity, battery-electric cars have a high potential to significantly reduce the greenhouse gas emissions of the transportation sector. But in case of electricity supply from fossil sources, the benefits are very limited and may reach the levels of cars driven by combustion engines with conventional fuels.

Considering future trends of an increasing implementation of electric power generation with low CO_2 equivalent emissions and the introduction of optimized manufacturing technologies, battery-electric cars have a great potential to contribute to a reduction of greenhouse gas emissions towards the ambitious targets of carbon-neutral economies.

Notice

The paper will be presented at MOTSP 2022 – 13th International Conference Management of Technology – Step to Sustainable Production, which will take place in Primošten/Dalmatia (Croatia) on June 8–10, 2022. The paper will not be published anywhere else.

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A Personalized and Scalable Machine Learning-Based File Management System

Bansal Veena*, Sati Dhiraj

Abstract: In this work, we present a hybrid image and document filing system that we have built. When a user wants to store a file in the system, it is processed to generate tags using an appropriate open-source machine learning system. Presently, we use OpenCV and Tesseract OCR for tagging files. OpenCV recognizes objects in the images and TesserAct recognizes text in the image. An image file is processed for object recognition using OpenCV as well for text/captions process using TesserAct, which are used for tagging the file. All other files are processed using Tesseract only for generating tags. The user can also enter their own tags. A database system has been built that stores tags and the image path. Every file is stored with its owner identification and it is time-stamped. The system has a client-server architecture and can be used for storing and retrieving a large number of files. This is a highly scalable system.

Keywords: document database; file tags; image tags; object detection; personalized filing system; scalable; tags database

1 INTRODUCTION

There are many organizations and individuals handling large volumes of documents. These organizations need to manage them efficiently without having to deploy expensive and complicated solutions available. Such an organization has documents containing text, images, videos and links in multiple formats in large numbers. Many of the documents are in paper format, physical media and others are in digital formats. These organizations need to scan and digitize the documents fast and process the documents in parallel on many computers. The documents must be stored in a way that facilitates retrieval based on content or on the purpose of the search. A system that retrieves desired documents with a near 100% recall rate and decent precision is desired. For micro and small organization, the cost of the system is also important, as they are usually tight on the budget. A massive parallel storage system does not fit in their budget. In this paper, a personalized file management system is presented that has been implemented and tested.

The activities that are part of a file management system include creating folders, uploading files and folders, naming, saving, searching and deleting files and folders [1]. There are many algorithms and techniques to retrieve information that focus on different aspects of performance. Recall rate, precision and speed are three main parameters for evaluating an information retrieval algorithm. Every operating system provides a directory structure for organizing the data and a search facility for finding a file by its name. A content-based image retrieval (CBIR) system focuses on retrieving images similar to a query image [2]. A text-based image retrieval (TBIR) system retrieves images that contain the query text. Images may also be retrieved by querying the objects contained in the images provided images have been tags associated with them. Automatic tagging has performance issues and manual tagging is very expensive. More advanced systems such as google photos automatically tag images and provide options to the user to include additional tags.

The command *grep* on Linux and *search* on windows can retrieve all documents that contain the query word in text documents. It has been shown that people spend more time navigating than searching as the search results are often less than satisfactory and search tools are complex [3, 4]. Individuals maintain thousands of files and folders [5] and the file management system provided by an operating system is just about adequate [3, 6].

All these systems become inadequate when an organization is in a business that involves scanning, storing and processing millions of documents and costs, privacy and regulations are also issues [3, 7]. There are systems such as Google file system (GFS) and Apache Hadoop among many others, which are designed for managing and processing volume and variety of data [8]. These systems have their own sharing and scheduling mechanisms. These systems are built using a client-server architecture. These systems are resource hungry, complex and expensive.

Micro and small organizations need a lightweight system to organize the data and facilitate retrieval based on contents as well as metadata. The scanned documents or images need to be processed to obtain their contents for retrieval [9]. The file management system may evolve as newer techniques become available for extracting the contents of the scanned images. It is also possible to deploy multiple extraction processes for better performance. For instance, the system could deploy two optical character recognizers (OCRs) for recognizing the text and two image-processing methods to identify objects contained in a scanned document. Depending on the area of the strength of each of the processors, the union of the output will give a superior set of contents. The system and its components have been described in the next section followed by a discussion and conclusion in section 3.

2 THE SYSTEM

The system has been built using a client-server architecture that facilitates scaling and parallel processing. The client system consists of four major modules- login, upload, process and search. The server system consists of a user management module, an upload management module, a processing management module and a search management module. The user management module does as the name suggests and requires no elaboration. The upload

management module manages storage locations, types of documents that can be uploaded, keeps track of the documents in the repository and the processes that are available for extracting contents. The processing module manages the technologies available for extracting information and contents of the files uploaded into the system. The server is also responsible for managing the repository where the files in the raw form are stored. The search module is responsible for facilitating the search and rendering the results.

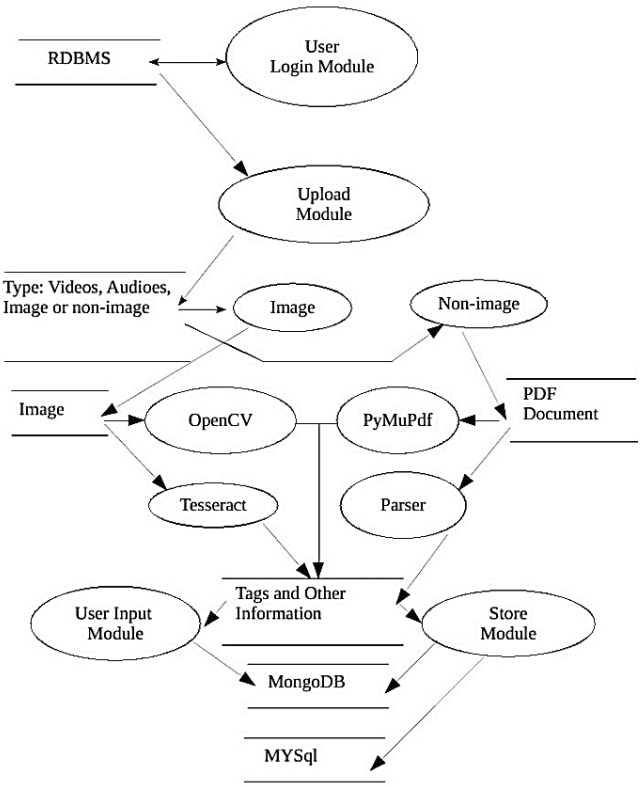


Figure 1 Data Flow Diagram(DFD) of the Client Module; an oval represents a functions, two parallel lines represent a data store and arrows indicate flow of data

The schematic diagram of the client system is shown in Fig. 1. We have used Data Flow Diagram (DFD) notation. This notation is a part of the unified modeling language. A function produces an output that goes to a temporary or permanent data store. The following function is executed when the required data becomes available in the data store. DFD naturally reveals processes that can progress in parallel.

2.1 The Upload Module

The system provides a GUI for uploading a file. The input to the system may be a file that has been generated by scanning a paper document that may contain text, images or both. A sample image is shown in Fig. 2.

The input can also be a document that is in digital form. The user can store a variety of documents in the system. The documents could be invoices, email, legal documents, mails, brochures or any other type of document originating from in-house systems, government agencies, business associates, legal agencies.

Every document has a Unique Identifier, Document type, date of upload, identification of the person who uploaded and document-specific details.

2.2 Processors

As discussed in the last subsection, there are three types of documents- images that are not editable, pdf files that may be edited using special editors and documents that are editable. Each type of document is processed differently.

A scanned file is processed using an appropriate machine learning tool to extract the contents of the file. Presently, a scanned file is processed using image detection function of OpenCV library which is a pre-trained image recognition system to obtain the objects contained in the image. It is also processed by Tesseract, an OCR, to extract the structure of the file and the text contained in the file. The extracted contents are further processed to obtain information that is useful for search operations. All stop words, punctuation marks and words of length two or less are removed. There are many open source software packages available for processing images and text images. An organization may choose other packages such as scikit-image for image processing and EasyOCR for text image processing.

If the document is in editable form and if the user has declared the type of the document, the document type-specific processing is done. For an email, all the fields are extracted such as to, from, subject, forwarded, date, time, attachments etc. Attachments if any are also stored in the repository.

Similarly, an invoice has an issuer, the date of issue, PAN number, invoice number, amount which are extracted from the invoice. If the type of the document is not known, only unique words present in the document are extracted. The system maintains a list of all unique words and objects. This list is available to the user at the time of search to pick keywords for search.

If a document is in pdf format, it is processed using PyMuPDF to extract the structure and contents of the document. A multipage file is divided into individual pages to facilitate search.

The processor outputs the location of each unit extracted. At the highest level, the location is the file and at the finest level, it is the line number and the page number. Notice that we have used pre-trained processors (OpenCV and Tesseract) and no training is required.

The output of the processors is inserted in a dynamic relational database MySQL and NoSql database MongoBD. Information about each file uploaded is also stored in both databases. The summarized content is stored in a MongoDB database. The advantage of storing contents in MongoDB is that search facilities provided by it become available. The front end assembles the input provided by the user into an SQL query that is translated into a MongoDB query using the MongoDB query transpiler.

Every document is saved in its original form as well as in pdf format. The advantage of saving documents in pdf

format is that the rendering becomes easy across platforms. The files are organized into a repository.

2.3 The Search Module

The search module provides a graphical user interface to the user. It has been built to provide support for regular expressions. A user can use *and*, *or* and *negation* operations for constituting a search string. The user first specifies the type of the files and the system renders additional relevant fields for the user to fill in. For an invoice, the user can select the name of the issuer, the range of date of the issue, the amount range, the range of the upload of the invoices, and a set of keywords. The set of keywords may be selected from a dropdown list. The search results are then rendered on the user screen, which includes a link to the original file.

2.4 Re-processing

There are significant advances being made in the OCR, Handwriting recognition, object detection and natural language processing. The server can add more processors and update its existing processors. Since the system has a repository of the original documents, the server can process its entire repository or selected files regularly without impacting the operations. This is done using batch processing on idle desktops.

The discussion so far has been centered on uploading files. However, the system permits a user to upload a folder also. The structure of the folder is maintained. The objective of maintaining the folder structure is to take advantage of the information in folder names and hierarchy. Presently, the system relies on the security provided by the operating system and no additional security features have been built.

3 DISCUSSION AND CONCLUSION

There are two parameters on which search results of a content-based file management system are judged, precision and recall rate. The precision and recall rate are defined as follows.

$$precision = \frac{|(relevant\ documents) \cap (retrieved\ documents)|}{|(retrieved\ documents)|}$$

$$recall = \frac{|(relevant\ documents) \cap (retrieved\ documents)|}{|(relevant\ documents)|}$$

Let us say, there are 100 files (relevant documents) in the system that match a query and the system retrieves a total of 90 files (retrieved documents) out of which 60 (relevant document retrieved) are from the matching files and 30 are some random files, then the recall rate is 60/100 = 60% and precision is 60/90 = 66.66%. The system described in this paper uses OpenCV and Tesseract for processing files for extracting contents. The recall rate and precision depend on the efficacy of the processors used. The state-of-the-art for extracting embedded text is 96.5% precision and 92.3% recall rate [10]. The image processing techniques are also improving and state-of-the-art for identifying common objects is at 77% accuracy [11]. The performance of the processors that have been used by us is slightly less than the state-of-the-art. However, the choice of processors is driven by their maturity and availability.

Since we have used pre-trained and publicly available processors, the performance of our system depends on the performance of the processors used. The system doesnot require separate testing for its performance.

3.1 An Example

Let us say, a user logs into the system and wants to upload the image shown in Fig. 2. The user declares that it is an image. The upload module uploads the files and the processing module is invoked to process the file. First it is processed by OpenCV [12] that detects an *aeroplane* and then it is processed by Tesseract [13] that detects text *N254EK*.

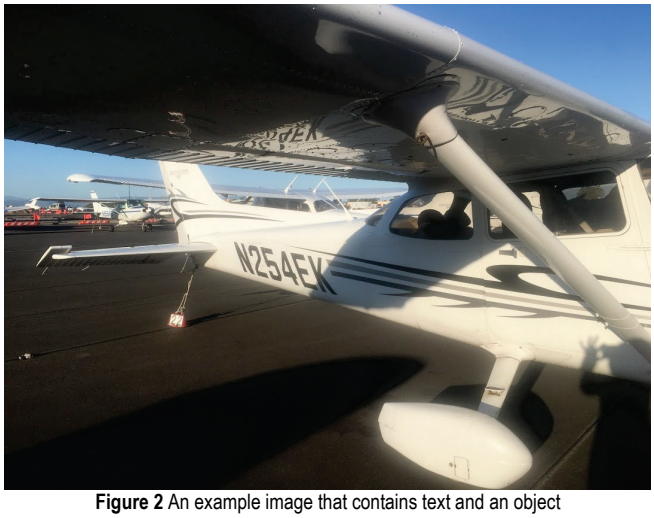
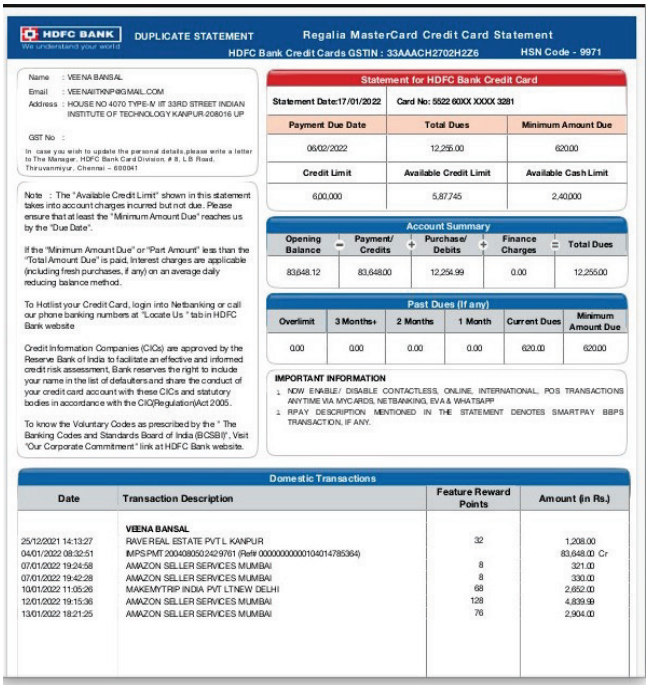


Figure 2 An example image that contains text and an object

The information about the file and metadata are stored in MySQL database. The output of the processers is stored in MongoDB. Metadata from the image such as Author, Title, Subject, Keywords, Category, Status and comments get stored in the MySQL database.

As another example, consider a pdf file shown in Fig. 3. This is credit card bill in pdf format. The processor is able to extract metadata about this file including author, creator, producer, header etc. and almost all the words contained in the pdf file. A subset of words extracted by PyMuPDF [14] as shown in Fig. 4. These words, metadata and file information make it possible to search for the file in multiple ways. One can search a file by name, its type, nature or by words and objects contained in the file. One can see that the output of the processor shown in Fig. 4 would require removal of stop words, punctuation marks and words that are less than 3 characters. This example clearly demonstrates the power of the file management system described in this paper. The output shown in Fig. 4 is stored in MongoDB to exploit the power of the search facility of MongoDB. The metadata is stored in dynamic MySql to enable entry of new metadata.



HDFC BANK DUPLICATE STATEMENT Regalia MasterCard Credit Card Statement

We understand your world

HDFC Bank Credit Cards GSTIN : 33AAACH2702H2Z6 HSN Code - 9971

Name : VEENA BANSAL

Email : VEENAIITKNP@GMAIL.COM

Address : HOUSE NO 4070 TYPE-IV IIT 33RD STREET INDIAN INSTITUTE OF TECHNOLOGY KANPUR-208016 UP

GST No :

In case you wish to update the personal details,please write a letter to The Manager, HDFC Bank Card Division, # 8, L B Road, Thiruvanmiyur, Chennai – 600041

Note : The "Available Credit Limit" shown in this statement takes into account charges incurred but not due. Please ensure that at least the "Minimum Amount Due" reaches us by the "Due Date".

If the "Minimum Amount Due" or "Part Amount" less than the "Total Amount Due" is paid, Interest charges are applicable (including fresh purchases, if any) on an average daily reducing balance method.

To Hotlist your Credit Card, login into Netbanking or call our phone banking numbers at "Locate Us " tab in HDFC Bank website

Credit Information Companies (CICs) are approved by the Reserve Bank of India to facilitate an effective and informed credit risk assessment, Bank reserves the right to include your name in the list of defaulters and share the conduct of your credit card account with these CICs and statutory bodies in accordance with the CIC(Regulation)Act 2005.

To know the Voluntary Codes as prescribed by the " The Banking Codes and Standards Board of India (BCSBI)", Visit "Our Corporate Commitment " link at HDFC Bank website.

Statement for HDFC Bank Credit Card

Statement Date:17/01/2022	Card No: 5522 60XX XXXX 3281	
Payment Due Date	Total Dues	Minimum Amount Due
06/02/2022	12,255.00	620.00
Credit Limit	Available Credit Limit	Available Cash Limit
6,00,000	5,87,745	2,40,000

Account Summary

Opening Balance	− Payment/ Credits	+ Purchase/ Debits	+ Finance Charges	= Total Dues
83,648.12	83,648.00	12,254.99	0.00	12,255.00

Past Dues (If any)

Overlimit	3 Months+	2 Months	1 Month	Current Dues	Minimum Amount Due
0.00	0.00	0.00	0.00	620.00	620.00

IMPORTANT INFORMATION

1. NOW ENABLE/ DISABLE CONTACTLESS, ONLINE, INTERNATIONAL, POS TRANSACTIONS ANYTIME VIA MYCARDS, NETBANKING, EVA & WHATSAPP
2. RPAY DESCRIPTION MENTIONED IN THE STATEMENT DENOTES SMARTPAY BBPS TRANSACTION, IF ANY.

Domestic Transactions

Date	Transaction Description	Feature Reward Points	Amount (in Rs.)
	VEENA BANSAL		
25/12/2021 14:13:27	RAVE REAL ESTATE PVT L KANPUR	32	1,208.00
04/01/2022 08:32:51	IMPS PMT 200408050242976 1 (Ref# 000000000001040147853 64)		83,648.00 Cr
07/01/2022 19:24:58	AMAZON SELLER SERVICES MUMBAI	8	321.00
07/01/2022 19:42:28	AMAZON SELLER SERVICES MUMBAI	8	330.00
10/01/2022 11:05:26	MAKEMYTRIP INDIA PVT LTNEW DELHI	68	2,652.00
12/01/2022 19:15:36	AMAZON SELLER SERVICES MUMBAI	128	4,839.99
13/01/2022 18:21:25	AMAZON SELLER SERVICES MUMBAI	76	2,904.00

Figure 3 An example of a pdf file

In case you wish to update the personal details,please write a letter to The Manager, HDFC Bank Card Division, # 8, L B Road, Thiruvanmiyur, Chennai – 600041
Name: VEENA BANSAL
Email: VEENAIITKNP@GMAIL.COM
Address : HOUSE NO 4070 TYPE-IV IIT 33RD STREET INDIAN INSTITUTE OF TECHNOLOGY KANPUR-208016 UP
00
GST No:0
01/2022
Note : The "Available Credit Limit" shown in this statement takes into account charges incurred but not due. Please ensure that at least the "Minimum Amount Due" reaches us by the "Due Date". If the "Minimum Amount Due" or "Part Amount" less than the

Figure 4 A partial output produced by PyMuPDF for the pdf document shown in Figure 3

The present system has plenty of room for evolution in terms of automatic reorganization of the repository, databases and inclusion of graph databases for representing interlinking of documents and information. The system can also be improved by summarizing the contents and understanding the context of the search based on the user interaction with the system. Presently, the system can store audio and video files without any processing. The processor for audio and video files can be integrated. Additional information from tables, graphs, and tickers can be captured using web scraping which allows for searching beyond what is stored in the system. The demographic data may also be added to improve search operations. Encryption and masking of sensitive information in the documents are required and remain to be done.

In this paper, a personalized filing system has been described. The system is scalable as it is based on the client-server architecture and is designed to use the idle computing resources in the organization without resorting to expensive hardware.

Notice

The paper will be presented at MOTSP 2022 – 13th International Conference Management of Technology – Step to Sustainable Production, which will take place in Primošten/Dalmatia (Croatia) on June 8–10, 2022. The paper will not be published anywhere else.

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[13] See https://www.tesseract-ocr.github.io
[14] See https://www.pymupdf.readthedocs.io/en/latest/

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Categorization of paper
Received: y-m-d, Accepted: y1-m1-d1

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Article Title Only in English (Style: Arial Narrow, Bold, 14pt)

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Ivan Horvat, Thomas Johnson, Marko Marić (Style: Arial Narrow, Normal, 10pt)

14pt

Abstract: Article abstract contains maximum of 150 words and is written in the language of the article. The abstract should reflect the content of the article as precisely as possible. TECHNICAL JOURNAL is a trade journal that publishes scientific and professional papers from the domain(s) of mechanical engineering, electrical engineering, civil engineering, multimedia, logistics, etc., and their boundary areas. This document must be used as the template for writing articles so that all the articles have the same layout. (Style: Arial Narraw, 8pt)

8pt

Keywords: keywords in alphabetical order (5-6 key words). Keywords are generally taken from the article title and/or from the abstract. (Style: Arial Narraw, 8pt)

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1 INTRODUCTION (Article Design)

(Style: Arial Narrow, Bold, 10pt)

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(Tab 6 mm) The article is written in Latin script and Greek symbols can be used for labelling. The length of the article is limited to eight pages of international paper size of Letter (in accordance with the template with all the tables and figures included). When formatting the text the syllabification option is not to be used.

10pt

1.1 Subtitle 1 (Writing Instructions)

(Style: Arial Narrow, 10pt, Bold, Align Left)

10pt

The document format is Letter with margins in accordance with the template. A two column layout is used with the column spacing of 10 mm. The running text is written in Times New Roman with single line spacing, font size 10 pt, alignment justified.

Article title must clearly reflect the issues covered by the article (it should not contain more than 15 words).

Body of the text is divided into chapters and the chapters are divided into subchapters, if needed. Chapters are numbered with Arabic numerals (followed by a period). Subchapters, as a part of a chapter, are marked with two Arabic numerals i.e. 1.1, 1.2, 1.3, etc. Subchapters can be divided into even smaller units that are marked with three Arabic numerals i.e. 1.1.1, 1.1.2, etc. Further divisions are not to be made.

Titles of chapters are written in capital letters (uppercase) and are aligned in the centre. The titles of subchapters (and smaller units) are written in small letters (lowercase) and are aligned left. If the text in the title of the subchapter is longer than one line, no hanging indents.

10pt

Typographical symbols (bullets), which are being used for marking an item in a list or for enumeration, are placed at a beginning of a line. There is a spacing of 10pt following the last item:

- Item 1
- Item 2
- Item 3

10pt

The same rule is valid when items are numbered in a list:

1) Item 1
2) Item 2
3) Item 3

10pt

1.2 Formatting of Pictures, Tables and Equations

(Style: Arial Narrow, 10pt, Bold, Align Left)

10pt

Figures (drawings, diagrams, photographs) that are part of the content are embedded into the article and aligned in the centre. In order for the figure to always be in the same position in relation to the text, the following settings should be defined when importing it: text wrapping / in line with text.

Pictures must be formatted for graphic reproduction with minimal resolution of 300 dpi. Pictures downloaded from the internet in ratio 1:1 are not suitable for print reproduction because of unsatisfying quality.

10pt

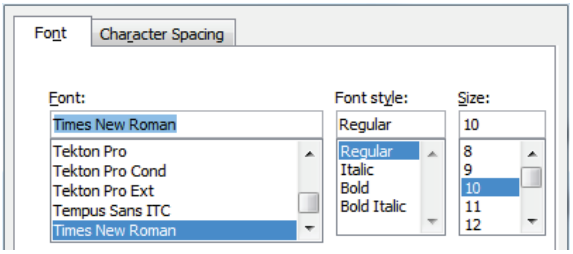

Figure 1 Text under the figure [1]
(Style: Arial Narraw, 8pt, Align Centre)

10pt

The journal is printed in black ink and the figures have to be prepared accordingly so that bright tones are printed in a satisfactory manner and are readable. Figures are to be in colour for the purpose of digital format publishing. Figures in the article are numbered with Arabic numerals (followed by a period).

Text and other data in tables are formatted - Times New Roman, 8pt, Normal, Align Center.

When describing figures and tables, physical units and their factors are written in italics with Latin or Greek letters,

while the measuring values and numbers are written upright.

10pt

Table 1 Table title aligned centre

(Style: Arial Narraw, 8pt, Align Centre)

	1	2	3	4	5	6
ABC	ab	ab	ab	ab	ab	ab
DEF	cd	cd	cd	cd	cd	cd
GHI	ef	ef	ef	ef	ef	ef

10 pt

Equations in the text are numbered with Arabic numerals inside the round brackets on the right side of the text. Inside the text they are referred to with equation number inside the round brackets i.e. ".... from Eq. (5) follows ...." (Create equations with MathType Equation Editor - some examples are given below).

10pt

$$F_{\text{avg}}(t, t_0) = \frac{1}{t}\int_{t_0}^{t_0+t} F\left[q(\tau), p(\tau)\right] \mathrm{d}\tau, \tag{1}$$

$$\cos\alpha + \cos\beta = 2\cos\frac{\alpha+\beta}{2}\cdot\cos\frac{\alpha-\beta}{2}, \tag{2}$$

$$(\boldsymbol{AB})^{\mathrm{T}} = \boldsymbol{B}^{\mathrm{T}}\boldsymbol{A}^{\mathrm{T}}. \tag{3}$$

10pt

Variables that are used in equations and also in the text or tables of the article are formatted as *italics* in the same font size as the text.

10pt

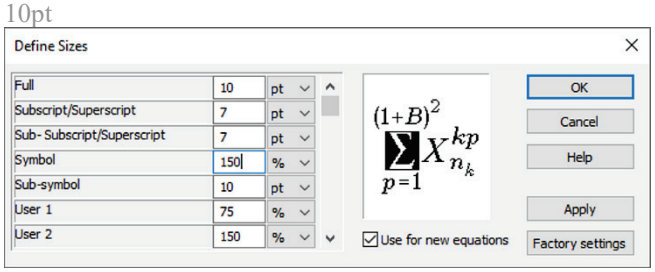

Figure 2 The texts under figures

(Style: Arial Narraw, 8pt, Align Centre)

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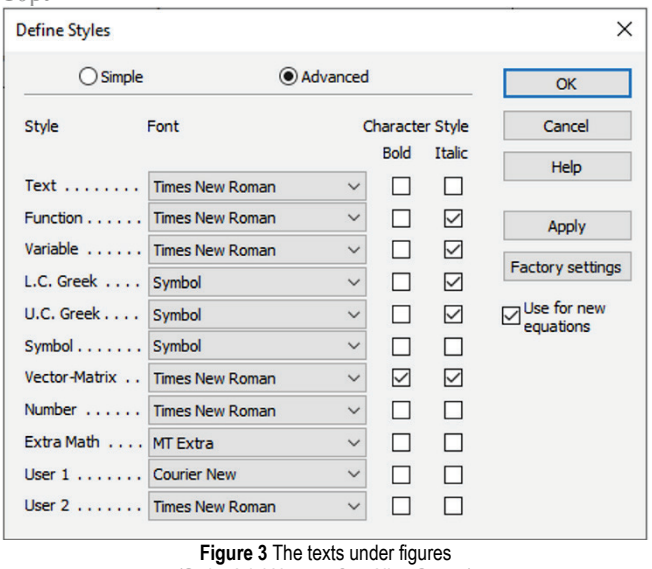

Figure 3 The texts under figures

(Style: Arial Narraw, 8pt, Align Centre)

Figures and tables that are a part of the article have to be mentioned inside the text and thus connected to the content i.e. " … as shown in Fig. 1…" or "data from Tab. 1…" and similar.

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2 PRELIMINARY ANNOTATION

10pt

Article that is offered for publication cannot be published beforehand, be it in the same or similar form, and it cannot be offered at the same time to a different journal. Author or authors are solely responsible for the content of the article and the authenticity of information and statements written in the article.

Articles that are accepted for publishing are classified into four categories: original scientific papers, preliminary communications, subject reviews and professional papers.

Original scientific papers are articles that according to the reviewer and the editorial board contain original theoretical or practical results of research. These articles need to be written in such a way that based on the information given, the experiment can be repeated and the results described can be achieved together with the author's observations, theoretical statements or measurements.

Preliminary communication contains one or more pieces of new scientific information, but without details that allow recollection as in original scientific papers. Preliminary communication can give results of an experimental research, results of a shorter research or research in progress that is deemed useful for publishing.

Subject review contains a complete depiction of conditions and tendencies of a specific domain of theory, technology or application. Articles in this category have an overview character with a critical review and evaluation. Cited literature must be complete enough to allow a good insight and comprehension of the depicted domain.

Professional paper can contain a description of an original solution to a device, assembly or instrument, depiction of important practical solutions, and similar. The article need not be related to the original research, but it should contains a contribution to an application of known scientific results and their adaptation to practical needs, so it presents a contribution to spreading knowledge, etc.

Outside the mentioned categorization, the Editorial board of the journal will publish articles of interesting content in a special column. These articles provide descriptions of practical implementation and solutions from the area of production, experiences from device application, and similar.

10pt

3 WRITING AN ARTICLE

10pt

Article is written in the English language and the terminology and the measurement system should be adjusted to legal regulations, standards and the International System of Units (SI) (Quantities and Units: ISO 80 000 - from Part 1 to Part 14). The article should be written in third person.

Introduction contains the depiction of the problem and an account of important results that come from the articles that are listed in the cited literature.

Main section of the article can be divided into several parts or chapters. Mathematical statements that obstruct the reading of the article should be avoided. Mathematical statements that cannot be avoided can be written as one or more addendums, when needed. It is recommended to use an example when an experiment procedure, the use of the work in a concrete situation or an algorithm of the suggested method must be illustrated. In general, an analysis should be experimentally confirmed.

Conclusion is a part of the article where the results are being given and efficiency of the procedure used is emphasized. Possible procedure and domain constraints where the obtained results can be applied should be emphasized.

10pt

4 RECAPITULATION ANNOTATION

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The literature is cited in the order it is used in the article. No more than 35 references are recommended. Individual references from the listed literature inside the text are addressed with the corresponding number inside square brackets i.e. "… in [7] is shown …". If the literature references are web links, the hyperlink is to be removed as shown with the reference number 8. Also, the hyperlinks from the e-mail addresses of the authors are to be removed. In the literature list, each unit is marked with a number and listed according to the following examples (omit the subtitles over the references – they are here only to show possible types of references):

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[2] See http://sites.umuc.edu/library/libhow/apa_examples.cfm

[3] (Style: Times New Roman, 9pt, according to APA)

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