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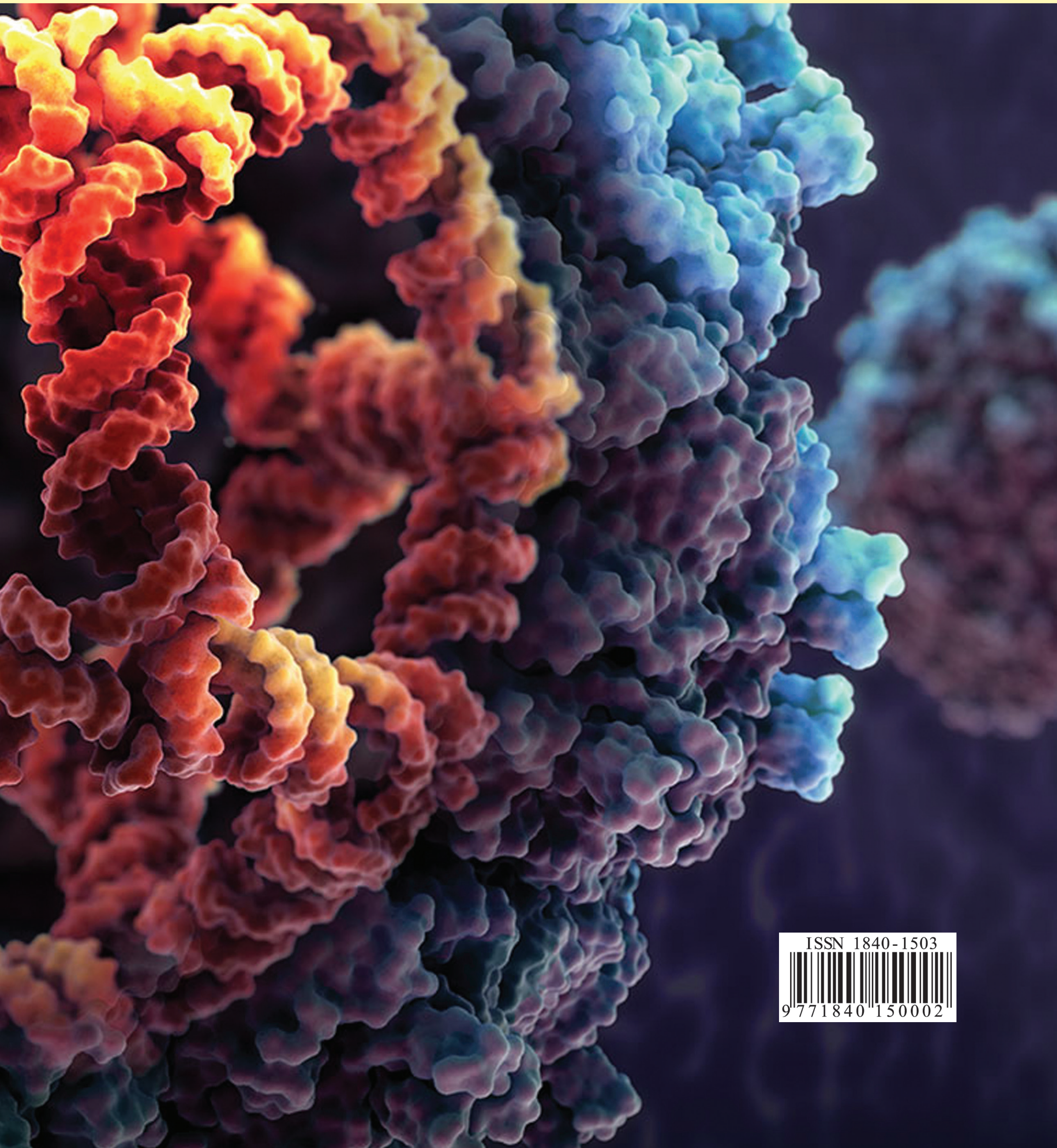

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Techno-economic analysis of Fused Deposition Modelling (FDM) system application

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Abstract

Due to the large supply of equipment with the same purpose but with different technical characteristics and significant differences in the market prices the purchase of modern equipment is an extremely complex issue. This issue is particularly pronounced in rapidly evolving technologies, such as Rapid Prototyping (RP), where are very important geometrical and technological characteristics of equipment (accuracy, building, strength of parts, etc.) on the one hand in comparison to the costs of direct application of that equipment on the other hand. In order to determine the justification of the procurement of a certain RP system in accordance to the set criteria to be fulfilled, in this paper the technical-economic analysis of application of one of the available RP systems i.e. Fused Deposition Modeling (FDM) is presented.

Key words: Rapid Prototyping, FDM proces, Three Dimensional process.

1. Introduction

The basic characteristic of the modern production systems towards achieving and maintaining competitive capabilities on the global market is reflected in short responses to market requirements. As a direct consequence of above mentioned fact, production companies needs to shorten the time necessary to launch a new / redesigned product on the market (so called: *Time-to-Market*), i.e. a vital interest of those companies becomes finding a production process that allows for shortening of time, reducing total costs and achieving set goals while retaining the existing the quality of the new / redesigned product[1]. It should be noted that this process should not be only refer to the final products, but it may be also relate to the visualization of the certain individual stages of the product development process in order to validate and test thecurrent solutions as soon as possible. Significant progress in this segment, within the many applications, is provided by RP systems.

Essentially, the term RP refers to a set of processes that are unique in that the process of production of parts is based on successive adding and merging of layers of building materials whereby solid physical objects are formed [2]. This is diametrically opposed to classical production methods such as milling or scraping where objects are formed through the processes of mechanical removal of the material.RP approach to the production of objects with its characteristics, bridges the big gap in *Computer Integrated Manufacturing* (CIM). Namely, the main problem with CIM is manual or semi-automatic planning of a process that complicates or even prevents the integration of design and production. Because RP systems create a physical object without tools, they can be perceive and considered as the missing link that enables the integration of above mentioned production segments [3].

2. Characteristics of FDM process

One of the RP processes which, thanks to its technical characteristics, favourable price and application possibilities, is increasingly being applied in everyday practice especially in the production of ready-to-use plastic based parts is FDM processand its belonging technical systems. The working principles of the FDM system is based on the melting of the plastic materials filament (building and supporting) in the wire form, their extruding through the nozzles and the successive adding of layers of materials, generating a *ThreeDimensional* (3D) physical model on the working platform, Figure 1. The thickness of layers of added material is depended on the constructive characteristics of the FDM device itself, and it is between 0.025 and 1.25 [*mm*], while the minimum thickness of the wall of the obtained 3D physical model is 0.2 [*mm*].

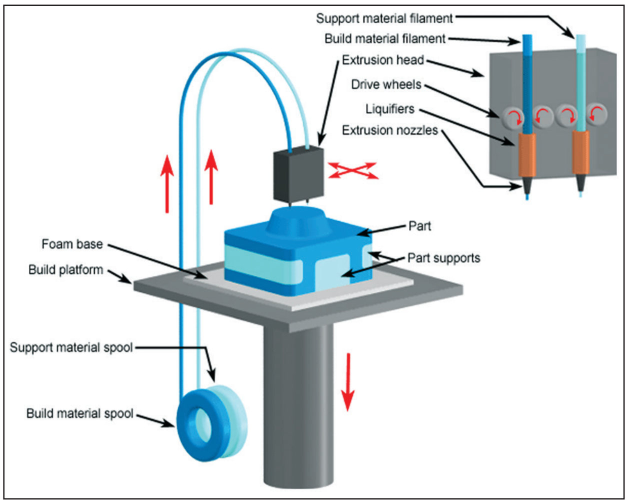

Figure 1. Principles of FDM processes [4]

Depending on the complexity and stability of the generated 3D *Computer Aided Design* (CAD) models, it is necessary to apply certain supporting structures that further increase the costs of FDM production of a 3D objects and the application of this production process in a whole, because the supported structure cannot be recycled. In accordance with the above-described characteristics of the FDM process and the characteristics of available building materials based on plastic, the application possibilities of manufactured FDM parts are as follows:

- production of functional prototypes of plastic parts and small-scale production of plastic parts with extremely complex geometry;
- production of prototypes for experimental tests;
- production of tools for indirect metal casting;
- production of components for the needs of plastics processing industry, automotive industry, machinery production, industrial consumer plastic goods, etc.;
- simulation of: assemblies, work collisions and required installation space;
- marketing presentation;
- production of exhibits for analysis of market response to product;
- production of art replicas;
- production of building models and samples, etc.

3. Problem of research

Selection and purchasing of any type of production equipment is a very complex issue requiring detailed analysis and comparison of the technological and economic characteristics of a wide range of marketable solutions that meet the set requirements, with the optimal ratio of "invested vs. obtained values" for afforded characteristics. A number of partial analyses of the mechanical characteristics of different RP / FDM systems, [5, 6, 7] can be found in the literature, without taking into account a numerous economic indicators. With the aim of better review and selection of a particular FDM system a comprehensive methodology of techno-economic parameters on the basis of an assessment of characteristics, as well as comparison of the analyzed system with other marketable systems, has been developed and presented in this paper. The methodology itself is based on analysis of:

- technological characteristics:
  - tensile strength,
  - elongation at breaking point,
  - ratio between tensile strength and elongation,
  - speed of production – speed of 3D printing process,
  - consumption of building and supporting material.
- economic characteristics:
  - determining of the costs of 3D printing,
  - determining of the costs of 3D printing per 1 [*kg*] or [cm^3] of building and supporting material.

4. Technical characteristics of Cube Pro FDM 3D printers

The presented methodology of the technical-economic analysis of the FDM process is realized on a concrete example with the parts produced on one of the marketable available FDM systems-*CubePro Trio* (Figure 2), producer*3D Systems,* *USA*. This is a low cost 3D FDM printer with the technical specifications presented in Table 1.

Figure 2. CubePro Trio 3D printer installed within RP&RE Lab at the Faculty of Mechanical Engineering in Tuzla

According to technical setup of *CubePro Trio 3D printer* users do not have possibility for detail customization of filling of the internal structure of produced parts, instead there are available four different default options of filament of the internal structure of produced parts set by manufacturer, as follow:

- *Solid* - Most amount of outer surfaces and tightest print pattern spacing making an entirely solid part. Gives the most robust parts. Best for a parts that will be stressed or need the heaviest weight and density. Only available with 200 microns print resolution;
- *Almost Solid*- Large amount of outer surfaces and the tight print pattern spacing. Good for parts that will be stressed;
- *Strong* - Medium amount of outer surfaces and smaller print pattern spacing. Best for parts that will have minimal physical abuse;
- *Hollow* - Fastest mode to produce a part. Hollow has fewer outer surfaces and larger print pattern spacing. Best for parts that will not be stressed.

Briefly summed up, there are some basic features of the *3D Printer CubePro Trio* that can be underline, such as: relatively low price, wide range of layer thickness of applied material, application of three different colours / materials at the same time, different internal filling structures of produced parts, etc. These features make this 3D printer a very interesting choice for anyone who needs the fast physical visualization of design and/or production of their prototypes and products. In the next section of this paper, the results of the technical-economic analysis of usage of *CubePro Trio 3D* printers in production in function of technological and economic characteristics will be show.

Table 1. Characteristics of CubePro Trio 3D printer

Technical specifications	Values
Dimensions	7.8(w) × 59.1(h) × 57.8(d) [*cm*]
Weight	44 [*kg*]
Maximum build size	20.04(w) × 23(h) × 27.04(d) [*cm*]
Z Axis resolution	0.100 [*mm*]
Layer thickness	70 [μm], 200 [μm]and 300 [μm]
Print tolerance	X and Y axis ± 1 [%] dimension or ± 0.2 [*mm*] whichever is greater. Z axis ± half the processed z resolution
Maximum operating temperature at extruder tip	280 [°*C*]
Support material	PLA / ABS / dissolvable natural PLA
Purchase price	3.499,00 [€]

5. Analysis of technological characteristics of FDM process

To test the technological characteristics (speed of production, ratio between tensile strength and elongation, etc.) of the parts produced on the *3D Printer CubePro Trio*, experimental tubes from ABS and PLA plastic as building materials are made. The test tubes used to determine the stress functions are made correspond to the regulations for mechanical tests i.e. EN ISO 527-2.In order to determine the influence of the direction of 3D printing on the technological characteristics of produced parts [2], testing tubes are produced with specific orientations in the working space of FDM machine, presented on the Figure 3.Due to the characteristic of the FDM process, i.e. the raster adding of building material and the relatively small transverse cross section of the testing tubes as well as the relatively high probability of the errors occurrence in the production process, the production of testing tubes oriented in parallel with the Z axis is omitted in this paper. According to the available settings of FDM machine, testing tubes are produced with three different thickness of the layers of building material is 70, 200, 300 [μm], where for each combination of the orientation and the layer thickness by 5 testing tubes are produced. The settings for the adding and filling process of building material of the testing tubes are follows:

- Test tubes filling according to Almost Solid configuration,
- Print Pattern: Cross (Fastest print fill pattern with minimal 2-direction cross bracing),
- Support Type: Points (Fine points that are easy to remove. It is best for curved surfaces).

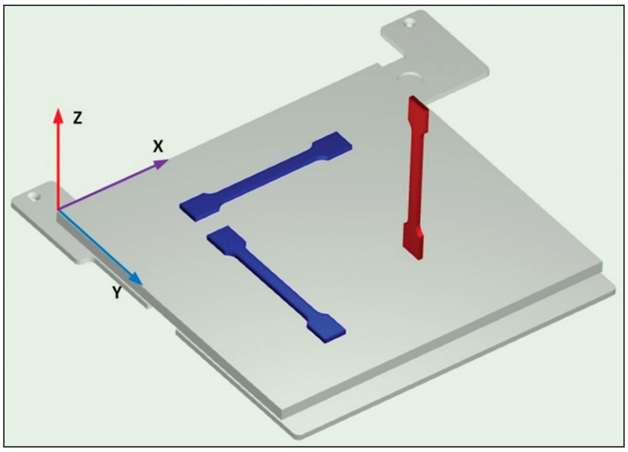

Figure 3. Orientation of test tubes in working chamber

The resulting production time and the consumption of the material for production of test tubes are given in the Table 2. The material consumption parameter contains the required amount of building material for production of the test tube, V = 8.04 [cm^3], as well as the amount of material used for a cleaning of the nozzles for extrusion of the material during the production of each layer.

After the production and post-processing of the test tubes, a tensile strength test was carried out, using the *Zwick&Roell* type *Z030TN* testing machine (Figure 4), with the testing parameters presented in the Table 3.

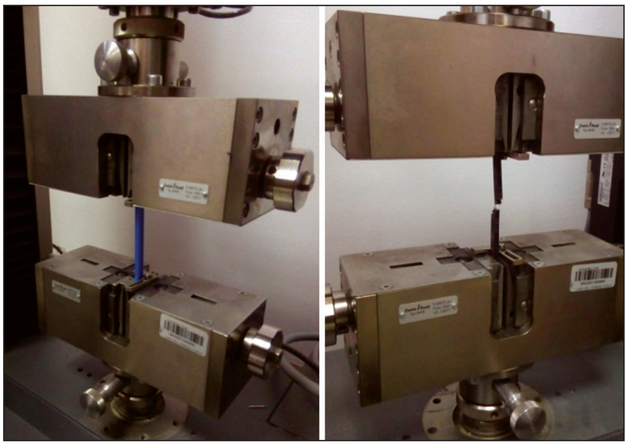

Figure 4. Tensile strength test of test tubes (left PLA –blue colour, right ABS – black colour) on Zwick&Roell type Z030TN testing machine

Table 3. Tensile strength testing parameters

Parameter	Value
Maximal force:	30 [*kN*]
Working area:	440×1780 [*mm*]
Measurement area:	60 [*N*] ... 30 [*kN*]
Pre-load:	10 [*N*]
Test speed:	30 [*mm/min*]
Accuracy of measurement:	Class 0,5
Software:	testXpert II V1.4

Table 2. Dependencies of time and weight of produced parts in function of material and process parameters

Material	ABS					
Test tube	70 X	70 Y	200 X	200 Y	300 X	300 Y
Time [*h*]	1:09	1:09	0:31	0:33	0:16	0:17
Consumption of material [*gr*]	27,76	26,78	13,39	13,64	10,58	10,66
Material	PLA					
Test tube	70 X	70 Y	200 X	200 Y	300 X	300 Y
Time [*h*]	0:45	0:45	0:24	0:26	0:16	0:16
Consumption of material [*gr*]	31,5	30,42	14,42	14,7	13,49	13,49

The results of the experimental studies are shown in the Table 4, as well as on the Figures 5 and 6.

Table 4. Average values of tensile strength at break

Test tube	Stress [*MPa*]	Elongation [%]
ABS X 70	20,81	5,08
ABS Y 70	23,96	4,83
ABS X 200	29,95	4,91
ABS Y 200	30,01	4,54
ABS X 300	16,14	4,76
ABS Y 300	16,96	4,54
PLA X 70	53,66	3,92
PLA Y 70	57,41	4,02
PLA X 200	36,54	4,57
PLA Y 200	37,58	4,13
PLA X 300	35,18	4,43
PLA Y 300	35,33	4,36

Based on the obtained and on the Figure 4 presented results of the measurements for ABS building material, the dependence between the thickness of building material layer and the resulting tensile strength is observed. The best results are noted in the test tubes produced with 200 [µm] layer thickness of building material. The obtained results represent a deviation from the expected results and require detailed analysis and additional research. Additionally, the obtained tensile strength of the ABS building material is significantly below the reference tensile strength value at min. 40 [*MPa*] [8], which can be explained by the production of non-fully filled structure of test tubes (function of the FDM process).The values of dilatation at break of nominal material at 5 [%] for ABS building material do not deviate from the reference values for the ABS material [8].From the aspect of the orientation of the test tube, the obtained results are approximately identical, that is, the influence of the orientation of test tubes in working chamber of FDM machine on the mechanical characteristics is not observed. Probable reason for this observed phenomenon can be found in the characteristic of the FDM process itself, i.e. in the raster adding of layers of building material.

Based on the obtained and on the Figure 5 presented results of the measurements for PLA building material, the dependence between the thickness of building material layer and the resulting tensile strength is observed. The best results are noticed in the test tubes produced with 70 [µm] layer thickness of building material. Those test tube achieve reference PLA material tensile strength value at break min. 53 [*MPa*], but do not achieve the reference values of dilatation at 6 [%]. [8] Obtained results of the test tubes with 200 [µm] and 300 [µm] layer thickness of building material are the similar and these test tubes have poorer mechanical characteristics from the previous ones.

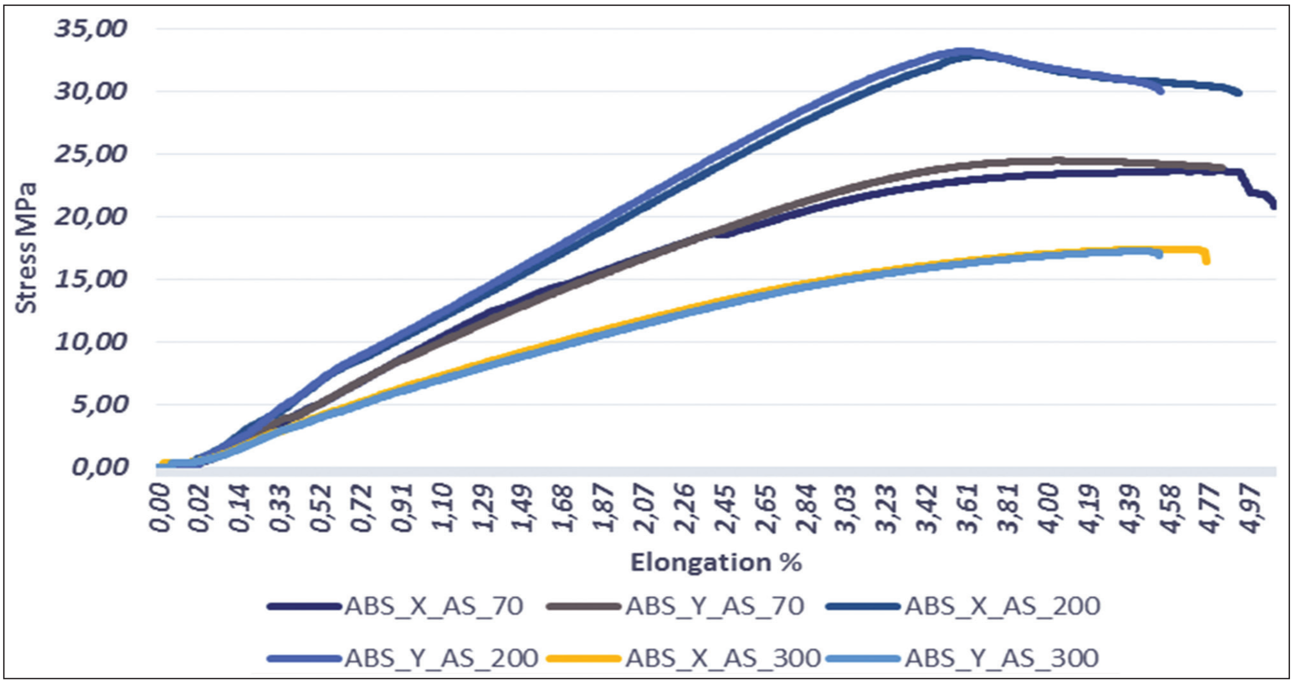

Figure 5. Dependency diagram of Tensile strength -Elongation for ABS material

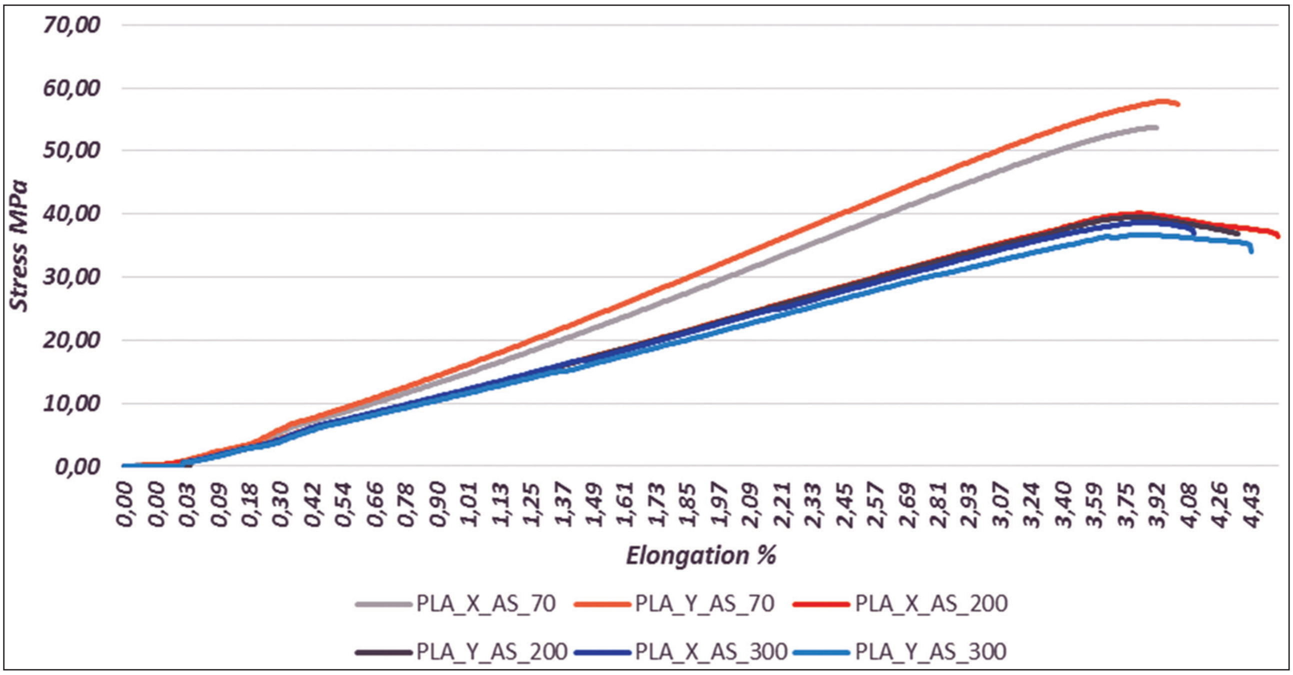

Figure 6. Dependency diagram of Tensile strength -Elongation for PLA material

6. Economic analysis of FDM process

Determining of the cost of FDM process usage should be based on integration of relevant parameters that define the realization of the FDM production process in essence. This practice of cost determination is standardized, however, in the case of cost calculation of any RP process and so in the case of FDM too, it can be noticed occurrence of certain specific subjective parameters associated with the complexity of the geometric shape of the parts who need to be produced. Based on the completed researches and experiences of the authors, as well as based on relevant research published by other researchers, the parameters that can be used to calculate the relevant costs of FDM production process are presented on the Table 5.In accordance with above presented parameters as a basis for calculation of the relevant costs of the FDM production process, the following equation can be used:

$$P_{3D} = \left\{ \left[Q_{st} \cdot P_{st} \cdot 0,6 + \left(P_{main} + p \right) \cdot \frac{P_{EQ}}{T_{year}} \right] \cdot \right.$$
$$\cdot T_{print} + \left(T_{pred} + T_{post} \right) \cdot P_{oper} + P_{bmat} \cdot \cdot Q_{bmat} + \; ..... \; (1)$$
$$\left. + P_{smat} \cdot Q_{smat} \right\} \cdot \left(1 + F_{rate} \right) [€]$$

The primary goal of applying the pre-presented equitation is the objectisation of the process of determining the costs of FDM parts production, taking into account a relatively wide range of parameters such as:

- Maintenance, depreciation and electricity costs depending on total scheduled production time and required FDM printing time of certain part;
- Pre-processing and post-processing costs of produced parts;
- Costs of building material consumed for part production;
- Costs of supporting material consumed for part production;
- Quantity of scrap in the production.

The monetary value obtained by application of equation (1) allows determining of the total net costs of the FDM production process. To determine the total gross costs of the FDM production process, it is necessary to calculate the add-ons for administrative costs, transport costs, packaging costs, and profits. All these parameters have direct links to the way of business of the one who provides the 3D print service.

Given that the fact that the cost of application of FDM process is influenced by the geometric shape which can vary in a wide range of shapes and dimensions of the parts being produced, in order to minimize the influence of this factor on the calculation of total cost of production of the FDM parts, for further analysis the cost of making of piece by 1 [*kg*] and/or 1 [cm^3] of spent building material according to equation (1) is determined. By this approach is provided the possibility of direct comparison of economic with technical characteristics of FDM production process.

Table 5. Relevant cost parameters of RPprocess

Parameter	Mark	Cube Pro Trio
Price of 3D printing process	P_{3D}	**[€]**
Price of the device	P_{EQ}	**3.499,00 [€]**
Annual depreciation rate	*p*	**25 [%]**
Consumption of electrical energy	Q_{st}	**1 [*kW/h*]**
Cost of electrical energy	*Pst*	**0,2 [*€/h*]**
Pre-processing time	T_{pred}	**1,5 [*h*]**
3D printing time	T_{print}	**[*h*]**
Post-processing time	T_{post}	**1 [*h*]**
Annual/average maintenance costs	P_{main}	**10 [%]**
Failure rate	F_{rate}	**10 [%]**
Planned annual operating time	T_{year}	**700 [*h*]**
Gross costs of operator	P_{oper}	**20 [*€/h*]**
Gross costs of building material	P_{bmat}	**110 [*€/kg*]**
Consumption of building material	Q_{bmat}	**[*kg*]**
Grosscosts of supporting material	P_{smat}	**130 [*€/kg*]**
Consumption of supporting material	Q_{smat}	**[*kg*]**

Therefore, to determine the cost of production of 1 [*kg*] of used building material on the *3D Printer CubePro*, taking into account different types of internal filament structures (Solid, Almost Solid, Strong and Hollow), it is necessary to define a unique geometric form that would in addition to basic production costs enabled insight into information on the cost of FDM production process by [cm^3] of used building material. The same procedure can also be used to determine the cost of usage of the supporting material in production at the *3D Printer CubePro*. For that specific geometric shape, the cube of 1 [*kg*] weight has been adopted. By this way the overview of deviation of specific lengths characteristic along of all three available production axis (*x*, *y*, *z* directions; Figure 3) of printers was enabled too. To fulfil above mentioned criteria, the cube should have the following dimensions (*a*-dimension of the side, *V*-volume of the cube) theoretically:

- ABS (1,08 [t/m^3]) *a*=97,467 [*mm*] – *V*=925,93 [cm^3],
- PLA (1,32 [t/m^3]) *a*=97,16 [*mm*] – *V*= 757,58 [cm^3].

Taking in to account the parameters of FDM process, presented at the Table 5, and in accordance to requirements that the produced cube, in dependency of chosen filament option, need to weight 1000±3 [*gr*], the scaling of adopted CAD geometrical form for certain type of setup options of filament is required. Resulting dimensions of cube deviate from calculated theoretical dimensions in percentage values presented on the Tables 6 and 7.

Table 6. Economic indicators of ABS material

Layer thickness [*mm*]	ABS		
	[*€/kg*]	**[%]**	**[*€/cm³*]**
0,07 Almost Solid	263,34	127,3	0,2234
0,07 Strong	263,58	145,0	0,1963
0,07 Hollow	286,02	189,1	0,1634
0,2 Solid	246,86	102,0	0,2614
0,2 Almost Solid	238,91	143,8	0,1794
0,2 Strong	242,38	179,0	0,1462
0,2 Hollow	248,76	225,7	0,1190
0,3 Almost Solid	238,82	176,0	0,1466
0,3 Strong	243,41	310,0	0,0848
0,3 Hollow	252,99	376,0	0,0727

7. Conclusion

The stimulation for the realization of the presented researches of the technological characteristics of building materials in the function of FDM process parameters, and to the presented approach to cost analysis of FDM production process, is to point out the possible ways of performing the comparative analysis of FDM systems that are available on the market with the aim of selecting the appropriate FDM system in accordance to the set criteria.

From the aspect of the analysis of the technological characteristics of the produced parts in the function of the FDM process parameters, it is noticed that in the case of usage of ABS plastic as the building material the best mechanical characteristics (tensile strength) are observed in test tubes with a layer thickness of 200 [μm], and they are better then mechanical characteristics of test tubes with a layer thickness of 70 [μm], Figure 5. This fact is in opposition to the expected results i.e. the thinner layer of applied building material should result in better mechanical characteristics of produced FDM parts. The reasons that led to the above mentioned results in this paper have not been analyzed in detail and certainly the observed phenomenon should be subject to more detailed research. In the case of usage of PLA plastic as the building material in production of the FDM parts expected results of mechanical characteristics (tensile strength and dilatation) in relation to layer thickness of applied building material are noticed, Figure 6.In both cases of used building materials (ABS and PLA plastic) measured values of tensile strength and dilatation are below the reference values for these materials [8].

Table 7. Economic indicators of PLA material

Layer thickness [*mm*]	**PLA**		
	[*€/kg*]	**[*%*]**	**[*€/cm³*]**
0,07 Almost Solid	250,94	135,0	0,2454
0,07 Strong	256,63	151,0	0,2243
0,07 Hollow	272,94	201,0	0,1792
0,2 Solid	234,11	91,6	0,3374
0,2 Almost Solid	231,73	154,6	0,1979
0,2 Strong	238,23	221,0	0,1423
0,2 Hollow	238,11	234,8	0,1339
0,3 Almost Solid	232,02	192,8	0,1589
0,3 Strong	238,41	303,2	0,1038
0,3 Hollow	242,36	376,9	0,0849

From the aspect of the economic analysis of the costs of the process of production of FDM parts, presented equation (1) is an attempt of the authors of this paper to in accordance to their knowledge and experience objectify the determination of the real costs of the FDM production process reduced to [*€/cm³*] of the used building/supporting material.

It must be noted that this way of presentation of the economic indicators is applicable only to the analysis of the ratio of "invested vs. obtained values" of different FDM systems available on the market, and it cannot be applied directly on any other RP systems i.e. it has to be adapted according to the specific characteristics of the concrete RP system.

On this way, it is possible to determine the cost of application of FDM systems of any manufacturer, and to perform a comparative analysis of the target function, set by the customer in the process of selection of appropriate equipment. For the purpose of broader and more practical application of the presented approach in the comparative analysis of the costs of usage of FDM systems available on the market, the next step is to generate a database with the cost characteristics of individual FDM systems from different manufacturers, which would further supplement the review of the techno-economic characteristics of available FDM systems.

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A General Approach to Measure the Students' Attitude to applay Virtual Reality Technology in Education in Their Distance Education Environment

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Abstract

Distance education has become a prominent and effective role in recent years. The factor of place and time became ineffective in the educational process. So that anyone can learn anywhere in the world. The educational services that benefit the learner during the educational process as well as the factors of assistance are important elements that help in the success of the educational process in the environment of distance education. The more these services, the greater the benefit from distance education. But its way of reviewing electronic content is still ineffective. Therefore it was necessary to create a suitable environment for the learner is similar to the real reality. Through which the learner feels the integration and concentration in the academic content as if it were realistic. So, the trend was to take advantage of the virtual reality technology that have become effective in all fields. The use of this technology will help the learner gain more realism and make full use of the electronic content. This study reviews the effect of the use of virtual reality technology in the review of the learner's electronic content, as well as the attitudes and opinions of the students of the Business Information Systems program at the Faculty of Commerce, Helwan University, Cairo, Egypt, about the use of this technology and to what extent will effect on change and effectiveness in the quality of educational process.

Key words: E-Learning, Distance Education, Educational Process, and Virtual Reality (VR)

1. Introduction

In recent years, technology has had the greatest impact in the development the educational environment and has led to the construction of a new learning environment that helps learners to increase knowledge. At present, virtual reality technology has become a new trend for all fields, especially in education.

Virtual reality is "a computer-generated simulation of a 3D environment, which seems very real to the person experiencing it, using special electronic equipment. The objective is to achieve a strong sense of being present in the virtual environment" [1]. In addition, simulation of tools and their action against the organs in the virtual environment is also required [2].

Virtual reality is not new. It has been here for decades, [3] immersive VR technologies have been present in our lives for decades. Even as far back as the 1960's, research labs were exploring ways to replace or augment our physical world with computer data.

Early of 90's, the first enterprise VR appeared in the form of computers costing upwards of $40,000, and consumer VR started to appear alongside Nintendo and Sega gaming consoles. Virtual reality cost up to $73,000, and a number of accessories sprung into the market to try and augment digital experiences [3].

Today's VR technology need for wearing a Head Mounted Display (HMD) to view stereoscopic 3D scenes. Anyone use HMD can moving your head for looking around, and using hand controls or motion sensors for walking around. In addition, involving in a fully immersive experience. It's as if you're really there in some other virtual world [1]. The following Figure shows example of HMD.

The features of VR technology include perception, presence, interactivity, etc. Besides the common visual perception of computer system, it also produces convincing auditory, tactile, and motion perception. The ideal digital environment created by VR technology helps users perceive everything as true as in reality [4].

Figure 1. Example of HMD

In today's world of limited attention spans, virtual reality plays an important role in providing immediate engagement with the learning system. By making VR experiences truly immersive, distractions are greatly reduced, resulting into more effective learning. Further, there are other benefits associated with VR that include cost-saving, safety, and convenience [5].

This study is a general approach that explores the attitude of learners in Business Information Systems (BIS) program, Faculty of commerce, Helwan University, Cairo, Egypt for applying virtual reality technology in education.

2. Background

Higher education has evolved in the last decade with the use of information technology. This change was called distance education, a teaching method in which the student does not need to meet with the teacher on a certain day and time. The student may be either at home or at work and may have no interaction with the other parts, either the teacher or other students. Distance education has allowed the institutions to resolve geographical gaps in order to reach the largest number of students. On the other hand, it paved the way for the "nontraditional" universities oriented for "adult work", in a narrow range of graduation programs, compatible with the current demands from industry [6].

Distance Education upgrading the education system for learners who cannot able to study at institutions. It helps students for acquiring wider opportunities to join higher education. The distance education is very helpful for the student and the people who cannot involve in regular courses. The distance education system not only reduced the initial fear of students but also opened various dimensions of correspondences in education field. The distance education institution may be the best option for increasing the literacy rate in education [7].

Many approaches for education can be discussed: firstly, full time education secondly, part time education which allow learner to learn part in a college and other as distance and finally, distance education based on virtual reality [6]. Full time education is the traditional type of education and the most widely used approach in normal courses at any level, requiring teachers and students to be together in the classroom. The second approach combines learning in the classroom and at a distance using modern technology as VR. Distance education may or may not need to have face-to-face moments as teachers and students are physically separated in space or in time, while being able to interact through communication technologies like virtual reality technology. Figure 2 represents the difference between traditional class room and virtual reality in real life education.

Figure 2. Difference between Traditional Classroom and Virtual Reality in real life education

3. Related works

Virtual reality technologies have the potential of making students feeling more dedicated and interested [8]. Researches on these technologies allows new trails for teaching [9]. There are many studies that investigate this area when using virtual reality technologies in educational process [10] [11], but these studies tend to be focused on specific experiences and topics. In addition is still not a clear vision of how to integrate these technologies in a stable way into an educational process. In this regard, there are difficulties like the resistance of traditional learning environments to integrate educational innovations, the opposition of teachers to adopt new technologies out of their comfort zone, and the costs involved to implement and maintain these technologies. However, taking into consideration the quick evolution of mobile technologies like smartphones and tablets, the use of VR is more feasible and affordable for educational institutions and students than ever before. Many application is built for educational propose. Jamed, Sharad (2017) built virtual reality instructional (VRI) modules based on gaming metaphors [12]. Travassos, Machado, Maciel (2013) presented a new system of learning a curricular unit of circuit theory using desktop virtual reality. The software provides the possibility to understand the relationship between the physical concepts of an electrical circuit [6].

4. Methodology and Empirical Study

Business Information Systems program, Faculty of commerce, Helwan University, Cairo, Egypt has been chosen as the main source of data for this research. Structured questionnaire, primary data collection and different secondary data have been used for this study. After correction and validation the questionnaire, 1153 questionnaires distributed to the students. Only 729 students' responses on this questionnaire. The statistical analysis was used to identify the opportunities of VR in education process and its constraints in colleges in Egypt. Cross tabulation was conducted after frequency analysis on the respondents' answers and the results are tabulated in the results section. Figure 3 shows the methodology of research.

The questionnaire that distributed to students is measuring the importance of applying VR in educational process in BIS. In addition, measuring to what extend the students aware with VR technology. Moreover, determining the factors effected on the current education process which led to use new technology in education.

Figure 3. Methodology of research

5. Findings Analysis and discussions

The flowing figures represent the responses for each question in questionnaire and the analyzing of these responses. These responses categorized into four sections. Each one shows specific aspects in the questionnaire.

A. Personal information

The nalysis from questionnaires' responses showed that 59.3% of students were female and 40.7% were male that represented in figure 4. Referring to figure 5, most of the students were in level 3, 4, 2, 1, or graduated respectively. This study found that the highest numbers of students 36.2% having GPA between 2.8 to 3.39 out of 4.00 as shown in figure 6.

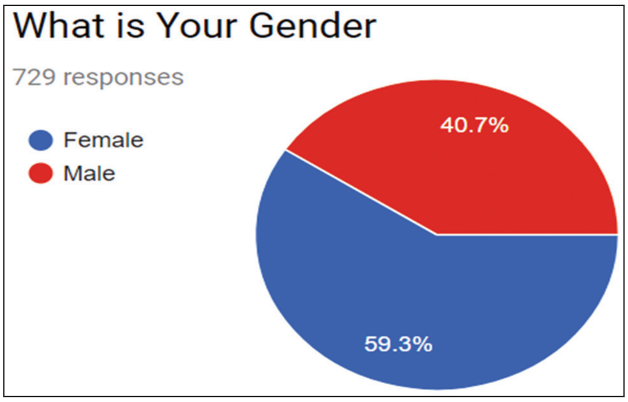

Figure 4. Respondents gender

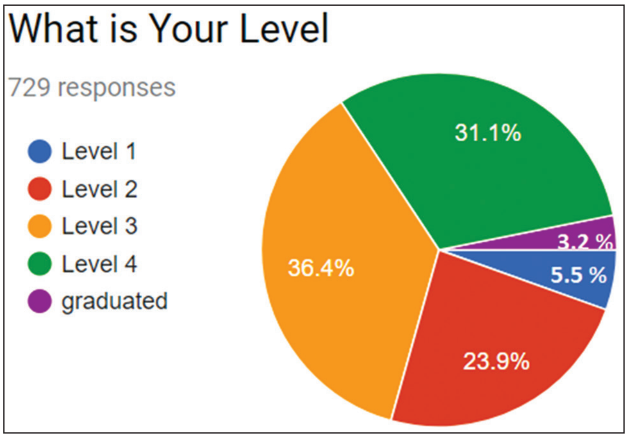

Figure 5. Respondents Academic Level

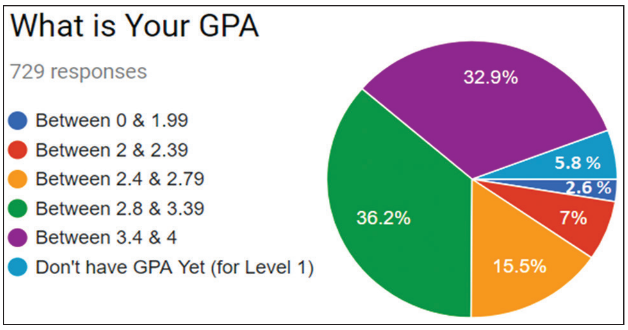

Figure 6. Respondents Academic GPA

By analyzing the previous responses notice that most of learners who was participating in this questionnaire in the third and fourth level, this is means students learned in the current environment of education process and needing to new methods for acquiring learning content. In addition, the Cumulative GPA between 2.8 & 4.00. This is means the academic level of learners is very good and leaners don't prefer VR technology for relaxation but to improve the quality of education process.

B. Relevant Factors

The following responses measured the effective of cost, location, and relaxation factors for applying VR in education process. Figure 7 displayed more than 70% of students stay away from the college with a distance of not less than 30 km. As shown in figure 8 least 71.5 % using public transportations for going to college like buses or metro and less than 28.5% using private transportations like taxi or owned car. 53.4% spent between 10 and 25 pound for going to college and 23.7% spent between 25 and 50 pound that represented in figure 9. As illustrated in figure 10, most of the students own smart phones compared to others devices.

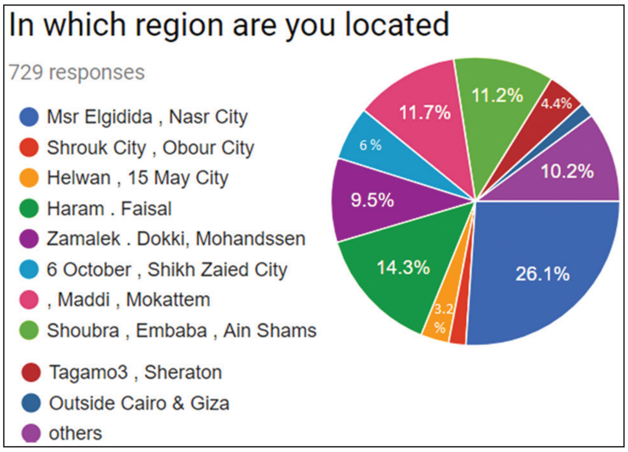

Figure 7. Respondents Locations

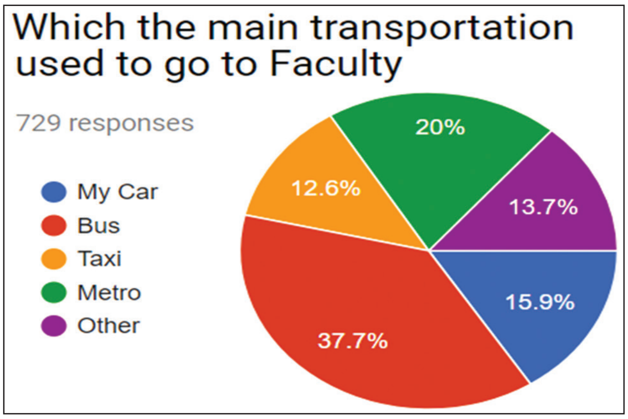

Figure 8. Transportation used to college

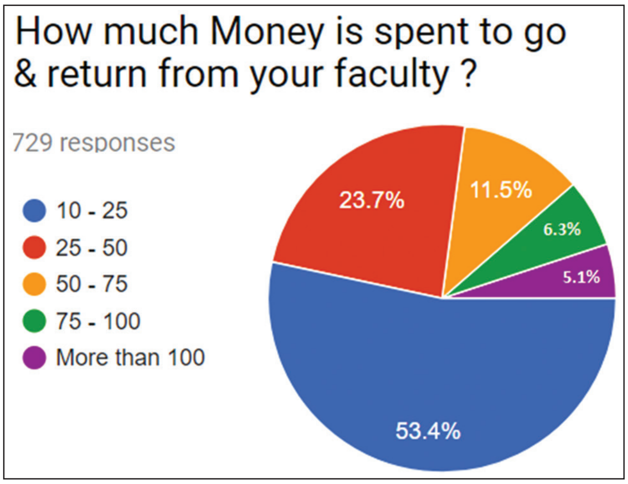

Figure 9. Transportation Cost

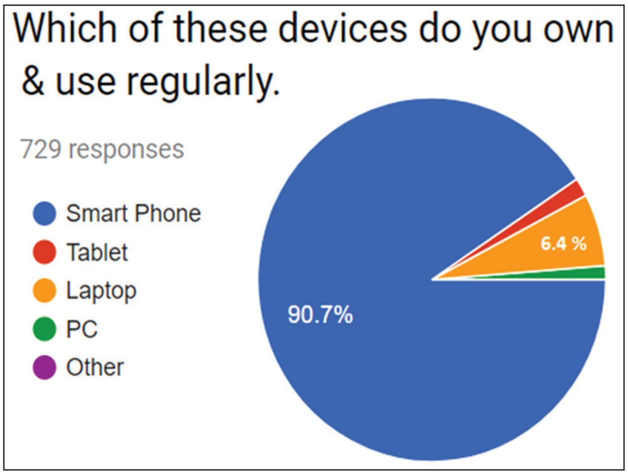

Figure 10. Best device used regularly

The previous section refers to the needing of applying VR technology in education is increasing. Because of cost, location, relaxation factors. Most of learners locate far of the college and other spent more money to go college, while some of learners use uncomfortable transportation for going to college. All of these factors effects on the quality of education process. In addition, if applying VR in education we not have any problem in how to use it because of more than 90% using smart phones that used to run VR applications.

C. Awareness of VR

In this section the researcher trying to know to what extend the students aware with VR technology and whether they know how to use this technology in general or not. Figure 11 showed that 40.6% of students just aware of VR, 30% else aware and use VR before, and 29.4% of students not aware of VR. In addition, most of students don’t use VR applications. And others use them sometimes that represented in figure 12. As shown in figure 13 which displayed only 9.6 % use VR in educational purpose, 35.4% use it for playing games, and the reminder of students don’t use it. Finally figure 14 reviewed that 56.2% prefer e-learning for lectures. And 32.1% still prefer to attend lectures in the group. But 11.7% prefer individual lectures (peer to peer).

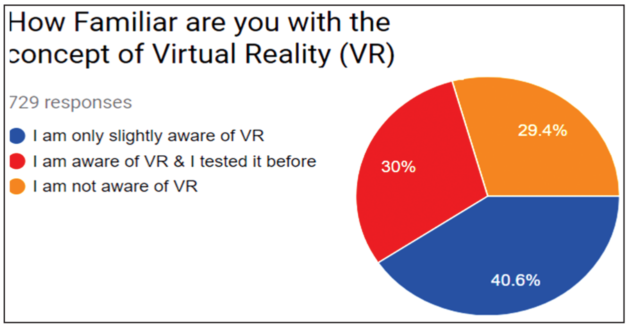

Figure 11. Aware of VR

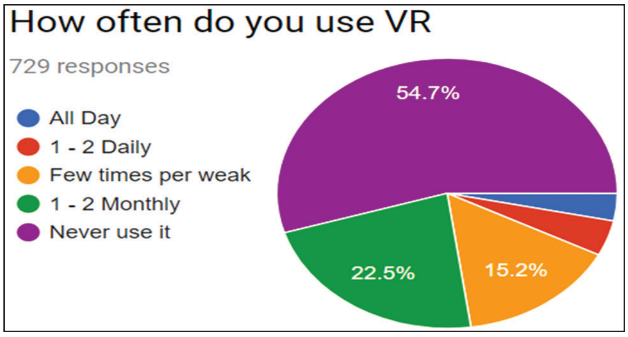

Figure 12. How often using VR

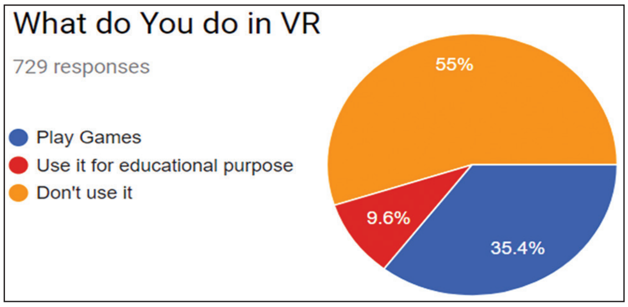

Figure 13. What do you do in VR

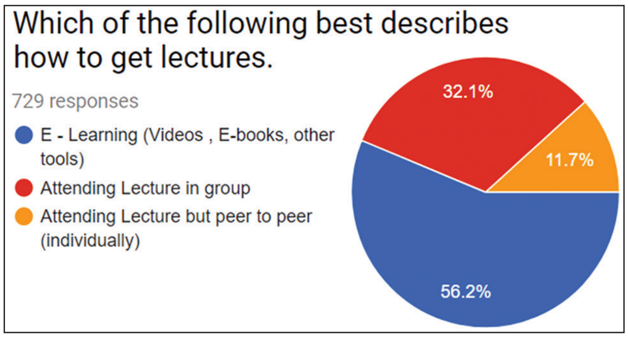

Figure 14. How to get lectures

It is clear that virtual reality technology has become known to most students but the majority of them have not used it before. In addition to the importance of e-learning for most students, the application of virtual reality technology in education will benefit students and accept it, this will be seen in the next section.

D. Attitudes of applying VR in education

Finally, the following responses represents the attitudes of BIS students for applying VR in education. In figure 15 showed that the lack in educational environment is the most problem in education process. On the other hand the least problem is doctor can't control on lecture. For the importance of VR in education. Figure 16 showed that 56% said yes while around 10 % said no. Finally, in term of participating in VR lectures the responses in figure 17 displayed that 55.1% of students will participate in VR Lectures for any course. And 37.6% of them will participate based on course type. While 7.3% not participate in VR lectures.

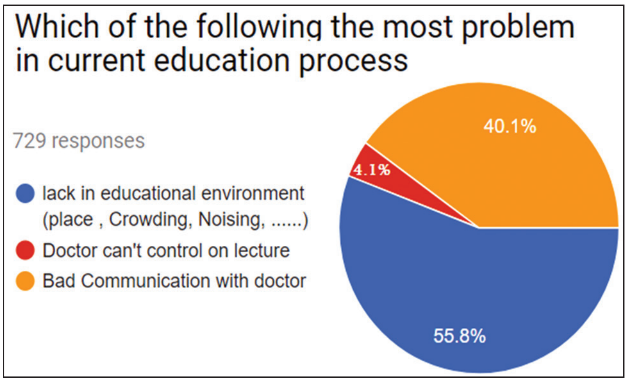

Figure 15. Most problem in current education process

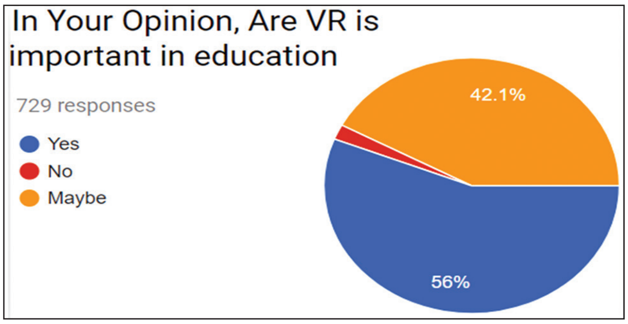

Figure 16. Importance of VR in education

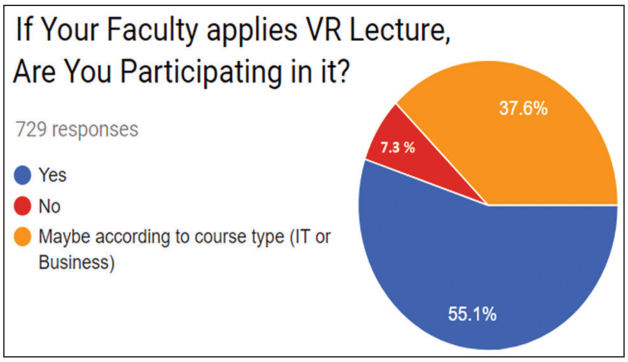

Figure 17. Participating in VR lectures

As a result of the problems currently faced by students in the traditional educational environment, which is characterized by the weakness of the possibilities available and the lack of quality of the surrounding environment, which helps to benefit from the educational process, it is necessary to look for other ways to help raise the efficiency of the educational process. The use of virtual reality technology in educational process is one of the modern solutions that will help. Students are also fully prepared to use this technology and interact with it.

6. Conclusion

With the continuous development of information technology in different fields, especially in the field of education, as well as with the differences in the environment and the factors affecting the educational process, it was necessary to find a modern way to help raise the efficiency of the educational process and in line with this development in information technology. In this study, students' attitudes in the Business Information Systems program, Faculty of commerce, Helwan University, Cairo, Egypt were measured using virtual reality technology as a modern way of teaching. As well as to know the current problems facing them. This study shows that most students prefer to use this technology in education process and will participate if it is implemented.

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Predicting Dropout Vs. Transfer Students using Different Machine Learning Methods

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Abstract

Predicting students' enrollment behavior is one of the most important managerial issues that concern the academic institutions. This issue presents a specific challenge due to a number of factors that can affect the students' decision. Three types of students' enrollment behaviors are discussed in this study and they include Continue, Dropout, and Transfer (or change major). This paper aims to identify those features affecting students' enrollment decisions during their study. Moreover, it investigates the effectiveness of a several machine learning classification algorithms for predicting students' enrollment decisions before the beginning of the semester. In order to propose a predictive model, we need to improve the ability of the decision makers to deal with needs for the next periods and to make more informed decisions. The final result showed that our model improves the accuracy to (95.15%) using the group of features that used in this study.

Key words: Enrollment management; Student Dropout; Student Transfer; Classification; Prediction; Machine Learning;

1. Introduction

Detecting withdrawal student has attracted the attention of the educational managers and professionals to understand the reasons why students are not able to complete their study. But, withdrawal problem is difficult to solve due to 1) a large number of features can affect student during different semesters, such as demographic, socio-economic, academic progress, personal characteristics and student motivation [1] the imbalanced nature of the educational datasets; 3) not all withdrawal students are equivalent, where some student re-enrolled again to new major (i.e. switch or change their majors) [2] . These difficulties make some researchers called this problem as the "one thousand factors problem"[3]. Next, is the discussion of the prior studies, and Table 1, illustrates the comparison between these studies.

Over the past decades, a large number of studies have been done to identify the most representative factors that can affect withdrawal students' [4]. For example, Tinto in [5] proposed the most influent theoretical model that explains this problem, it causes, and cures. This model points out the importance of using social and academic integration of students into an academic institution to identify certain characteristics that can affect student completion such as the student's family background, personal characteristics, academic achievements, psychosocial features and interaction between student and faculty. On the other hand, the distinctive factors between not/re-enrolled students who have been studied by Woosley in [2]. Woosley pointed to the importance of distinguishing between not/re-enrolled students.

Recently, a consensus has been reached that early detection of withdrawal student is more important than remediation [6]. Both statistical techniques and Data mining (DM) techniques are used, examined, and compared to predict withdrawals [4, 7]. Under statistical techniques, the correlation analyses have been applied to identify features that affect students in distance education [8] and predict dropping out of online distance learning courses [9]. Linear discriminant analysis with bootstrapping have been used to predict whether a student will be dropout or graduate [10]. Logistic regression model has been applied to predict success and failure in the curriculum [11], and factors affect the students' decision to change their academic major [12]. Multilevel discrete-time hazard model has been proposed to determine the association between students characteristics and retention [13].

On the other hand, Serumola and Seymour in [14] used inductive and retroductive approaches to identify the factors that can make student change his/her major. In this context, the statistical studies pointed to the difference between the factors affecting dropout students and those affecting students who changed their major. In other words, the factors affecting dropout students may not be so important to identify those students who have changed their major and vice versa [12].

DM is called Educational Data Mining (EDM) when it is used in the context of education [15]. The EDM is concerned about developing methods to explore the unique types of data that come from educational context and to use these methods to understand students and their learning settings. In this context, an effective way to detect withdrawal is the use of Data Mining (DM) techniques, where it has been successfully applied in many domain areas such as medical, e-commerce, and bioinformatics[16]. These works have shown promising results with respect to those socio-economic and educational characteristics, which may be more significant for predicting withdrawal students. In fact, there are many examples of who to apply EDM techniques to predict withdrawal students [17]. For example, the decision tree is used to identify features affect student retention [18], and to predict wither students will withdrawal or not [19]. Thus, Random Forests has been applied to identify factors that affect student decision to withdrawal or persistence in science and engineering majors [20]. On the other hand, Burgo et.al. in [21] proposed logistic regression models for analyzing historical student course grade data in order to predict whether or not a student will drop out of a course. More advanced, neural networks, decision tree, and random forests have been used to classify students into three categories based on the risk of failing their study including low-risk, medium-risk, and high-risk [22]. Logistic regression, decision trees, neuron networks and support vector machines have been investigated to predict student attrition[23]. Similarly, Kabakchieva in [24] applied decision tree C4.5, Naive Bayes, Bayesian networks, and K-nearest neighbors (KNN) to predict students' performance at university based on their personal, pre-university and university performance characteristics. The latest comparative study conducted by [25] uses four EDM techniques (Decision Tree, Support Vector Machine, Neural Network and Naive Bayes), to investigate the effectiveness of EDM for early prediction of students failure in introductory programming courses.

Based on the previous, at first, it is important to note the most studies are applied to the specific case of withdrawal problem. In particular, these studies focused on the withdrawal and failed to examined where student go after leaving his/her specific major (i.e. not/re-enroll to another academic major). Secondly, statistical studies have been discussing the changing-major problem while EDM studies have not addressed this issue in advance. Moreover, statistical studies focused on identifying features rather than predicting withdrawal students (i.e. how may switching major). Thirdly, most of EDM studies addressed the withdrawal problem as a binary decision problem which leads to wrong estimations since the withdrawal group includes re-enroll (transfer) students. Finally, although a series of methods and techniques have been proposed and implemented, no agreement has been reached so far on which method is the best one for predict withdrawal students'. The main contributions of this work are summarized as follows:

Firstly, to the best of our knowledge, none of the prior studies discussed the three types of student enrollment decisions together as addressed in this paper. Moreover, the student enrollment decisions problem is converted from binary classification problem into a multi-classification problem. Secondly, we identified a suitable data structure that can be used for training purposes, and we also identified a set of features that affect students' decision during the study period. Thirdly, we investigated the ability of different machine learning classifiers for predicting students' decision before the beginning of the semester. Fourth, we introduced a set of rules that can be used to identify the dropout and transferred students for each semester. These rules can support the decision-making process in universities. Finally, although students' enrollment problem is the main concern for many academic institutions around the world, few studies have been conducted in Palestine with respect to predicting the enrollment behavior of students. Thus, this study comes to fill this gap in the academic literature.

The remainder of this paper is organized as follows: Section two provides a brief overview of the main related studies that utilized machine learning algorithms in the academic domain. In addition, the proposed methodology and the used materials are described in section three. Section four provides an experimental design, the corresponding results, and discusses. The conclusion and recommendations for future research discussed in section five.

3. Materials and Methods

This section consists of two parts. The first part describes the proposed method, while the second is the description of the materials that were used as a case study in this paper.

3.1. Method

The objective of this paper is to propose a predictive model for three classes of students' enrollment behaviors. Figure 1, illustrates the proposed model, which consist of four phases. These phases start by understanding the domain and collecting students' data from different sources. The second phase is related to cleaning and preparation data. In addition, the third phase includes investigation of seven classifiers in order to identify the "best" classifier for the proposed model. The last phase consists of the evolution of the proposed model. Next, we discuss these phases that consist of the proposed model.

3.1.1. Phase 1

The data for most universities are distributed across different departments and platforms. This phase aims to prepare student data collected from various sources in order to remove incompatibility and inconsistency, then convert it to an appropriate format which can be used for the next stages. In this regard, we have benefited from prior educational researchers especially that intersect with data mining research. Educational researchers provide us the basic understanding of common students' features that can be used in this study, as conducted by Bowers et al. [9]. The description of students' data and features used in this study are available in section (3.2.1).

3.1.2. Phase 2

In this phase, the preparation process is performed to make data appropriate for classifiers. Data integration and cleaning process are applied to remove outliers and incomplete data. The high

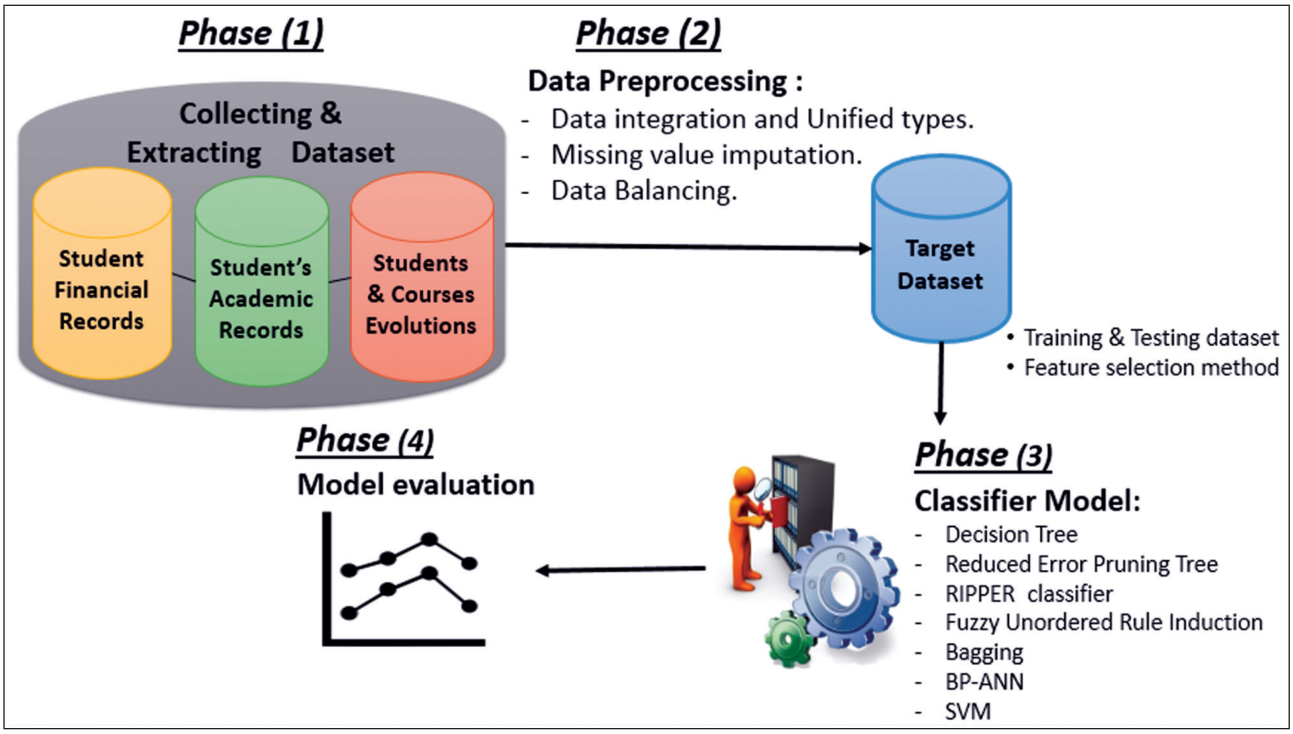


Figure 1. Interpretable predictive model

dimension of the dataset should take into consideration reduction of attribute size when applying an algorithm for prediction. Section (3.2.2) describes the methodology of the preliminary procedure used to prepare these datasets for various experiments.

3.1.3. Phase 3

Thus, the combined dataset (or the resulted dataset) is divided into two parts. The first division includes 70% of the data-examples (Training dataset) which is used for training purposes, while the reminder examples (Testing dataset) are used for testing purposes. The training dataset aims to enable a classifier adjusting its internal parameters to deduce the mapping implied by the training data. The testing dataset is used for evaluation purpose in order to investigate the ability of classifier when using parts of data that have not been used before in the training process. The aforementioned processes are applied for ten independent runs, where the examples are selected randomly in each run.

With the aim of building a powerful classification model, seven classification algorithms are investigated in order to identify the best classifier for the proposed model. These classifiers include:

– Decision tree (C4.5) which is the most common decision algorithms. This algorithm is an extension of the ID3 algorithm, and it generates an initial set of rules using direct method. The C4.5 algorithm applies kind of normalization for information gain ration which is calculated using Equation 1.

$$GianRatio(A) = \frac{Gain(A)}{SplitInfo(A)} \quad \text{.............} (1)$$

$Gain(A)$ denotes the information gain for attribute A, and $SplitInfo(A)$ denotes the splitting information value. The splitting information value represents the probable information generated by splitting the dataset D into a set of P partitions, corresponding to P outcomes on attributes A. The splitting information is calculated using Equation 2.

$$SplitInfo_A(D) = \sum_{i=1}^{P} \frac{|D_i|}{|D|} \times log_2 \left(\frac{|D_i|}{|D|}\right) \quad \text{....} (2)$$

Where $|D|$ denotes the number of elements in the training dataset D, and $|D_i|$ denotes the number of elements into partition P.

– Reduced Error Pruning Tree (REPTree) is a fast decision tree learner. In addition, it produces suboptimal tree under the restriction that a subtree prune is applied when it does not contain sub-tree with a lower classification error.
– Repeated Incremental Pruning to Produce Error Reduction (RIPPER) is based on association rules. In the learning process, RIPPER orders a training dataset according to the class frequencies, then it selects one class as a default prediction. After generating rules set for that class, all instances covered by these rules are extracted from the dataset. This process is repeated for other classes. The algorithm uses direct method for generating the initial rules set.
– Fuzzy Unordered Rule Induction Algorithm (FURIA) is an extension of the RIPPER algorithm where it learns from fuzzy rules to generates unordered rule sets. Moreover, it makes use of an efficient rule stretching method to deal with uncovered examples.
– Bagging or Bootstrap Aggregation is an ensemble learning which generates multi-versions of predictors to make more accurate predictions. This algorithm can avoid overfitting problem.
– Artificial neural network with Backpropagation (ANN-BP) is mathematical model biological neural networks. It consists of an interconnected group of neurons and processes information as shown in Figure 2. Backpropagation is a common method of ANN. In this method, the artificial neurons are organized in layers, and send their signals "forward," and then the errors are propagated backward. This method aims to reduce the error due to the learning process.

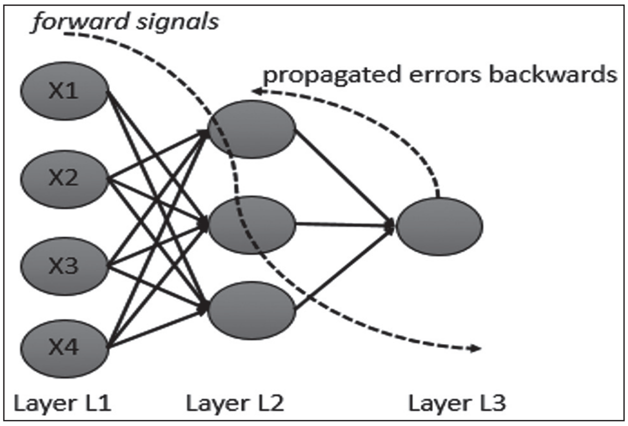


Figure 2. The neural network back propagation architecture

Support vector machine(SVM) is a discriminant classifier which aims to find an optimal linear or nonlinear hyper-plane to construct a minimum margin between classes. Thus, the SVM finds the nearest data vectors or support vectors (SV). In high-dimensional space, a kernel trike can be used to find the optimal nonlinear decision confinement between classes. In this study, the polynomial kernel [26] is used with the SVM algorithm for the non-linear model. In addition, this algorithm combines the advantages parametric and nonparametric models. Moreover, it can represent a complex function. The hyper-plane function for the multi-class problem is defined as:

$$h(x_i) = w^T x_i + \mathrm{b} \text{ ....} (3)$$

Given a training dataset (x_i, y_i) where $i = \{1, \cdots, N\}$, and let $y_i \in \{1, \cdots, K\}$ is a class label for x_i with $x_i \in \mathbb{R}^d$, w is a dimensional weight vector and b is a scalar called the bias, and the goal is to minimize $\frac{1}{2}\|w\|^2$. Because we considered the problem of student enrollment as a multi-class problem, we used one of the most popular strategies for the multi-class problem by SVM approach, namely One-against-all (1 v all) [27]. In (1 v all) approach, a set of SVMs are used for operating a single class from all remaining classes, where positive examples are all from class i, and the negative example be from other classes. Then computing the margin between class i and other classed using Equation 4. This process is repeated for all other classes as shown in Figure 3.

$$h(\mathrm{x}) = \arg max_i \; h_i(x) \text{ ....} (4)$$

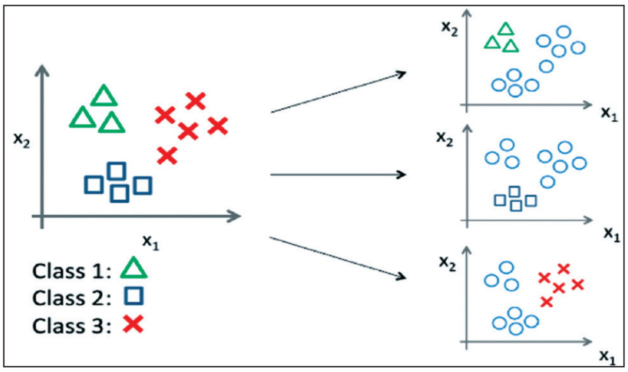


Figure 3. One-against-all SVM approach to the multi-class problems

3.1.4. Phase 4

In this phase, the testing process is carried out to examine the classification algorithms using unseen data (i.e., the testing datasets). In addition, different evaluation criteria are used for distinguishing between classifiers in order to identify the "best" one for the proposed model. Next is the description of these criteria.

– True Positive rate denotes the preparation of positive predictions that are correctly identified by the classifier. The True Positive rate is calculated using Equation 5.

$$TPr = \frac{TP}{TP+FN} \text{ ....} (5)$$

– True Negative rate is the ratio of the number of negative prediction that truly classified as negative and the actual number of the negative class. It is calculated using Equation 6.

$$TNr = \frac{TN}{FP+TN} \text{ ....} (6)$$

– Accuracy denotes the ratio of correct prediction to the total number of cases evaluated, which specifies the degree of classifier success. It is worth mentioning that the Accuracy measurement is unreliable for evaluating a classifier when using imbalanced data because a classifier is affected by a majority class [28]. The accuracy is calculated using Equation 7

$$Accurecy = \frac{TP+TN}{TP+TN+FP+FN} \quad \text{................ (7)}$$

- Root Mean Squared Error (RMSE) is a frequently used measurement for the difference between the predicted values and the actual corresponding values. The RMSE measure is calculated using Equation 8.

$$RMSE = \left[n^{-1} \sum_{j=1}^{n} |e|^2\right]^{\frac{1}{2}} \quad \text{................ (8)}$$

where |e| is the difference between actual and predictive values, and n denotes the number of elements in the training dataset.

– Cohen's Kappa measures the difference between the accuracy of classifier compared to the accuracy when classify the dataset using a random system. In other words, it measures the degree of inter-rater reliability of the prediction. The Kappa measurement is calculated using Equation 9.

$$K = \frac{P(A)-P(E)}{1-p(E)} \quad \text{.......................... (9)}$$

Where $P(A)$ denotes the accuracy of a classifier, $P(E)$ denotes the accuracy obtained using a random system.

3.2. Materials

This section illustrates the description of students' data that are used as a case study in this paper and the preprocessing methods that conducted for preparing data to be fit for the used classifiers.

3.2.1. Data Description

In this study, the dataset was collected from Palestine Technical University (PTU). These data are related to 1,520 students who have enrolled from 2010-2015 and involved five different majors: Architectural Engineering, Industrial Automation, Computer Programming, Computing & Database, Office Automation, and Fashion Design. Three various sources of data have been used: Firstly, the Enrolment System provides information about a social, economic, personal data and prior performance related to the students. Secondly, the University Management System provides information about students' performance progresses during semesters. Finally, the Online Evaluation System questionnaire which provides information for three indicators that are used in this study, and it includes evaluation of the university, lecturers, and courses.

Based on the literature reviews in the related educational research, 72 features are available for predicting students' enrollment decision as illustrated in Table 1. These features are categorized into five groups as illustrated in Table 2. The description of these groups is:

1. Demographic characteristics (DCF.)

The student demographic data have been studied extensively by many researchers as essential predictors [29]. In this study, the demographic data including age, gender, marital status, mother's level of education, and the distance between residence and the university campus.

2. Performance and Personality Factors (PPF)

This group describes a student performance and personal ability during the study, and it includes:

A) High school grade point average (HSGPA) [30].

B) Global point average (GPA).

C) Uncompleted Courses (ICC) is the difference between the registered courses and passed courses.

3. Socio-Economic Status (SES)

Several social and financial conditions affect students' decision [31]. Twelve factors are used to describe student socio-economic status, includes Number of family members, Special case in the family, monthly income, residence (i.e. lives with family or alone), the type of family house (i.e. owned or rented), number of students in a family, parents' status (i.e. alive or dead), needy student with/out financial support. All these features are reduced to one predictor called (SES). The SES value is used by Student Lending department (SLD) as an indicator of the level of the student need.

4. Student Satisfaction Factor (STF.)

The vast majority of universities have an online university evaluation system to manage and save

Table 1. Data sources and students' attributes used based on sources.

Source	Attributes	#attributes
Enrollment System		23
Demographical (Dm.)	Age, gender, marital status, Region, Work, Distance to university	
Historical performance (Hp.)	High school GPA, Branch high school, Graduated year	
Socio-economic (Se)	#Family members, #Family under 16 years old, #Married members, Father education, Mother education, Father job, Mother job, Family income, #children, Home type, #Special case In family, #University students in family, Leave with family, Needy status	
University Management System		18
Enrollment (E.)	Major, year, #Enrolled Courses, #Completed Courses, Semester Type, Have scholarship, #absent	
Student performance (Sp)	Course ID, First exam mark, Second exam mark, activities mark, final mark, Course status, Course type, Semester GPA, overall GPA, Semester Type, attendance	
Evaluation System	Questionnaire includes 30 indicators	30

students' response to periodic questionnaires. The PTUK University has this kind of online questionnaire. The students should answer this questionnaire at the end of each semester, and before getting semester grads.

The questionnaire includes 30 questions that grouped into three categories of questions. These categories describe a students' satisfaction with the learning process instructors, courses, and institution services & environment. The questionnaires use a 5-point response scale for each question as follows: 1: very dissatisfied, 2: dissatisfied, 3: neutral, 4: satisfied, 5: very satisfied. Based on this data, three predictors were extracted according to the median values of the categories of questions. These categories used to produce predictors for instructors (Ev_{ins}), courses (Ev_C), and for university services & environment (Ev_{un}). Each item in the questionnaire associated with weight to indicate the degree of importance of that question as shown in Equation 10.

$$Ev_{kl} = \frac{1}{\sum l} \times \frac{\sum_{i=1}^{M_k}(\omega_i C_i)}{\sum_{i=1}^{M_k}\omega_i} \quad \text{................ (10)}$$

Let k be one of the three predictors used to express on student satisfaction, $k \in \{ins, c, un\}$. l is the evaluation score per semester (where a student evaluates a set of courses and instructors in each semester), ω_i is the weight of i-th question in the questionnaire, C_i is the response to i-th question. M_k denotes the number of questions about k-th predictor.

5. Semester characteristic (SCF.)

In this context, three features have been used to characterize each semester includes the level of the semester, Previous enrollment decision (PDecision), and the next enrollment decision (Class) "as dependent variable". In this study, we propose a model for predicting three classes of student enrollment behaviors namely:

– Continue: when a student decides to register for the next semester.
– Dropout: it is a state when a student decides to terminate this study.
– Transfer: it is the state when a student decides to change his academic major in the next semester.

According to the statistical analysis, the ratio of the dropout students at the first semester is (14.5%), while it decreased in the following two semesters. The ratio of dropout students' returns to increase again at last semester as the result of failure to obtained acceptable results to continue their study. In addition, the observation showed that the (5%) of students are transferred during the first semester, and this number increase in the second semester to (13%), then it returns to decrease during the third and fourth semesters. Figure 4 illustrates the distribution of students' enrollment behaviors per semester.

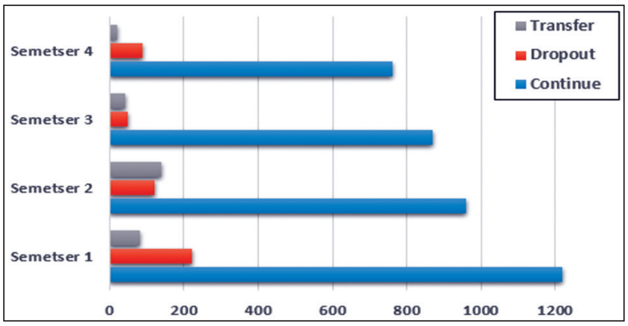


Figure 4. The percentage distribution of students' enrollment behavior per semester

3.2.2. Data Description

This stage aims to prepare data to feed classifiers in different experiments. Three steps are conducting during this stage as shown in Figure 5. In the first step, we create two groups of data includes: full students' data and four subsets of students' data divided per semester, namely (P1, P2, P3, and P4). The second step aims to reduce the dimension of these datasets and to identify influent features that affect students' enrollment decisions. In the third step, we applied resampling method in order to solve the problem of imbalanced datasets.

In order to identify the important features for each dataset, five features selection methods (FS) are applied in the voting process. These methods integrated into Waikato Environment for Knowledge Analysis (WEKA), and included CfsSubsetEval, CorrelationAttributeEval, GainRatioAttributeEval, and ReliefFAttri-buteEval, ConsistencySubsetEval.

Under the datasets that used full student's data (i.e. DB1 and DB2), fourteen independent features are identified as important features of the learning process. Table 2 illustrates these features ordered by its frequency values. On the other hand, we applied the voting process for the four sub-datasets (P1, …, P4). Base on the results shown in Table 3, a student in the first semester period (P1) is affected by demographic, past/present performance, and student satisfaction of the university. In the second semester (P2), the impact of demographic features of a student was reduced, while the effect of the student satisfaction features was increased. In addition, the observation in the third semester and fourth (P3, P4) showed that the impact of student satisfaction features and student performance progress are increased.

The imbalance data is a common problem that appears in this kind of application. Based on this fact, we checked its presence in the dataset using the frequency distribution instances over different enrollment behaviors. The analysis reveals that 69.7% of students are classified as continue students and 22.5% classified as dropout students and the remaining are classified as transfer students.

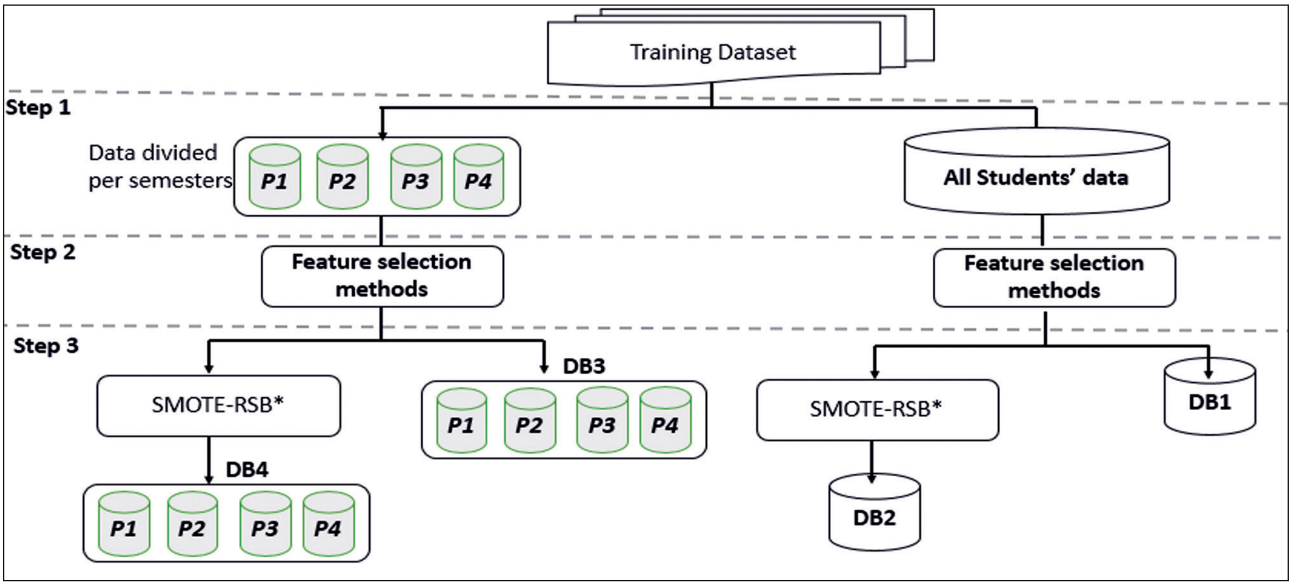


Figure 5. Three preparing process steps for creating the training datasets.

Table 2. Features ranked by frequency of appearance, experiment 1

Feature	Freq.	Feature	Freq.
GPA	5	Gender	3
UCC	5	SES	3
Ev_{un}	5	HSGPA	3
Ev_{c}	5	Distance	2
Ev_{ins}	5	Age	2
Married	4	Mother Education	2
PDecision	3		

The imbalance problem affects the accuracy of results because the algorithms tend to gravitate towards the largest class of the enrollment behaviors. A number of methods have been introduced to solve the imbalanced problem such as [32,28].

In this step, we used one of the newest resampling methods which are based on Rough-Set theory to evaluate the quality of the new synthetic instances. This method is called SMOTE-RSB* [33]. The method combines the Synthetic Minority Oversampling Technique with an editing technique based on the Rough Set to construct new samples from monitory classes. Based on aforementioned steps, four combinations of the datasets are results and feed to classifiers into the experiments in the next section.

4. Results

Two experiments were conducted to select the best model for predicting students' enrollment decision and estimate the semester of event occurrence. In each experiment, we used one of the aforementioned datasets. The description of these datasets is illustrated in Table 4 below.

The results of the conducted experiments were discussed using the evaluation metrics as presented in section (3.4.1). Furthermore, the results have been displayed in a matrix of order $n \times m$, where n is the number of classifiers and m is the number of criteria that have been used in this study.

The entries of the comparison tables were displayed in the form of (mean, (standard deviations)). The key findings and discussions are detailed below.

4.1. Experiment 1

In this experiment, all students' data were used to examine the classifiers using imbalanced and balanced datasets (i.e. DB1, and DB2 respectively). Figure 6 illustrates the comparison between the classifiers using these two types of datasets. As shown in Figure 6, the accuracy values of the most classifiers increase after applying resampling method on data.

Table 3. The used features distribution based on the features groups Experiment 3, 4

Semester	Features	DCF	PPF	SES	STF	SCF	Total
P1	Distance, Married, work, HSGPA, GPA,Ev_{un}, Ev_{ins}, SES, UCC	3	2	2	1	1	8
P2	Work, MotherEducation, HSGPA, GPA, SES, Ev_{c}, EV_{ins}, UCC , PDecision	2	1	1	3	2	9
P3	Married, Work, GPA, SES, Ev_{c}, EV_{ins}, Ev_{un}, UCC, PDecision,	2	1	1	3	2	9
P4	Gender, Married, ESE, GPA, UCC, PDecision, Ev_{un}	1	1	1	2	4	7

Table 4. The description of the datasets used in experiments.

	Testing dataset	Training dataset				
		DB1, DB2	DB3, DB4			
			P1	P2	P3	P4
Size	417	4170	1210	900	660	520
N. Attributes	12	12	8	9	9	7

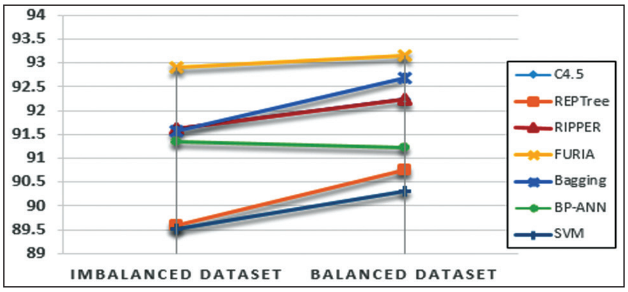


Figure 6. The accuracy of the classifier that obtained using imbalanced and balanced datasets

Under imbalanced group in Table 5, the observation results showed that the SVM algorithm obtained the worst values with respect to accuracy (89.52%), TN rate (92%), Kappa (82%), and RMSE (30%). Although the C4.5 performed much better than SVM with respect to accuracy (91.64%), and TN rate (97%), this did not give C4.5 the superiority on other classifiers. In addition, the FURIA algorithm achieved the best values with respect to accuracy (92.91%), TP rate (97%), TN rate (79%), Kappa (94%), and the lower value for the RMSE (15%).

Under Balanced group in Table 4, the observation showed that the TN rate values for all classifiers were decreased compared with the imbalanced group, while the values of the TP rate increased in different percentages. In addition, the FURIA algorithm achieved the best algorithm in term of accuracy (93.16%), and the lowest value in term of RMSE (15%). On the other hand, the SVM algorithm obtained the lower values with respect to accuracy (90.30%), with the highest RMSE value (30%). Based on these results, we recommend using FURIA algorithm in such kind of datasets.

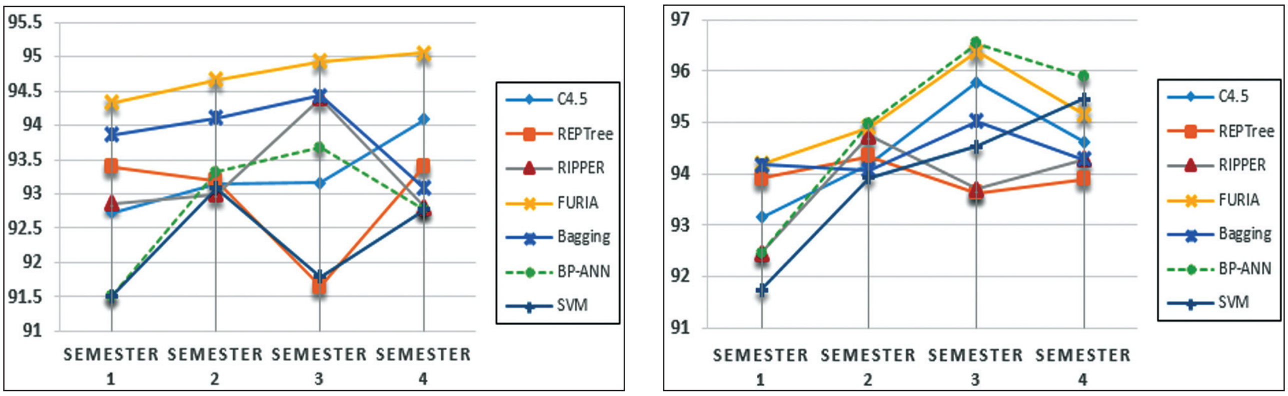
4.2. Experiment 2

This section discusses the results that obtained from using imbalanced and balanced students' data (i.e. DB3, and DB4 respectively) during training and testing processes. The aim is to identify the best classifier for this kind of data structure. Figure 7 (a), and (b) illustrates this comparison using these two types of datasets.

The observations in Table 6 under the imbalanced dataset (P1) showed that there is a convergence in the results obtained by the FURIA and Bagging algorithms with respect to TP rate (99%), and Kappa (91%). However, the Bagging algorithm achieves the best value in term of accuracy (94.86), the Bagging algorithm obtained high standard deviation value compared with the FURIA algorithm. The high standard deviation in the accuracy obtained by the Bagging algorithm indicates that it has less confidence than the accuracy obtained by the FURIA algorithm. Nevertheless, each BP-ANN and SVM algorithms achieve the same value in term of accuracy (91.51%), the BP-ANN is superior to SVM because it achieved better value in term of TN rate (90%) and RMSE (86%).

Table 5. The classifiers result that used the imbalanced and balanced students' datasets

	Imbalanced dataset					Balanced dataset				
	TP	**TN**	**RMSE**	**Acc.**	**Kappa**	**TP**	**TN**	**RMSE**	**Acc.**	**Kappa**
C4.5	0.95 (0.01)	0.97 (0.01)	0.18 (0.01)	91.64 (0.77)	0.92 (0.01)	0.98 (0.00)	0.91 (0.01)	0.17 (0.01)	92.24 (0.03)	0.89 (0.01)
REPTree	0.95 (0.01)	0.96 (0.01)	0.20 (0.01)	89.60 (1.03)	0.89 (0.02)	0.97 (0.01)	0.89 (0.02)	0.19 (0.01)	90.74 (0.62)	0.85 (0.04)
RIPPER	0.95 (0.01)	0.97 (0.01)	0.18 (0.01)	91.63 (0.80)	0.92 (0.01)	0.98 (0.01)	0.90 (0.02)	0.17 (0.01)	92.24 (0.36)	0.89 (0.02)
FURIA	0.97 (0.01)	0.97 (0.01)	0.15 (0.01)	92.91* (0.49)	0.94 (0.01)	0.99 (0.00)	0.89 (0.01)	0.15 (0.01)	93.16* (0.01)	0.91 (0.01)
Bagging	0.96 (0.01)	0.97 (0.01)	0.17 (0.01)	91.58 (0.85)	0.92 (0.01)	0.99 (0.00)	0.90 (0.01)	0.15 (0.01)	92.68 (0.11)	0.90 (0.01)
BP-NN	0.95 (0.01)	0.97 (0.01)	0.18 (0.01)	91.35 (0.46)	0.92 (0.01)	0.98 (0.01)	0.89 (0.01)	0.19 (0.01)	91.22 (0.33)	0.86 (0.02)
SVM	0.95 (0.01)	0.92 (0.01)	0.30 (0.00)	89.52 (0.86)	0.82 (0.01)	0.99 (0.00)	0.85 (0.02)	0.30 (0.01)	90.30 (0.11)	0.83 (0.01)



(a) *(b)*

Figure 7. The classifier comparison using (a) the imbalanced datasets and (b) the balanced datasets that distributed by semesters

Table 6. Comparison classifiers using imbalanced and balanced P1 dataset.

	Imbalanced dataset					**Balanced dataset**				
	TP	**TN**	**RMSE**	**Acc.**	**Kappa**	**TP**	**TN**	**RMSE**	**Acc.**	**Kappa**
C4.5	0.99 (0.01)	0.91 (0.03)	0.14 (0.03)	92.73 (1.77)	0.91 (0.05)	0.95 (0.02)	0.98 (0.01)	0.13 (0.02)	93.16 (0.94)	0.94 (0.01)
REPTree	0.99 (0.01)	0.92 (0.02)	0.13 (0.03)	93.39 (0.60)	0.90 (0.02)	0.95 (0.02)	0.97 (0.01)	0.12 (0.01)	93.91 (0.99)	0.92 (0.01)
RIPPER	0.99 (0.01)	0.92 (0.01)	0.14 (0.01)	92.86 (0.78)	0.91 (0.02)	0.95 (0.02)	0.97 (0.01)	0.12 (0.01)	92.45 (0.58)	0.93 (0.01)
FURIA	0.99 (0.01)	0.91 (0.02)	0.14 (0.01)	94.33* (0.23)	0.91 (0.01)	0.95 (0.02)	0.98 (0.01)	0.10 (0.01)	94.19* (0.55)	0.94 (0.01)
Bagging	0.99 (0.01)	0.89 (0.03)	0.13 (0.02)	94.86** (1.41)	0.91 (0.04)	0.95 (0.02)	0.98 (0.01)	0.11 (0.01)	94.18 (0.62)	0.94 (0.01)
BP-ANN	0.97 (0.02)	0.90 (0.03)	0.17 (0.03)	91.51 (1.36)	0.86 (0.03)	0.95 (0.01)	0.97 (0.01)	0.15 (0.01)	92.45 (0.64)	0.93 (0.01)
SVM	0.97 (0.02)	0.89 (0.05)	0.30 (0.01)	91.51 (2.08)	0.85 (0.05)	0.94 (0.02)	0.97 (0.01)	0.29 (0.00)	91.74 (0.85)	0.92 (0.01)

Under the balanced group of Table 6, the FURIA algorithm performs much better than other algorithms, where it achieves high value in term of accuracy (94.19%), TN rate (98%), TP rate (95%), and Kappa (94%). Moreover, the FURIA algorithm has less standard deviation values for all measurements. These values give us confidence in the FURIA algorithm results.

According to results shown in Table 7, and under the imbalanced dataset for (P2), the FURIA algorithm achieved the highest values in term of accuracy (94.66%), when used with the imbalanced dataset, while the Bagging algorithm is the second better algorithm in term of accuracy (94.11%).

In addition, under the balanced dataset, the BP-ANN algorithm achieved high values with respect to accuracy (94.98%), and it also achieves the lower value in term of RMSE (1%). On the other hand, the SVM algorithm achieves the lower value using either imbalanced or balanced dataset.

Using imbalanced data of the third semester (P3), the observation in Table 7 showed that the REPTree and SVM algorithms slightly obtained lower values in term of accuracy (91.65%, and 91.69% respectively). The SVM algorithm obtained less standard deviation values compared with REPTree.

The FURIA algorithm obtained the best values with respect to accuracy (94.93%), TPrate (99%), and the low value in term of RMSE (20%). On the other hand, using the balanced dataset group of Table 7, the BP-ANN achieves better values in term of accuracy (96.54%). Thus, the RIPPER

Table 7. Comparison classifiers using imbalanced and balanced P2 dataset

	Imbalanced dataset					Balanced dataset				
	TP	**TN**	**RMSE**	**Acc.**	**Kappa**	**TP**	**TN**	**RMSE**	**Acc.**	**Kappa**
C4.5	0.99 (0.01)	0.99 (0.01)	0.07 (0.03)	93.15 (0.59)	0.98 (0.01)	1.00 (0.00)	1.00 (0.00)	0.02 (0.03)	94.18 (0.35)	1.00 (0.01)
REPTree	0.98 (0.01)	1.00 (0.00)	0.08 (0.02)	92.99 (0.51)	0.98 (0.01)	0.99 (0.01)	1.00 (0.00)	0.06 (0.03)	94.34 (0.46)	0.99 (0.01)
RIPPER	0.99 (0.01)	0.99 (0.01)	0.07 (0.02)	93.15 (0.59)	0.98 (0.01)	1.00 (0.00)	1.00 (0.00)	0.03 (0.02)	94.71 (0.27)	1.00 (0.01)
FURIA	1.00 (0.00)	0.99 (0.01)	0.05 (0.02)	94.66* (0.29)	0.99 (0.01)	1.00 (0.00)	1.00 (0.00)	0.02 (0.01)	94.90 (0.13)	1.00 (0.00)
Bagging	0.98 (0.01)	1.00 (0.00)	0.08 (0.03)	94.11 (0.51)	0.98 (0.01)	0.99 (0.01)	1.00 (0.00)	0.05 (0.02)	94.07 (0.45)	0.99 (0.01)
BP-ANN	1.00 (0.00)	0.89 (0.04)	0.04 (0.04)	93.32 (1.17)	0.99 (0.02)	1.00 (0.00)	1.00 (0.00)	0.01 (0.00)	94.98* (0.00)	1.00 (0.01)
SVM	1.00 (0.00)	0.95 (0.02)	0.28 (0.01)	93.08 (0.51)	0.97 (0.01)	1.00 (0.00)	1.00 (0.00)	0.27 (0.00)	93.92 (0.24)	1.00 (0.01)

Table 8. Comparison classifiers using imbalanced and balanced P3 dataset

	Imbalanced dataset					Balanced dataset				
	TP	**TN**	**RMSE**	**Acc.**	**Kappa**	**TP**	**TN**	**RMSE**	**Acc.**	**Kappa**
C4.5	0.95 (0.01)	0.77 (0.11)	0.23 (0.02)	93.16 (1.58)	0.71 (0.05)	0.91 (0.03)	0.96 (0.02)	0.19 (0.03)	95.78 (0.78)	0.91 (0.03)
REPTree	0.99 (0.01)	0.68 (0.14)	0.24 (0.05)	91.65 (4.17)	0.67 (0.17)	0.88 (0.04)	0.94 (0.03)	0.22 (0.01)	93.63 (0.37)	0.87 (0.02)
RIPPER	0.99 (0.01)	0.81 (0.06)	0.21 (0.03)	93.40 (2.27)	0.78 (0.07)	0.89 (0.03)	0.94 (0.02)	0.22 (0.02)	93.71 (0.36)	0.88 (0.02)
FURIA	0.99 (0.01)	0.80 (0.07)	0.20 (0.02)	94.93* (0.77)	0.79 (0.04)	0.93 (0.02)	0.96 (0.02)	0.18 (0.02)	96.38 (0.70)	0.92 (0.03)
Bagging	0.99 (0.01)	0.78 (0.04)	0.19 (0.02)	94.43 (1.58)	0.80 (0.04)	0.94 (0.02)	0.95 (0.02)	0.18 (0.02)	96.03 (0.40)	0.91 (0.02)
BP-ANN	0.97 (0.02)	0.83 (0.06)	0.22 (0.01)	93.67 (1.52)	0.76 (0.03)	0.92 (0.03)	0.96 (0.02)	0.18 (0.02)	96.54* (0.16)	0.92 (0.02)
SVM	0.97 (0.02)	0.54 (0.06)	0.31 (0.01)	91.69 (0.76)	0.63 (0.04)	0.89 (0.03)	0.98 (0.02)	0.32 (0.00)	94.54 (0.88)	0.83 (0.03)

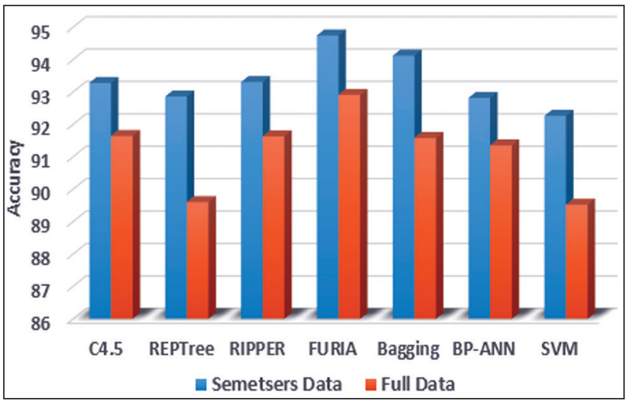
algorithm obtained the lowest value in term of accuracy (93.63%), Kappa (2%).

Finally, by using the imbalanced dataset for the last semester (P4), the results in Table 9 stressed the superiority of the FURIA algorithm using imbalanced dataset, where it achieved the best values in term of accuracy (95.05%), and Kappa (94%). Using the balanced dataset (P4), the BP-ANN achieves the best values in term of accuracy (95.88%), Kappa (98%), and the lowest RMSE (8%). Based on previous results, we recommend the use of BP-ANN classifier for the balanced datasets.

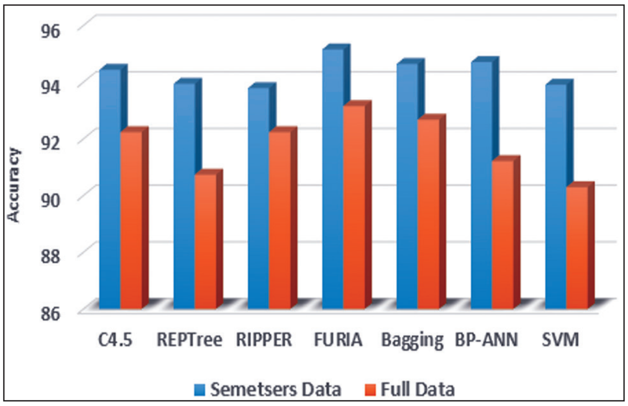
In order to determine the better data structure for the prediction process, we compared the accuracy of the classifiers that fed by the full students' data with the average accuracy obtained by the classifiers using the divided datasets (i.e. P1, P2, P3, and P4). Figure 9, illustrates this comparison where (a) describes the imbalanced dataset and (b) describes the balanced dataset. As shown in Figure 9, the accuracy of all classifiers performed better when using the semester datasets instead of using the full students' dataset. In addition, we can observe that all classifiers accuracy values were improved after applying resampling method.

Table 9. Comparison classifiers using imbalanced and balanced P4 dataset

	Imbalanced dataset					Balanced dataset				
	TP	TN	RMSE	Acc.	Kappa	TP	TN	RMSE	Acc.	Kappa
C4.5	1.00 (0.00)	1.00 (0.00)	0.11 (0.00)	94.08 (0.21)	0.96 (0.00)	1.00 (0.00)	1.00 (0.00)	0.12 (0.02)	94.63 (0.74)	0.96 (0.01)
REPTree	1.00 (0.00)	1.00 (0.00)	0.12 (0.09)	93.41 (3.15)	0.92 (0.07)	1.00 (0.00)	1.00 (0.00)	0.14 (0.03)	93.90 (0.92)	0.95 (0.02)
RIPPER	0.99 (0.01)	0.95 (0.09)	0.12 (0.02)	92.81 (1.11)	0.87 (0.03)	0.99 (0.01)	1.00 (0.00)	0.13 (0.04)	94.29 (0.97)	0.96 (0.02)
FURIA	1.00 (0.00)	1.00 (0.00)	0.10 (0.00)	95.05* (0.01)	0.94 (0.03)	1.00 (0.00)	1.00 (0.00)	0.10 (0.03)	95.16 (0.76)	0.97 (0.01)
Bagging	1.00 (0.00)	1.00 (0.00)	0.12 (0.01)	93.08 (1.97)	0.92 (0.04)	1.00 (0.00)	1.00 (0.00)	0.12 (0.02)	94.29 (0.73)	0.96 (0.01)
BP-NN	1.00 (0.00)	1.00 (0.00)	0.14 (0.03)	92.77 (1.12)	0.91 (0.02)	0.99 (0.01)	1.00 (0.00)	0.08 (0.02)	95.88* (0.77)	0.98 (0.01)
SVM	1.00 (0.00)	1.00 (0.00)	0.25 (0.00)	92.77 (1.12)	0.91 (0.02)	1.00 (0.00)	1.00 (0.00)	0.28 (0.00)	95.45 (0.69)	0.98 (0.01)



(a)



(b)

Figure 8. The classifiers comparison using (a) the imbalanced datasets and (b) the balanced dataset distributed by semesters.

Base on that, we recommend using the semester datasets because these datasets focus on the prediction by selecting the required students' examples that predict the next students' decisions rather than using all students' examples which affect the data distribution.

In addition, the previous experiments show the superiority of using FURIA algorithm for the imbalanced and the balanced datasets, while the BP-ANN algorithm suitable for the balanced datasets. Although the BP-ANN achieved the best accuracy using most balanced semester datasets, the FURIA algorithm achieved the highest value in term of the average accuracy (95.15%) in all semesters. In addition, the FURIA algorithm obtained the highest accuracy values for all imbalanced semester dataset. Consequently, this algorithm is suitable for the balanced and imbalanced dataset. This result is consistent with that found in [34], which shows that the FURIA algorithm can succeed in different domains. Based on that, we recommend the use of FURIA algorithm not only for having the best accuracy but also the ability to produce a list of rules that are more interpretable for end-users.

According to the obtained results, the semester datasets is the area of concern to identify features that affect student enrollment decision. As shown in section (3.2.2), the demographical data include gender, marital status, work, and mothers' level of education. The observation showed that the effect of this features reduced throughout the four semesters. In addition, the impact of the student performance progress and the semester characteristic features (GPA, HSGPA, uncompleted courses, and previous student decision) increased throughout the four semesters. Furthermore, the observation showed that the student satisfaction features are more important during the second and third semesters. The student satisfaction features affect the dropout decision in the second semester, while the student satisfaction features affect transfer decision during the third semester.

Finally, the illustration of the rulesets that are generated for P1, P2, P3, and P4 using the FURIA algorithm are available in Figure A.1, A.2, A.3, and A.4 (see the Appendix section).

5. Conclusions

This paper discusses students' enrollment behavior as a multi-class classification problem rather than a binary-class problem. The first goal is to identify the suitable data structure that can be used for predicting the next students' enrollment behavior. The second goal is to identify the features that affect student enrollment decision. Finally, we aim to propose an intelligent model for predicting student enrollment decision early in order to support manager in educational institutions. Two experiments are conducted to determine the appropriate dataset for extracting those features. The first one uses all students' data, while the second experiment uses student data per semester. In this context, the results show that the use of the semester datasets improves the prediction accuracy more than the full students' data. We identify influent features that affect student decision per semesters. These features include demographical features (i.e. age, gender, marital status, distance), student performance (i.e. GPA, and HSGPA), social-economic indicator, number of uncompleted courses, and student satisfaction factors. Several machine learning algorithms were investigated during the aforementioned experiments. The results show the proposed model using the FURIA algorithm achieved high accuracy (95.15%) using balanced dataset. For future works, we will investigate additional enrollment behaviors to provide a comprehensive model that can predict different student enrollment behaviors. The interpretability of the predictive model is our concentration in order to build recommender system for university students.

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Appendix A

```
if(SatUni between 3,4)&(GPA between 62,63)&(HSGPA between 58,59 )&(GPA between 46,47) then Class= Continue
if(GPA between 53,62)(HSGPA between 66,67)&  (SatUni between 2,3)&(HSGPA between 74,79) then Class= Continue
if SatUni between 2,3)&(Distance between 11,54)&(SatUni between 3,4)&(UCC between 9,11) then Class= Continue
if(SatUni between 2,3)&(Distance between 11,15)&(SatUni between 3,4)&(Distance between 0,5) then Class= Continue
if(SatUni between 2,3)&(UCC between 3,9)&(Distance between 59,60)&(Distance between 57,59)&(HSGPA between 54,58) then Class= Continue
if(Distance between 0,1)&(UCC between 3,6)&(SatUni between 2,3)&(HSGPA between 56,58 )&(Ages between 18,19) then Class= Continue
if(GPA between 78,79)  then Class= Continue
if(GPA between 53,57)&(gender between 0,1)&(Distance between 0,2)&(Distance between 11,12)&(Married between 0, 1)&(HSGPA between 57,58 )  then Class= Continue
if(HSGPA between 55,56)&(Distance between 15,95)&(SatUni between 2,3)&(Ages between 18,19)&(Married between 0,1)  then Class= Continue
if(UCC  between 0,1)&(SatUni between 2,3)&(Distance between 54,79)&(Distance between 36,50)&(HSGPA between 58,62)&(SatUni between 4,5)  then Class= Continue
if(SatUni between 2,3) then Class= Dropout
if(Distance between 59,79)&(GPA between 46,50) then Class= Dropout
if(Distance between 0,6)&(SES between 0,1)&(SatUni between 2,3)&(SatUni between 4,5) then Class= Dropout
if(Distance between 0,6)&(GPA between 38,39)  then Class= Dropout
if(Distance between 93,100)&(Distance between 120,121)&(HSGPA between 59,60) then Class= Dropout
if(Distance between 0,1)&(SatUni between 3,4)&(UCC between 4,5)&(SatUni between 3,4)&(HSGPA between 58,59)&(GPA between 60,61)& HSGPA between 63,65) then Class= Dropout
if(Distance between 0,1)&(Married between 0,1)&(SatUni between 3,4)&(GPA between 54,62)  then Class= Dropout
if(Distance between 0,10)&(Ages between 18,19)&(SatUni between 3,4)&(GPA between 59,60)&(HSGPA between 58,59)&(GPA between 65,66)&(HSGPA between 52,53)  then Class= Dropout
if(Distance between 11,12)&(SatUni between 3,4)&(GPA between 59,64)&(SatUni between 3,4)&(gender between 0,1) then Class= Dropout
if(Ages between 17,18)&(Distance between 93,185) then Class= Dropout
if(UCC between 5,6)&(SatUni between 2,3)&(SatUni between 2,3)&(Distance between 54,55) then Class= Transfar
if(UCC between 4,5)&(SatUni between 2,3)&(SatUni between 2,3)&(GPA between 50,51)&(HSGPA between 53,54) then Class= Transfar
if(SatUni between 2,3)&(SatUni between 2,3)&(Distance between 12,15)&(HSGPA between 57,58) then Class= Transfar
if(UCC between 0,1)&(SatUni between 2,3)&(SatUni between 3,4)&(Distance between 23,53)&(Distance between 1,2) then Class= Transfar
if(SatUni between 2,3)&(SatUni between 2,3)&(UCC between 2,3)&(GPA between 47,50)&(Ages between 18,19) then Class= Transfar
if(GPA between 58,59)&(SatUni between 2,3)&(HSGPA between 59,60)&(Distance between 53,54)&(Ages between 21, 22)  then Class= Transfar
if(GPA between 53,61)&(SatUni between 3,4)&(SatUni between 4,5)&(GPA between 72,73)&(Distance between 0,24)  then Class= Transfar
if(UCC between 2.3)&(GPA between 53.54)&(SatUni between 2.3)&(HSGPA between 56.58) then Class= Transfar
```

Figure 1. Rules List for P1 dataset

```
if(Married between 0, 1) then Class=Continue
if(SatUni between 2,3)&(work between 0,1)&(UnCompleate between 0,3) then Class=Continue
if(SatUni between 2,3)&(work between 0,1)&(UnCompleate between 0,1)&(GPA between 59,60) then Class=Continue
if(Sat_Cource between 2,3)&(UnCompleate between 0,2)&(Gender between 0,1)&(Distance between 41,45) then Class=Continue
if(GPA between 51,57)&(SatUni between 3,4)&(Sat_Cource between 2,3)&(Married between0,1,inf,inf) then Class=dropout
if(GPA between 0,45)&(SES between 3,4) then Class=dropout
if(SES between 2,3)&(Married between 0,1)&(GPA between 46,49) then Class=dropout
if(GPA between 35,37)&(SatUni between 1,2) then Class=dropout
if(GPA between 49,52)&(UnCompleate between 5,6)&(Married between 0,1) then Class=dropout
if(Pdecision between 0,1)&(Married between 0,1) then Class=dropout
if(UnCompleate between 6,7)&(GPA between 44,46) then Class=Transfar
if(Married between 0,1)&(GPA between 50,53)&(SES between  0,1) then Class=Transfar
if(UnCompleate between 12,13)&(SatUni between 3,4) then Class=Transfar
if(GPA between 52,53)&(UnCompleate between 0,1)&(UnCompleate between 2,3) then Class=Transfar
if(UnCompleate between 5,6)&(SatUni between 3,4)&(SES between  0,4)&(Ages between  18,19) then Class=Transfar
if(UnCompleate between 6,7)&(Pdecision between  0,1)&(Pdecision between 0,1) then Class=Transfar
if(Pdecision between 0,1)&(Married between 0,1)&(UnCompleate between  4,6)&(Distance between 15,40) then Class=Transfar
if(UnCompleate between 5,6)&(SatUni between 2,3)&(Pdecision between 0,1)&(SES between  0,4)&(UnCompleate between  8,12) then Class=Transfar
```

Figure 2. Rules List for P2 dataset

```
if(GPA between 70,71)&(Married between 0,1) then Class=Continue
if(Sat_Inst between 2,3)&(work between 0,1)&(UnCompleate between 0,3) then Class=Continue
if(Sat_Inst between 2,3)&(work between 0,1)&(UnCompleate between 0,1)&(GPA between 59,60) then Class=Continue (CF = 0.91)
if(Sat_Cource between 2,3)&(UnCompleate between 0,2)&(SES between 0,1)&(Distance between 41,45) then Class=Continue
if(Sat_Cource between 2,3)&(UnCompleate between 0,1)&(SES between 0,4)&(Distance between 5,10) then Class=Continue
if(Sat_Cource between 2,3)&(UnCompleate between 0,1)&(SES between 0,4)&(Distance between 9,10)&(gender between 0,1) then Class=Continue
if(Sat_Inst between 2,3)&(Sat_Cource between 3,4) then Class=Continue
if(Sat_Inst between 2,3)&(gender between 0,1)&(SatUni between 3,4) then Class=Continue
if(GPA between 54,60)&(PDecision between 0,1)&(work between 0,1)&(SatUni between 3,4)&(UnCompleate between 5,8) then Class=Continue
if(SatUni between 4,5) then Class=Continue
if(GPA between 52,54)&(Ages between 23,25) then Class=Continue
if(Sat_Cource between 2,3)&(SatUni between 3,4)&(Distance between 0,67) then Class=Continue
if(SatUni between 3,4)&(Sat_Cource between 2,3)&(GPA between 43,49)&(Sat_Inst between 2,3) then Class=dropout
if(SES between 0,1) then Class=dropout
if(GPA between 48,49)&(Sat_Inst between 2,3) then Class=dropout
if(GPA between 49,50)&(Sat_Cource between 2,3)&(gender between 0,1)&(Sat_Inst between 2,4) then Class=dropout
if(GPA between 43,45)&(Sat_Inst between 2,3) then Class=dropout
if(UnCompleate between 2,3)&(SatUni between 3,4)&(Sat_Cource between 3,5)&(Ages between 18,19) then Class=Transfar
if(UnCompleate between 3,4)&(GPA between 48,49)&(work between 0,1)&(GPA between 54,55)&(Sat_Cource between 1,2) then Class=Transfar
if(GPA between 52,53)&(UnCompleate between 0,1)&(UnCompleate between 2,3) then Class=Transfar
if(GPA between 49,53)&(SES between 0,1)&(SatUni between 3,4)&(PDecision between 0,1) then Class=Transfar
if(GPA between 35,53)&(UnCompleate between 6,7) then Class=Transfar
if(GPA between 52,53)&(SES between 0,1)&(Sat_Cource between 2,3) then Class=Transfar
if(GPA between 51,53)&(GPA between 69,85)&(UnCompleate between 0,1)&(work between 0,1)&(PDecision between 0,1)&(UnCompleate between 5,6) then Class=Transfar
if(GPA between 50,53)&(GPA between 69,70)&(SES between 3,4) then Class=Transfar (CF = 0.93)
if(SatUni between 3,4)&(GPA between 64,65)&(GPA between 60,61)&(Sat_Inst between 2,3)&(gender between 0,1) then Class=Transfar (CF = 0.95)
if(HSGPA between 73,75)&(Sat_Cource between 2,3)&(Sat_Cource between 3,4)&(Distance between 0,53) then Class=Transfar (CF = 0.81)
```

Figure 3. Rules List for P3 dataset

```
if(Married between 0, 1) then Class=Continue
if(SatUni between 2,3)&(work between 0,1)&(UnCompleate between 0,3) then Class=Continue
if(SatUni between 2,3)&(work between 0,1)&(UnCompleate between 0,1)&(GPA between 59,60) then Class=Continue
if(Sat_Cource between 2,3)&(UnCompleate between 0,2)&(Gender between 0,1)&(Distance between 41,45) then Class=Continue
if(GPA between 51,57)&(SatUni between 3,4)&(Sat_Cource between 2,3)&(Married between0,1,inf,inf) then Class=dropout
if(GPA between 0,45)&(SES between 3,4) then Class=dropout
if(SES between 2,3)&(Married between 0,1)&(GPA between 46,49) then Class=dropout
if(GPA between 35,37)&(SatUni between 1,2) then Class=dropout
if(GPA between 49,52)&(UnCompleate between 5,6)&(Married between 0,1) then Class=dropout
if(Pdecision between 0,1)&(Married between 0,1) then Class=dropout
if(UnCompleate between 6,7)&(GPA between 44,46) then Class=Transfar
if(Married between 0,1)&(GPA between 50,53)&(SES between  0,1) then Class=Transfar
if(UnCompleate between 12,13)&(SatUni between 3,4) then Class=Transfar
if(GPA between 52,53)&(UnCompleate between 0,1)&(UnCompleate between 2,3) then Class=Transfar
if(UnCompleate between 5,6)&(SatUni between 3,4)&(SES between  0,4)&(Ages between  18,19) then Class=Transfar
if(UnCompleate between 6,7)&(Pdecision between  0,1)&(Pdecision between 0,1) then Class=Transfar
if(Pdecision between 0,1)&(Married between 0,1)&(UnCompleate between  4,6)&(Distance between 15,40) then Class=Transfar
if(UnCompleate between 5,6)&(SatUni between 2,3)&(Pdecision between 0,1)&(SES between  0,4)&(UnCompleate between  8,12) then Class=Transfar
```

Figure 4. Rules List for P4 dataset

Design analysis of the steam boiler furnace by using the gate cycle

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Abstract

The operation analysis of the steam boilers at thermal power plants showed deviations of parameters in relation to their design values. In order to analyze the size of deviations in this paper, the operation analysis of the steam boiler in Thermal Power Plant Kakanj was performed. The status of the boiler plant was identified during their regular operation. On the basis of these data and project-normative documentation, simulation models were made in the software package Gate Cycle™. "Design" and "off-design" simulation models were set to determine the connections between the boiler furnace design and the boiler furnace energy parameters.

Key words: Steam boiler, Design of the furnace, Modeling and Simulation

1. Introduction

The fact is that after the construction of the boiler or parts thereof, such as furnaces, there is almost no possibility of affecting them. Therefore, the possibilities for the subsequent correction of the furnace boiler configuration are almost non-existent. Thus, when calculating the boiler and its parts, certain "reserves" are left in relation to their properties. Of course there are possibilities of partial change in the conception of the boiler during the planned revitalization, but this change in the concept does not guarantee the improvement of the plant performance. In this regard, this issue should be given special attention, and strive for more modern software support that would be specialized for this part of the boiler plant. Therefore, it has been aimed to improve the monitoring of the plant with a clear goal of parameters selection that are essential for the smooth operation of the plant. The purpose of this power plant monitoring is a measurement process with a reduced amount of information using the appropriate models of the analyzed system [1-4]. Special attention is paid to the combustion analysis and other processes within the boiler using mathematical models and other methods and technologies.Many experts in their papers [5-11] deal with the analysis of such systems in order to come up with improvements concerning the constructional charateristics of the plant, system monitoring, emission of harmful gases, etc., with the aim of adjusting the plant to new, more difficult working conditions (changes in fuel quality, more stringent environmental demands, etc).

2. Creating simulation models in the Gate Cycle™ software

The base for setting simulation models are the data taken from the normative tests of the plant as well as the data of everyday measurements in the boiler plant operation [3]. Normative test is a procedure for the verification of warranties given to the purchaser by the manufacturer of the equipment. By conducting the test, the actual condition of both equipment and all operating parameters is determined. Normative tests are performed with measuring equipment that is more accurate than the measuring instruments used during standard plant monitoring. The simulation model was set up in the commercial software Gate Cycle™. This software is used to design and evaluate the performance of thermal power systems in the project and exploitation phase. The maximum model error for the observed sizes was approximately 10 [%], which is correct enough to verify the model and as such use in further research.Figure 1 shows the display of the design model of the boiler, where graphic elements that symbolically represent the elements of the boiler can be noticed. The red lines indicate the flow of flue gases and air flow, the green line represents the flow of the water steam, and the blue lines represent the flow of the feed water [1], [2], [12], [13].

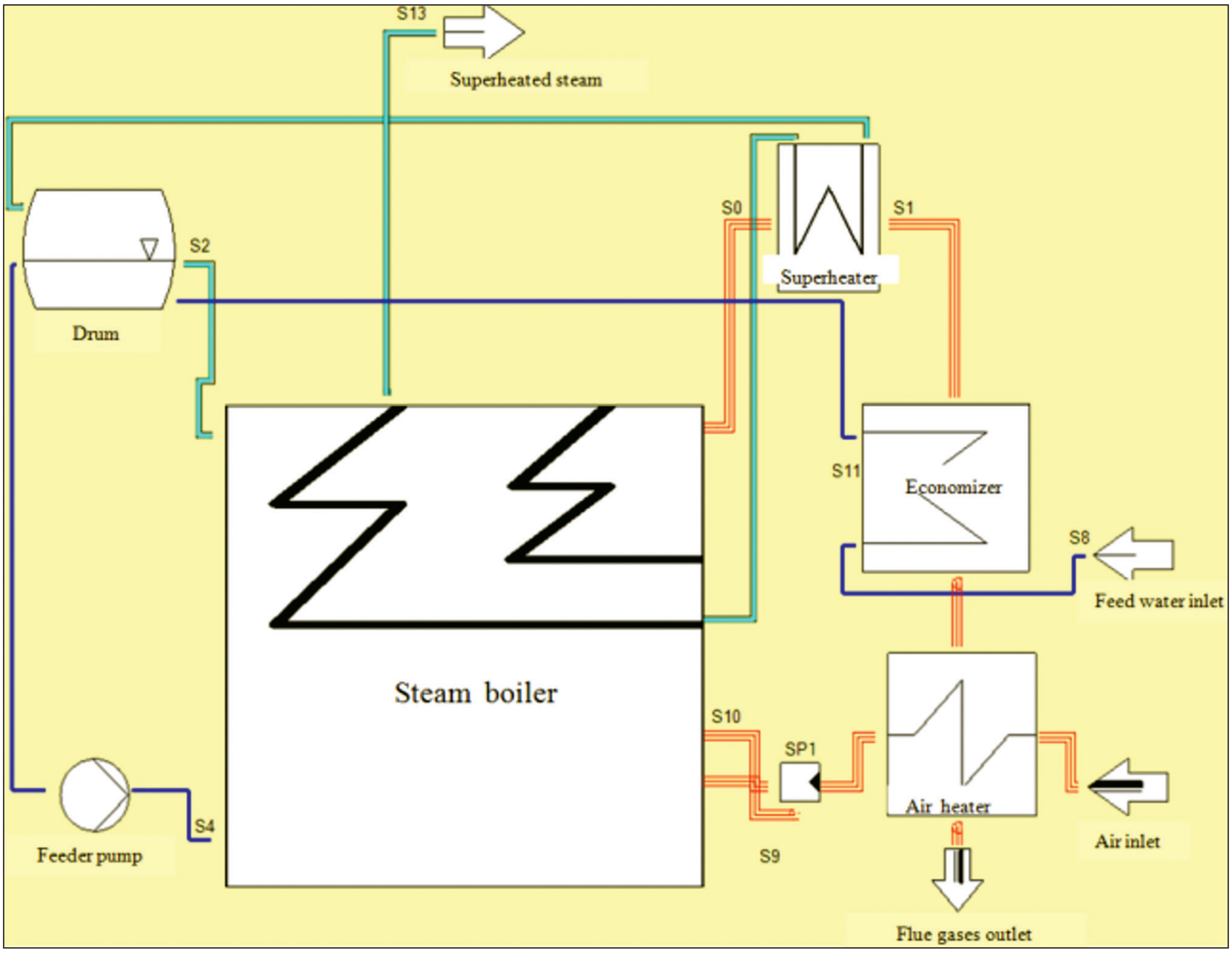

Figure 1. Display of the design model of the boiler

3. Comparison of the experiment and the simulation

In this part of the paper, comparison of the experimental values with the data obtained in the simulation design model was performed. A comparison of the steam amounts obtained at the exit from the design model and the experimental value in relation to the power of the plant is shown in Figure 2. Measured quantity of the steam amount follows the change in the plant power, which is not

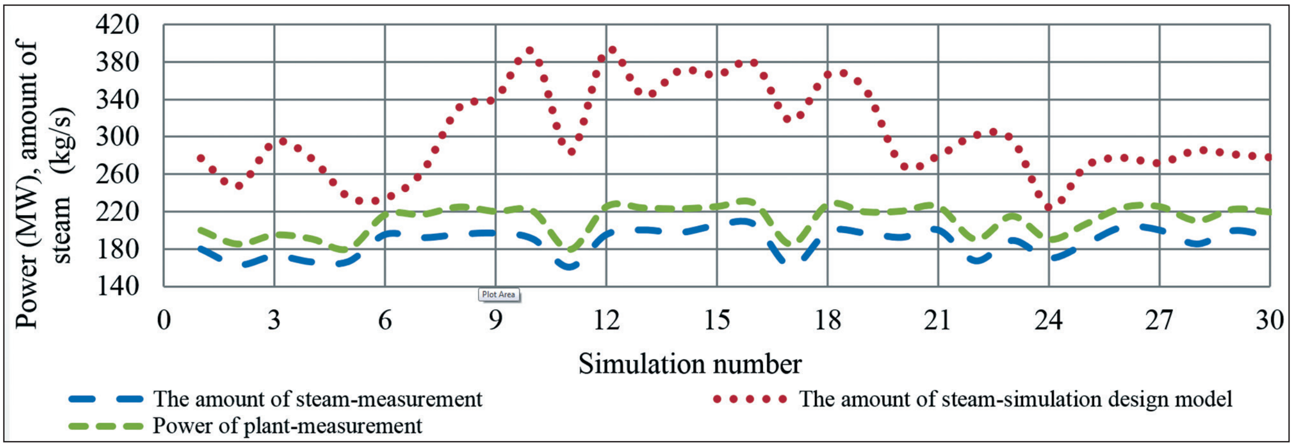

Figure 2. Change in plant power with a display of the deviation of the steam quantity obtained by modeling in relation to the steam amount obtained by measuring at the boiler

the case with the simulation results of the design model. For most of the analyzed cases there has been a significant deviation of these two parameters, as a consequence of lower flue gas temperatures in those cases. The lower flue gas temperature led to an increase in steam production and the exploitation level. In fact, it is considered that all the heat amount from the flue gases is delivered to the water steam. Realistically, the flue gas temperature drop can be a consequence of a number of problems in the process itself, and this increase in production and thus the degree of exploitation is only apparent.

A comparison of the air amount in the experiment and the model with the change in plant power is shown in Figure 3. The measured air quantityfollows the power change in a large number of analyzed cases. What needs to be emphasized here is the fact that the realistic, i.e. measured air quantity for almost all cases smaller than that obtained by the model. In a few cases, it can be seen that the air amount obtained by the model varies to a considerable extent from the one measured. The reason may be a measurement error or an unrealisticair amount generated by the model without taking into account all the necessary process indicators. The deviation for these two parameters is much smaller than it was with the steam amount.

The change in the volume of the boiler furnace depending on the change in the coal amount to be thrown into the boiler is shown in Figure 4. In contrast to the previous case, it can be seen that the change in the volume of the furnace is growing with the increase in the coal amount, and vice versa. The exception is several cases where the increase in the volume of the furnace with a decrease in the amount of coal was recorded. These are cases number 5, 6, 7, 17 and 28. This coincides

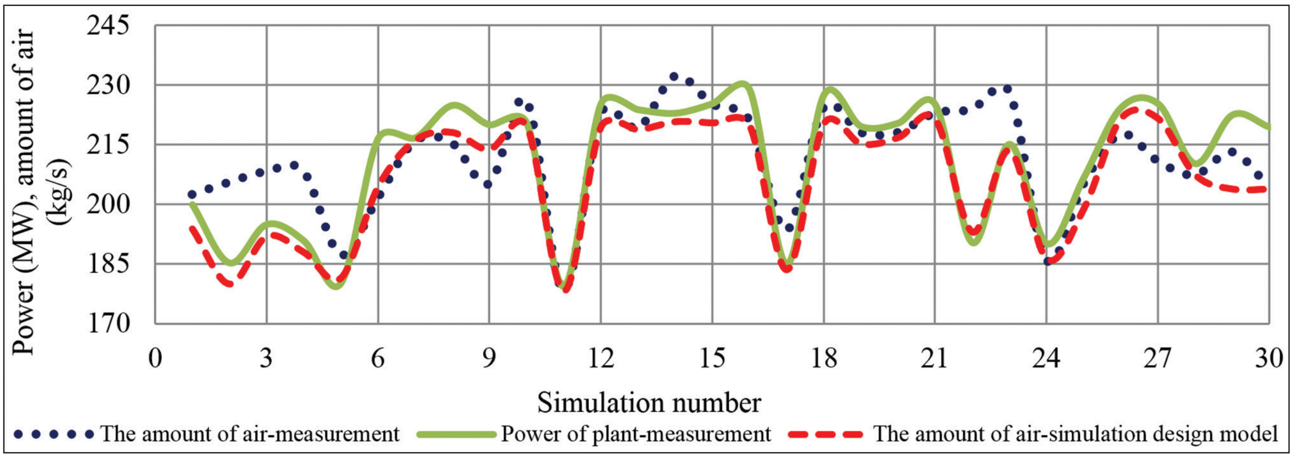

Figure 3. Change in plant power with display of deviation of the model amount in relation to the measured air amount at the inlet to the boiler

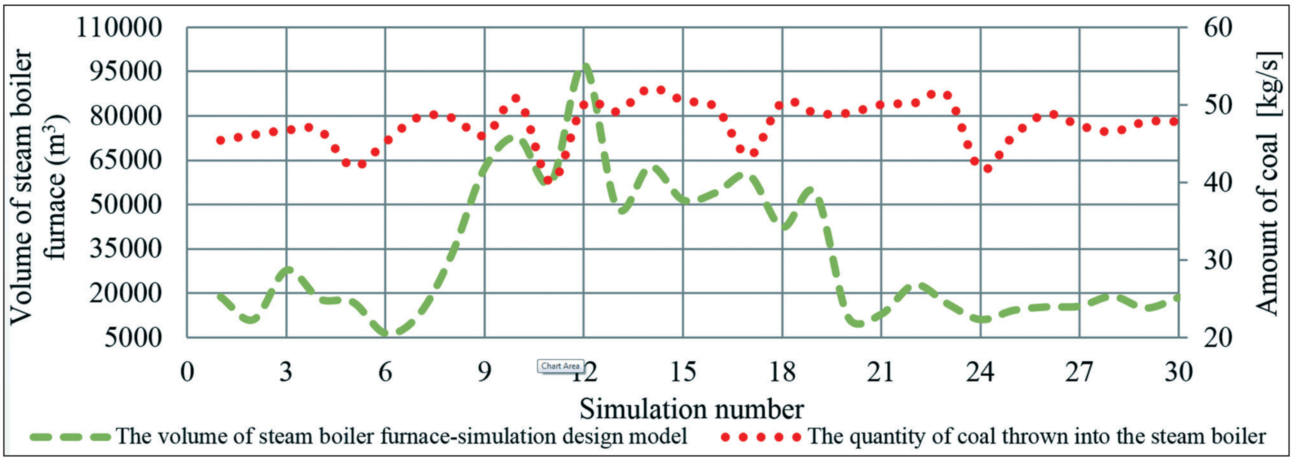

Figure 4. Display of the apparent volume change of the steam boiler furnace for different values of the coal quantity thrown into the boiler

with the fact that the coal amount thrown into the boiler dictates the change in the constructional characteristics in order to maintain the continuity of heat transfer over the furnace surfaces.

The change in the volume of the boiler furnace was also analyzed, depending on the value of the flue gas temperature at the end of the furnace (Figure 5). An increase in the flue gas temperature reduces the apparent volume of the furnace, and it is also valid vice versa.

3.1 Comparison of results obtained in design and off design simulation model

In order to prove the influence of the constructional and energy characteristics of the furnace on the combustion process, the process in the boiler furnace was analyzed by setting the corresponding number of so-called "off design" simulations. In these models, the fixation (freezing) of geometry was performed with the possibility of correcting the operating parameters. The normative model of the boiler was used as the starting basis for the development of the "off design" simulation. In the case of the "off design" simulation, the values of the selected parameters in the boiler furnace had to "adapt" to the predefined geometric characteristics. In this way it was determined which values depend on the furnace geometry. Figure 6 shows the correction of the steam amount obtained in the design model in relation to the amount of steam obtained in the off design model.

In the case when the furnace characteristics were higher than the normative, there was a fall in the steam production, and when the surfaces were smaller, there was an increase in the steam amount. This indicates appropriate interdependence. The value of the steam production for the design model

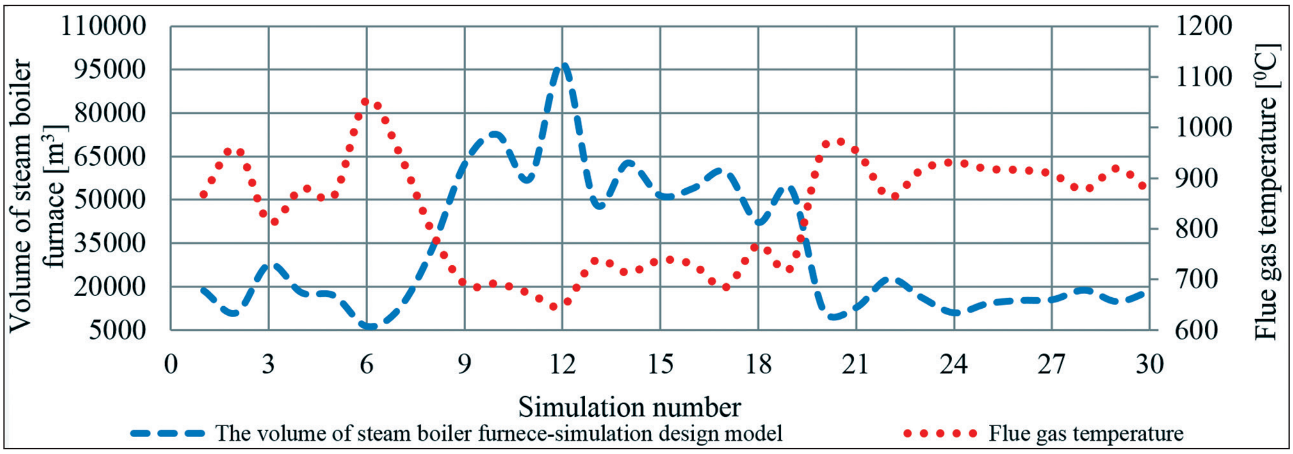

Figure 5. Display of the apparent volume change of the boiler furnace depending on the temperature of flue gases at the end of the boiler furnace

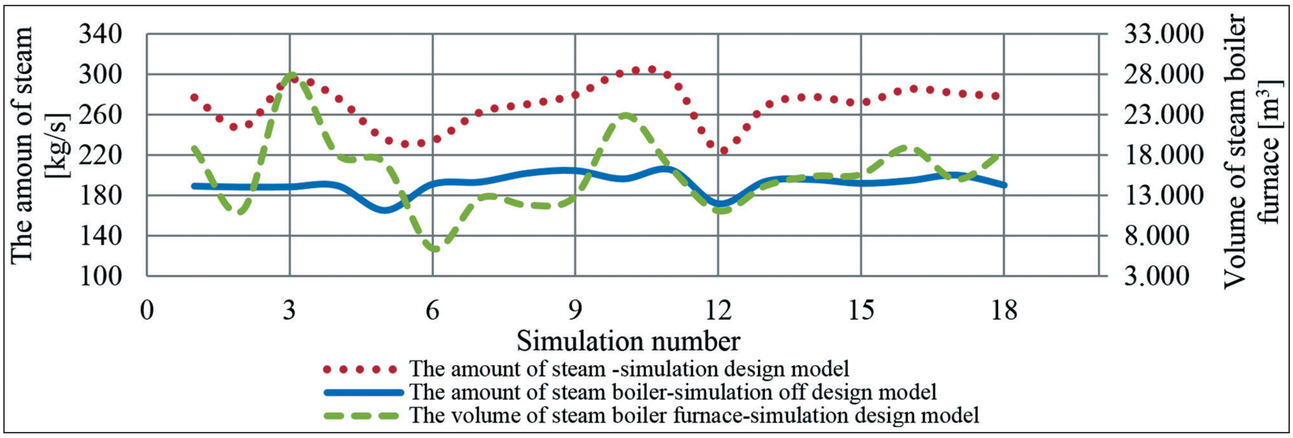

Figure 6. The correction of the steam production from the design model in relation to the steam amount obtained in off-design model with different coal amount and fixed furnace volume

ranges from 224-395 [kg/s] while in the off-design model is within the limits of 164-207 [kg/s].The second interval actually represents a realistic image of the steam production value for the steam boiler. Figure 7 shows the difference in flue gas temperature for the design model with respect to its value in the off design model. Here it is apparent that, in contrast to the steam amount, almost all the temperatures from the off design model are larger than those measured in the design model. In the design model, we had a significant deviation of the furnace geometry in relation to the design value. The reason for the deviation is the flue gases temperature that oscillated in relation to the normative and projected values. The curve of the flue gases temperature in the off design model is much more even, and its values are in the narrower range from 1098-1175 [° C], which is close to the normative values. For example, increasing the temperature in the off-design model by 175 [° C] would, on the other hand, create a reduction of the apparent height of the furnace in the design model from 40.96 to 28.9 [m], indicating close links between the mentioned parameters.

4. Modelling results

Analyzing the set design and off design models of the steam boiler, it was found that the greatest influence on the geometry of the steam boiler furnace is the coal amount at the boiler inlet and the flue gas temperature at the end of the furnace. Table 1 shows the values and intervals of these parameters and their changes.

Table 1. The interval of the observed parameters

Parameter	Min.value	Max.value	Step
B_g	35 [kg/s]	55 [kg/s]	5 [kg/s]
T_{dp}	800 [°C]	1200 [°C]	100 [°C]

The effect of the shape factor of the furnace factor on the constructional parameters for different values of the coal amount was also observed. The shape factor of the furnace is the ratio of the height and depth of the boiler furnace. It was analyzed in the interval from 2 to 6 with step 1. The constructional parameters whose change was analyzed were: the boiler furnace volume, the surface of the boiler furnace walls and the surface of its cross-section.

4.1 The influence of the flue gas temperature on the furnace design

The change in the boiler furnace volume depending on the flue gas temperature at the end of the boiler furnace on one hand and the shape factor of the furnace [F] on the other side is shown in Figure 8. It is evident that the change is of the exponential nature. At lower temperatures than normative, the apparent volume of firebox is more pronounced, i.e. its value increases with respect to its design value. However, in the event of a higher flue gas temperature, the apparent change in the apparent volume of the furnace is lower. Here it is worth pointing out that, by increasing the shape factor of the furnace, at a constant value of the flue gas temperature, the

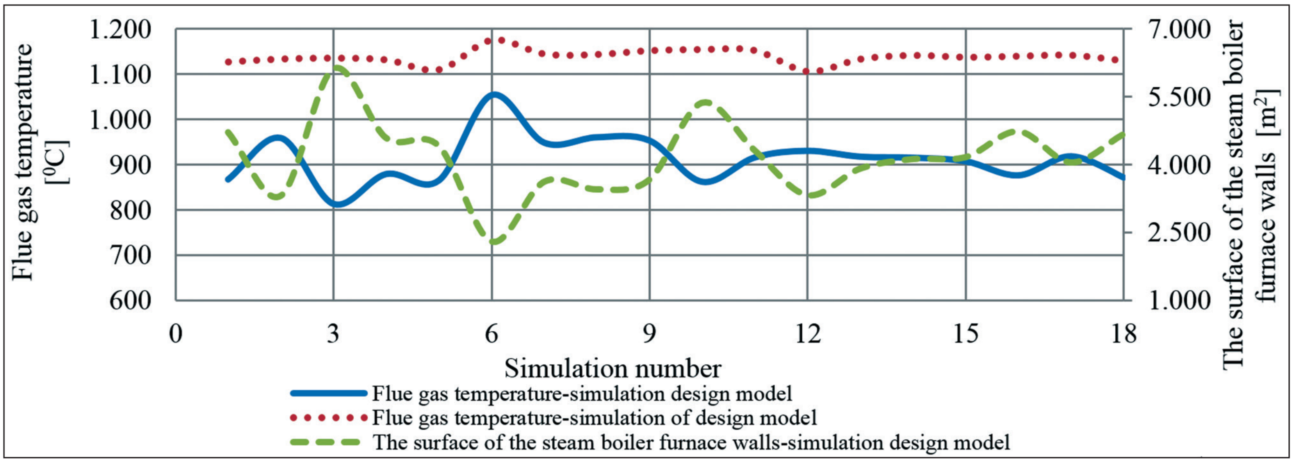

Figure 7. The correction of the flue gas temperature from the design model in relation to the flue gas temperature obtained in off-design model with different coal amount and fixed the surface of the furnace walls (m^2)

boiler volume increase is of lesser intensity. This suggests that with the optimal choice of constructional parameters, the possible differences between the projected and the actual utilized volume of the furnace space can be reduced.

The change of the boiler furnace cross-section area is shown in Figure 9. For the different values of the shape factor of the furnace and a certain interval, the temperature of the flue gases at the end of the furnace, the change in the cross-section area

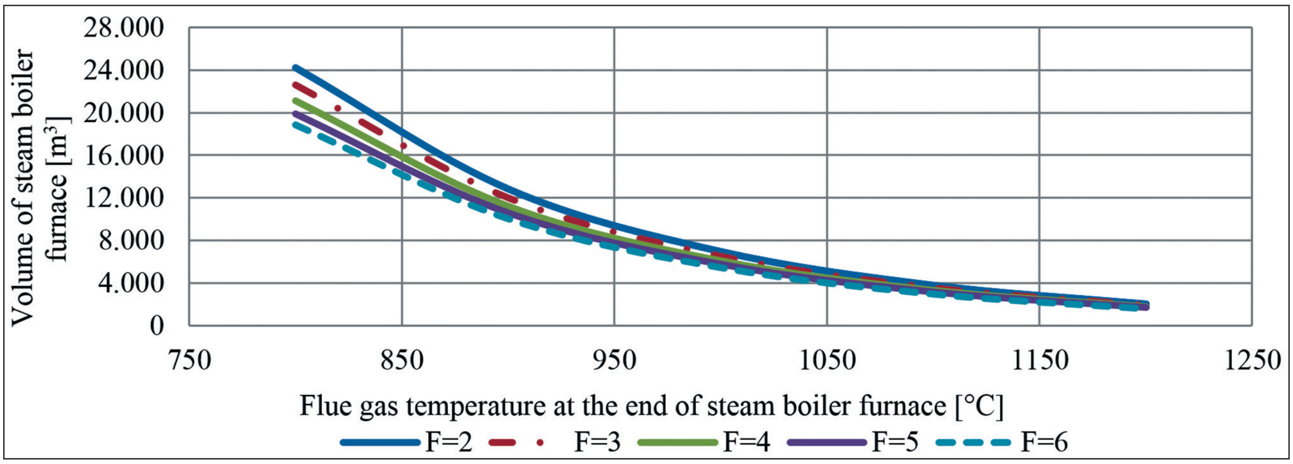

Figure 8. Change of the furnace volume in case of the change offlu gas temperature at the end of the furnace and for the different values of the furnace shape factor

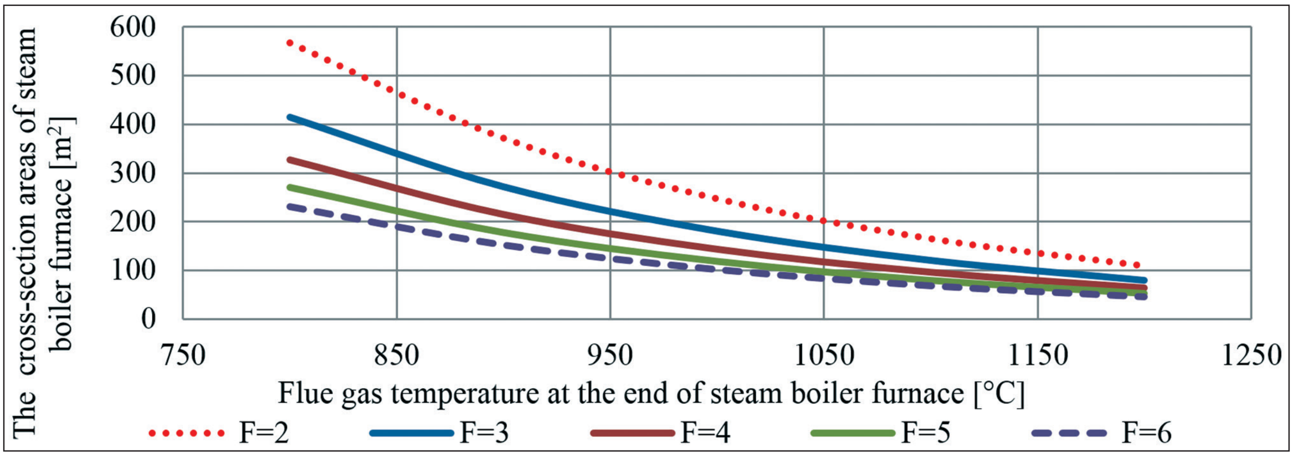

Figure 9. Change of the furnace cross-section area in case of change of the flu gas temperature at the end of the furnace and for different values of the shape factor

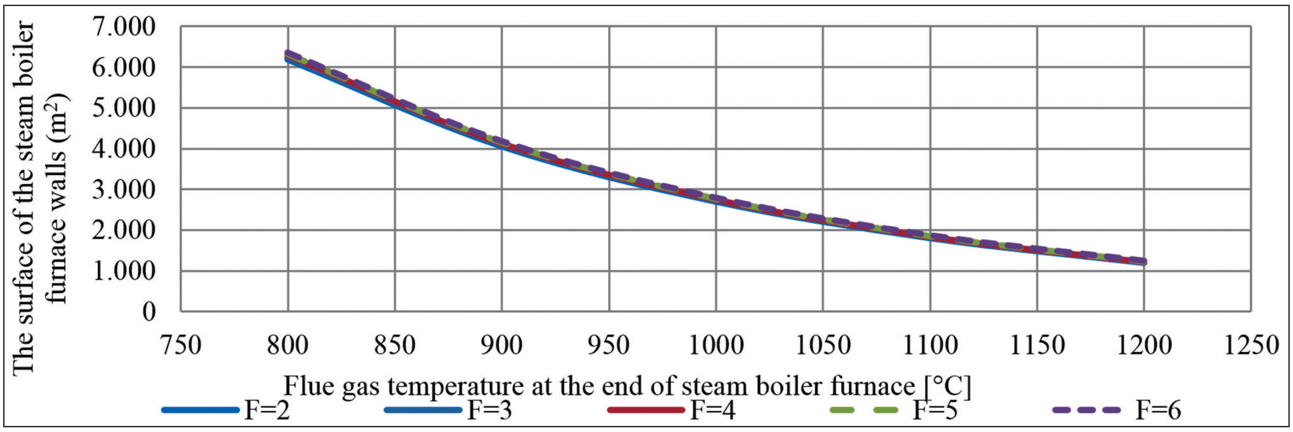

Figure 10. Change of the surface of the furnace walls in case of the change of the flue gas temperature at the end of the furnace and for the different values of the furnace shape factor

is exponential. It can be noticed in Figure 9 that a more intensive change in lower flue gas temperatures is observed.

The same procedure was applied in the analysis of the effect of changing the flu gas temperature on the surface of the boiler furnace walls (Figure 10). It is evident that the influence of the shape factor of the furnace has no significant impact on the surface of the furnace walls.

4.2 The influence of the coal amount on the furnace design

The same procedure was applied to the parameter of the coal amount that was thrown into the boiler furnace. In Figure 11, it can be noted that the furnace volume is changed linearly in relation to the fuel amount. The shape factor of the furnace influences the volume of the furnace space. For a maximum value of fuel quantity by increasing the shape factor, the volume decreases on average about 6%.

Diagram 12 shows a linear change in the surface cross-section of the boiler furnace in the function of the coal amount, while the shape factor of the furnace has a significant effect. For example, for a standard coal quantity of 45 [kg/s], a shape factor 2, and a normative flue gas temperature, the surface area of the cross-section can be read in the amount of 148.3 [m^2], while for the shape factor 6 we obtain that the cross-section area is 60,8 [m^2].

Diagram 13 provides the information on the impact on the surface of the furnace walls both on the coal amount and on the shape factor of the furnace. Influence of shape factor of the furnace on this parameter can be ignored.

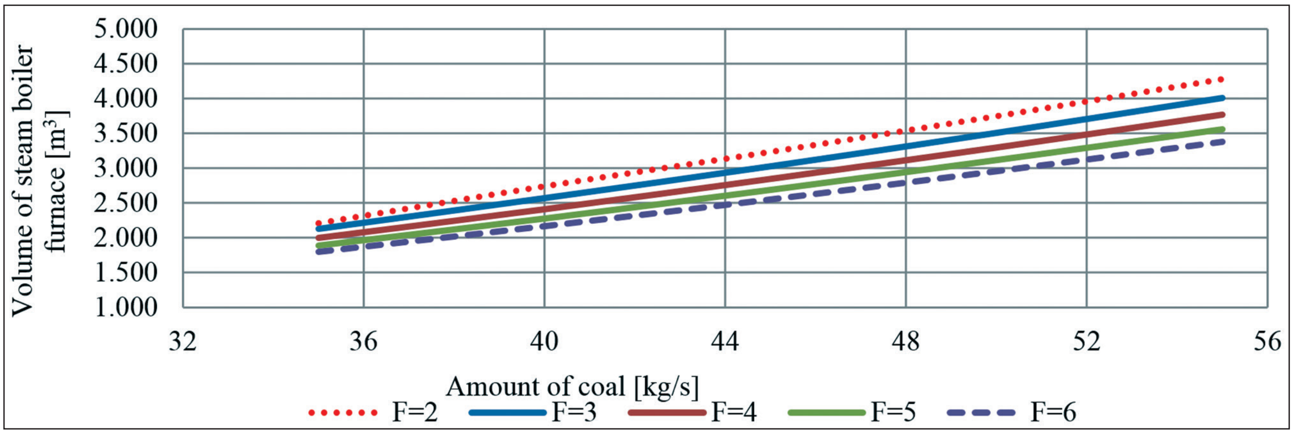

Figure 11. Change of the furnacevolume in case of the change of the coal amount at the inlet of the boiler and for different values of the furnaceshape factor

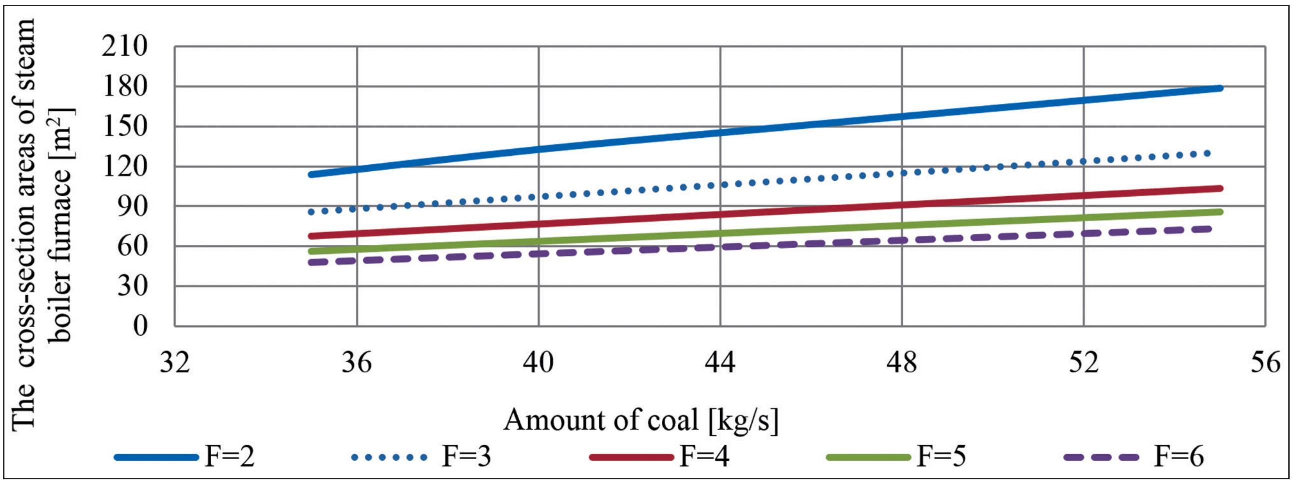

Figure 12. Change of the furnace cross-section area in case of the change of the coal amount at the inlet of the boiler and for different values of the furnace shape factor

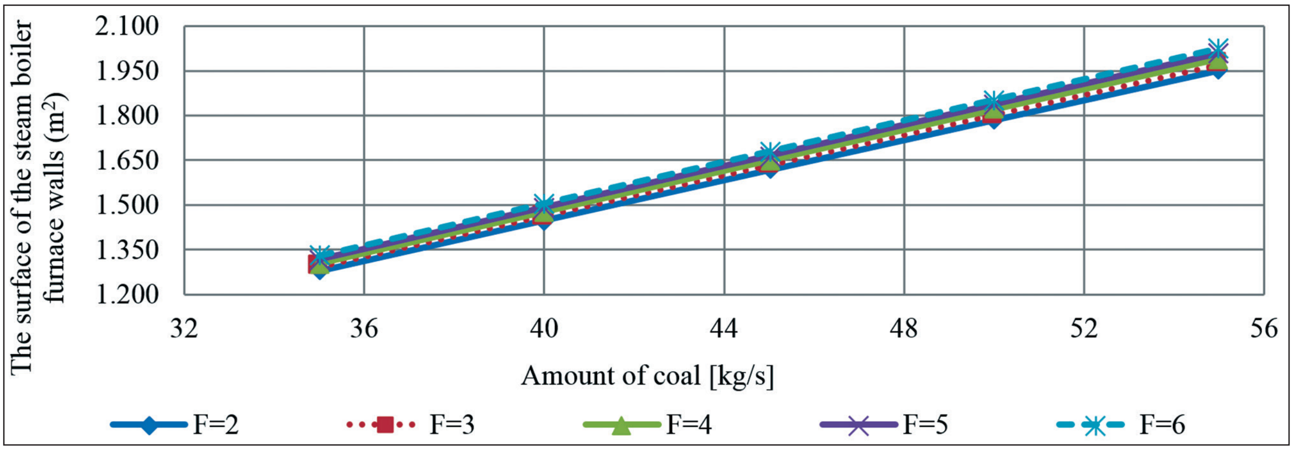

Figure 13. Comparison of the furnace walls surface in case of the change of the coal amount at the inlet of the boiler and for different values of the shape factor of the furnace

5. Conclusion

The conducted research showed that the boiler furnace geometry has been influenced the most by the flue gas temperature at its end and the coal amount at the inlet to the furnace. The basic characteristics of the furnace analyzed in this case are: the furnace volume, the surface of the furnace walls and the surfaces of its cross-section. An analysis of the results of the simulation study showed that the flue gas temperature at the end of the furnace is a highly sensitive parameter that has a significant effect on the constructional characteristics. For values of the flue gas temperatures higher than the norms, accurate results are obtained, while the values of the constructional parameters are close to the project values. However, for flue gas temperatures less than the normative, an increase in the parameters monitored. In the analysis of the influence of the coal amount the observed parameters were changed linearly. It has been shown that there are significant deviations in the exploitations from the project defined values of the parameters, especially in the conditions when the boiler is working with loads less than its nominal values. Consequently, it can be concluded that special attention must be paid to improving the methods and method of budgeting as well as monitoring such systems. Due to the ecological requirements and the market price of energy, the proper design of the boiler furnace can provide better efficiency in variable loads and operating conditions of the thermal power plants.

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Impact of air pollution on COPD exacerbation among patients with COPD in Tuzla Canton

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Abstract

Chronic obstructive pulmonary disease (COPD) is both preventable and treatable disease, characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveoli deformity commonly caused by a significant exposure to noxious particles and/or gases. Prevalence of COPD in developed societies is 3-17%, while in undeveloped societies prevalence of COPD is 13-27%. The most significant proven environmental risk factors are cigarette smoke and occupational exposure along with outdoor and indoor pollution. COPD is a chronic disease with progressive course and severe exacerbations. Acute exacerbation of COPD represents acute worsening of typical symptoms of a stable disease. Patients with frequent exacerbations have greater deterioration of lung function and quality of life, more frequent admissions, that is also related to higher death risk. Air in urban areas, especially where large industrial complexes and /or dense traffic are present, is contaminated with specter of pollutants that can cause COPD. Exposure to fine particles like gases, dusts and other harmful substances made by industrial production, heating plants and by burning petrol and diesel (smog, smoke, sulfur dioxide, nitrogen oxide, ammonia, carbon dioxide, carbon monoxide, methane, polycyclic aromatic carbohydrates) leads to development of COPD. Our goals is to determinate impact of air pollution on COPD exacerbation among patients with COPD in Tuzla Canton.

Key words: air pollution, exacerbation, chronic obstructive pulmonary disease.

1. Introduction

Chronic obstructive pulmonary disease (COPD) is both preventable and treatable disease, characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveoli deformity commonly caused by a significant exposure to noxious particles and/or gases according to GOLD (Global Initiative for Chronic Obstructive Lung Disease - GOLD, 2017) [1]. COPD includes a group of disorder characterized by respiratory system symptoms: shortness of breath, cough, expectoration, bronchial obstruction and chronic airway inflammation [2]. It affects all lung structures: airways, lung parenchyma and blood vessels. COPD is multicomponent disease that includes: airway and lung parenchyma inflammation, bronchial tree airflow obstruction, mucociliary dysfunction and structural changes. However, COPD is not only pulmonary disease, but also multisystemic. Frequency of cardiovascular diseases is notable, risk of lung carcinoma is higher and frequently present disorders are: metabolic syndrome, osteoporosis, cachexia and depression [3]. COPD is chronic disease with progressive course and severe exacerbations. Acute exacerbation of COPD represents acute worsening of typical symptoms of a stable disease. Patients with frequent exacerbations have greater deterioration of lung function and quality of life, more frequent admissions, that is also related to higher death risk [4]. Symptoms usually appear after significant loss of forced expiratory volume in 1 second (FEV1< 50%) and progress with further deterioration of lung function. Incidence, prevalence and mortality rates are increasing. Prevalence of COPD in developed societies is 3-17%, while in undeveloped societies prevalence of COPD is 13-27%. COPD is 4th major cause of death among adults and by 2020 could be 3rd major cause of death in the world. Estimated, COPD will be responsible for 4, 5 millions of deaths/year [5].

The most significant proven environmental risk factors are cigarette smoke and occupational exposure to harmful particles and gases [6]. Occupational exposure to air pollution at a working place- dust, chemicals, biological agents- significantly contribute to morbidity and disability caused by COPD. Exposure to fine particles like gases, dusts and other harmful substances made by industrial production, heating plants and by burning petrol and diesel (smog, smoke, sulfur dioxide, nitrogen oxide, ammonia, carbon dioxide, carbon monoxide, methane, polycyclic aromatic carbohydrates) leads to development of COPD. Air in urban areas, especially where large industrial complexes and / or dense traffic are present, is contaminated with specter of pollutants that can cause COPD. Percentage of urban population is increasing, which further contribute to environmental pollution because of higher consumption of fossil fuels. Therefore, the level of these substances is measured: sulfur dioxide (SO), nitrogen dioxide (NO2), nitrogen oxide (NO), suspended particles (PM10, PM2,5), carbon monoxide (CO), ozone (O3), lead (Pb), benzene (C_6H_6), arsenic (As), cadmium (Cd), mercury (Hg), Nickel (Ni), benzopyrene (C_20H_{12}). This kind of air pollution cause development of acute and chronic disease, genetic alterations and decline in immune response of organism [7]. Air particles include every dispersed substance (solid or liquid), whose size ranges from molecular proportions to 0,5 mm. Particle role depends on its size. Particle pollution includes particles with a diameter of 2.5 – 10 nm and fine particles with diameter of less than a 2,5 nm. Size determines where particles will stop after inhalation. Larger particles are filtered in nose and throat, thus do not cause problems. However, particles smaller than 10 μm (PM10) could precipitate in bronchi, lungs and cause problems. Particles smaller then 2,5 2.5 μm (PM2.5) reach lungs. Particles smaller than 10 nm can affect also other organs. They induce formation of arterial plaques causing atherosclerosis-sclerosis of arteries, reducing their elasticity, what brings to many cardiovascular diseases. Particles smaller than 100 nm can penetrate cell membrane.

Outcome of COPD includes: symptoms, physical activity intolerance, decline of life quality, intensive use of healthcare resources and death. There is no unique parameter that reflects many pathological effects of COPD or that can describe nature or severity of COPD. Acute exacerbation of COPD is important outcome factor, because repeated exacerbations lead to decline of life quality and when associated with hypoventilation, they lead to disability and sudden death [8]. Life quality, ability to work and mortality depend on severity und frequency of exacerbations. Lung function testing: Decrease in FEV1 more than 20% of the predicted value are considered pathological, suggesting COPD. Forced vital capacity (FVC) is normal or reduced. FEV1/FVC ratio is decreased. Residual volume (RV) and total lung capacity (TLC) are increased. Forced expiratory volume in 1 second (FEV1) is used as a global marker of COPD.

2. Materials and methods

In this retrospective controlled research, patients registered at Pulmonary Medicine Clinic of UKC Tuzla, were included (n=720) . Data on patients treated for COPD were recorded in clinical information system (BIS) from 01.01.2015.-31.12.2016. Participants were patients earlier admitted, and according to current protocols, diagnosed with COPD (history, spirometry confirmed obstruction) with presence of etiology factors (smoking, environmental and occupational risk factors). All lung function testing were conducted by spirometer (Jaeger Masterlab ML 3500; Flow/Volume curve, FEV1 and FVC) according to methods proposed by American Thoracic Society(ATS). Patients were classified in 4 stages:

Table 1. Spirometry classification GOLD 2006

Classification	FEV1/FVC	FEV1	FEV1*
Stage I- mild	< 0.70	>80%	>80% predicted
Stage II- moderate	<0.70	>50%	<80% predicted
Stage III- severe	<0.70	>30%	<50% predicted
Stage IV –very severe	<0.70	< 30%	< 50% predicted + HRI

Before inclusion, patient were informed about procedure and methodology of the research. Data on air pollution were acquired from official web page of Ministry of urban development and environment.

Result: Existing databases in Bosnia and Herzegovina are healthcare information systems with data referring to primary secondary and tertiary levels of healthcare. Data on air pollution were acquired from official web page of Ministry of urban development and environment.

By a comparative analysis of data on air pollution with particles and gases with number of recorded exacerbations in Tuzla Canton, the most common respiratory diseases on tertiary healthcare level are COPD and lung cancer.

Table 2 shows the number of patients treated in Clinic of Tuberculosis and Pulmonary Diseases with COPD.

Tables 3 show level of harmful particles and gases in air durin 2015 and 2016.

Limit levels of pollutants yearly are: SO_2: 50 µg/m^3 , NO_2 : 40 µg/m^3 , CO: 3 mg/ m^3 i $PM_{2,5}$: 25 µg/m^3.

By comparing levels of harmful particles during 2015 and 2016, significant increase in $PM_{2,5}$ and SO_2 levels above upper limit , during winter period (01.October- 30.April) was noted, while these values during summer period (01.05.-01.09.) were within referent values.

Table 2. Number of patients treated in Clinic of Tuberculosis and Pulmonary Diseases with COPD 2015/2016

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Okt.	Nov.	Dec.
2015	53	43	39	32	18	12	10	11	13	18	32	39
2016	72	68	63	22	18	13	12	13	19	29	33	38

Table 3. Average monthly values of pollutants in 2015

Pollutant	Measuring unit	Average 2015.										
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Okt	Nov
$PM_{2,5}$	µg/Nm^3	119,8	65,9	42,3	28,5	21,1	*	21,0	*	*	*	*
SO_2	µg/Nm^3	209,4	117,1	78,7	59,3	26,9	26,0	21,0	33,3	32,9	53,4	73,7
NO_2	µg/Nm^3	47,9	38,9	29,1	24,1	20,5	16,3	32,4	15,3	20,9	23,6	34,1
CO	µg/Nm^3	*	1266	1006	801	855	827	374	1015	1263	2040	2092
O_3	µg/Nm^3	8,1	20,2	12,8	15,6	21,0	32,4	*	46,3	37,2	15,3	12,9

**Analyzer not functional because of technical issues*

Table 4. Average monthly values in 2016

Pollutant	Measuring unit	Average 2016.										
		Jan	Feb	Mar	Apr	May	Jun e	July	Aug	Sep	Okt	Nov
$PM_{2,5}$	µg/Nm^3	137,3	82,0	42,8	26,3	15,7	17,7	15,0	17,0	16,5	41,2	67,6
SO_2	µg/Nm^3	229,4	139,9	69,7	41,6	19,1	31,1	29,2	23,9	23,3	46,2	70,9
NO_2	µg/Nm^3	53,1	44,9	30,0	21,2	14,0	12,8	13,4	18,3	17,2	25,0	34,5
CO	µg/Nm^3	3119	2368	1000	*	568	634	748	962	1183	1828	1954
O_3	µg/Nm^3	14,0	11,9	17,4	20,4	28,6	45,4	54,6	56,9	36,3	20,2	8,0

***Analyzer not functional because of technical issues*

By descriptive analysis, higher levels of harmful particles were observed during winter 2016 than in 2015. The greatest number of patients with COPD were treated during I,II,III,X,XI and XII month. Significantly higher levels of harmful particles and gases above allowed levels may have important role in occurrence of acute COPD exacerbations. According to statistical data of Ministry of urban development and environment of Tuzla Canton, Tuzla was, during December 2016, the most polluted town in Europe and the second most polluted town in the World. According to WHO guidelines SO2 daily levels are 50 µg/m^3 and should not be exceeded more than 35 days/year. However, in period January – October. 2016 upper limit level was exceeded during 600 hours. At one measuring station in the center of Tuzla in 2016 only, more than 700 hours the air was excessively polluted. Law allows only 24 hours of upper limit exceeding.

3. Conclusion

air pollution of everyday and occupational environment is significant etiology factor in development of COPD in Tuzla Canton. By evading exposition to harmful particles and gases, frequency of exacerbations, one of the main cause of death in COPD, especially during winter would decrease.

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Management of modern school and information technology

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Abstract

Starting from the fact that the education reform has been continually talked about over the past several years, a complete change of teaching system as well as school management is needed. School management was predominantly imposed, chiefly, and the organization of school work was made more difficult, as was the case of traditionalism in the teaching itself. Hence, there is an idea for the needs of reform in all forms of education, both in teaching and in the organization, management and management of educational work and the entire school system. Schools should be equipped with information technologies that would represent a revolutionary change in the organization, but also in the teaching process.

The aim of the research is the fact that the new organization of the school function with the application of new technologies, certainly improves the quality of education.

The survey covered a sample of 34 respondents in 12 primary schools from the Republic of Srpska, Brcko District, Federation of Bosnia and Herzegovina. Respondents were from management, directors, pedagogues and psychologists. Data collection was carried out through a survey questionnaire, using a survey questionnaire created for the purpose of this research, as a data carrier, with a total of seventeen questions.

We were tasked with examining attitudes and opinions of directors on the equipment of schools in information technologies, and examining their opinions and attitudes about the possibilities of new organization of school work using modern methods and technologies. A great significance can be found in expanding knowledge in the field of application of ICT in teaching and knowledge in the field of school pedagogy and management, based on which we will get a better and more efficient teaching, better and more efficient organization of school work, and also improve school performance as educational institutions.

Key words: School, Management, Teaching, Reform, Internet, Information Technology.

1. Introduction

When we look around we see changes that take place in all spheres of human life. As a man lives and works, he expects new investments every day, a belief in a better tomorrow. It is known that a man learns while he is alive. In accordance with the time in which we live, continuous improvement is needed in all fields of human activity. The current issue of today is the so-called. a contemporary school, that is, a school of the 21st century, and also management of that school, that is, school management. We believe that it is not easy to implement these functions in a better and more efficient way. Accordingly, school directors and professional staff must be specially prepared and trained for this job. They must have developed certain competencies that this job requires, as well as the ability to accept changes, as well as the ability and the will to realize them. They must be able to get as close contact as possible with their employees, teachers, auxiliary workers, administrative staff, and parents and students. Competencies are acquired already in the basic study, but they are occasionally lost if they are not replenished and upgraded. We need continuous training of professional people, searching on the Internet where great and fast information is available. Good knowledge of information technologies will certainly facilitate and improve how the entire school system continues, as well as school management. School management is a very difficult and complex job. Each organization requires that it develops and progresses. Our school today is able to progress more and more, we only need people who want to change and take risks. Directors must strive for good preparation, planning and realization of certain goals of the school, with the goal of better results and satisfaction of all participants of this organization.

2. School management

Management is a process that achieves the goals of a particular organization using available resources. These resources can be called input, while achieving certain goals of the output of that process. Managers oversee the entire process of the organization and try to optimize it. The success of managers is often measured by the relationship between resources and achievement of certain goals [1]. When it comes to school management, there are definitely uncertainties about that term. Education management can be spoken in a wider sense, such as management and management in the entire educational activity (education management), in the narrow sense, as about leadership and leadership in the school, as well as about the work (leadership) of the leaders of educational institutions (school management). When talking about the entire field of expertise we use the sintagme management in education, or school management. This includes management in the whole of education and education. Therefore, management in education can be defined as the coordination of human, physical and financial potentials in the field of education and education in order to achieve the goals set by the state, local and school educational policies, system legislation, and the concepts and projections of educational development. This concept includes the management of the entire education activity, the management of educational institutions, the management of educational and other staff in educational institutions, internal development, and the organization of the work process in the school [2]. In the process of planning work in education, common divisions include time criterion. In most cases, different designation names are divided into two dimensions: strategic planning (over a period of more than one year) and operational planning that involves the definition of specific activities to be undertaken in achieving strategic goals for a period of one year, month, week or day, which enables a positive effect on the creation of a good school climate [3].

One school organization has to plan its development path. Good strategic planning will certainly contribute to a better organization of work, as well as better results of the school as an institution. Goals must be clearly defined in order to lead to the realization of the same. The school development plan should be used by a team of trained people who will give their suggestions and aspire to achieve them.

In Stanojlovic (2010), among other things, we can see and connect that there are rare cases that schools are developing plans or development strategies that are related to a longer period (long-term and medium-term development plan). Creating an annual school program can not be classified into strategic planning, despite the great similarity in approach. The strategic planning process involves several activities: defining objectives, analyzing the situation, defining a mission and a vision. [4]

Managers, in our case, school directors must be able to make the right decision and take the initiative. The decision is the choice that an individual or group makes between two or more alternatives. Decisions are diverse and are brought on a permanent basis, and decision making is a systematic process. The decision-making process consists of three phases: research, modeling and selection. School principals, as well as the entire professional service, need IT support (information technology). The general well-known fact is that decisions are made under the pressure of short deadlines. The key to good decision making is to explore and compare many relevant alternatives. The more alternatives exist, it will be more necessary to research and compare with a computer. School managers must be trained in the management of information technology, they should be primarily computer literate. The director is the one who must be able to solve all these problems in the best possible way. In this regard, in the further work we will just say something about the necessary competencies of the director of the school of the XXI century.

Competencies of the school principal and his professional associates for the success of school work

It should be emphasized that the following competences are of particular importance:

- The ability to make a decision
- Has good relationships with peers and adults
- Literate and successful in communication

- Adjustable
- Adventurer and Voljan try out new things
- Cooperates as part of the team
- Has a sense of responsibility and discipline
- Morally and spiritually conscious
- Prepared for the challenges that society offers
- Tolerant and overcoming stereotypes [3]

It should be noted that the school should strive for better business and success. It is necessary for the school to have the following:

- Special social interest
- Necessary material conditions
- Good teaching staff
- Adapting basic goals to social needs
- Connecting the school to life
- Work based on the results of pedagogical research.
- Permanently raising quality
- Increased assistance by PPZs and other authorities in solving the problem [3].

The problem of some of our schools is still unwillingness to the changes that are necessary. Some teachers and directors are still not ready for change, so they are in the process of doing so. In order for the school to be successful, that is, the school of the 21st century, the one that needs a contemporary student must be approached to modernize both its management functions, as well as the functions of teaching and teaching process, and strive for better cooperation and good relations with the wider community, with students.

3. Information technologies

Innovative computers enter the information society in a modern society, because the traditional methods and tools of work have been significantly changed by the use of computers in many areas of human labor. These changes required the definition of a new term called information technology. The term technology is derived from the Greek words teachné-skill and the logos-power of thinking, or reasoning. There are different definitions for information technologies such as:

Information technologies include the organization, procedures, and resources used in the "processing" of information.

Information technologies include methods and tools used in the collection, transfer, processing, storage and display of dana [5].

Multimedia offers great benefits in classical classroom. Computer speed is measured by millions of instructions per second, and allows us to get a real idea about the concept of speed in the context of information technology [6]. Multimedia also provides distance learning, which is very much needed today. Teachers who are not trained enough to use multimedia on lessons can be consulted by distance learning with older experienced colleagues, where they can receive instructions for a specific problem via e-mail [7].

The Internet is a new and unique medium. Its basic characteristic is that it is a global computer network that connects about a million computer networks in more than two hundred countries of the world, including Antarctica. Networked computer systems, referred to as nodes, include personal computers, local area networks, databases, and mainframe computers. With it, teachers and other staff exchange data, messages and documents. Thanks to him, the geographical location of the participants in the communication becomes a negligible factor. [6] Distance learning versus the traditional way of teaching brings with it a number of advantages, but also some disadvantages. Among the first frontiers, first of all, are economic factors, since such learning enables students to have a simple 24-hour access to the information they want. Then they give them the opportunity to study subjects independently of space and time [8].

First of all, directors, pedagogues and professional associates must be able to work and work in the school using information technologies, which relates exactly to their stated competencies, readiness to change and take risks, and flexibility and perseverance in work and progress.

3.1. Electronic (ON-LINE) learning

On-line, or Electronic Learning is a learning experience that is especially topical today and in any case useful. Various definitions of electronic learning are used. Electronic learning has been and has been in operation for more than a decade as a learning experience facilitated and enhanced by the use of information and communication technology. Such devices at this technological moment include a computer with additional devices, digital television, portable and pocket computers and mobile phones. Communication enables the use of the Internet, e-mail, discussion groups, and collaborative learning systems [9]. Using modern information technologies, new learning approaches are created, such as non-linear approach, learning requiring the skills of finding, processing and organizing information, etc., and we also get a better organization of the school's work as an institution. Using different information technologies can provide different school activities (the same) .

To conclude, the school of the 21st century requires a drastic change in its organization. School management must be ready to work on changes, and apply it and develop it in terms of everyday suggestions and new searches on how to improve school work. With the use of information technology, schools will improve their development, and encourage others to do likewise.

4. Methodology

Research was carried out in 12 primary schools from the following areas: Brcko District, Republic of Srpska, Republic of Croatia, and FBiH. The survey included a sample of 34 respondents. Respondents were from management, directors, pedagogues and psychologists. The method of data collection was a test method, using a survey questionnaire as a data carrier. Examining the acceptance of the knowledge of others and the statement of them as a valid basis of collective knowledge. The technique was a survey, which implied systematic, relative short-term and cost-effectiveness [10]. The instrument used for this research was a questionnaire.

The research tasks concerned the following:

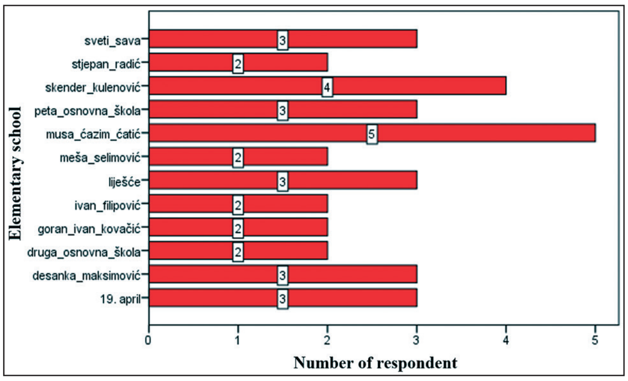
1. Examine attitudes and opinions of teachers about the equipment of schools in information technologies.
2. Examine directors and associates about the possibilities of a new organization of school work using modern methods and technologies.

Here we set out the tasks that point to the necessity of introducing IT into the work of the school as a whole organization, both in the teaching process, as well as in the management of the school, and the change in the field of school management of the XXI century. Directors must be ready for change, and enable continuous advancement to both teachers and students.

5. Results

On the basis of research objectives, these tasks were carried out by survey of school management.

The following results were obtained on questions about the modernity and equipment of the school, the use of IT and their influence on the reorganization of the school:



Graph 1. Representation of school management respondents

Table 1. Modernity, school equipment, use of IT and their influence on the reorganization of the school

Claims	No		yes	
	N	%	N	%
1. Is your school equipped with media?	20	58.8	14	41.2
2. Are you using information technology in your school?	4	11.8	30	88.2
3. Is your school contemporary?	8	23.5	26	76.5
4. Does information technology influence the reorganization, ie reengineering school?	8	23.5	26	76.5
5. Are the acquired knowledge in information technology applicable in practice?	2	5.9	32	94.1

Table 2. How much would it be useful to hold sessions of expert bodies electronically?

Answer	Number	%
Not enough	8	23.5
Sufficient	7	20.6
Medium	12	35.3
very good	7	20.6
Excellent	-	-

When asked how useful it would be to hold sessions of expert bodies electronically, the highest number of responses was a rating of a total of 12 respondents, or (35.3%).

Table 3. How much would the holding of sessions by electronic means influence the better organization of school work and its efficiency and economy?

Answer	Number	%
Not enough	6	17.6
Sufficient	9	26.5
Medium	13	38.2
very good	6	17.6
Excellent	-	-

Asked how much the electronic session attendance would have helped to better organize the work of the school and its efficiency and cost-effectiveness, we received the highest number of answers, a total of 13 respondents, or 38.2%, respectively, a mid-term rating.

Table 4. How useful would it be to hold working meetings electronically?

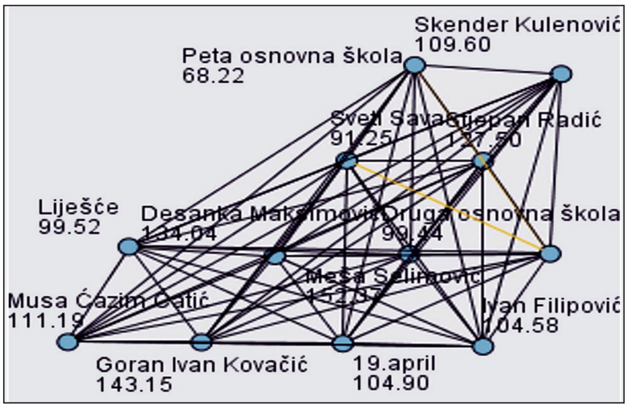
Answer	Number	%
Not enough	5	14.7
Sufficient	5	14.7
Medium	12	35.3
very good	10	29.4
Excellent	2	5.9

The results show that 14 respondents or 41.2% advocate for giving information to parents electronically.

Table 5. How satisfied are you with the use of information technology in your school?

Answer	Number	%
Not enough	-	
Sufficient	7	20.6
Medium	18	52.9
very good	8	23.5
Excellent	1	2.9

Respondents show satisfaction with the use of information technologies at the middle level, namely 18 or 52.9% respectively.



Graph 2. Multiple comparisons (black line - no significance, yellow line - significant difference) schools on the question: How much use of information technologies and the Internet affects the quality of your school's work as an educational institution?

6. Conclusions

Schools need the use of IT, if teachers, students, directors and even parents want to follow today's way of life and education, or to be ready for lifelong learning. Directors are also ready to make changes to the current mode of operation. It is widely known that schools must be prepared for transformation with the help of people who lead them. Directors must have clearly set goals, which they will achieve in the near future. The results clearly indicate that schools are equipped with information technology, and that they are used in the workplace. Then the results of the research also show that information technology contributes to better public activity of the school, and that knowledge in information technologies is practical in practice. Directors and their professional associates declare that maintaining the sessions by electronic means will influence the better organization of school work and its efficiency and economy, which was one of the goals set and proposed. A very important result is the idea and opinion of school management that using information technology can improve the work of the school as an educational institution in all fields. It is still necessary to emphasize that tolerance and cooperation are needed at a higher level, where teachers, together with directors, students and parents, will create and follow an innovative school, a 21st century school that will enable easier and faster development and a safer life in the future. We will still note that everything around us is progressing, and in this regard, we are all forced to learn throughout our life.

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Numerical analysis of the sludge height influence on the efficiency of coal particle separation

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Abstract

Proper operation of the settling basin work require the accurate prediction of flow and sediment deposition patterns. The aim of the present paper is to study the influence of the basin geometry on the flow patterns, by means of numerical modelling of the flow behaviour. Different geometries were considered (characterized by different depth of the basin), but with fixed inflow discharge. In spite of the symmetric setup, leading to symmetric hydraulic and geometrical conditions, the numerical experiment generally produced an asymmetric flow pattern that can easily switch sides depending on the initial and boundary conditions. The numerical simulations revealed that the observed asymmetry in flow patterns can be explained by the high sensitivity of the flow with respect to initial and boundary conditions. These numerical simulations succeed in predicting the influence of the depth of the basin on the flow pattern.

Key words: numerical simulation, coal particle, fluid flow, settling basin

1. Introduction

In the technological water of the separation plant RMU Đurđevik there are significant quantities of coal particles. From the commercial (small coal from technological water, after natural drying and elimination of rough humidity can be used as high calorific fuel) and for environmental reasons (preventing waterborne pollution), the aim is to improve the degree of separation of coal particles from waste water.

The procedure is carried out by deposition in the settling basin of the separation plant. O. Jukić [1] presents the calculation of the waste water flow in the separation process in the settling basin. Since the CFD analysis has been used for predicting the fluid flow distribution in a large number of applications, many researchers have shown interest in this topic. Dufresne et al. [2] [3], used the numerical model to simulate the symmetric and asymmetric flows that can take place in rectangular shallow basins. The effect of turbulence on the mean flow was modeled using k-ε model. This turbulence model is based on the work by Erpicum [4] and Erpicum et al. [5]. Commercial CFD codes were used by several authors, such as Adamsson et al. [6], for the study of sedimentation in storage tanks, or Kantoush et al. [7] and Dewals et al. [8] for the analysis of shallow basins.

1.1 Design settling basin

The basic principle of an ideal basin is shown on the Figure 1. Following assumptions are made for an ideal horizontal settling basin;

– the flow is steady and
– solids entering in deposition zone are not resuspended.

Figure 1 shows a definition sketch of an ideal basin. To determine the length 'L' and width 'B' of the basin, consider a particle entering the basin at point A.

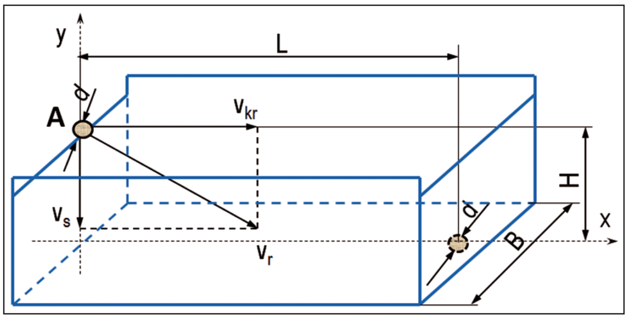

Figure 1. Representation princip of the settling basin

The settling velocity of coal particles in water is calculated according to the Stokes law of water partitioning approved by expression:

$$v_{st} = \frac{d^2 \cdot g(\rho_{coal} - \rho_w)}{18 \cdot \mu}$$

where d (m), g (m/s^2), ρ_{coal} (kg/m^3), ρ_w (kg/m^3), μ (Pas) denote the particle diameter of coal, the acceleration due to gravity, the density of coal, the density of water and dynamic viscosity coefficient, respectively.

Table 1. Granulometric composition of naturally dried coal [1]

	Granulation [mm]	Weight [g]	Participation [%]
Model No.1	2,000 – 3,000	391,38	45,84
	1,000 – 2,000	28,41	3,33
	1,000 – 0,710	54,00	6,33
	0,710 – 0,500	77,65	9,10
	0,500 – 0,250	132,52	15,52
	0,250 – 0,125	116,51	13,65
	0,125 – 0,075	39,79	4,66
	- 0,075	13,50	1,58
	TOTAL:	**853,76**	**100,00**
Model No.2	2,000 – 3,000	99,75	14,25
	1,000 – 2,000	29,15	4,16
	1,000 – 0,710	72,06	10,30
	0,710 – 0,500	103,97	14,85
	0,500 – 0,250	168,91	24,13
	0,250 – 0,125	119,59	17,08
	0,125 – 0,075	63,82	9,12
	- 0,075	42,74	6,11
	TOTAL:	**699,99**	**100,00**

Critical settling velocity is the settling velocity of particles which are 100% removed in the basin. The motion of the particles is influenced by the settling velocity and the horizontal velocity of the fluid movement. The latter carries a particle and prolongs deposition in relation to deposition without movement. The critical velocity of fluid motion in the settling basin is calculated from:

$$v_{kr} = \frac{L \cdot v_{st}}{H}$$

where L (m), v_{st} (m/s) and H (m) denote the length of basinr, the settling velocity and depth of basin, respectively. Due to the different particle dimensions, their settling velocities are different. An analysis of the granulometric composition of naturally dried coal samples from the sedimentary waste water basin was performed. The results of the analysis are shown in Table 1.

2. Methodology

Good approximation of the real process with numerical model is done, when we have set up good mathematical model and when we have done good spatial discretization. Such numerical model gives us reliable results that can be easily validated. The basic things about selected mathematical model, boundary conditions, and spatial discretization will be presented below.

2.1 Basic mathematical equations

The governing equations of general fluid dynamics are NSE. For the isothermal, incompressible single Newtonian fluid, the NSE can be written as:

$$\nabla \cdot \mathrm{u} = 0 \quad (1)$$

$$\frac{\partial \rho \mathrm{u}}{\partial t} + (\rho \mathrm{u} \cdot \nabla) \cdot \mathrm{u} - \nabla(\mu \nabla \mathrm{u}) = -\nabla P \quad (2)$$

where ρ(kg/m^3), u (m/s), P (Pa), μ (Pa · s) and t (s) denote the density of a fluid, the velocity vector, the pressure, the viscosity coefficient and time, respectively. The two equations are mass conservation equation and momentum conservation equation respectively.

2.2 Spatial discretization

One of the main factors that has influence on quality of the obtained results is spatial discretization. In this case, spatial discretization has been done by using polyhedral mesh, while, for representation of results, several suitable plains have been chosen, which can be seen in the Figure 2.

2.3 Numerical methods and boundary conditions

To determine the fluid flow distribution inside the settling basin, the governing equations were solved numerically using the CFD code, Star CCM. This CFD code uses the finite volume method (FVM) uses a volume integral formulation of the problem with a finite partitioning set of volumes to discretize the partial differential equations.

Of course, essential step in conducting the numerical simulation is proper defining of the initial and boundary conditions. Therefore, while defining boundary conditions, the specific features of the process were taken into account. For that purpose, three regional boundaries were defined:

- Fluid inlet (the boundary where inlet velocity and temperature are set up);
- Fluid outlet (the boundary where fluid leaves the domain);
- Wall (the boundary where the value of thermal flux is defined if exists).

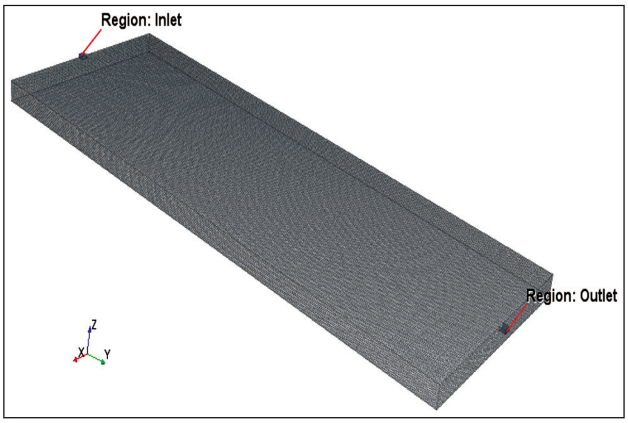

Figure 2. Numerical mesh of the model with defined boundaries

On the basis of the data obtained from the fluid flow calculation, the following starting conditions have been defined.

Table 2. Initial data for the numerical simulation

Size	Value	Dimension
Flow in reservoar	14,6	m^3/h
Temperature of the water	20,0	°C
Environmental temperature	20,0	°C
Basin length	90,0	m
Basin widht	30,0	m
Minimal depth	1,5	m
Maximal depth	3,0	m

3. Results and discussion

Simulation of the operation of the settling basin facility with variable depth of the settling basin was performed. The aim is to determine the influence of the settling layer on the settling efficiency. The primary aim of numerical simulation is to determine the nature of the flow in the cross-section of the settling facility to determine the effect of depth on the settling efficiency.

The simulation results for all models are shown in Figure 3. An analysis of the simulation data shows that reducing the depth of the settling basin affects the increase in water velocity in the settling basin.

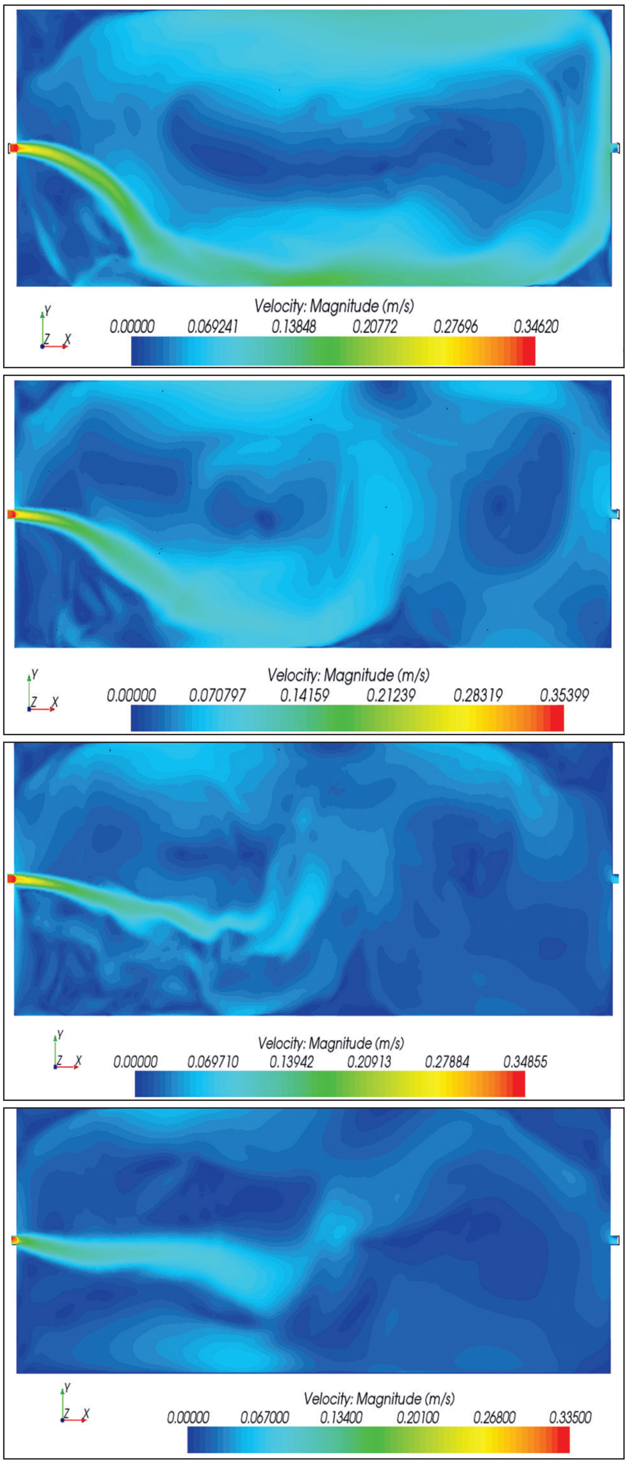

Figure 3. Distribution of velocity in the cross-section of the model in scalar form a) H=1,5 m, b) H=2 m, c)H=2,5 m d) H=3

In the same Figure 3, zones with expressed eddies of fluid flow can be extracted. Eddy represents dissipation of energy which is desirable in termsof loss of the flow kinetic energy and enhanced deposition of particles. However, due to the nature of turbulent current, the main fluid flow is created, which carries a certain part of the particles and thereby reducing the efficiency of the deposition.

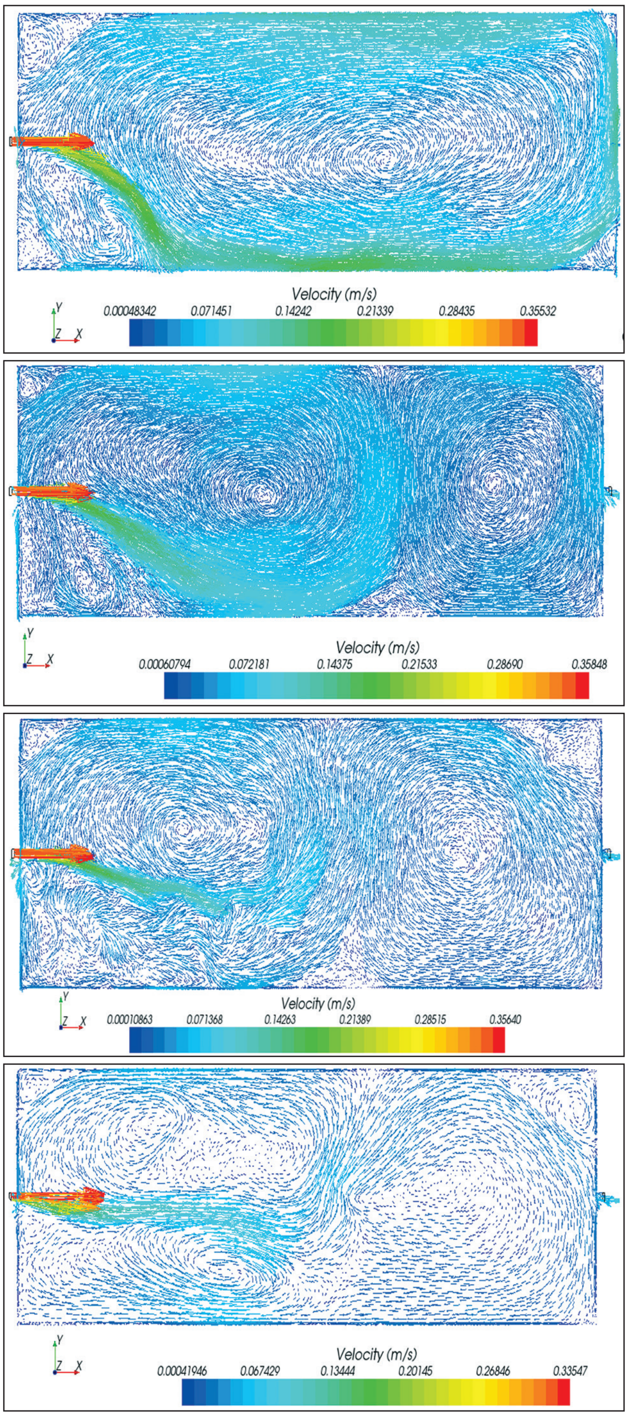

Figure 4. Distribution of velocity in the cross-section of the model in vector form a) H=1,5 m b) H=2 m c)H=2,5 m d) H=3 m

During certain period deposition decreases the depth of the settling basin. Reduction of depth increases the flow velocity and descreases the coal particles deposition in the settling basin.

Velocity distribution at the basin with the greater depth shows a smaller number of eddies in the settling basin compared to a lower depth. With a settling basin with maximum depth, it can be noticed that the flow velocity is low and that there is no expressed swirling. This case shows good efficiency of the settling basin.

The vector velocity distribution is shown in Figure 4. In this figure, in cases with lower depth, eddies in the settling basin are more expressed. Due to the uneven eddy distribution, the coal particles deposition is also uneven. This causes the reduction of the settling depth in certain places faster than others. It is possible to create a major flow of fluid at a higher velocity carrying coal particles. In this way, the efficiency and non-ecological operating of the settling basin facility is reduced.

In order to determine the efficiency of coal particles deposition in the basin, it is necessary in those cases to extract the mean velocity values in the function from the increasing of the settling layer (Figure 5).

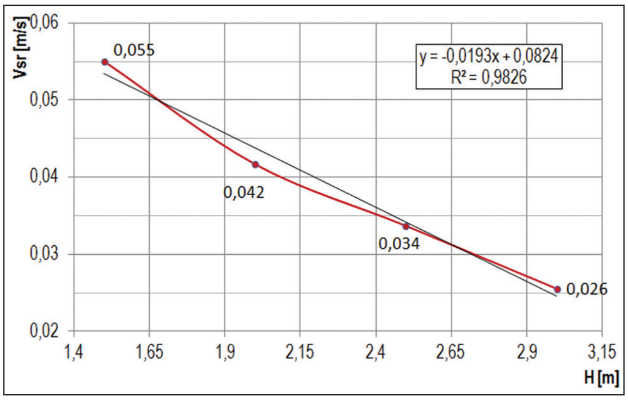

Figure 5. Average velocities in the settling basin

According to the data from Table 1 for granulometric composition of naturally dried coal from the settling basin, a diagram 6. was created for settling velocity in function of the coal particle diameter.

According to the calculated settling velocities for the particle diameters being in the composition of coal in the settling basin, critical velocity of fluid flow in the specified settling zone will be determined. According to the critical velocity of the fluids obtained for each coal particle diameter, the settling zone efficiency can be determined, or the settling basin. The values of the critical velocities for different coal particles are shown in diagram 7.

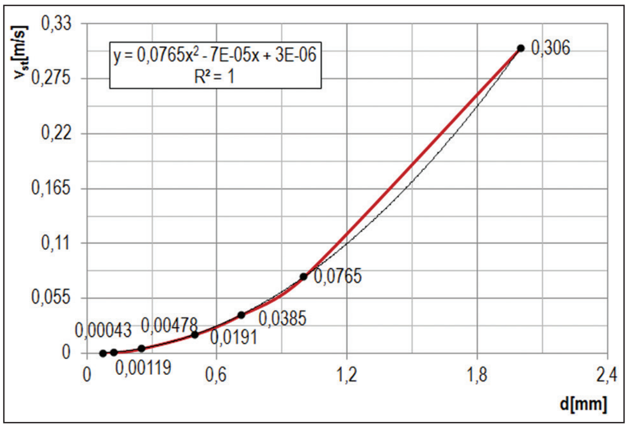

Figure 6. Settling velocity in the function of coal particle diameter

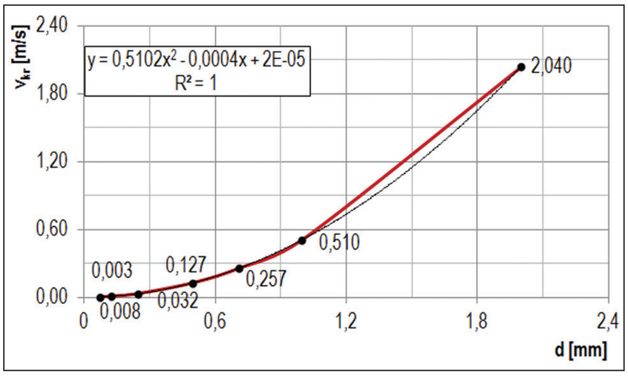

Figure 7. Critical velocities of fluid flow in relation to the size of the coal particle

When determining the efficiency of the settling basin, it is determined how much coal particles have a higher velocity in the first 30 meters of the basin from the critical velocity in the settling basin.

The particles pass into the next settling zone at a higher velocity, while the particles with lower velocities settle down from the fluid flow in the first basin zone. By repeating the previous step for the next two settling zones, the amount of particles leaving the basin is reached. This determines the efficiency of each zone separately, and then the overall efficiency of the basin. The velocity profiles in the characteristic zones of the settling basin are shown in Figure 8, and the mean velocity values in these zones in Table 3.

The following diagrams show the velocity profiles at the exit from the characteristic zones for different basin depths, which have been previously described.

In the previous part of the paper, the results of the performed simulation in the form of velocity distribution in the characteristic cross-section have been shown. The average velocity for all basin models is given in the table 3.

Table 3. The average velocity

Depth	Velocities [m/s]		
H [m]	Zone I	Zone II	Zone III
3,0	0,03365	0,01913	0,01598
2,5	0,05048	0,02295	0,02397
2,0	0,04038	0,02869	0,01917
1,5	0,06731	0,03826	0,03196

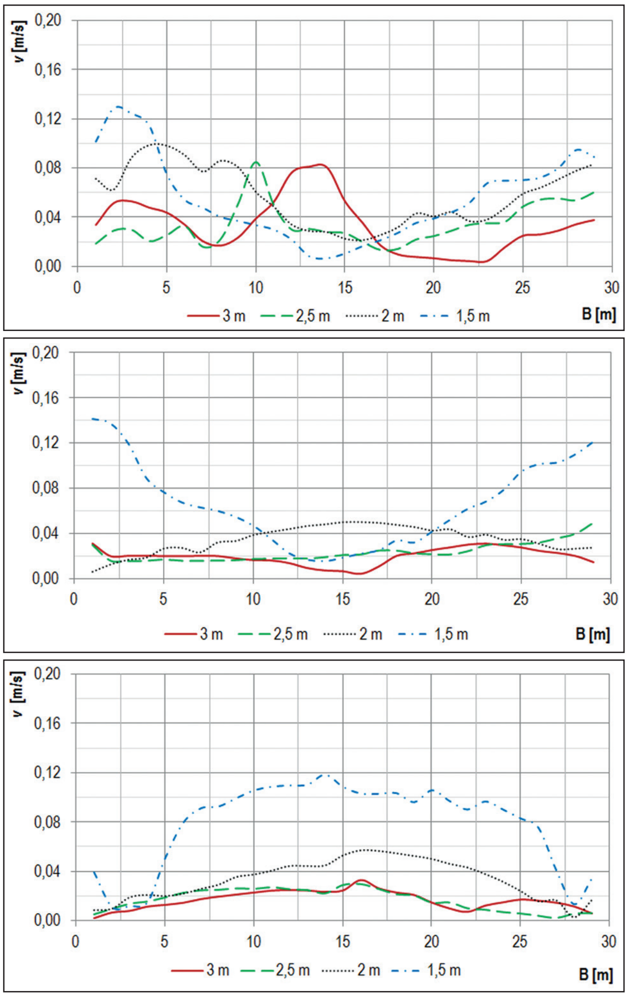

*Figure 8. Diagram of fluid velocity at the exit of the settling zone **I, II** and **III** with different depths*

It can be seen from the diagram 8 that the depth has an impact on the velocity of the fluid flow in the settling basin. Consequently, the efficiency of the coal particles deposition is also affected. On the basis of all the above, the efficiency value of the coal particles deposition in the settling basin of the coal separation plant RMU Đurđevik depending on the height of the deposited particles in the settling basin. This is shown in Figure 9. The efficiency is calculated on the basis of granulometric samples having different composition of coal particles.

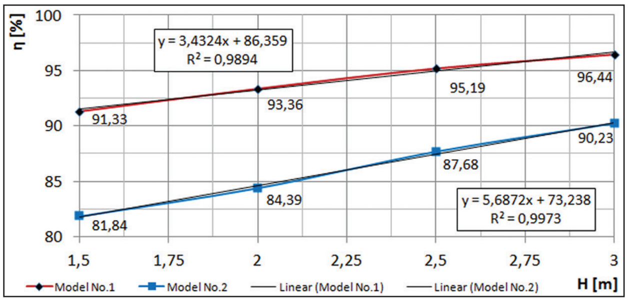

Figure 9. Efficiency of coal particles deposition depending on the basin depth

According to the diagram in Figure 9 for sample number 1 efficiency has functional efficiency dependence from the depth of the settling basin in the following form:

$$efficiency\,[\%] = 3{,}4214 \cdot H + 86{,}359$$

While the efficiency on the basis of sample 2 has functional efficiency in the following form:

$$efficiency\,[\%] = 5{,}6872 \cdot H + 73{,}238$$

where:
H - is the depth of the settling zone [m].

4. Conclusion

Given that the settling basin of the separation plant RMU "Đurđevik" has dimensions that exceed the recommended by the given literature examination, it was necessary to analyze its operating. A numerical simulation of the flow in the settling basin was conducted, which showed that the settling basin has an uneven deposition of coal particles. In this paper, it was shown that by reducing the depth of the basin, the settling efficiency decreases according to the increase in the flow velocity in the cross section of the settling basin. If we keep in mind meeting ecological criteria, virtual simulations are imposed as a cheap test tool. The performed procedure for analyzing the settling basin is a step closer to satisfying the ecological standards that await us in the future. By constant monitoring of the ground level of the deposited layer of coal particles, the final moment can be determined when the loss of undeposited coal causes both economic and ecological damage by discharging from the settling basin. In practice, it is clearly necessary to count on reducing the effect of deposition and the interaction of particles and flows in the settling zone caused by various influences (flow due to the difference in density, blowing of the wind through uncovered basins, etc.).

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