Data visualization tools applied to the analysis of school dropout at higher-level institution

Herramientas de visualización de datos aplicadas al análisis de la deserción escolar en una institución de nivel superior

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Abstract

School dropout at a higher level is a problem that afflicts all higher education institutions in all countries of the world, in Mexico, and in particular in the state of Oaxaca. At the present work, data visualization tools are applied to analyze a data set of students who dropped out of the Computer Systems Engineering career at TecNM/I.T. of Oaxaca, with the objective of finding the relationship that the variables of such a data set have. To achieve this, the data analysis methodology proposed by Google is applied, as well as the Tableau and Orange tools for visualizing trends, relationships between variables, etc. of the data set. This research contributes to the instances that make decisions about the strategies to follow to prevent school dropout to some extent. In the same way, it also contributes as a guide for the application of the tools that exist under a free and not free license to carry out similar analyses, so that those interested can start their own analyses.

Resumen

La deserción escolar a nivel superior, es un problema que aqueja a todas las instituciones de educación superior de todos los países del mundo, de México, y en particular del estado de Oaxaca. En el presente trabajo se aplican herramientas de visualización de datos para analizar un conjunto de datos de estudiantes desertores de la carrera de Ingeniería en Sistemas Computacionales del TecNM/I.T. de Oaxaca, con el objetivo de encontrar la relación que tienen las variables de tal conjunto de datos. Para ello se aplica la metodología de análisis de datos que propone Google, así como las herramientas Tableau y Orange para la visualización de las tendencias, las relaciones entre variables, etc. del conjunto de datos. Con la presente investigación se contribuye con las instancias que toman las decisiones sobre las estrategias a seguir para prevenir en cierta medida la deserción escolar. Del mismo modo, también contribuye como una guía para la aplicación de las herramientas que existen de licencia libre y con licencia para la realización de análisis similares, para que los interesados puedan iniciar sus propios análisis.

Analysis, Visualization, University dropout

Análisis, Visualización, Deserción universitaria

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Introduction

In different countries around the world, school dropout at all educational levels is a constant concern, since, by Law, education is a right that must be guaranteed to citizens. It is known through different reports from international organizations such as UNESCO, the United Nations, among others, that the percentage of citizens who access education decreases as the educational level increases. According to the report of the National Institute for the Evaluation of Education (2019), in Mexico, at the beginning of the 2016-2017 school year, the school dropout rate was 5.3% in secondary education and reached 15.2% in medium superior education.

An important finding in this report is that, in general, men drop out more than women do. On the other hand, the INEGI (2022) reports a dropout of 8.8% at the national level, at the higher level in the 2020/2021 school year, which includes a degree in Teacher's College, University and Technological Education, and excludes Postgraduate Studies.

While in the state of Oaxaca, specifically in that same school year it presents 12.2% above the national average.

The state of Oaxaca has been classified by INEGI as one of the most lagging states in terms of education at the national level, and although it currently has 103 higher education institutions (HEIs), according to COEPES (2020), the Student retention rate at this level remains low.

Kuz and Morales (2023) state that dropout, retention and attraction of students are key indicators, forming part of the sustainability of educational institutions through an approach based on data analysis decision making. This idea reinforces the present research; since it precisely seeks that, the results support decision-making through student retention strategies. Therefore, for the Oaxaca's Technological Institute, which is one of the eleven higher education schools of the Mexico's National Technological subsystem that exist in the state, it also represents a latent problem, because, statistically it has a worrying school dropout rate, specifically in the Computer Systems Engineering career.

Only in the August-December 2022 School period, according to the Mindbox Information System (2023), there was a dropout rate of 10.35% compared to the previous period, February-June 2022.

The dropout of university students, according to Zimányi et al (2022), is a problem that persists in Higher Education Institutions (HEIs), affecting the terminal efficiency and the graduation rate of educational programs. Indicators that every HEI uses to measure the achievement of institutional goals. According to SEP (2022), school dropout is defined as "school dropout," which is the number of students who leave school in the school year, for every 100 students who enrolled at the beginning of courses at that same educational level. That is, it interprets it as a percentage of the total number of students who started the school period. In the case addressed in this work, the school period is defined by semester.

The objective of this work is to analyze the school dropout data from the years 2020 to 2023 of the Computer Systems Engineering degree offered at the Mexico's National Technological /Oaxaca's Technological Institute, and visualize the relationship between the selected variables with tools such as Tableau or Orange.

To this end, it is important to be clear about what data analysis is. According to Stevens (2023), any company collects data that by itself means nothing; however, with data analysis, significant and actionable information is obtained that subsequently informs and leads to an intelligent decision-making.

Amazon (2023) defines data analytics as the conversion of raw data into actionable insights. With data analysis, you can find trends, solve problems, and thus make institutional or business decisions.

The tools used in the data analysis of this research work are Tableau and Orange. The official Tableau website (2023) defines it as a visual analytics platform that transforms the way data is used to solve problems, allowing people and organizations to get the most out of their data. It is important to note that this tool has a cost, but you can register for free to try it for 14 days and, it offers various products, including desktop and online version.

The second visual tool used for data analysis is Orange, according to Hoyt (2022) it is a free educational data science platform created by computational biologists at the University of Ljubljana, Slovenia. In the background, it uses Python to process the required operations, although users do not need to know programming in said language. Orange is client-based and runs on the most widely used operating systems such as Windows OS, MacOS and Linux.

The results of this investigative work will provide relevant information to take actions in the institution, focused on student retention, in order to make decisions aimed at retaining students in the Computer Systems Engineering career.

The paper consists of nine sections, the introduction, the developed methodology, the development, obtained results, acknowledgments, findings, conclusions, future work and references.

1. Developed methodology

There are different data analysis methodologies; for example, Gautam (2021) shows the six phases of Google data analysis, as seen in Figure 1.
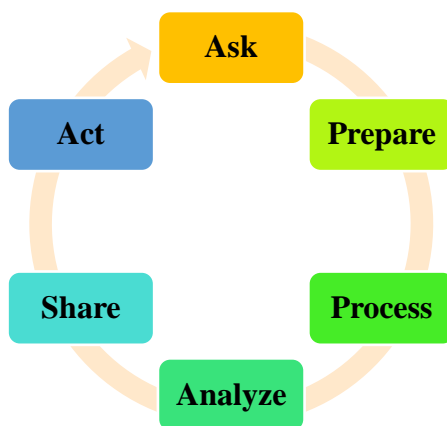

Figure 1 Data analysis phases
Gautman (2021)

On the other hand, BPB Online (2021) considers that data analysis mainly involves six important phases that are carried out in a cycle, as you can see in Figure 2.
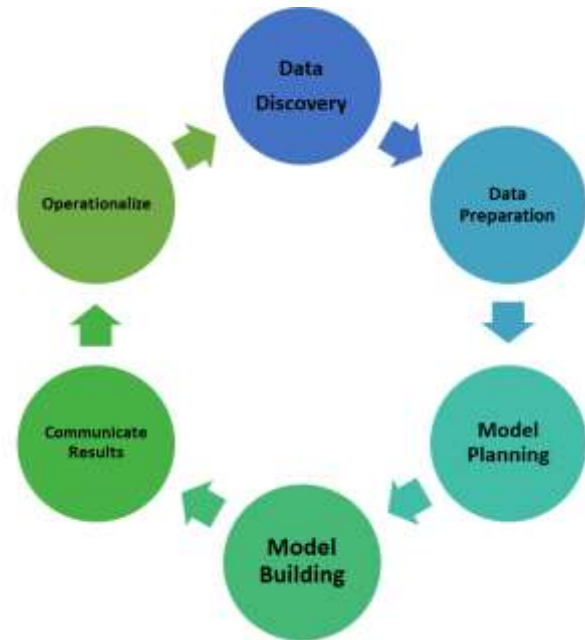

Figure 2 Phases of data analysis
BPB Online (2021)

For his part, Hillier (2023) explores the main steps in the data analysis process, as illustrated in Figure 3, and although it is apparently a linear process, the author emphasizes that it is really an iterative process.

Figure 3 The Data Analysis Process
Hillier (2021)

Each of the methodologies offer similar phases, and the variation between them is minimal, for this reason in this work, the methodology proposed by Google has been taken as a basis, in accordance with the article by Gautam (2021), since it is important for the institution to know the possible causes of dropout and make decisions about it.

2. Development

For this document, the methodology described by Google is used, which phases are listed below:

1. Ask
2. Prepare
3. Process
4. Analize
5. Share
6. Act

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The following sections explain the procedure followed in each phase listed previously.

2.1 Ask

In this first phase, it is about asking the right questions to understand the problem you are trying to solve. For this case, the problem addressed is school dropout from the Computer Systems Engineering (ISC) degree at TecNM/ITOaxaca. The analysis of the data available is carried out to identify the causes that lead the student to abandon their professional studies, in order to deliver a report to the corresponding instances of the institution. And, in turn, an intervention proposal is made to avoid desertion as much as possible.

To do this, the Department of School Services is requested to provide the information it has about students in different school status, specifically from the years 2020 to 2022, that is, three years that correspond to six semesters. It is important to note that this Department is in charge of safeguarding student data; therefore, the data requested does not have the names of people; the records provided contain the columns shown in Table 1.

Column Number	Column Name
1	Control Number
2	Gender
3	Birth Day
5	Career
6	Curriculum
7	State
8	Semester number
9	Campus
10	Internship
11	Specialization
12	Electronic Mail
13	Entry period
14	Aproved credits
15	Credits taken
16	Credits loaded
17	Medical Service Unit
18	Medical Service Key
19	Last period average
20	Certificate average
21	Arithmetic average
22	Personal Phone Number
23	Job Phone Number
24	Last period average

Table 1 Original columns from the database of Computer Systems Engineering students at TecNM/ITOaxaca
Mindbox (2023)

The database contains 3863 records, which are in any of the statuses shown in table 2.

No	Status
1	Active
2	Active with a special course
3	Activo with special courses
4	Permanent dropout, due to internal career validation
5	Permanent dropout for reaching the maximum number of semesters allowed
6	Permanent dropout, due to failed special course
7	Voluntary permanent dropout
8	Graduated

Table 2 Different statuses of Computer Systems Engineering students at TecNM/ITOaxaca
Mindbox (2023)

2.2 Prepare

For the present investigation, in the data preparation phase, the first thing that was carried out was a selection of columns, of the 24 columns that were originally available, only the 10 columns listed in table 3 were selected.

No	Selected Column
1	Control Number
2	Gender
3	Birth Day
4	Status
5	Semester Number
6	Entry period
7	Aproved credits
8	Credits loaded
9	Promedio aritmético
10	Último Periodo Inscrito

Table 3 Selected columns
Mindbox (2023)

2.3 Process

Once we had the database with only ten columns of data from the 3683 records, a filtering process was carried out to obtain only those that matched statuses 4, 5, 6 and 7 of table 2, which were those who represent the students who drop out of the ISC program. When filtering the data, the working group noticed different anomalies in the database, such as null data, repeated data, incomplete data, for this reason, reviews of the data were made in order to get a list of the missing data, again requesting the Department of School Services that will provide a second block of information.

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Likewise, the work team took on the task of filtering the repeated records, using the student's control number, and with this, the database was reduced to 198 records with ten columns of data.

2.4 Analyze

For this phase, two tools were used: Tableu and Orange, which have already been briefly described in previous paragraphs.

Analysis with Tableau

The first aspect that is analyzed is the relationship that exists between the gender of the students and their dropout. When the tool is applied, the first result shows a table like the one illustrated in table 4.

|	Estatus			
Gender	**1**	**2**	**3**	**4**
Female	11	3	18	7
Male	25	14	88	31

Table 4 Dropout students grouped by gender
Own creation with Tableau.

The status is coded as follows:

1. Permanent dropout for reaching the maximum number of semesters allowed
2. Permanent dropout, due to internal career validation
3. Permanent dropout, due to failed special course
4. Voluntary permanent dropout

Table 4 is projected in graph 1, where the same information can be observed, but with greater visual impact.

As can be seen, the information is clarified when visualized graphically.
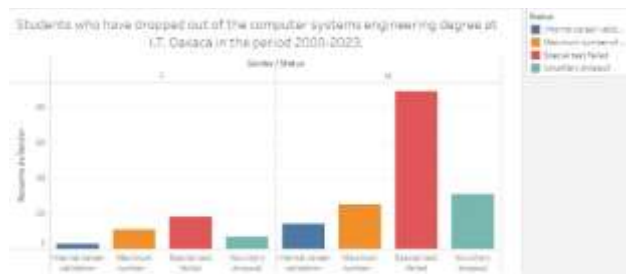
Graph 1 Dropout students grouped by gender
Own creation with Tableau

On the other hand, the number of dropouts per semester completed was also analyzed; graph 2 shows the information obtained.
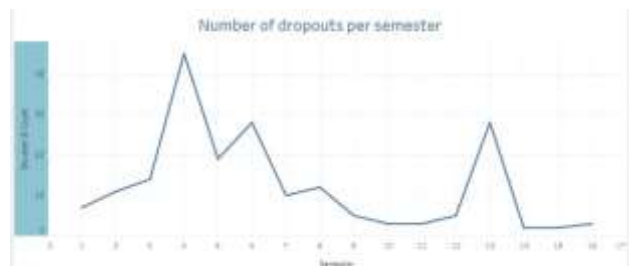

Graph 2 Dropout students per semester
Own Creation with Tableau.

In graph 2, it is noticeable that in the 4th semester the highest dropout occurs with 45 occurrences, in the subsequent semesters it decreases and increases again in the 6th and 13th semester with 28 occurrences. With this information, it is possible to propose strategies that support students to be successful in the subjects they take in those particular semesters.

An analysis is also carried out on how many students dropped out per admission period; the school periods identified are 3 per year.

For example, the first semester of the year is identified as 20201, the summer course that takes place during the month of July is identified as 20202, and the second semester of the year is identified as 20203, there is regularly a new admission only in 3 periods of each year. However, there may be some students, who join from other institutions in the first period of the year (for example, 20201). Therefore, a graph is prepared where it is observed in which period the dropout students entered and how many of them dropped out, as illustrated in graph 3.
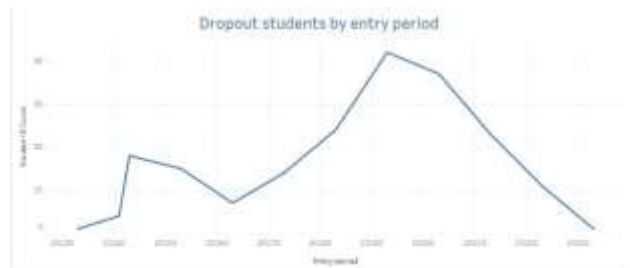
Graph 3 Number of students who dropped out of each admission period
Own creation with Tableau

It can be seen from the graph that the highest number of dropouts in the 3 years analyzed was among students who entered the institution in the August-December 2019 semester, this data may be related to the coronavirus pandemic, since the following semester of their entry, on-site classes were interrupted to continue virtually. During this period, the enrollment of all the careers at the institution decreased significantly.

Analysis with Orange

Using the Orange tool, the possible relationship between the students' arithmetic average and the reason for their dropout (status) was analyzed. The tool uses visual elements called widgets, to find if this relationship exists, different widgets were applied such as: file, data table, select columns, tree and tree viewer, as seen in Figure 4.

Figure 4 Flowchart to contrast the arithmetic average against the reason for dropout
Own creation with Orange.
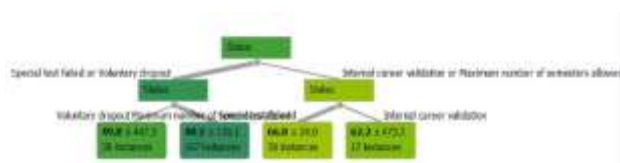
The flowchart visualization is shown in Figure 5.

Figure 5 Number of dropout students due to desertion cause
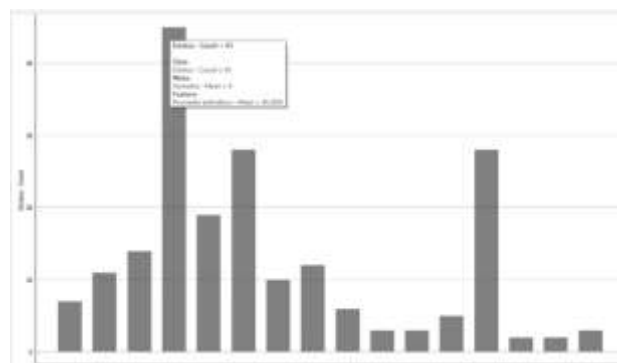*Own Creation with Orange*

It is observed that there are 107 students who permanently dropped out due to failing a special course with an arithmetic average of 40.5 (the minimum passing rate is 70), from which it follows that poor performance leads the student to drop out.

Another analysis that is carried out with Orange is how many students dropped out in each of the semesters, and what average grades they have. For this, the flowchart in Figure 6 is constructed.

Figure 6 Dropout students, for dropout reasons and arithmetic averages
Own Creation with Orange.

The result of processing this flowchart with the dropout database is shown in graph 4.

Graph 4 Number of students per semester completed and with arithmetic average
Own Creation with Orange

In graph 4, three variables are related: the arithmetic average, the status and semester that the dropout student was studying. The information found in Tableau is corroborated, the largest number of students drop out in the 4th semester. And, the group of them, has an average grade of 36, a very low average if it is known that the minimum passing grade is 70, thus putting It is evident that poor academic performance leads to dropout, and this occurs to a greater extent in the first semesters.

2.5 Share

The information obtained from the analyzed data is presented in a report to the Department of School Services of the I.T. of Oaxaca, where there is a student support office for obtaining scholarships.

It is also shared with the Department of Academic Development, who is responsible for proposing institutional strategies to prevent school dropouts. For example, the tutoring program, psychological support, vocational guidance, academic advice, among others.

It is also important to share the findings with the directors of the Institution, both the Academic Subdirector and the Campus Director.

The visualization of the data becomes highly relevant when presenting the information found in the behavior of the school dropout phenomenon, since the graphs more clearly project the dropout trends, the main causes and the probable relationships between the ten variables explored, according to table 3.

Within the information found, it can be observed that there is a relationship between failure and dropout. Since, in the data analyzed, 106 dropouts were found due to failure of a special exam, which implies that the student takes the subject 3 times and does not accredit in none of the 3 opportunities. Which is associated with poor academic performance.

For all of the above, it is important to share with the relevant internal bodies, so that, where appropriate, the best decisions can be made in order to retain the greatest possible number of students, improve the quality of professional education and, consequently, achieve terminal efficiency goals.

2.6 Act

In this phase, the graphs obtained with the data visualization tools will be very useful, since visually they have a greater impact on the people who can make decisions in the institution. In this work, only some of the possibilities of relating the variables of the analyzed data set are presented.

The internal bodies in the institution, with the information found in this research, will be able to propose strategies aimed at reinforcing the permanence of students in the institution before they drop out. And, rethink the strategies that are currently being developed such as the institutional program of tutoring, vocational guidance, change of career, academic advice in subjects with a high failure rate, among others that can be implemented not only for the ISC career but for the 10 careers that are offered at the Institution.

3. Results

The information found as a result of the application of the data analysis methodology proposed by Google, and visualization tools such as Tableau and Orange, is presented in the following paragraphs, where an interpretation is made of each of the graphs of the section "2.3 Analyze".

Table 4 shows how many men and women dropout according to the four statuses found in the data set:

1.   Permanent dropout for reaching the maximum number of semesters allowed
2.   Permanent dropout, due to internal career validation
3.   Permanent dropout, due to failed special course
4.   Voluntary permanent dropout

What is observed in table 4 is that the highest dropout occurred in men due to a failed special exam. And, in general, the trend shows that more men drop out than women, which indicates that there may be an important relationship between gender and possible dropout from the Computer Systems Engineering career.

Graph 1 contains the same information as table 4; however, it has a greater visual impact and the comparison between the dropout rates of men and women can be established very quickly. It follows that men drop out more than women do, the largest number of dropout students is 88 and they are men. While, the lowest number of dropouts is 3 and corresponds to women, the cause being the change of career in the same institution.

Likewise, it is also observed that the cause of the highest dropout has been due to failing special courses, a special course is the third opportunity that the institution gives the student to pass a subject. From the above it can be deduced that failing subjects is a factor that strongly affects student dropout.

Graph 2 shows the number of students who dropped out and in which semester they did so, that is, how advanced they were in the curriculum at the time of dropping out.

According to the data set analyzed, dropout is presented from the first to the 16th semester. Graph 2 indicates that the highest peaks of dropout occur in the 4th semester with 45 occurrences, which indicates that another important factor in dropout is the difficulty represented by the subjects of the first half of the curriculum plan. Other semesters where there are also peaks in dropouts are the 6th and 13th semesters with 28 dropouts.

Dropout approximately in the middle and at the end of the curriculum plan gives rise to considering some support program for students before they complete half of the curricular progress, as well as in the last semesters, since important factors could be found that contribute to the dropout figures.

Graph 3 shows how many dropout students there were for each admission period, observing the highest peak in the August-December 2019 period, where there were 42 dropout students from that cohort. This dropout affects the terminal efficiency of the career. It is observed that after this period dropout decreases and contrary to what might be thought during the pandemic period, dropout decreased. The information found in this graph is interesting for the research work, since it seems that the period in which the students entered does not have a significant impact on their dropout.

Figure 5 shows a tree resulting from the flowchart in Orange (see Figure 4). It is observed that there are 107 students who permanently dropped out due to failing a special course with an arithmetic average of 40.5 (the minimum passing rate is 70). In contrast, with the rest of the reasons for withdrawal, it is the highest. 38 students due to voluntary permanent dropout and 36 students who dropout due to having reached the maximum number of semesters allowed (12 semesters allowed) follow them. Therefore, the low-grade average affects desertion.

Another interesting fact is that those who voluntarily withdrew permanently had a grade average of 49.8. Finally, 17 students dropped out due to a change of major. Although, they dropped out of the computer systems engineering career, but they continued at the institution in another career, which according to the definition given by the SEP, is not considered dropout.

In graph 4, as mentioned in previous paragraphs, three variables are related: the arithmetic average, the status and semester that the dropout student was studying. The information found in Tableau is corroborated, the largest number of students drop out in the 4th semester, and the group of them has an average grade of 36, a very low average if it is known that the minimum passing grade is 70. With these visualizations, it can be observed that the variables that have a strong weight in dropout are reprobation and low school achievement.

4. Acknowledgments

5. Findings

Once the data analysis has been made and the visualization tools Tableau and Orange have been applied, the following findings are obtained.

5.1 Tableau

There are important factors that affect the dropout from the Computer Systems Engineering degree at the Technological Institute of Oaxaca such as:

– The failure of the subjects, which can be a precedent that could lead with a high probability to students dropping out of their higher level studies, since in the same regulations of the Mexico National Technological, when the student fails a special course, it causes definitive dropout from the system.

– The gender of the students, since it is observed that men are the ones who drop out the most and in general their academic performance is lower than women, which would have to be studied more thoroughly to know if it is a determining factor in the dropout phenomenon.

– The number of semester in which students drop out, in this case, there is important information, the highest dropout occurs in semester 4, where there are 45 dropouts and is reduced by approximately half in semesters 6 and 13 where they occur 28 deserters. This indicates that it is important to develop a strategy that allows students to remain during the first semesters of the degree.

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–   The period of student entry does not seem to have much relevance in dropout, since it only shows that in a particular year – 2019 – there is the highest number of dropouts in the data set analyzed.

5.2 Orange

–   Similar aspects were found regarding the variables with the greatest weight in dropping out of the Computer Systems Engineering degree, which are: failure of subjects in special courses; as well as low academic performance defined by the accumulated arithmetic average of the studied subjects.

–   Likewise, it is observed that the semesters in which the highest number of dropout incidents occur are the 4th, 6th and 13th semesters, noting that the delay in reticular advancement is also a reason for dropout. It is relevant to note that semester 13 is outside the permitted range in terms of the maximum number of semesters taken. Given this finding, it would be important for the entities involved to propose a plan to prevent students from reaching semester 13.

6. Conclusions

After having carried out the analysis of a set of real data provided by a public higher education institution, it is concluded that among the relevant factors of dropout is the subject's reprobation. However, in the data there is a cause for dropout classified as "definitive voluntary withdrawal". It contains other unknown factors, and although there are 38 in total, it is considered that it would be important to investigate the causes that do not have to be do with their school performance, but they are generating 19% of dropouts in relation to the 198 that are in the analyzed data set. Another important factor is gender; it is visible in the graphs obtained with Tableau that there are more male dropouts than females.

Although to have clearer evidence, it would be necessary to establish a real proportion of the gender of deserters, since there is a smaller population of women compared to men. Apparently, gender is an influencing factor, since in two graphs where this characteristic is related, a greater dropout is observed in men.

Data visualization tools are great support in data analysis, and even more so in decision making, since they attractively present information that cannot be seen in the original data shown in tables. In the case of this research, two specific tools were used: Tableau and Orange.

In the case of Tableau, it was very useful since it has various options to present the information extracted from the data. Although it is worth making the observation that when learning it, it took time to achieve the first results. Tableau has enormous potential for presenting executive dashboards that show only important and previously classified information, which will support the right people to make informed decisions.

On the other hand, the application of the Orange tool allowed us to corroborate the hypotheses that were had about the factors with the greatest impact on dropping out of the Computer Systems Engineering degree. Among which we found again that they are: failure of subjects between the first and fourth semester, as well as the failure of courses in particular, which implies that the student has poor academic performance, having failed the same course on 3 occasions.

7. Future Work

A next research will be to expand the range of periods to have a greater amount of data, applying a contrast between the analysis of raw data and preprocessed data using some Big Data technique.

Thus, it is also possible to establish direct contact with deserters, to get more data about the causes of "voluntary permanent dropout." This can be done through an online questionnaire.

Likewise, other visualization tools can be applied to establish comparisons about which of them can respond more clearly to the needs of the institution in the early prevention of school dropouts.

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