www.revistageintec.net
ISSN: 2237-0722
revista GEINTEC
Gestão, Inovação e Tecnologias

Optimization Software in Operational Research Analysis in a Public University

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Abstract
The objective of this research was to determine the influence of the Invessoft program in the use of Solver, POM-QM and Lingo as didactic resources for problem solving in operations research in students of a public university in Lima, Peru. This decision was made because the participants had difficulties in solving problems with the use of traditional strategies. The quantitative, applied research had 80 participants (40 in the experimental group and 40 in the control group). The research adopted a quasi-experimental design with measurement only after. The experimental group applied the program for 12 weeks, while the control group continued with traditional methodology. To measure the achievements, a performance test was used, which underwent a content validity by expert judgment that evidenced 0.94 in Aiken's V; while the reliability kr21=0.965. The results evidenced significant differences between both groups at a confidence level $p<0.05$, being that the students of the experimental group showed better performance than the control group. In conclusion, the use of digital tools facilitates the resolution of operational research problems.

Key-words: Optimization, Solver, POM-QM, Lingo, Teaching-learning.

1. Introduction

Operational Research is a scientific discipline that consists of building mathematical models that represent real problems and determining an optimal solution (in time, resources, costs, production, among others). These models are solved using mathematical algorithms that serve to help in decision-making (Alzate, 2018).

Operational Research is used in different areas such as transportation, health, finance, manufacturing, public services, marketing, business management, among others (Andia, 2016; Niquin-Alayo et al., 2018; Peñaherrera-Larenas et al., 2020; Roca, 2019). The system used begins with the process of observation, data collection and the formulation of the problem, followed by the construction and validation of the model (generally mathematical), with which it is sought to separate the background from the real problem, to culminate by providing answers and deductions that contribute to decision-making before the solution of the original problem (Argota & Coasaca, 2016; Bedoya-Flores, 2020; Bermúdez, 2011; Broz et al., 2017; Riveros, 2015; A. Velásquez, 2008a, 2008b; C . Velásquez et al., 2008). With regard to the viability of projects, these tools are useful to reliably predict the success of projects (Hinostroza, 2016). For complex projects, the CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) network models are very useful (G. Rojas & Reyes, 2019). As a discipline within Operations Research, queuing theory studies and analyzes situations in which a certain service is demanded, which cannot be instantly satisfied, thus causing waiting (Cao, 2002). Through mathematical models, the efficiency is determined in different service situations such as in care management in health establishments (Mayorga, 2018; Velázquez & Vinueza, 2017), in library services (Muñoz-Vergara, 2019), in attention in the bank (Barreto, 2018), in transport services (Corcino & Ramos, 2018), among others.

The teaching of Operations Research provides the student with a comprehensive training that is based on the acquisition of knowledge in linear programming, waiting queue theory, project management and forecasts; Linear programming is essential to solve highly complex problems in which many variables are used, which by manual methods would take a long time; Therefore, the use of digital tools is viable to achieve a rapid understanding and resolution of problems (Nares & Trovato, 2012; Puente & Gavilánez, 2018; Valencia & Hidalgo, 2018), being the Simplex method one of the most important used in linear programming for operational calculations (Ansari, 2019).

With the development of Information and Knowledge Technologies (ICT) these limitations have been overcome (Juan et al., 2006; Rodríguez, 2018; M. J. Rojas et al., 2014). ICTs have had a great impact in different areas of life and, especially in the educational context, it has evolved in what is known as Learning and Knowledge Technologies (TAC) that seeks to achieve meaningful student learning with the contribution of computer technologies (Ureta & Rossetti, 2020). A variety of programs have been developed for operational research that can be used as support for better teaching-learning of optimization and decision-making courses (Falco et al., 2018, 2019; Medina et al., 2008; Simón- Marmolejo et al., 2013). The Operational Research course is important in the training of an industrial engineer, its purpose is to optimize the use of resources in real life for decision-making, through mathematical modeling and making intensive use of algorithms (Kowalski et al., 2015). With the advancement of computer science, software becomes a didactic tool for students and teachers that enhance the teaching-learning process, being also necessary an adequate theoretical base in regard to Operational Research (Sánchez & Rosete, 2020). Currently, the use of computer resources in teaching-learning is essential since the development of virtual classes has been implemented at all educational levels since COVID-19 was declared a pandemic by the World Health Organization in March of 2020 (Bravo & Quezada, 2021; Canaza-Choque, 2020; Navarro-Hudiel, 2020). Faced with this health emergency, the educational system has taken a profound turn in the development of face-to-face classes towards the online modality which has constituted a great challenge for both students and teachers (Figallo et al., 2020; Romero et al., 2020) .

In the teaching process of the Operations Research course, which has a quantitative approach, it is in many cases very laborious for students, causing them to fail to understand the benefit of the course for their academic training, being necessary to apply teaching-learning strategies that be easy, flexible, user-oriented and interesting to the extent that students cooperate proactively in the construction and analysis of mathematical models of real-world scenarios, and that it becomes a business optimization application which is a powerful tool help and analysis for decision making (Cavallin et al., 2017).

In the Professional School of Industrial Engineering of a public university in Peru, the Operations Research course is a compulsory subject because it allows optimizing problems to make the correct decisions; however, the course has been developing in a traditional way through problem solving through manual calculations. The manual resolution of linear programming problems, waiting queues, project management, and forecasts increases their complexity as the variables increase, hence the need for computing resources. Teachers, for the most part, are unaware of the new digital skills that allow optimization in teaching, which means that students do not acquire these essential skills effectively and efficiently for the development of scientific knowledge and analytical skills in the profile of the future. industrial engineering professional.

The purpose of this research work was to determine the use of the Invessoft optimization program as support in the teaching-learning process in the Operational Research subject, which is a compulsory course according to the study plans of the Professional School of Industrial Engineering from a Public University of Peru. The Invessoft program includes a set of software: Solver, POM-QM and Lingo for solving linear programming problems in industrial engineering. Today, due to the pandemic, the production and supply chain has been affected, so companies have had to reformulate their production plans. Based on this situation, problems have been formulated for their resolution through linear programming.

Main Software for Learning Operations Research

Solver

It is a Microsoft Excel tool that determines the maximum or minimum value of a cell by modifying other cells called variable or adjustable cells in a worksheet. This tool uses three main algorithms: LP Simplex. Nonlinear and Evolutionary GRG. The first of them is used to solve problems with linear constraints (Abdelwali et al., 2019; Fylstra et al., 1998; Rosales & Chávarri, 2021).

POM-QM

This tool is the easiest to use used in various areas including operations research (Stojanović & Regodić, 2016).

Lingo

It is a simple tool to solve linear and nonlinear optimization problems. It helps us find the best result that frequently involves the most efficient use of resources (Krishnaraj et al., 2015; Men & Yin, 2018; Rosales & Chávarri, 2021).

This research aimed to determine the influence of the Invessoft program in solving problems in operations research in industrial engineering students from a public university in Lima, Peru, where Solver, POM-QM and Lingo used it as teaching resources.

2. Methodology

The population consisted of 80 students, from sections A (control group) and B (experimental group) of the morning and afternoon shifts of the Operational Research course, academic semester 2020-II, of the Professional School of Industrial Engineering of a public university. The course was developed in the virtual modality. The applied sampling was non-probabilistic; the research design is quasi-experimental with measurement only afterwards, because the students did not have previous experiences related to the contents of the study subjects; Furthermore, the research groups were selected by convenience criteria (Hernández-Sampieri & Mendoza, 2018). Students were selected according to the order of enrollment for enrollment. The study was carried out with an experimental group and a control group made up of 40 students each group; For the experimental group, the Solver, POM-QM and Lingo software were used to solve optimization problems applied to industrial engineering, while the control group did not use any digital tool. Before the execution of the research project, the students were informed about the characteristics of the research and respect for anonymity, on the basis of which they gave their consent to participate in the research.

In the experimental group, the Operational Research classes were developed using Solver, POM-QM and Lingo software, while in the control group no software was used. Both groups had no previous experiences with such software. At the end of the semester, the academic performance of both groups was evaluated with respect to solving optimization problems applied to industrial engineering. A written test with 20 questions distributed in four dimensions was used as an evaluation instrument: Linear Programming (5 items), Waiting queues (5 items), Project Management (5 items), Forecasts (5 items) using dichotomous scales: Yes (1), No (0). The test was individual and the duration of the exam was 120 minutes; that it was validated by five experts (a methodologist, two operations research engineers, a mathematician and an industrial engineer), whose coincidences were 0.94; In addition, reliability was found with the statistic Kr21 = 0.965 (Hernández-Sampieri & Mendoza, 2018). After the examination was completed, the data was graded and processed. The SPSS version 23 program was used for statistical analyzes.

Before the beginning of the evaluation, the participants were informed of the reason for the investigation, the informed consent was generated through Google Drive in consideration that we are in social isolation due to COVID-19.

Example of Linear Programming Analysis using Software

The company "Protection" belongs to the production sector, which is dedicated to the manufacture of two products that are sold in its different stores in Lima, very useful to avoid the greater risk of being infected with COVID-19; the company manufactures face shields and overalls. Based on a study carried out by the Ministry of Health of Peru, the current inventories and in the face of the exponential demand for this new wave of infections, the “Protection” company is forced to increase its combined production between face shield and overalls, these they must total at least 450 units. On the other hand, it must also supply the order of 250 face shields and 136 overalls at least respectively, to the district of Lima with the highest risk of contagion; the face shield takes 6 minutes to manufacture, while the overalls require about 30 minutes to manufacture; in addition, for the following week, there is 100 hours of manufacturing time. The objective of the company "Protection" is to achieve the manufacture of these products with minimum costs to supply the Peruvian population. Production costs are $ 0.5 for the face shield and $ 5 for the overalls.

Step 1: The decision variables are identified, the objective function, the restrictions and the non-negativity condition are formulated, (see Fig. 1).

Fig. 1 - Identification of Variables

$$\text{Mín. (Z)}=0.5x_1 + 5x_2$$
$$x_1 \geq 250$$
$$x_2 \geq 136$$
$$1x_1 + 1x_2 \geq 450$$
$$0.1x_1 + 0.5x_2 \leq 100$$
$$x_1, x_2 >= 0$$

Decision variables
x_1 = number of face shields.
x_2 = number of coveralls.

Step 2: We solve with the traditional method: we standardize and add slack variables, (see Fig. 2).

Fig. 2 - Standardization and Slack Variables

$$\text{Min } Z = 0.5x_1 + 5x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_2 + 0x_9$$
$$1x_1 - 1x_3 + 1x_7 = 250$$
$$0x_1 + 1x_2 - 1x_4 + 1x_8 = 136$$
$$1x_1 + 1x_2 - 1x_5 + 1x_9 = 450$$
$$0.1x_1 + 0.5x_2 + 1x_6 = 100$$
$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9 \geq 0$$

Tabla 1			0	0	0	0	0	0	-1	-1	-1
Base	Cb	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
P7	-1	250	1	0	-1	0	0	0	1	0	0
P8	-1	136	0	1	0	-1	0	0	0	1	0
P9	-1	450	1	1	0	0	-1	0	0	0	1
P6	0	100	0.1	0.5	0	0	0	1	0	0	0
Z		-836	-2	-2	1	1	1	0	0	0	0

In column P0 we can observe the equivalences of each restriction and in columns P1 and P2 the coefficients of each restriction are observed. Then we take the first term in column P1 to use as a pivot.

Fila pivote (Fila 1):	Fila 2:	Fila 3:	Fila 4:
250 / 1 = 250	136 - (0 * 250) = 136	450 - (1 * 250) = 200	100 - (0.1 * 250) = 75
1 / 1 = 1	0 - (0 * 1) = 0	1 - (1 * 1) = 0	0.1 - (0.1 * 1) = 0
0 / 1 = 0	1 - (0 * 0) = 1	1 - (1 * 0) = 1	0.5 - (0.1 * 0) = 0.5
-1 / 1 = -1	0 - (0 * -1) = 0	0 - (1 * -1) = 1	0 - (0.1 * -1) = 0.1
0 / 1 = 0	-1 - (0 * 0) = -1	0 - (1 * 0) = 0	0 - (0.1 * 0) = 0
0 / 1 = 0	0 - (0 * 0) = 0	-1 - (1 * 0) = -1	0 - (0.1 * 0) = 0
0 / 1 = 0	0 - (0 * 0) = 0	0 - (1 * 0) = 0	1 - (0.1 * 0) = 1
1 / 1 = 1	0 - (0 * 1) = 0	0 - (1 * 1) = -1	0 - (0.1 * 1) = -0.1
0 / 1 = 0	1 - (0 * 0) = 1	0 - (1 * 0) = 0	0 - (0.1 * 0) = 0
0 / 1 = 0	0 - (0 * 0) = 0	1 - (1 * 0) = 1	0 - (0.1 * 0) = 0

Notice the length of the procedure to get each table. In this problem we only use 2 variables and 4 restrictions, which makes us see how complex it would be to solve it manually with a greater number of variables and restrictions.

After several interactions we reached the final table. Final table analysis, (see Fig. 3).

Fig. 3 - Results, Production, Shadow Prices

Tabla 1			-0.5	-5	0	0	0	0
Base	**Cb**	**P0**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
P1	- 0.5	314	1	0	0	1	-1	0
P2	-5	136	0	1	0	-1	0	0
P3	0	64	0	0	1	1	-1	0
P6	0	0.6	0	0	0	0.4	0.1	1
Z		-837		0	0	4.5	0.5	0

Finally, we arrive at the last table and observe the responses of both variables X1 and X2, which corresponds to the number of face shields (314) and overalls (136).

Also, we obtain the optimal solution that would be 837

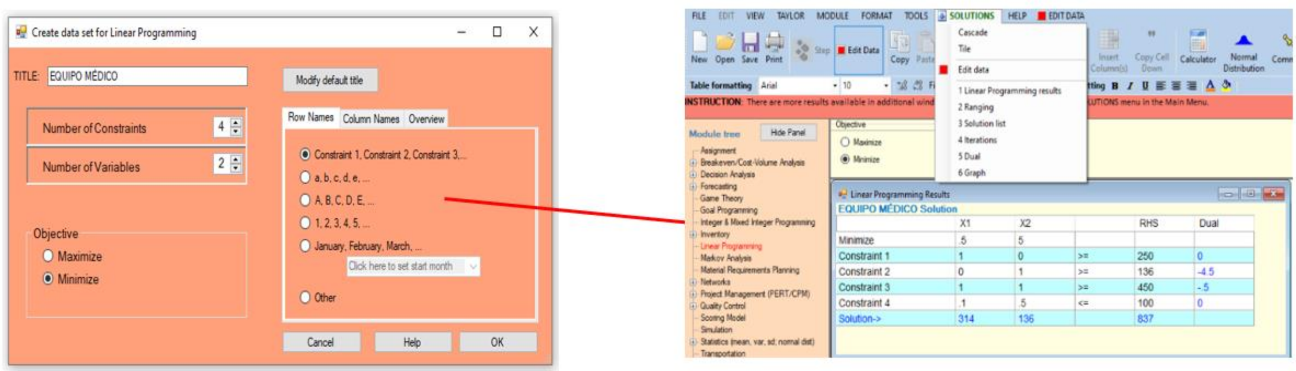
Using POM-QM

Step 1: We open the program, in this case the problem is about optimizing results, in this case minimizing costs, so we will open the inventory tab in the module tree and enter "linear programming".

Step 2: Now we are going to create the data, let's put a title to this case to register it and have it ordered. Then we add the quantities of restrictions and variables that we are going to analyze, as well as the objective to want (minimize in this situation since we will find costs).

Step 3: In addition to this we have 5 more results, which complements the result obtained, such as the graphs or the detailed procedure, (see Fig. 4).

Fig. 4 - Data Entry, Decision Variables

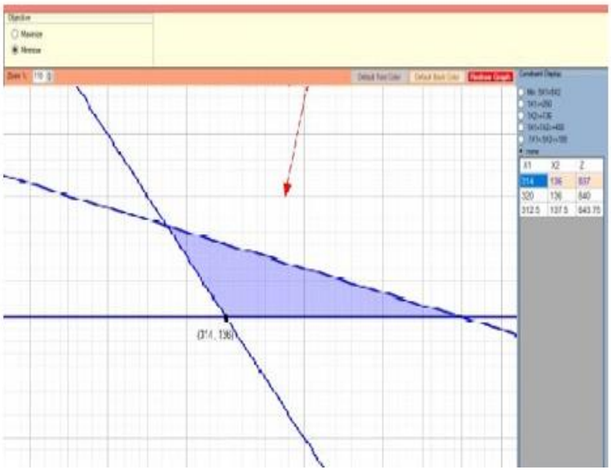


ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 10.06.2021 – Accepted: 11.07.2021

With Solver

Step 1: We start by creating our database in Excel, with the formulas for each box painted, (see Fig. 5 and Table 1).

Fig. 5 - Graph of Variables



With the POM-QM software, the responses of both variables X1 and X2, which correspond to the number of face shields (314) and overalls (136).

Also, we obtain the optimal solution that would be 837.

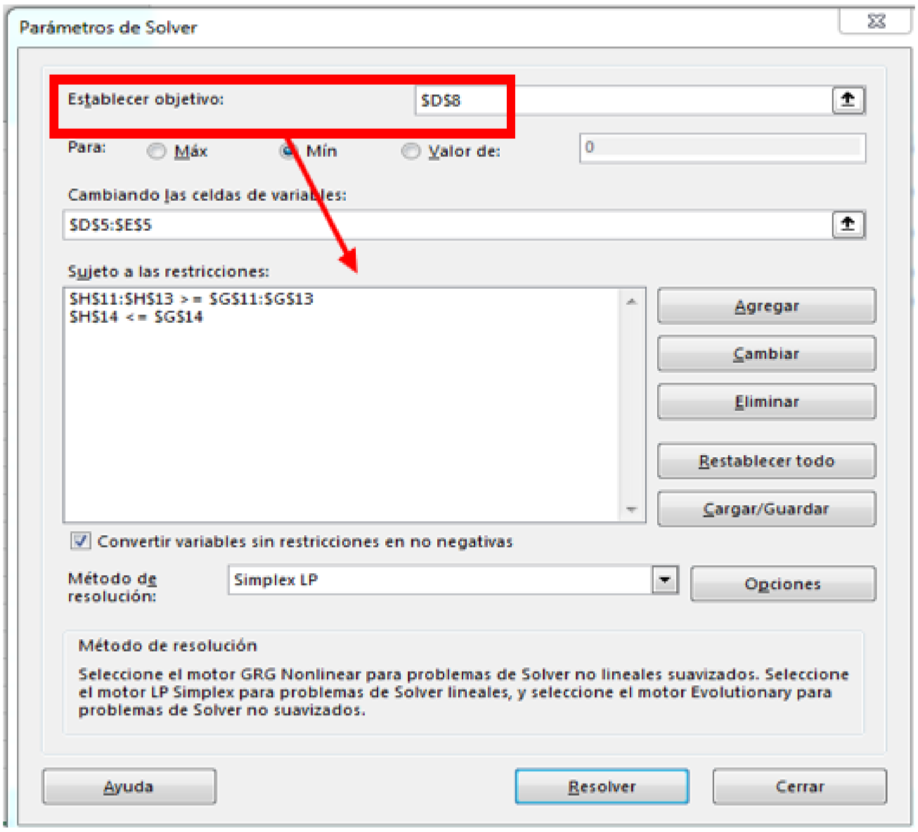
In addition, values are obtained for the sensitivity analysis

Table 1 - Determination of Variables in POM-QM

PRODUCTS	**Face protectors**	**Coveralls**				
Amount(u)						
Production Cost($/u)	0.5	5				
TOTAL COST	0					
Restrictions				Excess	Used	Requirement
Minimal production of face shields	1		>=	250	0	-250
Minimum production of coveralls		1	>=	136	0	-136
Minimum Production of both products (u)	1	1	>=	450	0	-450
Production time (hr)	0.1	0.5	<=	100	0	100

Step 2. Using Solver we establish the objective, which in this case would be the cost it will take to manufacture the implements, (see Fig. 6).

Fig. 6 - Cost of Manufacturing the Implements



Step 3: we find the solution, answer sheet, (see Table 2).

Table 2 - Target Cell (Min)

Cell	Name	Original value	Final value
F24	TOTAL COST Face shields and coveralls	0	837

The total cost of production is $ 837.

Step 4: find the sensitivity sheet, (see Table 3).

Table 3 - Variable Cells

Cell	Name	Final Value	Reduced Cost	Target Coefficient	Allowable Increase	Allowable Reduce
F21	Quantity (u) Face shields	314	0	0.5	4.5	0.2
G21	Quantity (u) Overalls	136	0	5.0	3.0	4.5

Optimum production is 314 face shields and 136 coveralls.

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 10.06.2021 – Accepted: 11.07.2021

The cost range of face shields can vary between \$ 0.5 - \$ 0.2 = \$ 0.3 and \$ 0.5 + \$ 4.5 = \$ 5.00, therefore the face shield target coefficient range is \$ 0.3 to \$ 5.0. Likewise, the range of the cost of coveralls can vary from \$ 5 - \$ 4.5 = \$ 0.5 and \$ 5 + \$ 3.0 = \$ 8.0. As long as the objective function coefficient is within these ranges the optimal production of face shields and coveralls will not vary.

Table 4 - Restrictions

Cell	Name	Final Value	Shade Price	Restriction Right side	Allowable Increase	Allowable Reduce
\$J\$27	Minimal production of face shields	314	0	250	64	1.00E+30
\$J\$28	Minimum production of coveralls	136	4.5	136	1.5	136
\$J\$29	Minimum production of both products	450	0.5	450	6	64
\$J\$30	Production time	99.4	0	100	1E+30	0.6

314 face shields are produced, 64 pieces more than the minimum quantity.

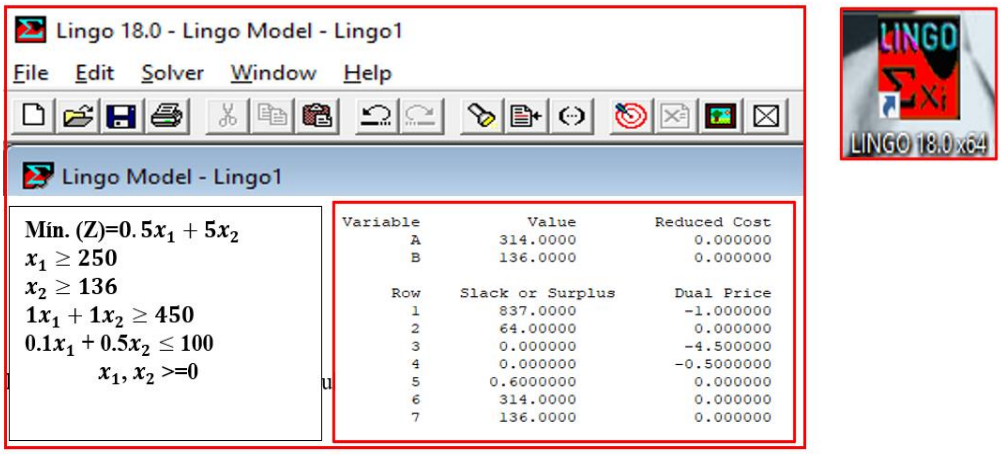
In Table 4, 136 overalls are produced, just like the minimum quantity required there is a permissible increase of 1.5 and a permissible decrease of 136, then the interval (0,137.5) is obtained, when working within this interval the costs will increase by this amount.

The company has 100 hours in the production area and uses 99.4 hours, it has 0.6 hours available that it can reduce for its best use.

Lingo

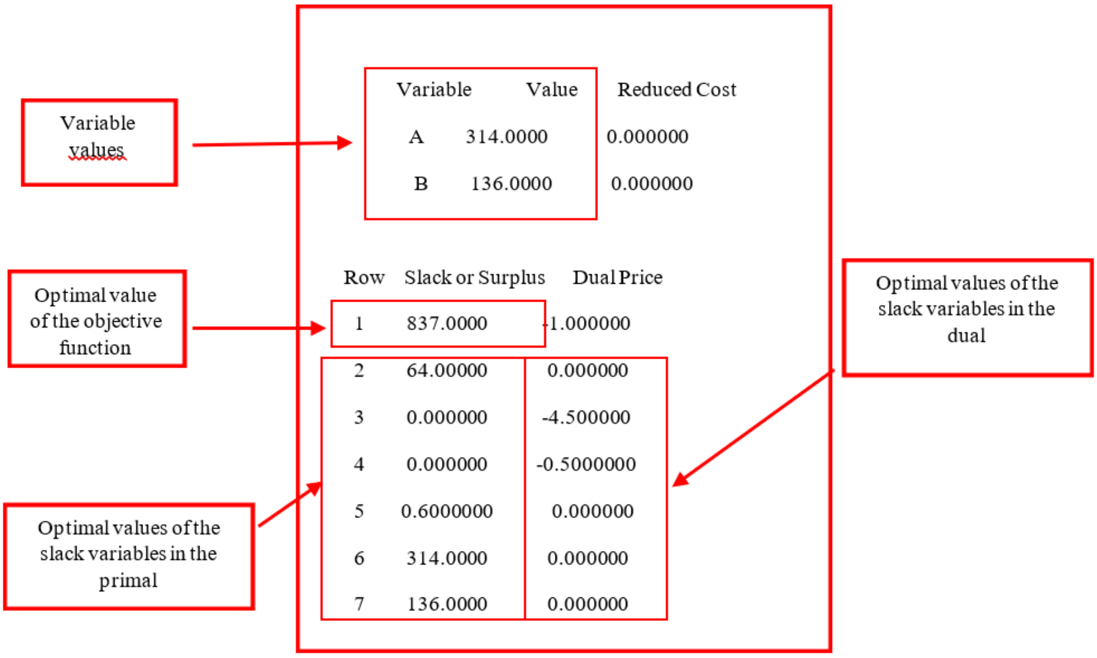
Step 1: We open Lingo and insert the objective function to minimize and the respective restrictions, (see Fig. 7).

Fig. 7 - Inserting Objective Function in Lingo Software



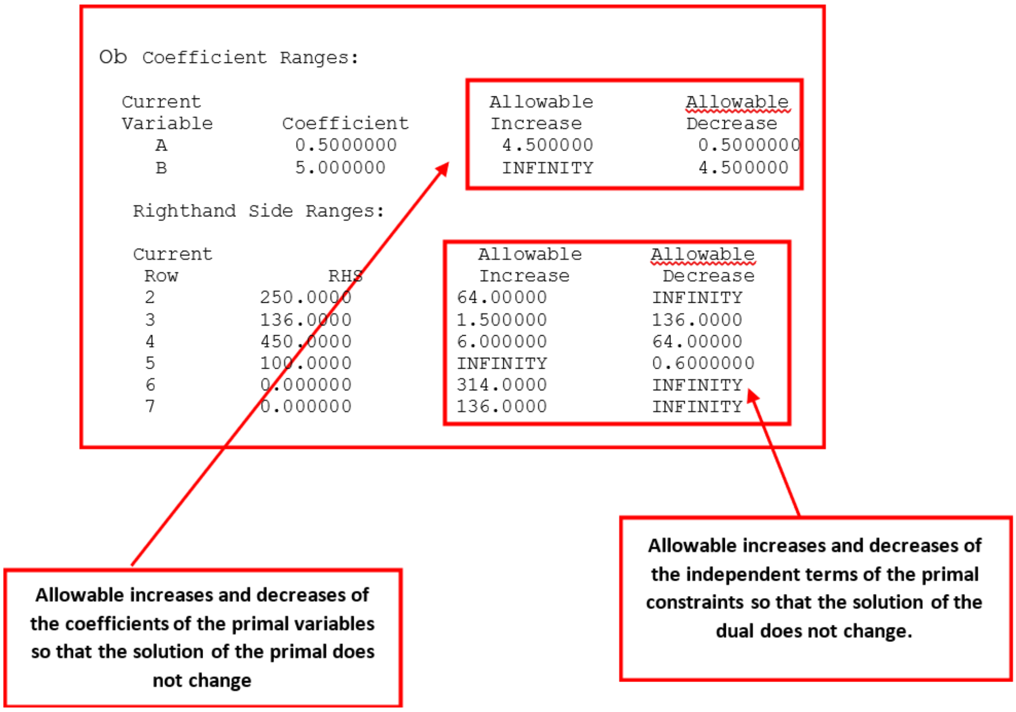
Step 2: Now we will analyze the results offered by Lingo, (see Fig. 8).

Fig. 8 - Results in Lingo



Step 3: Now we will analyze the sensitivity report obtained from Lingo, (see Fig. 9).

Fig. 9 - Sensitivity Report Analysis in Lingo



ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 10.06.2021 – Accepted: 11.07.2021

3. Results

The performance levels of the students of the Operational Research course in the dimensions Linear Programming, Waiting Queue, Project Management and Forecasts are shown in tables 5, 6, 7 and 8 respectively, evidenced an increase in the performance of the experimental group.

In table 5 it can be observed that in the Start and Process levels the performance levels were higher in the control group than in the experimental group, however, in the Achieved level the opposite is observed (20.0% and 52.5% for the control groups and experimental respectively) indicating that students showed better performance at the end of the course with respect to Linear Programming.

Similarly, in the Waiting Queue dimension, at the Start and Process levels, the performance of the control group exceeds in percentage those of the experimental group, but at the Achieved level, this last group presented higher performance (70.0%) compared to the control group (15.0). %) (Table 6).

With regard to the Project Management dimension, the percentages of returns of the control group, at the Start and Process levels, are higher in the control group than in the experimental group. However, at the Achieved level, the percentage of performance of the experimental group (67.5%) is higher than that of the control group (30.0%) (Table 7).

In the Forecasts dimension, higher performances of the control group are also observed in the Start and Process levels, however, in the Achieved level the experimental group (65.0%) exceeds the control group (30.0%) by more than double in the percentage of yield (Table 8).

Table 9 shows the performance levels in percentage considering the set of dimensions. Similar to the previous results, in the Start and Process levels the control group presented higher percentages of performance than in the experimental group, the opposite occurred in the Achieved level, thus showing that in the final stage of the course the students that make up the experimental group had greater aptitude in solving problems applied to industrial engineering compared to those of the control group.

According to the results obtained, in the Start and Process levels the control group presents higher performance, this can be explained because at those levels the students of the experimental group are in a process of familiarization and learning of the software, however, once who manage to master the use of softwares, their performance is evidenced in the quality, speed and efficiency for solving the problems posed.

Table 5 - Comparison of Performance Levels of the Linear Programming Dimension

Levels	Control group		Experimental group	
	%	Count	%	Count
Start	12.5	5	5.0	2
Process	67.5	27	42.5	17
Achieved	20.0	8	52.5	21
TOTAL	100.0	40	100	40

Table 6 - Comparison of Performance Levels of the Queue Dimension

Levels	Control group		Experimental group	
	%	Count	%	Count
Start	15.0	6	5.0	2
Process	70.0	28	25.0	10
Achieved	15.0	6	70.0	28
TOTAL	100.0	40	100.0	40

Table 7 - Comparison of Performance Levels of the Project Administration Dimension

Levels	Control group		Experimental group	
	%	Count	%	Count
Start	15.0	6	7.5	3
Process	55.0	22	25.0	10
Achieved	30.0	12	67.5	27
TOTAL	100.0	40	100.0	40

Table 8 - Comparison of Performance Levels in the Forecasts Dimension

Levels	Control group		Experimental group	
	%	Count	%	Count
Start	10.0	4	7.5	3
Process	60.0	24	27.5	11
Achieved	30.0	12	65.0	26
TOTAL	100.0	40	100	40

Table 9 - Comparison of Performance Levels of the Operations Research Variable

Levels	Control group		Experimental group	
	%	Count	%	Count
Start	5.0	2	0.0	0
Process	82.5	33	10.0	4
Achieved	12.5	5	90.0	36
TOTAL	100.0	40	100	40

A normality test was applied to the data obtained by each group, which, since it comprised 40 elements in the sample, the Shapiro-Wilk test was used. It was determined that the data do not have a normal distribution at a confidence level of $p < 0.05$, so the Mann-Whitney U test was used in order to contrast the results. According to this non-parametric test, differences were found between the control group and the experimental group ($p < 0.05$) with respect to the qualifications obtained considering each of the four dimensions linear programming, waiting queue, project management and forecasts. These differences are reflected in a higher performance of the experimental group in contrast to the control group.

4. Discussion

Various studies show that the use of Software contributes satisfactorily to the teaching and learning process of the Operational Research subject in university students, thus corroborating the results obtained in this research work. A similar study was carried out by Pérez & Ramírez (2019) in which the experimental group received the classes of the Operational Research course using the WinQSB and Solver software, this group had better grades than the control group students who received the classes the way traditional without the use of software. In the study by Cavallin et al. (2017), a pedagogical method was used for the teaching of Operations Research, using the POM-QM software and resulted in a greater interest in the subject on the part of the students. Similarly, Sousa (2014) determined that the use of the LOpt Calculator (calculator for linear optimization) contributed significantly to the teaching and learning process of Operations Research. It is worth mentioning that there are investigations oriented to the development of software that may be useful in the teaching of Operations Research; In this regard, a software prototype was developed for use in linear programming with a pedagogical approach; which was characterized by being simple and didactic for systems engineering students of the Operative Research course, which led to a greater interest in the subject on the part of students (Ávila, 2019). In another study, for didactic purposes, the Simplex algorithm was integrated into an Excel spreadsheet, creating an automated program in VBA (Visual Basic for Applications) for Excel, with which the algorithm was implemented (Ferreira, 2015).

The research carried out shows that in the operational research analysis, 90% of the students who were taught with the Invessoft program and 12.5% of the control group obtained the level achieved; in the same way, 10.0% of the experimental group and 82.5% of the control group were at the process level; On the other hand, 0.0% of the experimental group and 5.0% of the control group were at the starting level; These achievements show that the use of the program had positive results in the experimental group; Furthermore, the hypothesis test showed that there were significant differences between the control group and the experimental group after applying the program. In this regard, Kowalski et al. (2015) affirms that in universities that train industrial engineers, the student should focus on solving problems through algorithms and the intensive use of software, in the same way Medel et al. (2018) develops educational software on a free platform, using Bootstrap, the JavaScript library JQuery, as well as HTML5 and CSS3 as a framework, when performing controls, they verified the quality of the application and the satisfaction of the requirements. Also (Falco et al., 2018) affirms that software is an important complement in the teaching of the operational research course as problems are formulated with many variables and the manual solution becomes complex. It is evident that our proposal in the analysis of operations research is of utmost importance the intensive use of software.

The analysis of the evaluation results of linear programming revealed that 52.5% of the experimental and 20.0% of the control group were at the achieved level; 42.5% of the experimental group and 67.5% of the control group were located at the process level; while 5% and 12.5% of the experimental and control group respectively at the beginning. In this regard, Rosales & Chávarri (2021) state that to solve linear programming the best softwares are solver, lingo and pqm, coinciding with our research on the use of softwares.

When analyzing the results of the evaluation of waiting queues, 70.0% of the experimental group and 15% of the control group reached the level achieved; 25% of the experimental group and 70.0% of the control group in process while 5% of the experimental group and 15.0% of the control group in the beginning. The research of (Vallejos et al., 2017) highlights the importance of the construction of graphic simulators in waiting queue models through the use of software in higher education, highlighting the generation of reports for their interpretation, agrees with our position of the use of tools that optimize learning.

Regarding the results of project administration, 67.5% of the experimental group and 30.0% of the control group were at the achieved level; 25.0% of the experimental group and 55% of the control group in process; while 7.5% of the experimental group and 15.0 of the control group at the beginning level. In this regard, Guerrero (2011) designs a learning model in project management skills based on employability and professional competitiveness, agreeing with our proposal on the use of tools that improve the teaching-learning process.

When analyzing the prognostic results, 65.0% of the experimental group, 65.0% of the experimental group and 30.0% of the control group were at the achieved level; 27.5% of the experimental group and 60.0% of the control group in process; while 7.5% of the experimental group and 10.0 of the control group at the beginning level. In the research carried out by (García et al., 2016) he develops a technological support based on cases, he applied the ARIMA model of Box and

Jenkins with the aim of improving the forecasting models by providing different improvement scenarios that coincide with our proposal in the intensive use of software

5. Conclusions

The results obtained show the importance of the application of computer tools in the development of skills by industrial engineering students to solve optimization problems applied to their professional careers. As a consequence, students also showed greater interest in the Operations Research course and the number of failed students has been significantly reduced. Due to the current pandemic situation, the implementation of virtual classes has made the use of digital tools essential, giving great emphasis to TACs.

The use of software in the Operational Research subject for the construction of mathematical models has had clear advantages compared to manual resolution. The present research work constitutes a contribution in the continuous improvement in the teaching-learning of the Operational Research course.

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