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ARTICLE 2

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DEVELOPMENT OF A MOBILE APPLICATION FOR OPERATIONS RESEARCH TRANSPORTATION METHODS

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Abstract: The project describes the development of a mobile application designed to optimize the resolution of transportation problems. As a starting point, the problem that led to its creation is presented: the need to compare several heuristic methods, a time-consuming process that hinders efficient decision-making due to the absence of a clear approach that guarantees optimal results. The efficiency and effectiveness of heuristic transportation methods is demonstrated through an interactive tool adapted to current needs. The waterfall methodology was used to structure the development of the application, integrating the Northwest Corner, Minimum Cost, and Vogel algorithms. These are traditional methods in transportation literature. In addition to these, three alternative heuristic methods were programmed: Southwest Corner, Maximum Demand, and Minimum Cost by Batches (Cofermin) algorithms. This methodology allows phases such as requirements gathering, design, implementation, and testing to be addressed to ensure a functional result that is adapted to the objectives. The document also presents examples of the code developed and its respective functions, illustrating the technical design and implementation of the application's key features, such as interaction with sliders, buttons, and cells. The results show that the application improves decision-making by providing fast and reliable solutions.

Keywords: mobile application, heuristic transportation methods, waterfall methodology, decision-making.

Introduction

Efficient transportation management is an essential challenge in modern logistics. Heuristic methods allow viable solutions to be obtained in less time, facilitating decision-making. This article presents a mobile application that integrates these methods in order to improve the teaching and practice of Operations Research.

The National Technological Institute of Mexico, Tuxtla Gutiérrez Campus, is a public higher education institution that forms part of the National Technological Institute of Mexico.

The mission of the Technological Institute is focused on the comprehensive training of professionals of excellence in the field of science and technology with an entrepreneurial attitude, respect for the environment, and adherence to ethical values. At the same time, its vision is to be an institution of excellence in technological higher education in the Southeast, committed to the sustainable socioeconomic development of the region. (Comunicacion, 2018).

Computer Systems Engineering trains professionals capable of designing, developing, and optimizing technological solutions through the use of software, hardware, and networks to solve complex problems in various sectors. This discipline combines knowledge of programming, networks, databases, artificial intelligence, and project management, allowing engineers to address both technical and strategic challenges in digital and physical environments.

A key subject in the curriculum is Operations Research, which focuses on applying mathematical and statistical models and algorithms to improve decision-making in complex systems. One of its most applied units is the study of transportation methods, which seek to minimize logistics costs through models such as the northwest corner method, minimum cost, Vogel's approximation, stream crossing, and the MODI method. These approaches are fundamental in sectors such as manufacturing, healthcare, and distribution, where operational efficiency is key.

Heuristic methods such as the northwest corner, minimum cost, Vogel's approximation, stream crossing, and Modification of Initial Distributions (MODI) play a fundamental role in optimizing resource allocation and strategic decision-making in transportation problems.

According to Sanchez (2021), "The transportation model refers to the exchange of items from a specific number of sources to a specific number of destination points at a minimum transportation cost." (para. 5)

The northwest corner method is considered one of the pioneers in this field. It was developed as a simple and sequential method for assigning units in a cost matrix. The minimum cost method specializes in minimizing costs, as indicated by Pacheco Molina (2019), by assigning "the largest possible amount to the cell with the minimum unit cost" (p.10), which resulted in improvements by offering more efficient and economical solutions. Vogel's approximation method, an improved intermediate version of the minimum cost and northwest corner methods, requires a generally greater number of operations than other existing heuristic methods. This intermediate approach allows for more flexible and adaptable allocation.

In the context of digital transformation, the optimization of logistics processes using technological tools has become indispensable. The proposed application responds to this need, allowing transportation problems to be solved in an automated, efficient, and adaptable manner for different operational scenarios, such as the distribution of medical supplies, food, or industrial products.

The project is a mobile application aimed at optimizing distribution routes. It is based on knowledge acquired in the field of Operations Research, which allows:

- Model the transportation problem as a cost matrix between origins and destinations
- Apply methods such as Vogel or MODI to find optimal routes with lower costs
- Translate mathematical models into functional algorithms
- Simulate logistics scenarios and visualize results in real time
- Evaluate the efficiency of each method through comparative testing

Thanks to this integration, the project not only meets technical objectives, but also incorporates a solid analytical basis that makes it scalable and applicable in real-world environments such as the distribution of medical supplies or consumer products.

Methods

To evaluate the efficiency and effectiveness of each heuristic transportation method, as well as the three proposals that the application generates for each problem posed by the user, all the results obtained will be analyzed. In this way, the method that achieves the lowest cost will be identified, in addition to counting the number of times that this method proves to be the most economical.

In any industrial, corporate, or business activity, the transportation of goods or products from production centers (origins) to consumption centers (destinations) is a fundamental task. Performing this activity optimally, that is, at the lowest possible cost, represents economic and competitive advantages.

A. Northwest Corner Method

The Northwest Corner Method is operationally very simple. It consists of starting with the first cell in the table and assigning the maximum possible quantity to that cell. This maximum possible quantity is the minimum requirement of the corresponding destination and the availability of the corresponding origin. The process then moves to the box on the right or below, depending on whether the requirements or availability have been exhausted, and the maximum possible quantity is assigned to that box, and so on until all requirements and availability have been exhausted. (Casuso, 2015 as cited in (Garzón Espinosa & Llumiquinga Pachacama, 2019, p. 14)).

B. Minimum cost method

According to Pacheco Monina (2019), the following applies:

The minimum cost method, or minimum cost method, is an algorithm developed with the aim of solving transportation or distribution problems, with better results than other methods, since it focuses on the routes with the lowest costs and determines a better solution by concentrating on the most economical routes. To apply it, the largest possible quantity is assigned to the cell with the minimum unit cost. If there are two or more cells with equal costs, the one that can satisfy the greatest demand is selected. Then, the satisfied row or column is crossed out, and the supply and demand quantities are used as appropriate. (p. 10).

C. Vogel's approximation method

This method is based on the concept of profit. The Vogel method strategy consists of assigning values to the lowest-cost unsaturated cells, ensuring that, among the rows or columns that may become saturated, the one with the maximum profit is chosen. In this way, it avoids saturating cells with low costs (although higher than the minimum) and, consequently, having to subsequently assign values to cells with high costs (Leyes, 2009, as cited in Garzón Espinosa & Llumiquinga Pachacama, 2019; Hernández Molina, 2021).

D. Stream crossing method

Hernández Molina (2021) defines the following in his work Operations Research I:

The Stream Crossing, Trampoline, or Stepping Stone method is a method for solving transportation problems in linear programming that consists of calculating the variation in shipping costs across possible routes, that is, assigning a certain quantity of items from various origins (factories/sources) to a set of destinations (customers/warehouses) in such a way as to reduce costs until the objective is optimized. It starts from a feasible solution of Minimum Cost, Vogel, or Northwest Corner. (p.1).

E. MODI Method

According to Barona, Pinto, and Molinares (2012), the MODI algorithm, also called the fictitious cost method, involves the inclusion of an additional row and column in the cost matrix, which contain predetermined fictitious costs (called MODI numbers). This technique allows the improvement indices for unused cells to be calculated, thus offering a strategy for optimizing the solution to the problem. (para. 1).

Technical Methodology

Explanation of the current general process:

Drawing the table: The procedure is performed manually. Whenever a student or teacher wants to solve a transportation problem, they begin by drawing the corresponding table.

Filling cells: All cells are filled in with the data from the problem.

Method selection: The solution method is chosen; normally the northwest corner method is used because it is the simplest.

Problem solving: Apply the selected method step by step.

Obtaining the result: The result is obtained in seconds or minutes, depending on the size of the table.

Comparison with other methods: If the result is not satisfactory, it is necessary to solve the same problem again using the remaining methods to identify which one provides the lowest transportation cost.

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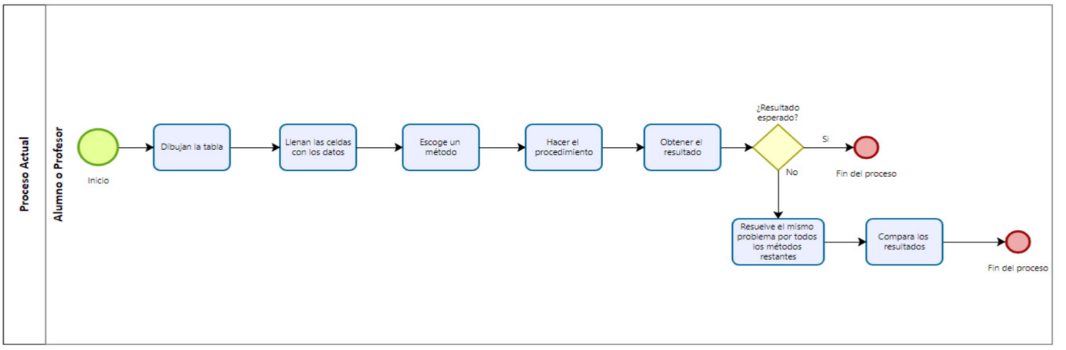

***Figure 1**. BMPN diagram of the current process Source: Own elaboration*

BPMN diagram of the current general process Figure 1 shows the current process in the BPMN diagram.

Development

Explanation of the process included in the proposal

1. **Open the application:** The user launches the application.
2. **Choose number of rows and columns:** Within the application, select how many rows and columns to use.
3. **Enter data:**

- You can manually fill in all the cells with the data from your problem.
- Or, fill in the cells randomly using random.

4. Request results: The user asks the application to process the information.

5. Solve the problem: The application's business logic solves the problem using all available heuristic methods.

6. Deliver results: All results are displayed, indicating which method obtained the lowest cost.

7. View the procedure:

a. The user can review the procedure for the chosen method step by step.

b. If they wish to consult another procedure, they must request the results again and select the new method.

8. Review history and documentation: This process is only possible if the user accesses the menu. Its use is optional and does not affect the main operation of the application.

BPMN diagram including the proposal

Figure 2 shows the BPMN diagram of the process that includes the proposal.

Software requirements specification

Functional requirements

Table 1 shows the functional requirements with their corresponding identifier, requirement name, description, and priority.

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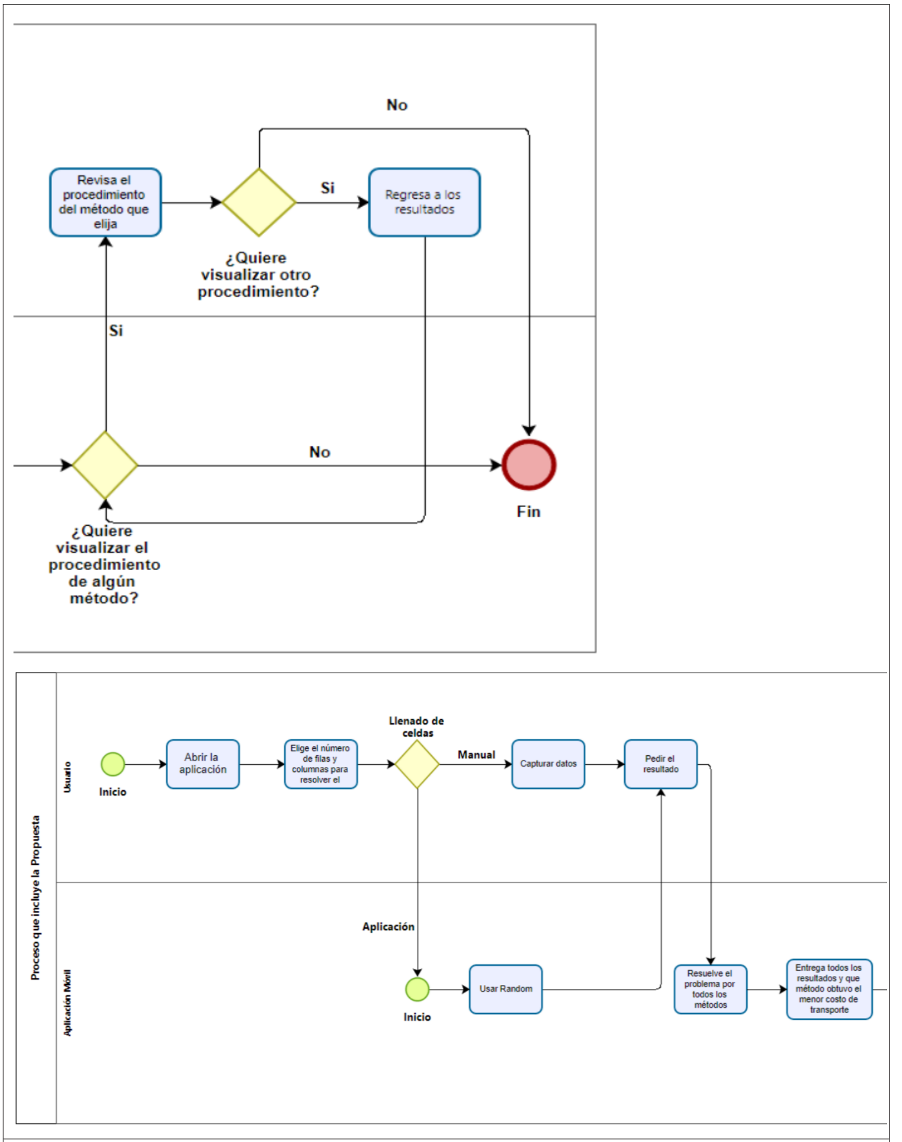

Figure 2*. BPMN diagram of the process that includes the proposal*

Source: Own elaboration

Identifier	Requirement name	Description	Priority
RF01	Row and column limitation	The application must allow users to choose the number of rows and columns they will use.	**High**
RF02	Filling cells	It must allow users to fill in all cells, otherwise they will not be able to obtain their results.	**High**
RF03	Random	The application will be able to fill cells randomly.	**Medium**
RF04	Balance the table	The application must review the problem entered by the user or the randomly generated problem to check if it is balanced. If it is balanced, it continues with the process of solving the problem; otherwise, it first balances and then solves.	**High**
RF05	Solution	The application must be capable of solving the problem using all heuristic transport methods and their proposals.	**High**
RF06	Response	It must provide all the results of the different methods.	**High**
RF07	Optimal Cost	The application must indicate which method resulted in the lowest transportation cost.	**High**
RF08	Step by Step	The application must show the step-by-step process for all heuristic transportation methods and their proposals.	**High**

Table 1. Functional requirements

Source: Own elaboration

Non-functional requirements

Table 2 shows the non-functional requirements.

Identifier	Requirement name	Description	Priority
RNF01	Performance	The application must respond immediately.	**High**
RNF02	Scalability	The application must support new code that needs to be added.	**High**
RNF03	Security	The application must comply with ISO 27001 security standards.	**High**
RNF04	Maintenance	The code must be well documented and follow best practices.	**High**
RNF05	Usability	The application must be intuitive and attractive to any user with a minimum knowledge of transportation methods.	**High**

Table 2. Non-functional requirements

Source: Own elaboration

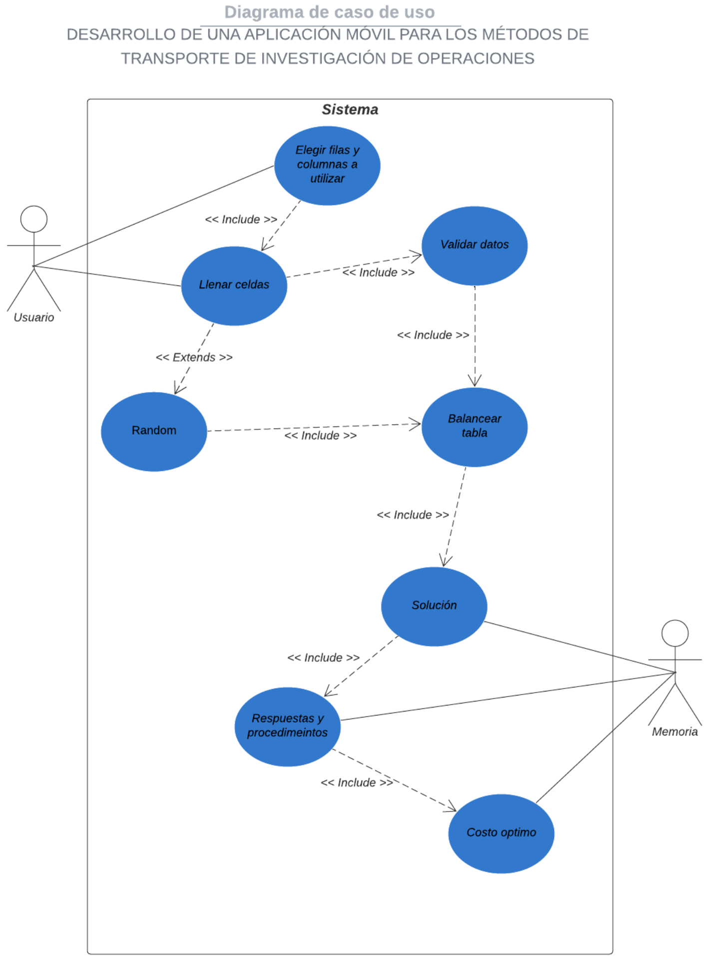

Figure 3. Use case diagram

Source: Own elaboration

Actor	User
Description	The user accesses the application to solve a transportation problem.
System functions	• Choose the number of rows and columns to use. • Enter data in the cells or choose random. • View the results. • View procedures for • transportation methods. • View the optimal cost.

Table 3. User role

Source: Own elaboration

Actor	Memory
Description	Memory is responsible for storing the total costs needed to determine which method was most effective in solving a problem.
Functions in the system	• Stores the total costs of the heuristic methods and the three proposals to indicate which one achieves the minimum transportation cost.

Table 4. Role of Memory

Source: Own elaboration

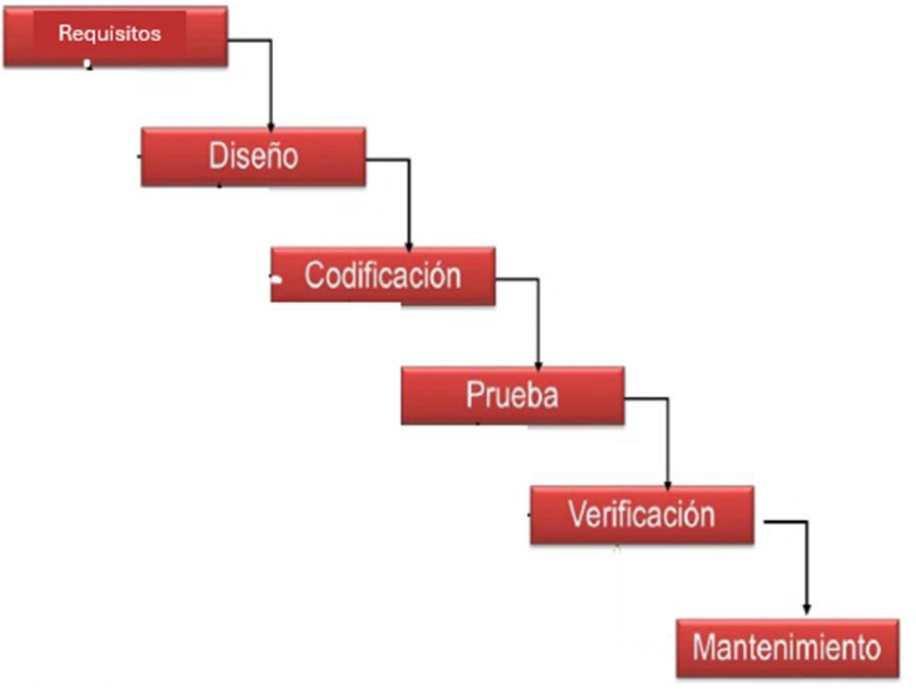

Figure 4. Waterfall methodology Source: own elaboration

Use case diagram

Figure 3 illustrates the use case diagram showing the system interactions for both actors.

User characteristics

Table 3 shows the description of the user's role and the functions they perform.

Table 4 shows the description of the role of memory and the functions it performs.

Development followed three main stages: (a) analysis of transportation methods (Northwest Corner, Minimum Cost, Vogel, Southwest Corner, Maximum Demand, Cofermin Cost per Lot), (b) technical design using BPMN diagrams and use cases, and (c) implementation of the mobile application using the waterfall methodology.

Waterfall Methodology

The waterfall methodology is applied in this project due to its linear and sequential structure, which is suitable for moderate-sized projects and ensures a systematic approach in each phase.

Requirements

Collect and document the functional and non-functional requirements of the system in collaboration with stakeholders. This includes defining key functionalities—such as the behavior of sliders, buttons, and cells—as well as the system acceptance criteria. Use case diagrams and requirement lists were used to formalize these needs.

Design

A detailed architecture of the application is developed, including the structure of the user interface through prototypes. Components—such as sliders, buttons, and cells—are defined, and the way they interact with each other is specified.

Coding

Implementation begins following the established designs. Kotlin is used as the main language and Android Studio as the development environment, integrating specific libraries for graphical interface management.

Testing

Unit testing: Automated tests are developed to validate the correct functioning of individual components. Specific cases are considered, such as the interaction of sliders and data generation.

Integration testing: The developed components are combined and tested to ensure they work cohesively. Critical interactions, such as the flow between the user interface and the system logic, are evaluated.

System verification:

Complete functional tests are run, simulating real-world usage scenarios together with the stakeholder, to ensure compliance with established requirements.

Maintenance:

When anomalies or improvement needs are identified during testing or the operational phase, bug fixes are managed and functional updates are proposed. An iterative approach is adopted that allows improvements to be incorporated based on

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stakeholder feedback, ensuring that the system remains up-to-date and functional in the face of possible changes in the operating environment.

Preliminary system design

Software architecture design

Modular architecture has the great benefit of dividing the application into independent modules, allowing each component to be scaled and modified separately. This allows you to add new heuristic methods or proposals in the future without having to rewrite the entire code or negatively affect other parts of the application.

Figure 5 shows the difference between a regular application and an application with modules.

Results

The mobile application correctly solved test cases based on balanced supply and demand data. The comparative tables show that the results match those obtained manually, validating the reliability of the system.

Analysis of the results obtained

The results show that the southwest corner method wins 22 times, while the northwest corner method wins 27 times, with ties occurring in several exercises.

This indicates that both methods perform similarly, with neither achieving a significant advantage over the other, and are therefore considered equivalent starting techniques, useful for educational purposes but not optimal compared to other heuristic algorithms.

In this comparison, both the **minimum cost method** and the **COFERMIN method** achieve **13 wins each**, in addition to recording **24 ties**.

These results reflect a **technical tie**: both methods have a similar level of effectiveness, and neither can be considered superior. The conclusion is that their practical usefulness depends more on the structure of the problem than on the algorithm itself.

When comparing these methods, **Vogel wins 25 times**, while **COFERMIN wins 6 times**, with **18 draws**. Here, Vogel shows a **clear advantage** over COFERMIN, as it obtains approximately **four times more wins**, positioning it as a more consistent method for obtaining low-cost solutions.

The comparison between Vogel and DEMAXMIN shows that, although they achieve **14 ties**, Vogel wins **31 times**, compared to only **5 wins for DEMAXMIN**.

The difference confirms that **Vogel is the more robust method**, as it far outperforms DEMAXMIN, which only has advantages in specific cases.

As a result of the above, when analyzing the results in the table, it can be seen that the Vogel and DEMAXMIN methods perform better in most exercises, often outperforming classic approaches such as the northwest or southwest corner. In particular, Vogel achieved the lowest cost in 31 out of 50 cases (62% effectiveness), while DEMAXMIN excelled in problems with more complex structures. In contrast, traditional methods such as minimum cost and COFERMIN achieved more modest performances, with competitive results in limited scenarios. These findings are consistent with those of Hillier and Lieberman (, 2010),

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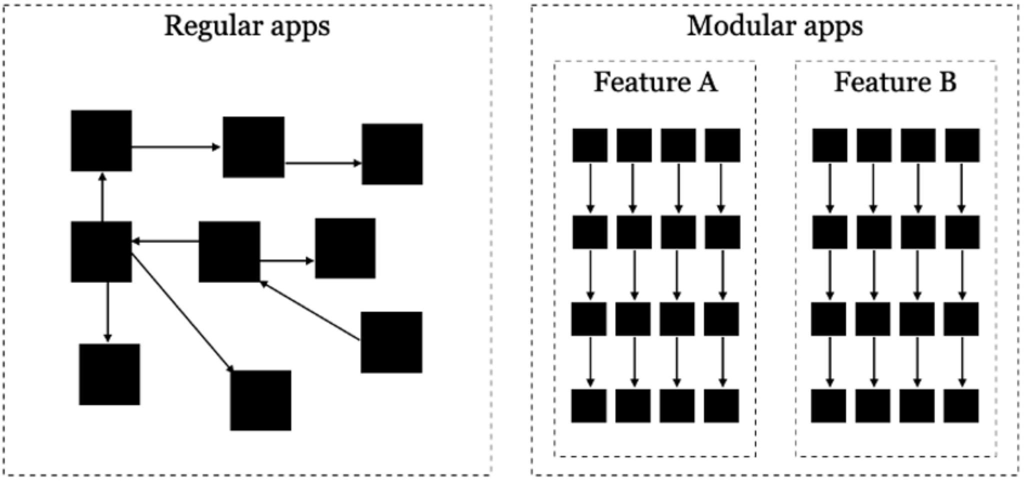

Figure 5. Regular architecture and modular architecture Source: Own elaboration

Component Diagram

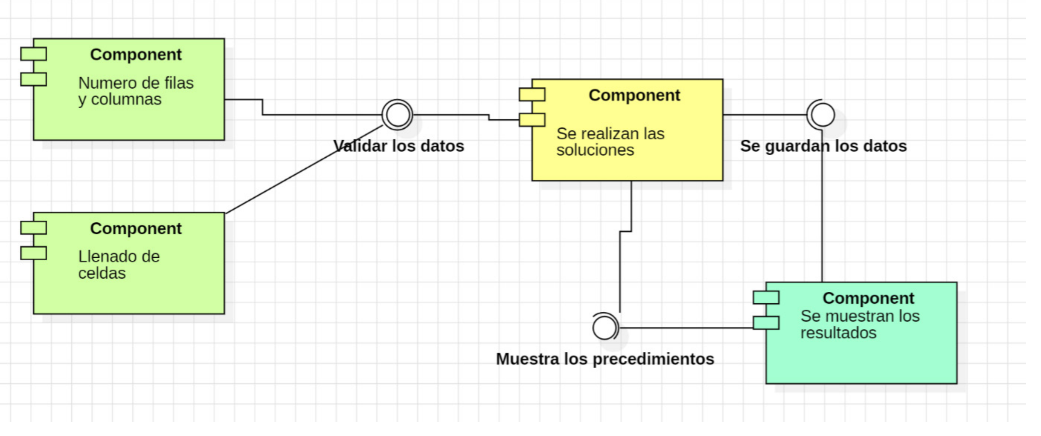

Figure 6. Component diagram Source: Own elaboration

Development of a mobile application for operations research transportation methods

Article 2

TRANSPORTATION METHODS

Exercises	Northwest	vs	Sou-thwest	Mini-mum cost	vs	COFERMIN	vs	Vogel approximation	vs	DEMAXMIN	Winner
1	655	s	645	510	e	510	e	510	D	505	DEMAXMIN
2	251,000	s	219,000	150,000	m	153,000	v	150,000	V	151,000	Tie
3	940	n	965	780	e	780	v	620	E	620	Tie
4	1,200	n	1,680	1,220	e	1,220	v	1,200	V	1,280	Tie
5	14,860	n	16,880	13,280	f	12,970	v	11,820	V	13,280	Vogel
6	14,300	s	12,800	11,000	m	11,400	v	11,000	E	11,000	Ties
7	41,950	s	28,000	24,750	m	25,500	v	24,750	E	24,750	Ties
8	430	n	440	230	f	220	v	200	V	250	Vogel
9	940	n	975	780	e	780	v	580	V	780	Vogel
10	275	n	318	229	f	214	e	214	V	224	Tie
11	43,805	n	43,925	37,335	m	38,385	v	37,335	E	37,335	Ties
12	940	n	965	780	e	780	v	620	E	620	Tie
13	1,430	s	940	840	f	820	e	820	V	830	Tie
14	520	s	460	475	m	520	v	475	V	505	Tie
15	3,640	n	6,920	2,820	e	2,820	e	2,820	E	2,820	Ties
16	35,420	s	34,300	29,490	f	29,250	v	27,000	V	29,710	VOGEL
17	1,200	n	1,320	820	f	810	e	810	V	830	Tie
18	330	s	320	270	e	270	v	230	V	250	Vogel
19	320	s	300	235	e	235	e	235	E	235	TIE
20	410	s	405	335	e	335	e	335	E	385	Ties
21	10,900	s	10,790	8,275	f	7,850	f	7,900	V	8,275	COFERMIN
22	715	s	705	550	e	550	e	550	D	525	DEMAXMIN
23	940	n	965	780	e	780	v	620	E	620	Tie
24	1,430	s	1,260	990	e	990	e	990	V	1,010	Ties
25	1,730	e	1,730	1,460	m	1,490	v	1,400	V	1,500	Vogel
26	585	s	545	405	e	405	e	405	V	420	Ties
27	1,050	n	1,185	560	e	560	e	560	V	560	Ties
28	7,151	s	3,448	2,170	e	2,170	e	2,170	V	3,106	Ties
29	555	n	655	405	e	405	f	445	V	455	Tie
30	1,430	s	1,260	990	e	990	e	990	V	1,010	Ties
31	360	n	1,130	630	e	630	e	630	E	630	Ties
32	770	n	830	720	f	700	v	645	V	680	Vogel
33	1,215	n	2,410	840	e	840	e	840	E	840	Ties
34	5,305	s	4,820	4,270	f	4,185	f	4,270	D	4,210	COFERMIN
35	23,500	s	20,500	20,500	e	20,500	e	20,500	V	21,500	Ties
36	2,750	n	3,690	2,570	f	2,540	v	2,510	V	2,570	Vogel
37	9,473	n	11,514	5,710	f	5,585	f	7,439	D	6,559	DEMAXMIN
38	9,688	n	10,466	8,632	e	8,632	f	8,694	V	9,001	Tie
39	8,899	n	11,042	5,528	f	5,403	f	6,959	D	5,745	Min cost
40	10,400	s	8,740	8,360	m	8,520	v	8,360	V	8,740	Tie
41	16,160	n	19,040	16,640	m	19,040	v	16,560	V	18,440	Northwest

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Exercises	Northwest	vs	Sou-thwest	Mini-mum cost	vs	COFERMIN	vs	Vogel approximation	vs	DEMAXMIN	Winner
42	251,000	s	219,000	150,000	m	153,000	v	150,000	V	151,000	Tie
43	1,025	n	1,250	925	m	980	v	910	V	935	Vogel
44	485	n	640	205	f	200	e	200	V	205	Tie
45	4,400	n	4,000	3,000	e	3,000	e	3,000	E	3,000	Ties
46	104	n	147	38	e	38	e	38	E	38	Draws
47	16,160	n	19,040	16,640	m	19,040	v	16,560	V	18,440	Northwest
48	2,025	s	1,325	1,325	e	1,325	v	1,300	V	1,375	Vogel
49	14,200	n	14,600	12,000	m	12,400	v	12,000	V	12,400	Tie
50	360	s	300	300	m	380	v	300	E	300	Ties

Table 5. Shows the comparative tables of the results of the transport methods

Comparison	Method 1 (Victorias)	Method 2 (Victorias)	Ties	Interpretation
Northwest vs. Southwest	Northwest: 27	Southwest: 22	Yes	Similar performance, no clear advantage, both useful as starting methods.
Minimum cost vs COFERMIN	Minimum cost: 13	COFERMIN: 13	24	Technical tie, both with similar effectiveness.
Vogel vs. COFERMIN	Vogel: 25	COFERMIN: 6	18	Vogel shows a clear advantage, with four times as many victories.
Vogel vs DEMAXMIN	Vogel: 31	DEMAXMIN: 5	14	Vogel is confirmed as the most robust method, with DEMAXMIN only winning in specific cases.
Overall (50 exercises)	Vogel: 31 (62%)	DEMAXMIN: 11 (22%)	Others: 8	Vogel is the most efficient, followed by DEMAXMIN; classical methods are less competitive.

Table 6. Shows a comparison of the results of the transportation methods

Method	Number of wins	Percentage (%)
Vogel	31	62
DEMAXMIN	11	22
Northwest Corner	3	6
Southwest corner	2	4
Minimum cost	2	4
COFERMIN	1	2
Ties	0	0
Total	50	100

Table 7. Analysis of transportation methods

who argue that intermediate methods tend to offer solutions closer to the optimum in real transportation problems.

The comparative table allows us to observe the relative performance between pairs of methods. While Northwest and Southwest, as well as Minimum Cost and COFERMIN, show similar performance and frequent ties, Vogel is clearly superior to COFERMIN and DEMAXMIN. Overall, Vogel confirms its status as the most efficient method (62% effectiveness), supporting its recommendation as the preferred heuristic technique for transportation problems.

In conclusion, the evidence obtained in the 50 comparative exercises confirms that the Vogel method is the most efficient in most scenarios, followed by DEMAXMIN in contexts with greater structural complexity. Traditional methods, although useful for teaching and simplicity of calculation, do not guarantee consistent minimum costs compared to more modern techniques. The application developed not only validated this behavior in a practical way, but also demonstrated the importance of having automated tools that reduce analysis times and facilitate decision-making in logistics and distribution.

The tally table confirms that the Vogel method was the most effective, solving 31 of the 50 exercises (62%) at the lowest cost. DEMAXMIN achieved 22% effectiveness, performing better on problems with more complex structures. In contrast, classical methods such as northwest corner, southwest corner, minimum cost, and COFERMIN achieved only between 2% and 6% effectiveness, demonstrating their low competitiveness in more demanding scenarios. These results reinforce the conclusion that intermediate and heuristic methods such as Vogel and DEMAXMIN are more robust for practical applications in logistics.

Conclusions.

The mobile application is an educational and practical tool for solving transportation problems in operations research. The application solves six transportation methods simultaneously and compares them to find the best solution among the proposed methods for evaluation. It also shows the step-by-step solution for each method to facilitate understanding of their development and the efficiency and effectiveness of each one. In the future, we propose to integrate more heuristic algorithms, optimize the graphics interface, and extend its application to unbalanced transportation problems.

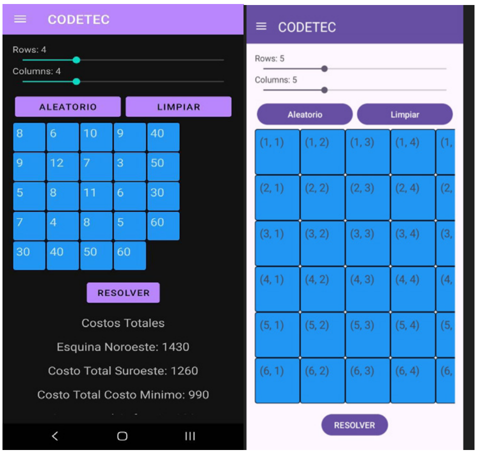

Figure 7*. View of the application Source: Own elaboration*

Figure 7 shows the first interface of the application, which has two sliders to choose the size of rows and columns required by the user, the Random button that works to fill all cells randomly, and the Clear button that deletes all data from the cells if you have any numbers. the Solve button, which solves the problem using the three heuristic methods

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and the three proposals, and finally the total costs

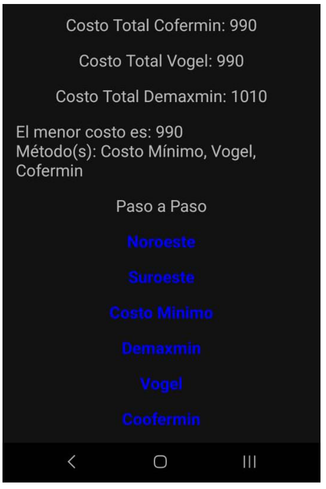


Figure 8. *Total costs 2/2 and links to see each method step by step*
Source: Own elaboration

Figure 8 shows the total costs 2/2, as well as which of the three heuristic methods and three proposals obtained the lowest cost, and the links to see the step-by-step process.

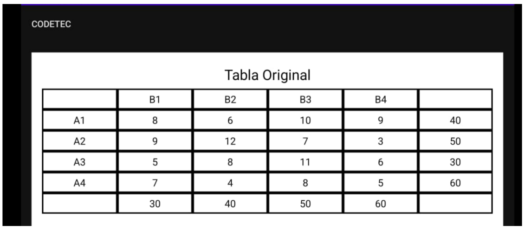
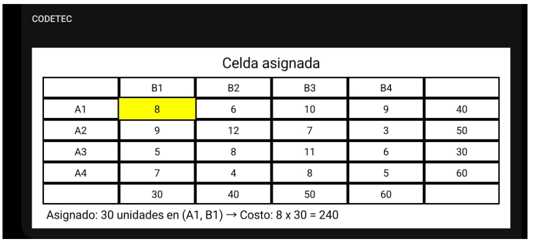

CODETEC

Tabla Original

	B1	B2	B3	B4	
A1	8	6	10	9	40
A2	9	12	7	3	50
A3	5	8	11	6	30
A4	7	4	8	5	60
	30	40	50	60	

Figure 9. First step-by-step table Source: Own elaboration

Figure 9 shows the first step-by-step table in a passive view. The table shown is the original one that the user entered the data into, or one that was filled in randomly.


CODETEC

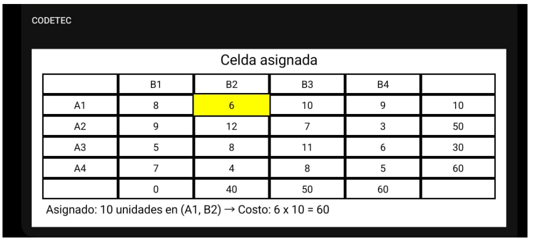
Celda asignada

	B1	B2	B3	B4	
A1	8	6	10	9	40
A2	9	12	7	3	50
A3	5	8	11	6	30
A4	7	4	8	5	60
	30	40	50	60	

Asignado: 30 unidades en (A1, B1) → Costo: 8 x 30 = 240

Figure 10. First iteration Source: Own elaboration

Figure 10 shows the first iteration of the step-by-step table. In this case, the Northwest step-by-step table was chosen, and below the table shows how much was assigned to each cell with its respective coordinates. as well as the multiplication of the cost of the cell by the amount assigned and the result of the multiplication. This process continues until there are no more offers and demands to be satisfied.

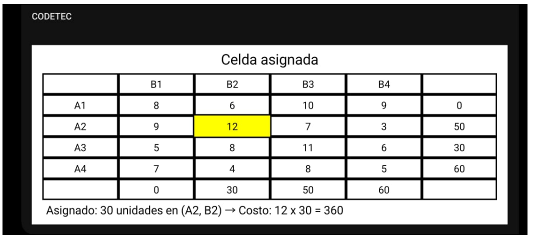

CODETEC

Celda asignada

	B1	B2	B3	B4	
A1	8	6	10	9	10
A2	9	12	7	3	50
A3	5	8	11	6	30
A4	7	4	8	5	60
	0	40	50	60	

Asignado: 10 unidades en (A1, B2) → Costo: 6 x 10 = 60

Figure 11. Second iteration Source: Own elaboration


CODETEC

Celda asignada

	B1	B2	B3	B4	
A1	8	6	10	9	0
A2	9	12	7	3	50
A3	5	8	11	6	30
A4	7	4	8	5	60
	0	30	50	60	

Asignado: 30 unidades en (A2, B2) → Costo: 12 x 30 = 360

Figure 12. Third iteration Source: Own elaboration

CODETEC

Celda asignada

	B1	B2	B3	B4	
A1	8	6	10	9	0
A2	9	12	7	3	20
A3	5	8	11	6	30
A4	7	4	8	5	60
	0	0	50	60	

Asignado: 20 unidades en (A2, B3) → Costo: 7 x 20 = 140

Figure 13. Fourth iteration Source: Own elaboration

CODETEC

Celda asignada

	B1	B2	B3	B4	
A1	8	6	10	9	0
A2	9	12	7	3	0
A3	5	8	11	6	30
A4	7	4	8	5	60
	0	0	30	60	

Asignado: 30 unidades en (A3, B3) → Costo: 11 x 30 = 330

Figure 14. Fifth iteration Source: Own elaboration

The final iteration shows the total cost of each assigned cell multiplied by the maximum available bid and, finally, the result of the sum of all these multiplications.

CODETEC

Celda asignada

	B1	B2	B3	B4	
A1	8	6	10	9	0
A2	9	12	7	3	0
A3	5	8	11	6	0
A4	7	4	8	5	60
	0	0	0	60	

Asignado: 60 unidades en (A4, B4) → Costo: 5 x 60 = 300

Costo Total: 8 x 30 + 6 x 10 + 12 x 30 + 7 x 20 + 11 x 30 + 5 x 60 = 1430

Figure 15 shows the total cost of each cost.

The project highlights the importance and complexity associated with selecting the most appropriate heuristic method for solving a transportation problem. The lack of certainty about which method is the most effective underscores the need for ongoing research and the development of more advanced and adaptable heuristic methods that can address the specific complexities of the problem in real time.

It is proposed that the mobile application will help users make efficient decisions in solving transportation problems using different heuristic methods.

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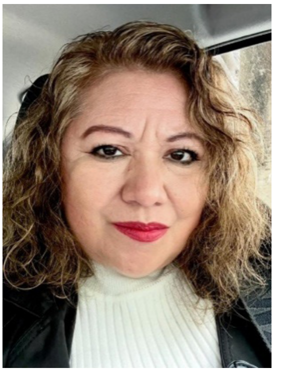

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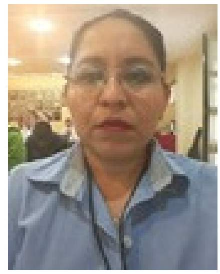

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