Using Decision Trees to Evaluate Courier Companies from the Perspective of Online Retailers

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The analysis of the research problem started from listing the issues of decision theory and the decision-making process that support the process of building decision trees. The area in question covers a procedure for building and proceeding when creating decision trees. The solution to the research problem consists in defining decision variables and arranging them into logical statements by writing down all possible variants and only accounting for the true ones. True solutions derived from coding were detailed and the number of occurring decision trees was calculated in the case under consideration. The decision problem was presented in the form of decision trees, which made it possible to select the optimum decision tree. The obtained results were considered and the optimum decision tree was chosen. At the same time, the record of decision variables was analyzed, providing the answer as to which courier company will best meet expectations of entrepreneurs and ensure the most satisfying cooperation. That company turned out to be K-EX. The article aimed to select a courier company from the perspective of online retailers, with the selection having been made using the method of decision trees based on four basic criteria defined within the research.

Keywords: decision-making process, decision trees, service companies, online sales.

1. RESEARCH APPROACH – DESIGN METHODOLOGY

In today's world, every day brings with it a variety of dilemmas of different kinds, occurring in different systems. Struggling with the making the right decision often proves laborious and time-consuming. To make the right choice is complicated, and an ill-informed decision can lead to a number of complications. In practice, the result of one decision triggers making another one. In situations where several decisions are made under indefinite conditions, and each of them depends on the results of the sample, decision theory (i.e. the graphical decision-support method), represented in the form of decision trees, should be applied. Applying this method in a quick and trouble-free manner will help make the right decision. Following the logic of decision-making processes, one needs to determine the search area for the solutions, relying on independent decision variables and creating a graphical solution to the problem. When analyzing the problem, one can separate logical statements that will solve the existing problem [[1]].

In business environment, decisions often determine whether a company will be able to maintain its position on the market. Decision-making in companies cannot be intuitive or based solely on experience from previous years - the wide range of opportunities that technology, tools and decision-support systems provide should be accounted for as well. Each of the implemented decisions should fulfill its assumptions, implementing decision theory and bringing about the expected results.

Decision theory, or the theory of choice, plays a key role in choice-making. It deals with issues such as decision analysis or decision support. Decision analysis determines most advantageous decisions, and in the case of making the worst possible of them, the search for the cause of the solution commences. On the other hand, decision support is based on an optimum solution with

[[1]] PENC J.: *Decyzje w zarządzaniu*; Krakow 1997.

knowledge of the possible consequences. Decision theory is used for solving problematic situations in which the individual is forced to make one of at least two variants of the choice. Methods of decision theory are normative and are applied where decision-making is difficult, or impossible, such as when:

- there is a lot of variants of solutions,
- the circumstances and the decision-making process are complex,
- there is a high risk of loss or gain,
- the importance of decision-making is high.

The decision tree is a graphical decision support method, presented as a logical tree structure in which the logical values of the variables are encoded on tree branches [2]. It consists of roots, bundles, edges and leaves. The bundles from which no edges protrude are leaves. The selected decision variables form the root of the tree, while the individual branches represent the values of those decision variables. The characteristic feature of decision trees is the hierarchical structure, which in subsequent stages divides the set of objects by answering questions about the values of the selected features or their linear combinations. The final decision depends on the answer to all of the existing questions. According to the tree construction algorithm, the key element is to choose the order, or arrangement, of the value of the characteristics, according to which the division of decision variables will take place at different stages. Only one logical variable can appear on each level of the decision tree, while the number of floors will be equal to the number of independent variables of the logical function. A set of all possible numerical combinations forms a variant tree with a number of floors equal to the number of parameters. One logical variable occurs only in the case of a traditional decision tree on a single floor. The number of subdivisions in a given range is the number of branches in one bundle, and the number of all branches from the bottom to the top of the logical tree matches exactly the number of all discrete combinations of the ranges considered. Where all the branches of a traditional logical tree represent a set of all theoretical variants of the discrete optimization process, only true variants that meet the optimization requirements should be separated [3]. Boolean functions that are multivalued by replacing the logical tree floors define the significance of the logical variables from those that are most important - they are at the root, with the least significant ones being located at the very top of the decision tree.

Supporting the decision-making process with the use of decision trees makes it possible to find the optimum solution that will help make the decision. Due to their structure and behavior, decision trees are very often used in making important business decisions. They are, by nature, universal, which in practice makes them multifunctional.

2. APPLICATION OF DECISION TREES

The search for the optimum solution is designed so as to help online retailers choose their preferred shipping (transportation) company. According to the indications of the surveyed entities, the following carriers formed part of the research considerations: (1) DPD, (2) POCZTA POLSKA, (3) K-EX, (4) UPS.

All decision variables are assigned specific values that assume a fixed coding. The solution should begin with a list of the decision variables that occur in the problem, along with their coding, as follows:

- Courier company (x_1):
  - DPD, which assumes the value of 0,
  - POCZTA POLSKA, which assumes the value of 1,
  - K-EX, which assumes the value of 2,
  - UPS, which assumes the value of 3.
- Shipping time (transit time) (x_2)
  - up to 5 hours , assumes the value of 0,
  - from 5 to 10 hours, assumes the value of 1,
  - more than 10 hours, assumes the value of 2.
- Shipping cost (x_3)
  - More than 50 PLN, assumes the value of 0,
  - Less than 50 PLN, assumes the value of 1.
- Additional services included in shipping cost (x_4)
  - tracking shipment, assumes the value of 0,
  - insurance, assumes the value of 1,

[2] DEPTUŁA A., *Analiza porównawcza optymalnych logicznych drzew decyzyjnych i indukcyjnych drzew systemu DeTreex w optymalizacji dyskretnej układów maszynowych*; Polskie Stowarzyszenie Zarządzanie Wiedzą: Seria Studia i Materiały; 2011.

[3] DEPTUŁA A., *Analiza porównawcza optymalnych logicznych drzew decyzyjnych i indukcyjnych drzew systemu DeTreex w optymalizacji dyskretnej układów maszynowych*; Polskie Stowarzyszenie Zarządzanie Wiedzą: Seria Studia i Materiały; 2011.

- text message notifications, assumes the value of 2,
- storage, assumes the value of 3.

It is possible to define logical statements by using the record of variables and their coding, and they are as follows:

- If DPD, the logical variable is 0.
- If POCZTA POLSKA, the logical variable is 1.
- If K-EX, the logical variable is 2.
- If UPS, the logical variable is 3.
- If the courier company's transit time is less than 5 hours, the logical variable is 0.
- If the courier company's transit time is 5-10 hours, the logical variable is 1.
- If the courier company's transit time is more than 10 hours, the logical variable is 2.
- If the courier company's shipping cost is more than 50 PLN, the logical variable is 0.
- If the courier company's shipping cost is less than 50 PLN, the logical variable is 1.
- If the courier company's has the additional service of tracking shipments, the logical variable is 0.
- If the courier company's has the additional service of insurance, the logical variable is 1.
- If the courier company's has the additional service of text message notifications, the logical variable is 2.
- If the courier company's has the additional service of storage, the logical variable is 3.

The next step toward solving the decision problem was to write down all the solutions and then select from among them only the true ones that resulted from coding, as shown in Tab. 1.

Table 1. True solutions derived based on coding.

L.p.	x_1	x_2	x_3	x_4
1	0	1	1	0
2	0	1	1	2
3	0	1	1	3
4	1	2	0	0
5	1	2	0	3
6	2	0	1	0
7	2	0	1	1
8	2	0	1	2
9	2	0	1	3
10	3	0	1	0
11	3	0	1	2

By following the entire process of writing out the algorithm to solve the problem using decision trees, one must define the true statements that characterize each of the shipping companies selected by the retailers:

- DPD, ships parcels in 5-10 hours, shipping cost is less than 50 PLN, has additional services such as: tracking shipments, text message notifications, storage;
- POCZTA POLSKA, ship parcels in more than 10 hours, shipping cost is more than 50 PLN, has additional services such as tracking shipments and storage;
- K-EX, ships parcels in less than 5 hours, shipping cost is less than 50 PLN, has additional services such as: tracking shipments, insurance, text message notifications, storage.
- UPS, ships parcels in less than 5 hours, shipping cost is less than 50 PLN, has additional services such as: tracking shipments, text message notifications.

The number of decision trees is determined by the number of variables. As far as the choice of courier companies, 4 decision variables were defined. We will calculate the number of decision trees using the factorial, and therefore 4! = 24 decision trees. The solution to this problem is to create for the existing variables 24 decision trees appearing in different combinations. The set of solution variants was then assigned successively to the decision trees, as presented below.

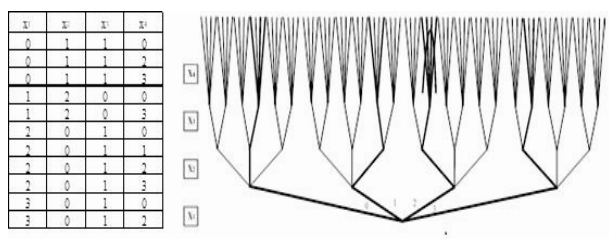

Fig. 1. Decision tree no. 1 x_1, x_2, x_3, x_4.

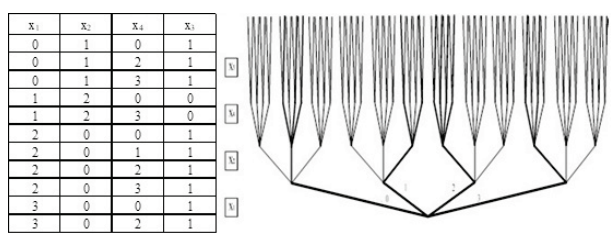

Fig. 2. Decision tree no. 2 x_1, x_2, x_4, x_3.

x_1	x_3	x_4	x_2
0	1	0	1
0	1	2	1
0	1	3	1
1	0	0	2
1	0	3	2
2	1	0	0
2	1	1	0
2	1	2	0
2	1	3	0
3	1	0	0
3	1	2	0

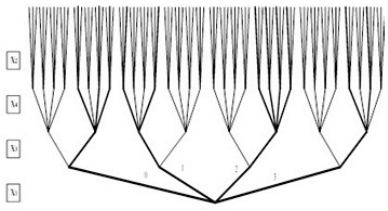

Fig. 3. Decision tree no. 3 x_1, x_3, x_4, x_2.

x_1	x_3	x_2	x_4
0	1	1	0
0	1	1	2
0	1	1	3
1	0	2	0
1	0	2	3
2	1	0	0
2	1	0	1
2	1	0	2
2	1	0	3
3	1	0	0
3	1	0	2

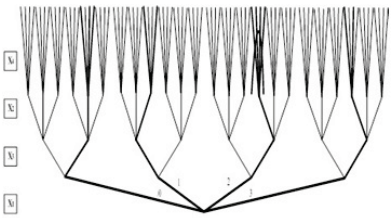

Fig. 4. Decision tree no. 4 x_1, x_3, x_2, x_4.

x_1	x_4	x_2	x_3
0	0	1	1
0	2	1	1
0	3	1	1
1	0	2	0
1	3	2	0
2	0	0	1
2	1	0	1
2	2	0	1
2	3	0	1
3	0	0	1
3	2	0	1

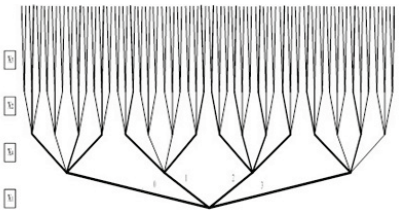

Fig. 5. Decision tree no. 5 x_1, x_4, x_2, x_3.

x_1	x_4	x_3	x_2
0	0	1	1
0	2	1	1
0	3	1	1
1	0	0	2
1	3	0	2
2	0	1	0
2	1	1	0
2	2	1	0
2	3	1	0
3	0	1	0
3	2	1	0

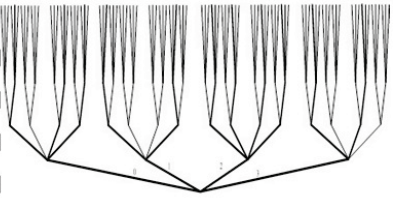

Fig. 6. Decision tree no. 6 x_1, x_4, x_3, x_2.

x_2	x_1	x_3	x_4
1	0	1	0
1	0	1	2
1	0	1	3
2	1	0	0
2	1	0	3
0	2	1	0
0	2	1	1
0	2	1	2
0	2	1	3
0	3	1	0
0	3	1	2

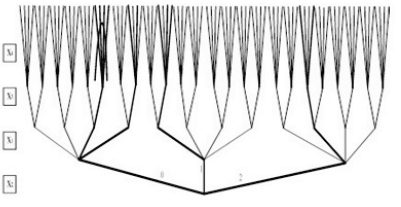

Fig. 7. Decision tree no. 7 x_2, x_1, x_3, x_4.

x_2	x_3	x_4	x_1
1	1	0	0
1	1	2	0
1	1	3	0
2	0	0	1
2	0	3	1
0	1	0	2
0	1	1	2
0	1	2	2
0	1	3	2
0	1	0	3
0	1	2	3

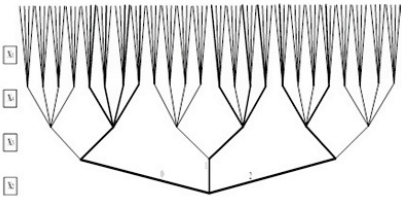

Fig. 8. Decision tree no. 8 x_2, x_1, x_4, x_3.

x_2	x_3	x_1	x_4
1	1	0	0
1	1	0	2
1	1	0	3
2	0	1	0
2	0	1	3
0	1	2	0
0	1	2	1
0	1	2	2
0	1	2	3
0	1	3	0
0	1	3	2

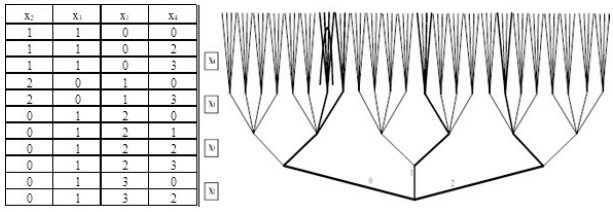

Fig. 9. Decision tree no. 9 x_2, x_3, x_1, x_4.

x_2	x_3	x_4	x_1
1	1	0	0
1	1	2	0
1	1	3	0
2	0	0	1
2	0	3	1
0	1	0	2
0	1	1	2
0	1	2	2
0	1	3	2
0	1	0	3
0	1	2	3

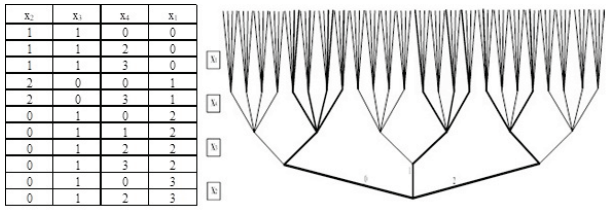

Fig. 10. Decision tree no. 10 x_2, x_3, x_4, x_1.

x_2	x_4	x_1	x_3
1	0	0	1
1	2	0	1
1	3	0	1
2	0	1	0
2	3	1	0
0	0	2	1
0	1	2	1
0	2	2	1
0	3	2	1
0	0	3	1
0	2	3	1

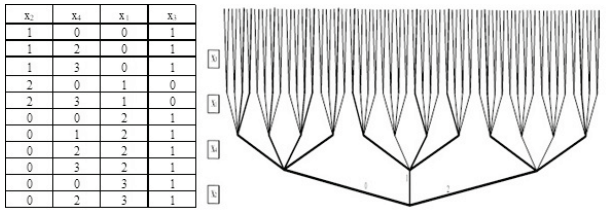

Fig. 11. Decision tree no. 11 x_2,x_4, x_1, x_3.

x_2	x_4	x_3	x_1
1	0	1	0
1	2	1	0
1	3	1	0
2	0	0	1
2	3	0	1
0	0	1	2
0	1	1	2
0	2	1	2
0	3	1	2
0	0	1	3
0	2	1	3

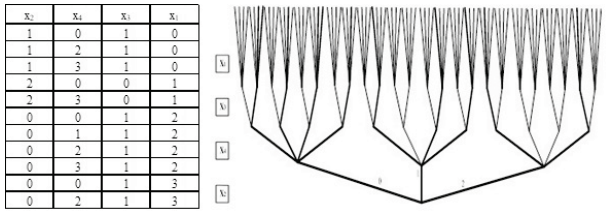

Fig. 12. Decision tree no. 12 x_2, x_4, x_3, x_1.

x_3	x_1	x_2	x_4
1	0	1	0
1	0	1	2
1	0	1	3
0	1	2	0
0	1	2	3
1	2	0	0
1	2	0	1
1	2	0	2
1	2	0	3
1	3	0	0
1	3	0	2

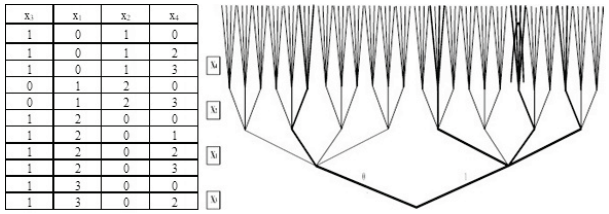

Fig. 13. Decision tree no. 13 x_3, x_1, x_2, x_4.

x_3	x_1	x_4	x_2
1	0	0	1
1	0	2	1
1	0	3	1
0	1	0	2
0	1	3	2
1	2	0	0
1	2	1	0
1	2	2	0
1	2	3	0
1	3	0	0
1	3	2	0

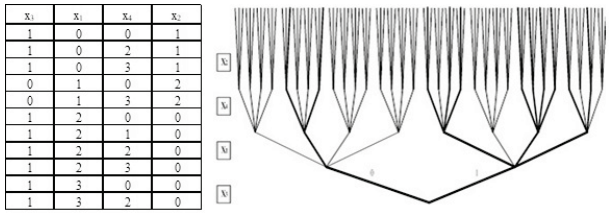

Fig. 14. Decision tree no. 14 x_3, x_1, x_4, x_2.

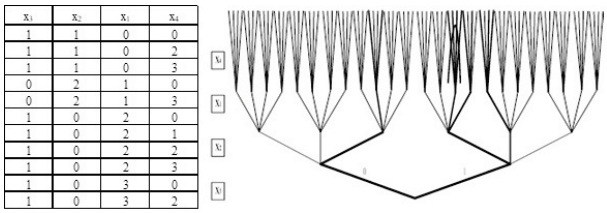

Fig. 15. Decision tree no. 15 x_3, x_2, x_1, x_4.

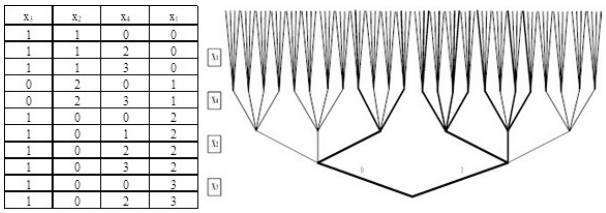

Fig. 16. Decision tree no. 16 x_3, x_2, x_4, x_1.

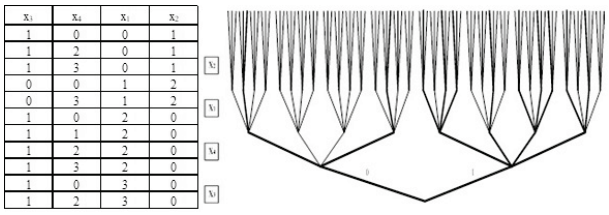

Fig. 17. Decision tree no. 17 x_3, x_4, x_1, x_2.

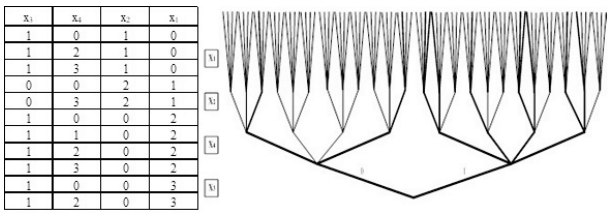

Fig. 18. Decision tree no. 18 x_3, x_4, x_2, x_1.

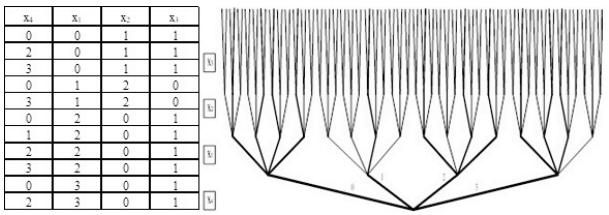

Fig. 19. Decision tree no. 19 x_4, x_1, x_2, x_3.

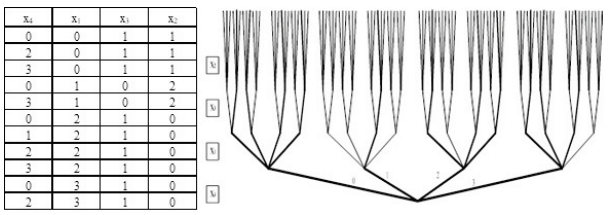

Fig. 20. Decision tree no. 20 x_4, x_1, x_3, x_2.

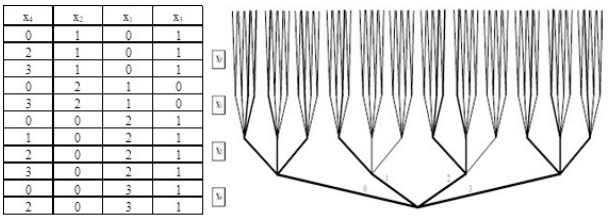

Fig. 21. Decision tree no. 21 x_4, x_2, x_1, x_3.

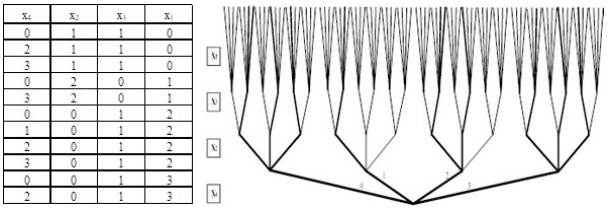

Fig. 22. Decision tree no. 22 x_4, x_2, x_3, x_1.

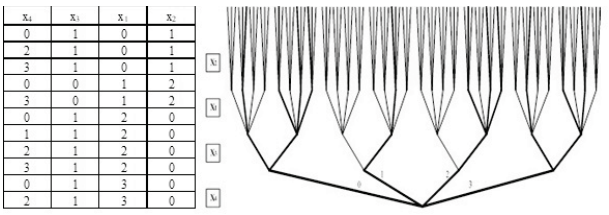

Fig. 23. Decision tree no. 23 $x_{4,}$ x_3, x_1, x_2.

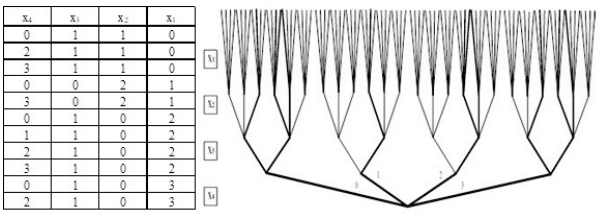

Fig. 24. Decision tree no. 24 $x_{4,}$ $x_{3,}$ $x_{2,}$ x_1.

3. ANALYSIS OF THE RESULTS

Decision variables determine the number of decision trees. In the case in question, the number of variables was 4, thus giving 24 decision trees. The analysis demonstrated the following branch structure of the true decision trees:

- decision tree 1: x_1, x_2, x_3, x_4 – 19 true branches,
- decision tree 2: x_1, x_2, x_4, x_3 – 30 true branches,
- decision tree 3: x_1, x_3, x_4, x_2 – 30 true branches,
- decision tree 4: x_1, x_3, x_2, x_4 – 19 true branches,
- decision tree 5: x_1, x_4, x_2, x_3 – 37 true branches,
- decision tree 6: x_1, x_4, x_3, x_2 – 37 true branches,

- decision tree 7: x_2, x_1, x_3, x_4 – 18 true branches,
- decision tree 8: x_2, x_1, x_4, x_3 – 29 true branches,
- decision tree 9: x_2, x_3, x_1, x_4 – 17 true branches,
- decision tree 10: x_2, x_3, x_4, x_1 – 26 true branches,
- decision tree 11: x_2, x_4, x_1, x_3 – 34 true branches,
- decision tree 12: x_2, x_4, x_3, x_1 – 32 true branches,
- decision tree 13: x_3, x_1, x_2, x_4 – 17 true branches,
- decision tree 14: x_3, x_1, x_4, x_2 – 28 true branches,
- decision tree 15: x_3, x_2, x_1, x_4 – 16 true branches,
- decision tree 16: x_3, x_2, x_4, x_1 – 25 true branches,
- decision tree 17: x_3, x_4, x_1, x_2 – 30 true branches,
- decision tree 18: x_3, x_4, x_2, x_1 – 28 true branches,
- decision tree 19: x_4, x_1, x_2, x_3 – 36 true branches,
- decision tree 20: x_4, x_1, x_3, x_2 – 37 true branches,
- decision tree 21: x_4, x_2, x_1, x_3 – 35 true branches,
- decision tree 22: x_4, x_2, x_3, x_1 – 33 true branches,
- decision tree 23: x_4, x_3, x_1, x_2 – 32 true branches,
- decision tree 24: x_4, x_3, x_2, x_1 – 30 true branches.

Considering all possible variants, one optimum decision tree - namely number 15 with 16 true branches - was identified. It is also worth setting apart the two decision trees in which the number of true branches is 17 and these are trees numbered 9 and 13. However, according to the theory of decision trees, a decision tree with the smallest number of branches should be chosen, i.e. tree number 15. This tree is the most important and its layout determines the choice of the courier company for the retailer.

The solution to this problem is to find the most favorable decision tree, that is the tree that has the smallest number of branches. The analyzed case showed one such decision tree, i.e.:

- decision tree 15: x3, x2, x1, x4 - 16 true branches.

The most important parameter in the decision-making process was the shipping cost – x_3, which occupies the highest position. It plays the crucial role in making the choice. The next parameter is shipping time (transit time) - x_2, which occupies the second highest position and is less important than shipping, but more important than the remaining parameters. The next place went to the company – x_1, whereas the last spot was reserved for x_4 - additional services included in the shipping cost - this parameter is least important and plays the least significant role in decision-making. According to this sequence of parameters, the best shipping company is K-EX.

4. CONCLUSIONS

The article outlines what the decision-making process is, how it works and how important it is in making decisions. The developed decision trees can be used to deal with different decision problems, they are universal. One of the best methods for decision-making is decision trees, which graphically represent the scale of the problem and what decision should be made in order to solve it in the most advantageous way. Company "X" struggled with a difficult decision of choosing the courier company to sign the contract with. Making such a decision is not easy regardless of the type of business or industry. Using decision trees, the decision-making problem faced by the company was resolved. The company will embark on cooperation with the shipping company K-EX, and this choice will prove to be the most advantageous.

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