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DECISION-MAKING SUPPORT SYSTEM FOR TERRITORIAL COMMUNITIES

Roman BIHUN[1], Vasyl LYTVYN[2*]

[1] Department of Information Systems and Networks, Lviv Polytechnic National University;
bigunroman@ukr.net, ORCID: 0000-0003-4363-4532
[2] Department of Information Systems and Networks, Lviv Polytechnic National University;
vasyl17.lytvyn@gmail.com, ORCID: 0000-0002-9676-0180
* Correspondence author

Purpose: The main aim of the study is to build a decision support system for the development of territorial communities.
Design/methodology/approach: The study includes linear multifactor regression for agro-industrial complex. The module for optimizing garbage collection consists of clustering garbage collection points using the k-means algorithm and the salesman's task to find the shortest path. The method of hierarchy analysis was used to choose the direction of development of territorial communities. For the development of tourism, PLS-PM modeling was used.
Findings: The system of decision support for the development of territorial communities has been implemented. The results of the program experiment were analyzed, and the scientific and practical significance of the developed program was shown. The study helps managers to make decisions for the development of territorial community. The separate components of the functioning of the decision support system which consists of four parts (modules) are analyzed. Each module can be used separately if necessary. Therefore, the methods of operation for each part were described using UML diagrams or a simple visualization of the steps of an algorithm or method.
Originality/value: The added value of the article is the support in the decision-making process of leaders for the development of local communities.

Keywords: territorial community, decision support system, mathematical model.

Category of the paper: Research paper.

1. Introduction

Today, several foreign countries are in the process of profound changes in the system of regulation of public relations. In terms of prospects for local development, decentralization has become an effective way to change the essential characteristics of society. The experience of

developed countries shows that the main prerequisite for successful community development is the unification of territories and resources, in which the state creates the necessary conditions for community development, and they must choose the priorities they need. Therefore, the question arises for each community "Which sector of the industry from the available resources can bring the most benefit to the community?".

Let us consider this issue on the example of the development of territorial communities of Ukraine, as in Ukraine there is also a tendency to decentralize power and unite several settlements, thus forming a prosperous territorial community. To effectively implement certain regional or local policy steps, community political forces need to have a few required skills. Such several managerial characteristics includes the ability to form compliance and unity between goals. Prioritization of tasks and activities at different levels of government of local governments (central, regional, and local) or executive authorities is also an important element of the above. This element plays an important role both in addressing key development challenges and in achieving long-term strategic goals.

Capable united territorial communities should be the main contenders for an effective system of government in Ukraine. Therefore, when creating new territorial communities with new legislative and financial functions, the relevant authorities have several responsibilities. They should form and explain to the newly created community the main priority areas of development, determine its route, and announce the means and methods needed to overcome it. The stage of creating new territorial communities also has several challenges, among which are the following:

- difficult adoption by the newly formed community of general priorities for the provision of basic services to its residents. This is since before the merger, each body had its own management methods and priorities;
- lack of understanding of the management and use of new resources available after the merger (land, territorial, budget);
- increasing the number of members of government with whom you want to coordinate certain management decisions.

Given such complications, the question of proper planning of the development of the territorial community is critical. The adopted strategy should include all the existing advantages of the united territorial community (natural, material, territorial, etc.). Then, with the proper organization of government work, you can achieve the most effective level of local development.

Over the last decade, a number of works have been devoted to solving the problem of development of territorial communities, which are based on the construction of efficient algorithms using natural systems (swarm algorithms, etc.) for various applications. Feldmann and Foschini (2012) used the problem of graph partitioning to construct balanced trees. Such mathematical models are also used for clustering problems (Alzate, Suykens, 2010).

Successful development of the regions requires certainty and the presence of consolidating ideas about the future. These are important needs of business and society, which are met through the mechanism of territorial socio-economic planning, especially strategic planning. Borbasova (2020) considered the concept of strategic management and described the differences between strategic and current management on the example of management of branches of the social bloc. The essence of management of territorial economy of the region, and questions of realization of life support and social service of the population, improvement of territorial economy, acquisition by it of new qualitative characteristics of higher level is investigated also.

On the example of Latvia, Lonska (2021) analyzed the structural scheme of assessment of the territorial state of development, developed earlier, assessing the territorial state of development of statistical regions of the country. The analysis showed that it is impossible to draw unambiguous conclusions about the level of their development, as each region of Latvia has its own quality or essence of development.

Filippetti, Sacchi, (2013) and Oates (2006) revealed a wide range of issues, including the study of the essence of the concept of "decentralization of public power", its types and forms, principles of implementation, evaluation of decentralization models, an algorithm for reform, and more. At the same time, some issues remain unresolved in both theoretical and methodological aspects, and therefore necessitate further research and finding ways to solve problems in this area.

Thoening (2006) analyzed the development and current state of reforms of state and local self-government in France and Germany.

Thus, the results of the analysis allow us to conclude that the development of territorial communities is a very important topic. This will better shape local budgets and improve the country's economy.

2. Materials and methods of research

The decision support system consists of four elements: agro-industrial (Bihun, Lytvyn, Oleksiv, 2022), optimization of garbage removal (Bihun, Lytvyn, 2022), choice of direction of development and tourism development (Bihun, Lytvyn, Oleksiv, 2021).

The structure of software for the decision support system of territorial communities consists of three categories: system programs, applications, and tools.

System programs include those that play a supporting role, such as the operating system. In our case, the operating system was Windows 11 Pro, version 21H2.

Tool systems, in other words, programming systems, provide the creation of new programs for the computer. In our case, for the garbage disposal optimization module, it was the Python programming language, the programming environment - PyCharm Community, because

Python has many useful libraries for working with data analysis, machine learning and others (Lutz, 2003). The C# programming language and the Windows Forms application programming interface were chosen to build the development direction selection system, as it is convenient for writing graphic applications and easy to use (Sells, 2003).

Applications are programs that directly provide the necessary work, such as building tables or databases, processing information arrays, and so on. In our case, such programs are Excel and SmartPLS.

3. The results of the study of the decision support system for the development of territorial communities

3.1. Building a decision support system for the development of territorial communities

All modules (elements) of the proposed decision support system: agro-industrial (Bihun, Lytvyn, Oleksiv, 2022), optimization of garbage removal (Bihun, Lytvyn, 2022), choice of direction of development and tourism development (Bihun, Lytvyn, Oleksiv, 2021) are written in those programs that best suited their functions and capabilities.

The diagram of components (Fowler, 2004) of decision support system is presented in figure 1.

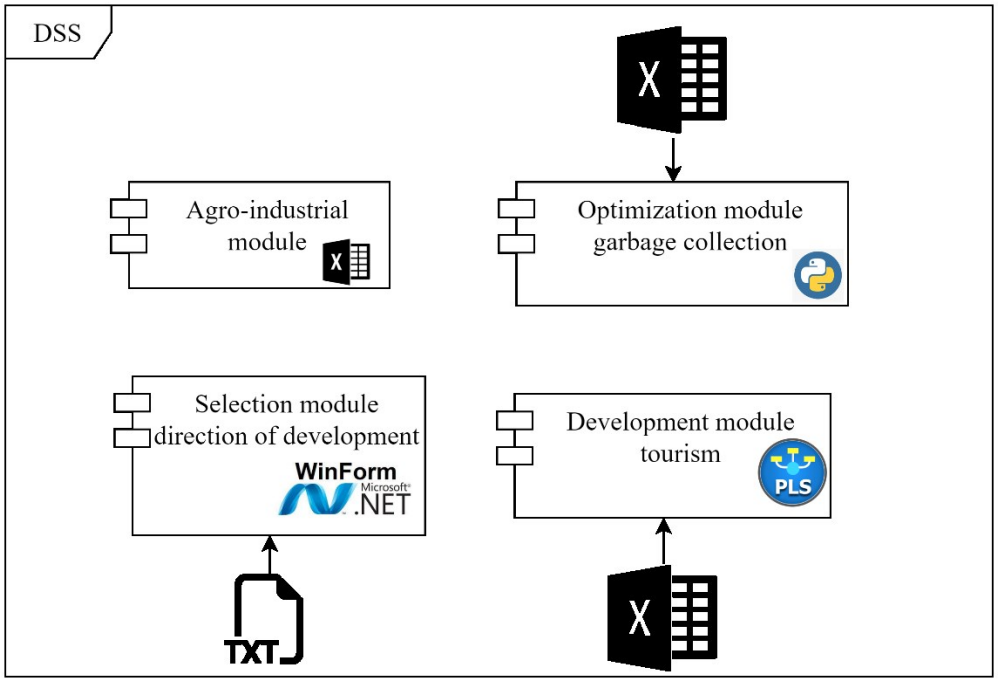

Figure 1. Diagram of components of decision support system for the development of local communities.

The block diagram of the decision support system for the development of territorial communities is presented in figure 2.

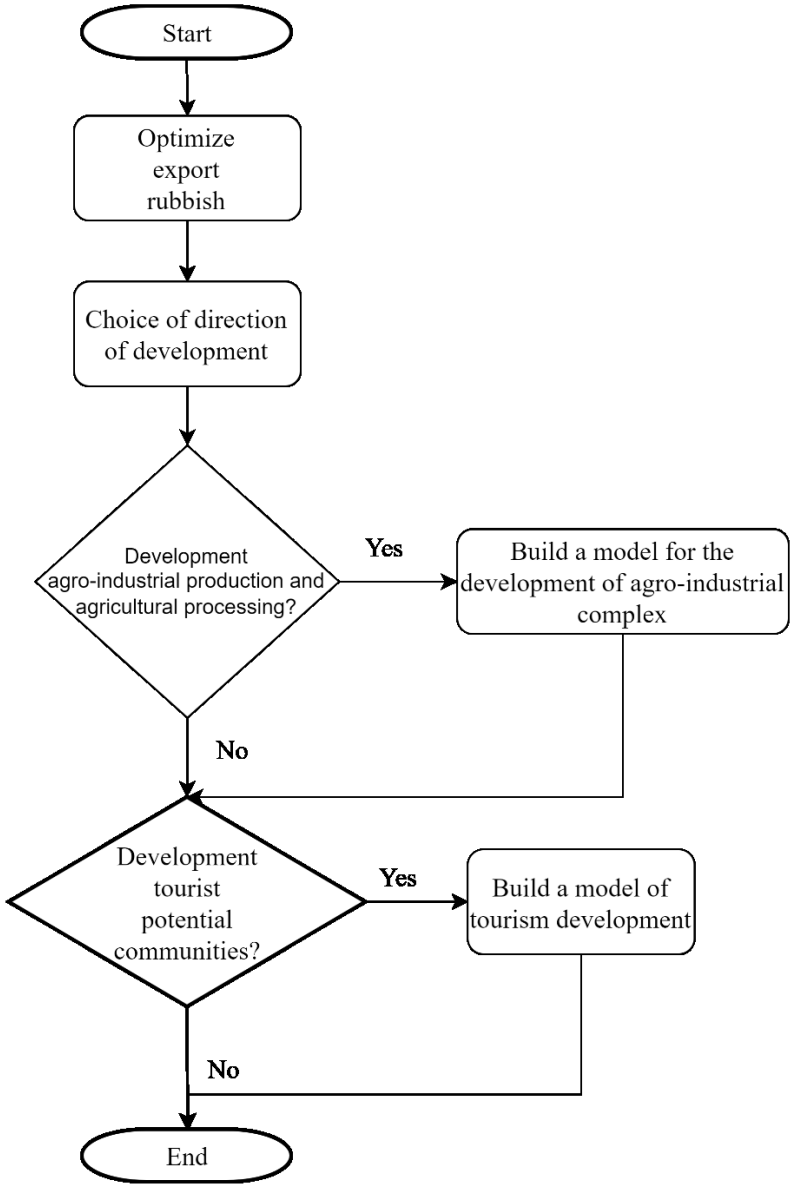

Figure 2. Block diagram of decision support for the development of territorial communities.

All modules can be used separately for any territorial community, except agricultural, as it depends on whether the community has agricultural land.

First, an algorithm for optimizing garbage collection is used. Then the direction of development of the territorial community is chosen. If in the process of calculation, the direction "Development of agro-industrial production and agricultural processing" is chosen, then the agrarian model is used, which analyzes the factors that affect the agro-industrial complex. If the direction "Development of the tourist potential of the community" was chosen, then we build a model of tourism development. Since there are several areas of development, both modules - tourism development and agro-industrial complex – can be used.

The first step in building a decision support system for the development of local communities is to optimize garbage collection. Next is the choice of direction of development. Depending on the calculated direction, the agro-industrial module (Bihun, Lytvyn, Oleksiv, 2022) or the tourism development module (Bihun, Lytvyn, Oleksiv, 2021) will be used (or both, depending on the number of selected areas). So, in the beginning we need to have data on landfills. To verify the decision support system, we will choose the Solonitsy settlement territorial community. First, it is necessary to import data that represent the location of garbage collection points. The tonnage of the garbage truck is 10 tons. The capacity of garbage collection points and their coordinates are given in the table (Table 1).

Table 1.
Capacity and coordinates of garbage collection points

Number	Position x	Position y	Garbage collection capacity
1	2	4	1,5
2	2,2	5,2	1
3	3,3	2,3	1,5
4	1,5	6	2
5	5,2	8	1
6	8	12	2
7	10,1	16,7	1
8	15	21	1
9	18	19,7	1,5
10	19,7	24	2
11	22	22	2
12	23,1	27	1
13	26	18,4	1
14	29,2	23,8	1,5
15	39	17,1	1
16	37,8	21,9	1
17	42,1	27,8	1
18	46,2	30,1	1,5
19	48	36,2	1,5
20	51,4	34,6	2
21	54,4	38	2

Source: own studies.

Using the algorithm of optimization of garbage removal, we get the result, which is visualized in figure 3.

That is, first, all garbage collection points are divided into the optimal number of clusters, which are highlighted in red. Next, we found the optimal route between clusters, which is indicated by green dotted arrows. After that, the first and last points in each cluster were found and dummy points were added, which were eventually deleted. Next, the optimal route within each cluster is constructed. The proposed location of landfills is any permitted location on the route represented by the green dotted arrows. The length of the shortest path by one garbage truck according to this algorithm is 23 km. The garbage truck must be unloaded 3 times.

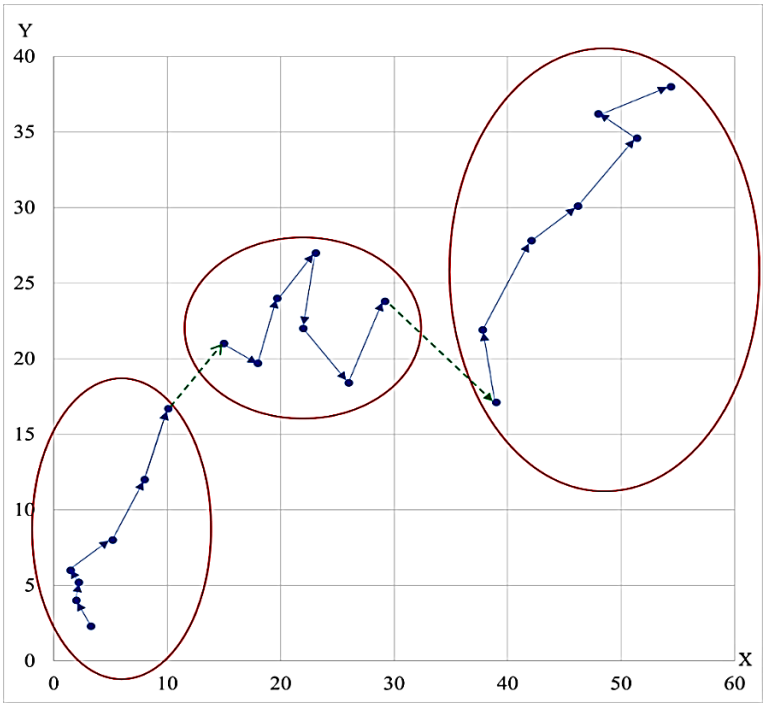

Figure 3. The result of clustering and the shortest way to collect waste.

To choose the direction of development, it is necessary to import data on available resources for the local community. The result is shown in table 2.

Table 2.
Available resources and their scales in Solonytsivska settlement territorial community

№	Resource	Scale: 1 - very little or very unsatisfactory, 9 - very much or very satisfactory, 2-8 - intermediate results
1	Minerals, oil, gas	1
2	Cultural heritage	4
3	Brownfields and Greenfields (investment attractive areas of the region)	3
4	Natural and recreational resources	5
5	Railway connections	3
6	Forests	7
7	Lakes, ponds, rivers	4
8	Tourist potential	7
9	Agricultural lands	8
10	Industrial enterprises	4
11	Land plots for individual development	5
12	Workforce	5
13	Recreation areas	4
14	Schools	7
15	Cultural institutions	5
16	Health care facilities	8
17	The level of medical care	4
18	Leisure networks	3
19	Creative cultural industry	4
20	Centralized water supply and sewerage	8
21	Sports infrastructure	6
22	Level of public activity	5

Cont. table 2.

23	Street lighting	3
24	Public transport	3
25	Logistics development	5
26	Efficiency of household waste management	3
27	Condition of roads	4
28	The state of engineering networks	4
29	Quality of mobile and internet coverage	6
30	Centralized water supply and sewerage (reverse)	9-8+1=2
31	Level of public activity (reverse)	9-5+1=5
32	Road condition (reverse)	9-4+1=6
33	Quality of mobile and internet communication coverage (reverse)	9-6+1=4

Source: own studies.

After applying the module for choosing the direction of development, we obtain a list of priorities, which is given in table 3.

Table 3.
Global priorities of alternatives (level 3)

Identifier of alternatives	**Alternatives (directions of development)**	**The value of global priorities**
a1	Creating a favorable investment climate	0.075
a2	Forming a positive community image and marketing	0.072
a3	Development of community tourism potential	0.081
a4	Development of agro-industrial production and agricultural processing	0.074
a5	Improving land management and their efficient use	0.062
a6	Transition to innovation-oriented and high-tech production, development of clusters and industrial parks, creation of a coworking center, youth business incubator, technology park	0.070
a7	Development of culture and sports	0.072
a8	Comprehensive development of children and youth	0.066
a9	Creating conditions for housing investment	0.069
a10	Preservation of historical identity and cultural traditions	0.060
a11	Modernization of the coal and oil industries. construction of modern mines	0.059
a12	Construction and reconstruction of water supply and sewerage networks	0.059
a13	Increasing the level of public activity and social cohesion in the community	0.061
a14	Repair of roads and roadside infrastructure	0.063
a15	Improving, expanding, improving the quality of communication and the Internet	0.060

Source: own studies.

Thus, the highest priority is direction a3 – the development of tourism potential of the community. That is what you need to focus on. If you need to choose several areas of development, for example, three areas, the following areas will be:

- a1 – formation of a favorable investment climate,
- a4 – development of agro-industrial production and agricultural processing.

If we implement all three areas of development, we can apply the module of tourism development and agro-industrial module. To apply the tourism development module, it is necessary to isolate indicators, find the necessary statistics and import them into the program. To apply the agro-industrial module, it is necessary to import into the system statistics of agricultural development in previous years to identify factors of production.

3.2. Operation of individual decision support system modules

Garbage removal optimization module

This module uses a correlation-regression model, which was built (Bihun, Lytvyn, 2022) for the agro-industrial complex. Since correlation and regression analysis is the construction and analysis of economic and mathematical models in the form of equations and tables – the agro-industrial module consists of a single component - Microsoft Excel - a spreadsheet for working with spreadsheets and data analysis. The use of Microsoft Excel spreadsheet allows you to create not only a correlation-regression model, but also to make predictions about the general indicators of the economic process and determine the development of enterprises in the future.

To model the algorithm of the agricultural module, we use UML (Unified Modeling Language) activity diagram (Fowler, 2004), which is presented in figure 4.

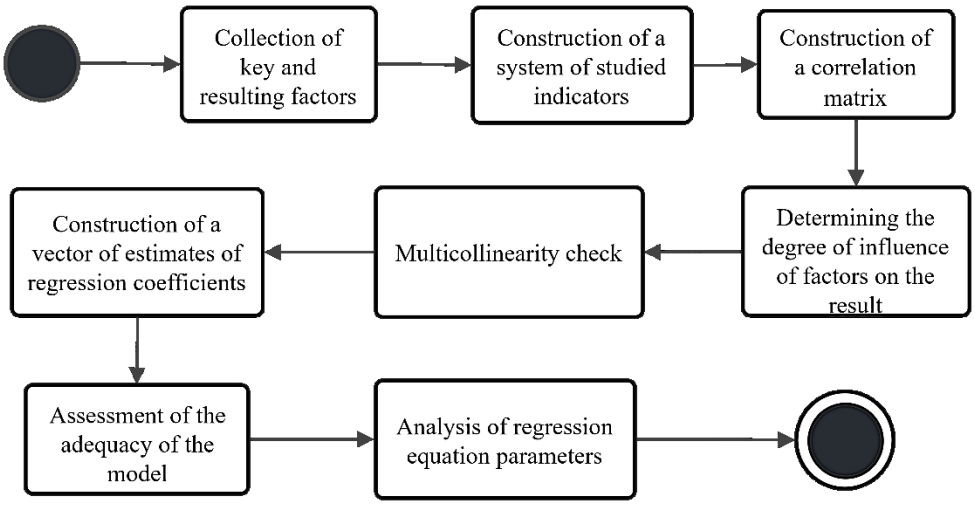

Figure 4. Activity diagram for correlation-regression analysis for agro-industrial complex.

In other words, it is a set of steps that need to be taken to build a correlation-regression model. The result will be a mathematical regression model, as well as an assessment of the adequacy of the model. All steps are taken by the researcher.

When adding or changing factors, as well as when new statistics appear, it is necessary to re-list all the steps of the algorithm.

Garbage removal optimization module

To model the garbage collection module (Bihun, Lytvyn, 2022) we use UML (Unified Modeling Language) precedent diagram (Fowler, 2004), which is presented in figure 5.

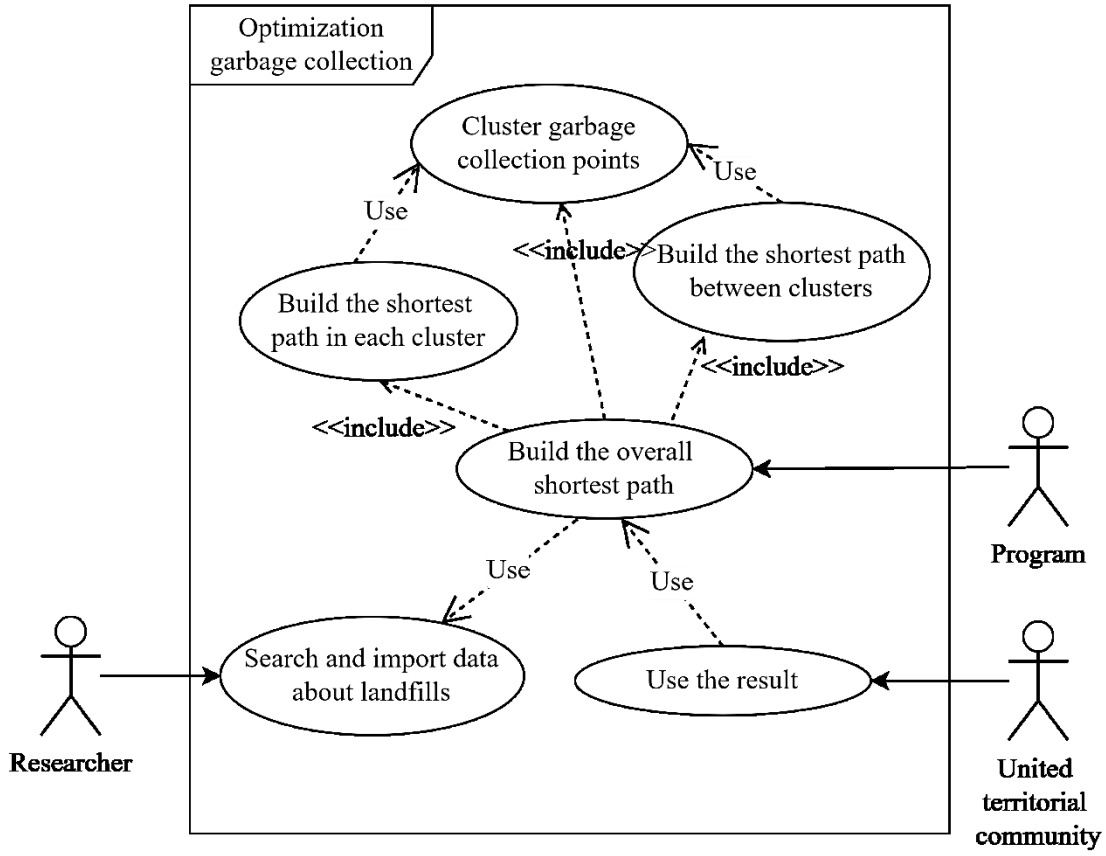

Figure 5. Garbage collection precedent diagram.

First, the researcher finds data on the location of landfills and their capacity. This data is then imported into a program that calculates the shortest garbage collection path. This result can be used by the local community to optimize garbage collection.

Module for choosing the direction of development

To model the module for choosing the direction of development, we also use the diagram of precedents (Fowler, 2004), which is presented in figure 6.

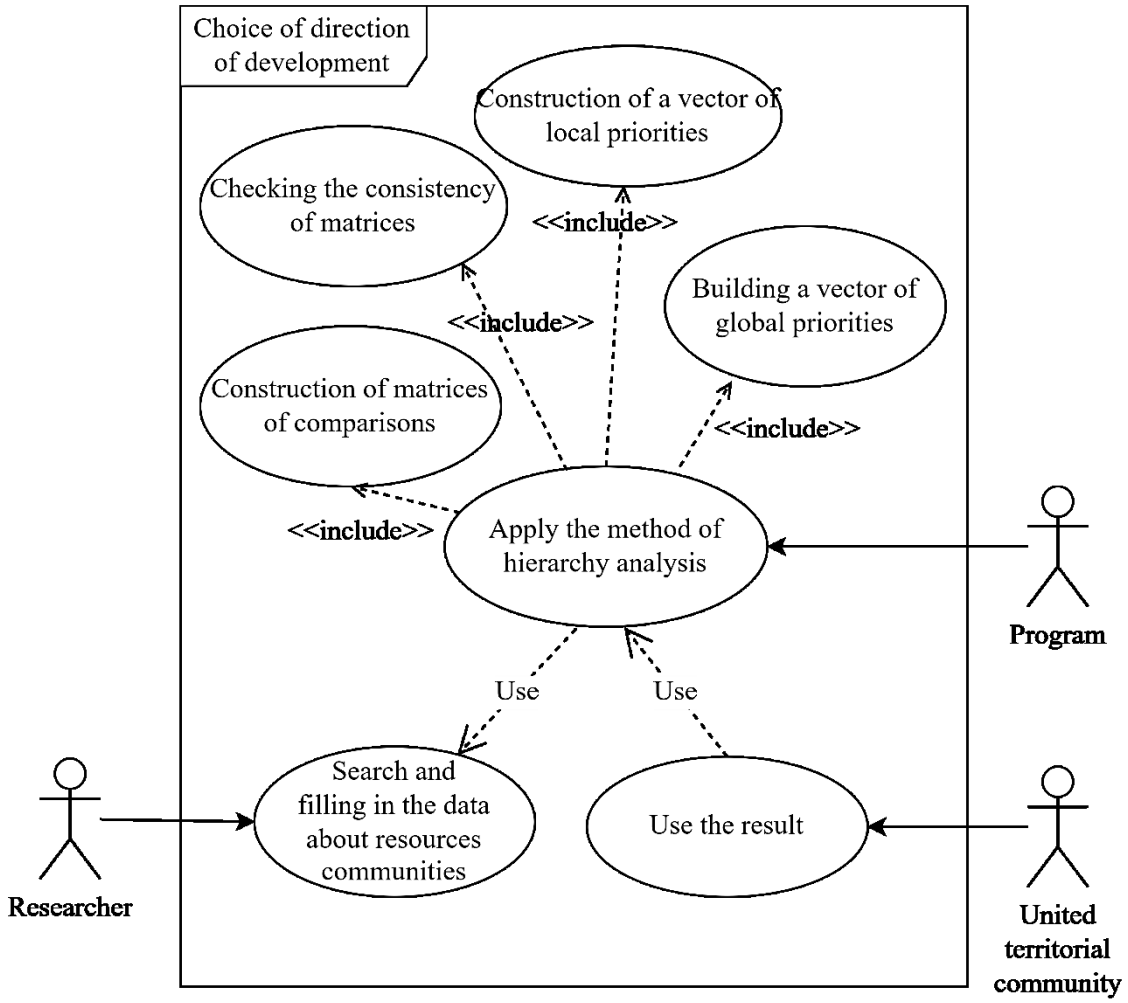

Figure 6. Diagram of precedents of the module for choosing the direction of development.

First, the researcher finds and fills in the data on the available resources of the territorial community on a scale: 1 – very little (if the number) or very unsatisfactory (if the state), 9 – very much (if the number) or very satisfactory (if the state), 2-8 – intermediate results. Then the data is used by the program to build matrices of pairwise comparisons and construct local and global priority vectors. At the end of the program gives a list of priorities of operational objectives. The united territorial community can choose one goal (the first from the list, which has the highest priority) or several (respectively, the first from the list of the highest priorities) to implement the development of the territorial community.

Tourism development module

The stages of PLS-PM modeling for the tourism module (Bihun, Lytvyn, Oleksiv, 2021) are presented in figure 7.

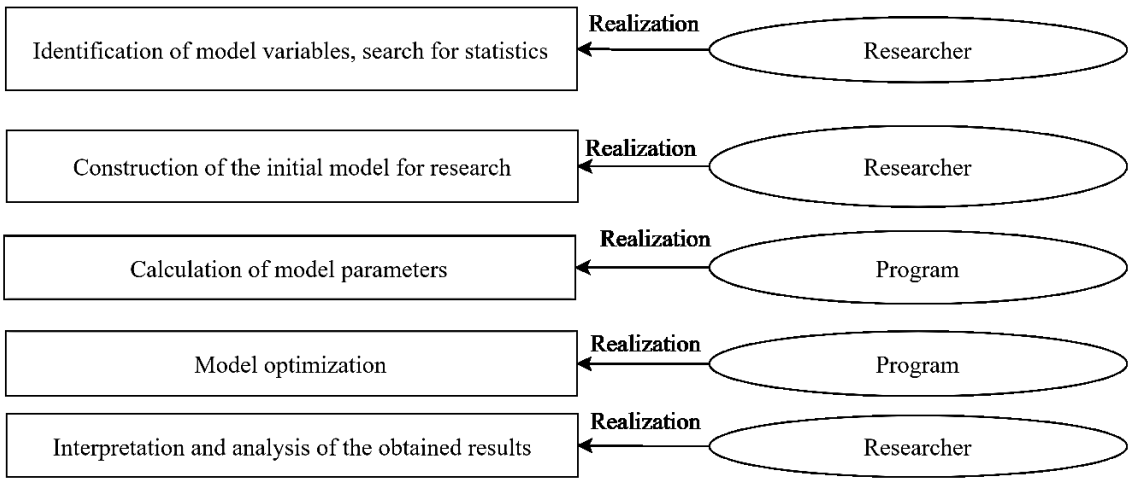

Figure 7. Stages of PLS-PM modeling.

Therefore, some steps cannot yet be automated programmatically. These steps need to be done by the researcher. The program calculates the parameters of the model and optimizes the model. The researcher needs to identify variable models, find the necessary statistics, and then build an initial model. In the end it is necessary to interpret the result by the researcher.

To model the algorithm of the tourist module, we use the block diagram of the algorithm PLS-PM, which is shown in figure 8.

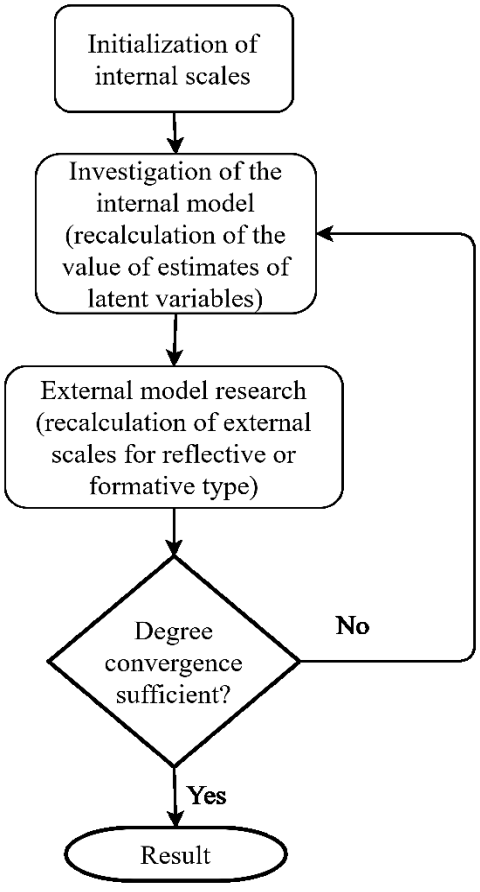

Figure 8. Block diagram of the PLS-PM algorithm.

SmartPLS program was used to implement the algorithm. First you need to initialize the internal scales. Next, the cycle is the recalculation of internal and external weights, which will be carried out until the degree of convergence is sufficient. Then we get the key factors that characterize the level of tourism development.

4. Discussion of the results of building a decision support system for the development of the territorial community

Analysis of the results of the software experiment will be allocated for each module separately:

- the result of the garbage collection optimization module will be a streamlined list of clusters and coordinates of garbage collection points, i.e., the garbage collection route, the reduction of which shows a reduction in costs allocated to the operation of the vehicle and reduce the total time spent on one route;
- the initial result of the module of choosing the direction of development will be the operational-strategic goal (or several goals if desired) of the territorial community, which best characterizes the development of the community based on its available resources;
- for the tourism module, the result will be data on key factors that characterize the level of tourism development, and the improvement of which will lead to positive changes in the tourism industry of the local community;
- the result of the agro-industrial module will be data on key factors, the regulation of which can have a positive impact on the growth of the economic component of the territorial community.

The scientific and practical value of the developed software can be divided according to the modules:

- the proposed module of optimization of garbage removal allows to facilitate the formation of financial solutions for the united territorial communities in the field of solving the problems of garbage collection and disposal in a certain area. This is possible due to the integration into the study of modern methods of machine learning in the section "learning without a teacher", one of which is the method of clustering, which is called k-average. To optimize the construction of clusters, namely their number in the area, an improved method of k-means was used, which includes consideration of the priority of garbage removal from certain clusters.

- the strengths of the agro-industrial module are that on the basis of representative economic indicators of the agricultural sector, key factors have been identified, the regulation of which can have a positive impact on the growth of the economic component of territorial communities. An important step in building a mathematical model is to consider the specifics of agriculture. Remember that natural conditions are an extremely important factor in production. That is why we need strategic planning that would formulate and implement community development strategies based on continuous monitoring and evaluation of change.
- the tourism development module allows to analyze the main factors influencing the development of the tourism industry, based on the PLS-PM model. This analysis can be used to successfully solve the problems of sustainable development of the tourism industry of local communities.
- the module of choosing the direction of development allows to prioritize the directions of development of territorial communities based on their resources, which allowed to analyze in detail these resources, as well as their impact on the direction of development of the territorial community.

5. Conclusions

The system of decision support for the development of territorial communities has been implemented. The results of the program experiment were analyzed and the scientific and practical significance of the developed program was shown. The separate components of functioning of the decision support system which consists of four parts (modules) are analyzed:

- development of the agro-industrial sector,
- tourism development,
- optimization of garbage removal,
- choosing the direction of development.

Each module can be used separately if necessary. Therefore, the methods of operation for each part were described using UML diagrams or a simple visualization of the steps of an algorithm or method.

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