UDC 687.016.5:658.512
DOI: 10.15587/1729-4061.2025.341457

DESIGN OF A DECISION SUPPORT SYSTEM FOR MAKING INFORMED DECISIONS ABOUT SELECTION OF MACHINES FOR MANUFACTURING LEATHER GARMENTS

Oksana Zakharkevich
Doctor of Technical Sciences, Professor*
Julia Koshevko
PhD, Associate Professor*
Tetyana Zhylenko
PhD, Associate Professor
Department of Mathematical Analysis and Optimization Methods
Sumy State University
Kharkivska str., 116, Sumy, Ukraine, 40007
Galina Shvets
Corresponding author
PhD, Associate Professor
Cluster Manager
Podillia Fashion Cluster
Proskurivskoho Pidpillia str., 61, Khmelnytskyi, Ukraine, 29000
E-mail: galyamet@ukr.net
Svitlana Kuleshova
Doctor of Technical Sciences, Professor
SC "Technology Consulting"
Shevchenka str., 11, Khmelnytskyi, Ukraine, 29000
Volodymyr Onofriichuk
PhD
Director
Limited Liability Company "Scientific park of KhNU"
Institytska str., 11, Khmelnytskyi, Ukraine, 29016
Alona Diakova
Department of Postgraduate and Doctoral Studies**
*Department of Technology and Design of Garments**
**Khmelnytskyi National University
Institytska str., 11, Khmelnytskyi, Ukraine, 29016

This study investigates the process of selecting sewing machines for the manufacturing of products from artificial leather. Despite the active development of technological solutions for automation, the task of choosing optimal equipment remains relevant, requiring additional tools that can provide a connection between scientific approaches and industrial conditions. This paper reports the results of designing an automated decision support system for the selection of sewing equipment, aimed at bridging the gap between theoretical models and production needs.

The technological advancement is based on a three-level database structure. At the data storage level, a matrix-based database of equipment parameters was constructed, ensuring the consistency of information regarding technological operations, materials, and machine characteristics. At the logical level, a multifactor analysis algorithm was developed, utilizing the principles of graph theory, a binary matrix, and the linear programming method to select the optimal equipment model. The representation level is an interactive interface based on MS Excel (USA). Input parameters are selected by simply clicking on buttons with corresponding names (seam type, worker qualification, material properties, and thickness). The system automatically analyzes the database and generates a list of recommended equipment in a table format.

Verification was carried out through a survey involving 30 participants (86.7% were representatives of the academic community). The results show that 93.3% of respondents noted the high speed of the simulator while 90.0% rated its practicality and 86.7% its convenience. At the same time, certain shortcomings were identified, outlining areas for further research: 23.3% of those surveyed highlighted the need to expand the database, and 16.7% emphasized the necessity of implementing a Ukrainian-language version.

It was established that the designed system is a universal tool that combines educational and practical-production dimensions. Its implementation in the educational process will contribute to achieving a number of program learning outcomes

Keywords: machine selection, database, technological operation, sewing production, decision support system

Received 01.08.2025
Received in revised form 29.09.2025
Accepted 10.10.2025
Published 30.10.2025

How to Cite: *Zakharkevich, O., Koshevko, J., Zhylenko, T., Shvets, G., Kuleshova, S., Onofriichuk, V., Diakova, A. (2025). Design of a decision support system for making informed decisions about selection of machines for manufacturing leather garments. Eastern-European Journal of Enterprise Technologies, 5 (1 (137)), 6–18. https://doi.org/10.15587/1729-4061.2025.341457*

1. Introduction

Modern garment production, despite the active development of technological innovations, faces serious challenges in the field of digitalization and automation. Although scientific research, in particular in this work, offers effective mathematical models and algorithms for selecting optimal equipment, their practical industrial application is often complicated.

This relates to the industry's resistance to change and the need to implement specialized databases based on internal, often unsystematized, data of enterprises.

Despite the active development of technological solutions for automation, the problem of selecting optimal equipment remains relevant, requiring additional research that would bridge the gap between theory and practice. Enterprises need a tool that will be not only mathematically sound but also accessible, understandable, and adapted to actual industrial conditions, thereby contributing to the introduction of innovations in light industry.

Thus, devising an automated method for the reasoned intelligent selection of sewing equipment for the production of artificial leather garments is a relevant task as such a solution enables high quality clothing production.

2. Literature review and problem statement

Scientists around the world are actively investigating issues related to the process of manufacturing clothing, footwear, and accessories made of leather, artificial leather, and fur. At the same time, more and more attention is paid to the study of materials that can replace natural leather. In particular, a comparison of the structure and technical characteristics of such materials is given in work [1]. The reported results make it possible to assess the potential areas of application of innovative materials. However, the issue of selecting appropriate equipment for performing technological operations related to the manufacture of products from the aforementioned materials remains unresolved.

The use of innovative materials implies the need for appropriate development of technological innovations aimed at automating key processes in the garment and leather production. At the same time, due to the significant variety of materials, technological operations and technological and structural solutions of products, process automation, and equipment selection face a number of difficulties. An option for overcoming them is to divide this complex task into a number of simple ones, in which automation of a specific part of the technological process is performed: for example, processing of a specific product node.

This is the approach used in [2, 3]. Their authors demonstrate successful automation of the processes of sewing elements (in particular, elastic [3]) without the use of clamps, which significantly increases the efficiency and accuracy of operations. At the same time, in work [2], attention is focused on the features of the manipulator, which provides the sewing process without clamps, and an automated sewing machine is described in [3].

Designing such high-tech equipment, capable of performing operations with minimal manual labor, will allow step-by-step automation of the entire technological process of manufacturing products. This approach is described in work [4], which contains a comprehensive overview of the possibilities of robotization of technological processes of sewing production. However, robotization is focused on typical products while customization and work with premium segment materials and products require devising new automation methods. Examples of such studies are given in [5, 6]. Paper [5] proposes the concept of human-dependent automation of leather polishing, which is especially relevant for the production of high-quality products in the premium segment. Study [6] reports an innovative use of two-armed robots for leather decomposition, which enables consistency of quality regardless of the human factor.

The issue of quality assurance is also closely linked to the automation of technological processes by the authors of [7, 8]. In work [7], technologies for automated fabric assembly are described, while work [8] emphasizes the importance of controlling sewing parameters in order to prevent damage to materials. However, the proposed technologies are only at the implementation stage or have limited scalability due to high cost and complexity of integration into existing production processes.

Another area of research is to develop various analytical models and algorithms that enable the effective functioning of sewing industries. In paper [9], time-scaled models are used to manage sewing operations, which allows flexible adaptation of processes to changes in load. Study [10] is aimed at optimizing the algorithm for manipulating product cutting details, which is important for reducing time and resource losses. In work [11], an algorithm for the reasoned selection of machine equipment for technological operations in the manufacture of leather and fur products is reported.

Highly detailed models of machine equipment selection [11], optimization algorithms of manipulations and control of sewing operations [9, 10] developed by scientists demonstrate significant potential in increasing productivity. However, such algorithms do not fully take into account actual industrial conditions, such as variability of physical properties of materials or human factors. This can reduce the accuracy of forecasts in a real environment, and forecast errors, in turn, have direct financial consequences. Therefore, the economic justification of automation in production processes is an important aspect of the implementation of innovative technologies in light industry.

In particular, the authors of [12] took into account such factors as cost, productivity, and safety when selecting machines. They argue that MCDM (Multi-Criteria Decision) methods are applicable to solving the problem of machine selection. In their study, an integrated gray MCDM model was built, which includes gray AHP and ROV-G, to select the most suitable sewing machine for a sewing company. However, the focus of the research is the realm of mathematical description and does not provide a practical tool for use by the average garment production technologist.

Closer to the requirements and needs of the end consumer (employee at a garment factory) are papers [13, 14]. Study [13] considers the possibility of automation after custom accounting of costs, which is of particular importance for small enterprises, where accuracy and economic efficiency are important. The authors of [14], in turn, offer a systematic review of sustainable technologies in the leather industry, emphasizing the connection between environmental friendliness and economic feasibility of implementing innovations. Both studies provide tools for analyzing the cost and assessing sustainable development, but their results need to be adapted to the specificity of particular industrial conditions since universal solutions are insufficient. At the same time, the task of analysis is complicated by a huge number of different factors that should be taken into account. That is why intelligent systems and large language models (LLM) are increasingly being implemented to optimize processes and make decisions in specific project situations of the modern production environment. Study [15] demonstrates how LLMs can be effective in equipment selection and production chain management, increasing the flexibility and adaptability of enterprises. Such flexibility is a necessary prerequisite for achieving strategic goals of sustainable development and determines the need to implement advanced technologies – nanotechnology, artificial intelligence, augmented reality, additive manufacturing, and the concept of total quality management, which form the innovative basis of modern evolution [16].

Study [17] identified simulation, fuzzy logic, genetic algorithms, and RFID technologies as key technologies in the garment industry. In addition, IoT technologies, cyber-physical systems (CPS), big data, cloud computing, digital twins, and machine learning were also included in the list of smart technologies that are used and should be used in the garment industry. However, compared to other industries, there are significant technological gaps in light industry. Dependent on technology, the garment industry lags behind other manufacturing industries by 11–22 years, which affects product quality and production performance.

The quality of manufactured clothing is determined by the technological process, the design features of parts developed using scientific and technical approaches (in particular, the use of mobile applications for calculating the design parameters of light clothing parts [18] and underwear [19]), as well as the correct choice of sewing equipment.

The selection of sewing equipment at sewing enterprises is a multi-criteria task that involves taking into account numerous, often contradictory parameters. In studies [20, 21], researchers selected machines for a textile enterprise. In this case, the CRITIC and MAUT methods were used in [20] and the integrated MCDM model combining Grey AHP in an environment of uncertainty and ROV-G in Grey formalism in [21]. The results confirm the feasibility of using these methods for making decisions regarding the selection of equipment.

Studies on the production of leather and fur products are of an applied nature and are aimed at solving specific problems in the textile and clothing industries, helping improve product quality or optimize processes. In [22], the effect of needle size and sewing thread type on the quality of seams on traditional fabrics is investigated. The paper aims to provide practical recommendations for improving the strength and appearance of seams. Papers [23, 24] tackle issues of materials science, namely the study of the properties of leather, natural and artificial, as well as their processing methods and the effect of this processing on the mechanical properties of the leather. Study [23] focuses mainly on artificial leather, while paper [24] discusses the differences between artificial and natural leather.

Work [25] offers a visual analysis of the textile sector in Turkey using Gephi software. The study uses the complex network method to display the relationships and structure of the industry.

As we can see, researchers around the world are solving some issues of the problem of machine selection, solving problems of materials science, working with the industry as a whole. However, currently, there are no publicly available examples of full-fledged simulators, decision support systems, or databases for automated selection of sewing equipment for specific technological operations on the global network. Most resources are catalogs where equipment is grouped by type (for example, sewing machines, overlockers, cutting tables), and not by technological operations.

Large manufacturers of sewing equipment (for example, JUKI, Durkopp Adler, Pfaff) have detailed catalogs on their websites. They often categorize equipment not only by type but also by purpose and recommended operations (for example, a machine for sewing jeans, for working with heavy fabrics). This makes it possible to manually select equipment by analyzing its characteristics.

Some large sewing factories may have internal databases for equipment management, but they are usually not public.

Thus, the combination of technological, analytical, economic, and intellectual approaches creates a comprehensive basis for the implementation of effective automation and optimization systems in the garment and leather industry. However, at present, such algorithms cannot be used in the practical work of a technologist. The impossibility of using the algorithm is explained by the fact that now there is no customized software implementation, an interface for entering input data, a description of individual optimization tasks at each stage of decision-making.

All this gives grounds to argue that it is advisable to conduct a study aimed at designing a decision support system for selecting the optimal equipment that could help automate and optimize garment and leather production.

3. The aim and objectives of the study

The purpose of our research is to design a decision support system for selecting the optimal machine equipment used to perform technological operations in the production of leather and fur clothing. This will allow the use of the database (storage level, logical and representation levels) in the process of training specialists in the sewing industry and in project situations for forming a technological sequence for manufacturing a product and designing a flow.

To achieve this aim, the following objectives were accomplished:

– to build a database of sewing equipment selection parameters that enables the preservation, integrity, and consistency of information about technological operations, materials, and machine characteristics;

– to substantiate the logic of the database functioning, which implements multifactor data analysis and enables the selection of the optimal sewing machine model for specific industrial conditions;

– to design an interface for interaction with the database that displays the results of the algorithms in a user-friendly format and performs the functions of an interactive educational and practical tool;

– to test the designed decision support system (database) in an educational environment and in a production project situation to determine its effectiveness, practical significance, and potential for implementation at garment enterprises.

4. The study materials and methods

The object of our study is the process of selecting sewing equipment for the manufacture of artificial leather garments.

The working hypothesis of this study is a set of the following assumptions:

Assumption 1. The technological advancement of a matrix database structure containing relationships between technological operations, material properties, and characteristics of sewing equipment creates the necessary prerequisites for automating the process of its selection.

Assumption 2. The implementation of such an approach in MS Excel (USA, developer – Microsoft) could be an effective solution that would allow us to use a decision support system as a multifunctional "simulator" for training and advanced training of specialists in the sewing industry.

A number of simplifications were adopted in the research process. First, only technological criteria and relationships were used to justify the choice of sewing equipment. Second, the choice of MS Excel is a deliberate simplification aimed at the possibility of using a decision support system without the involvement of specialized software and additional training of specialists. Third, empirical verification is limited to assessing the functionality, convenience, as well as practicality of the simulator, without testing the accuracy of the algorithm under actual industrial conditions.

The study was conducted using a set of analytical, theoretical, and empirical methods. At the first stage, methods for analyzing scientific sources and existing solutions were used. A review of the literature [1–9] related to the automation of sewing production, modeling of production processes, and multi-criteria selection of equipment was carried out. In parallel, an analysis of existing commercial and open equipment catalogs [26–30] was performed to form the information basis of the database. These analytical steps made it possible to determine the current state of the problem and collect input data for further development. The next stage included the application of modeling methods. To structure the problem, a matrix database model was used, reflecting the relationships between various selection parameters, such as the type of seam, material properties, and equipment characteristics [31–33]. This matrix is the basis for the selection algorithm. Next, using the principles of graph theory, a network model was built that visualizes possible options for choosing equipment and forming a technological sequence. The task of finding the optimal option was solved using the linear programming method, which made it possible to find the most effective combination of parameters.

The instrumental execution of the model involved the MS Excel environment, which was chosen as the platform for software implementation. Three main levels of the system were built: a data storage layer, a logic layer that implements the selection algorithm, and a representation level that is a user interface.

Economic, operational, service, as well as technical and ergonomic criteria are accepted as those that are taken into account at the preliminary stage of equipment selection when designing a sewing shop (sewing shops) at a particular enterprise. At the same time, the economic ones include cost, energy consumption, company image, market price, and warranty period. Operational and service criteria combine maintenance and service, availability of spare parts, serviceability, and durability. The following criteria are included in the technical criteria: power, maximum operating speed, thread tension accuracy, stitch type, access to the pattern programmer, lubrication system, productivity. Ergonomics, smoothness of the presser foot lever, lamp position, light flux, safety, noise level, and vibration level form a group of ergonomic criteria. The listed criteria are considered to be taken into account at the preliminary stage of forming the technological flow and are not part of the selection process within the database being built (and the simulator based on it).

The final part of the study included empirical testing of the designed tool. For this purpose, an experiment was conducted, in which 30 people from the academic and business environment participated. Data on the use of the simulator was collected using a survey. The results were analyzed to assess the functionality, convenience, and compliance of the tool with the stated criteria.

The Google Forms platform was chosen to conduct the survey. The choice of Google Forms was justified by its ease of use, the ability to automatically collect answers in a tabular form, as well as ease of access for respondents.

The questionnaire consisted of two main sets of questions: quantitative (evaluative) questions and qualitative (open) questions. Respondents were asked to evaluate the key aspects of the simulator database on a five-point scale (from 1 to 5). These included ease of use, clarity of use, practicality (usefulness for work). Survey participants were asked to provide detailed comments, which allowed for detailed feedback. These questions related to the reasons for participating in the survey, the strengths and weaknesses of the designed tool, and the possibility of making suggestions for its improvement.

In addition, the questionnaire included identification questions (e.g., about the level of training/position) and questions about general awareness of automation methods.

In the process of preparing this study, modern artificial intelligence (AI) tools were used to improve the quality of the text. In particular, large language models (LLMs) were applied to correct grammatical and stylistic sentences, eliminate ambiguities, and improve the readability of the text.

5. Results of investigating the database "Sewing Machine Selection"

5. 1. Construction of a database on sewing equipment selection parameters

MS Excel is the chosen environment for designing the interface and database. The tool is intuitive and easy to use, so constructing a simple database is quick and easy. Excel is a tabular tool, so the best layout is a database table. It should be noted that such a database is a spreadsheet.

Databases have a much larger structure than spreadsheets, so building databases requires more work than Excel workbooks. Moreover, this is why so many companies try to use Excel as a database. Programming in Excel is cheaper. Office workers may have to learn Access or SQL Server, but they are most likely fluent in Excel, so its use is relevant. Market research has shown that approximately 54% of companies use Excel, which does not include other spreadsheet programs. Over two billion people worldwide use spreadsheet technologies such as Excel and Google Sheets [31].

As stated in [11], Microsoft Excel is used for reporting tasks at small and medium-sized companies around the world. However, most people prepare reports manually in Microsoft Excel, and manual work takes a huge amount of time. A comparison of manual and automated methods showed that automation of reports saves 83.18% of employees' time. The automated method also results in error-free reporting, which reduces the workload on the employee.

The initial data for compiling a database of parameters for selecting sewing equipment are the results reported in [11], according to which, the necessary data for selecting a sewing machine are:

– type of seam/type of operation (1.01.01; 2.01.01; 1.06.02; 2.02.01; 5.01.01; 6.02.01);

– worker qualification (high, low);

– material properties (material base, material coating);

– sewing equipment characteristics (manufacturer, model, purpose, speed, material movement mechanism, stitch type).

The list of seam types was formed based on the content of the mobile application "TechLab" [11, 33]. The application contains descriptions of modern methods for joining elements of leather and fur clothing, as well as features of the technology for processing natural and artificial fur and leather products. Numerical seam markers are designated in accordance with "ISO 4916:1991 Textiles – Types of seams" [34].

The main table of the database is the "Selection" table (Fig. 1), which contains selection factors, sewing machine parameters and their specific model names.

The list of available sewing equipment in the table "Sewing machines" (Fig. 2) includes sewing machines of a certain brand ("Juki"). The compilation of the list is based on information found by searching through marketplace sites [26–34]. If necessary, users can add machine equipment (Fig. 2, *b*).

Since all this data are interconnected, records in one database table contain references to data in another table (Fig. 3), logically linking records from one table to another.

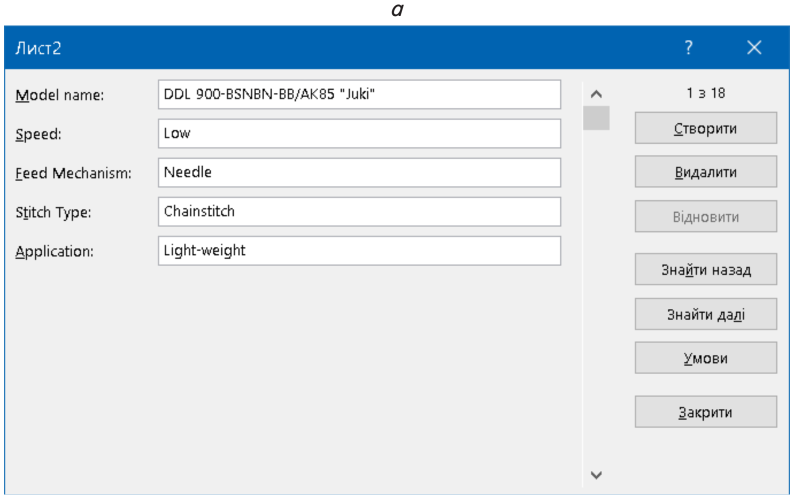
The possibility of using the database as a simulator for training specialists in the field of "Light Industry Technologies" is confirmed by analyzing relevant educational programs (open access on the websites of higher education institutions). In particular, the program learning outcomes (PLOs) of the educational program (EP) for the "Master" level at Khmelnytskyi National University were analyzed [35]. The results of our analysis are given in Table 1.

Operation type	Employee Qualification	Material Coating	Material Thickness	Material Base	Speed	Feed Mechanism	Stitch type	Model name
1.01.01	High	Polyvinyl chloride	Light-weight	Knitted material	High	Differential	Chainstitch	MS-1261 "Juki"
1.01.01	High	Polyvinyl chloride	Light-weight	Fabric	High	Differential	Lockstitch	DDL-900-BSNBN Juki
1.01.01	High	Polyvinyl chloride	Light-weight	Non-woven material	High	Differential	Chainstitch	MS-1261 "Juki"
1.01.01	High	Polyvinyl chloride	Medium-weight	Knitted material	High	Differential	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Polyvinyl chloride	Medium-weight	Fabric	High	Differential	Lockstitch	LH-3568ASF "Juki"
1.01.01	High	Polyvinyl chloride	Medium-weight	Non-woven material	High	Differential	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Polyvinyl chloride	Medium-weight	Artificial fur	High	Differential/Needle	Chainstitch/Lockstitch	LH-3568ASF "Juki"
1.01.01	High	Polyvinyl chloride	Heavy-weight	Knitted material	High	Differential	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Polyvinyl chloride	Heavy-weight	Fabric	High	Differential	Lockstitch	DU - 1181 N "Juki"
1.01.01	High	Polyvinyl chloride	Heavy-weight	Non-woven material	High	Differential	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Polyvinyl chloride	Heavy-weight	Artificial fur	High	Differential/Needle	Chainstitch/Lockstitch	DDL-7000A "Juki"
1.01.01	High	Capron	Light-weight	Knitted material	High	Differential/Needle	Chainstitch	MS-1261 "Juki"
1.01.01	High	Capron	Light-weight	Fabric	High	Differential/Needle	Lockstitch	MH - 380 FU "Juki"
1.01.01	High	Capron	Light-weight	Non-woven material	High	Differential/Needle	Chainstitch	MS-1261 "Juki"
1.01.01	High	Capron	Medium-weight	Knitted material	High	Differential/Needle	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Capron	Medium-weight	Fabric	High	Differential	Lockstitch	LH-3568ASF "Juki"
1.01.01	High	Capron	Medium-weight	Non-woven material	High	Differential/Needle	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Capron	Medium-weight	Artificial fur	High	Differential/Needle	Chainstitch/Lockstitch	LH-3568ASF "Juki"
1.01.01	High	Capron	Heavy-weight	Knitted material	High	Differential/Needle	Chainstitch	MS - 1190 "Juki"
1.01.01	High	Capron	Heavy-weight	Fabric	High	Differential	Lockstitch	DU - 1181 N "Juki"

Fig. 1. Database fragment (table "Selection")

Model name	Speed	Feed Mechanism	Stitch Type	Application
DDL 900-BSNBN-BB/AK85 "Juki"	Low	Needle	Chainstitch	Light-weight
DNU-140 "Juki"	Low	Differential	Chainstitch	Heavy-weight
DU-141H "Juki"	Low	Differential	Chainstitch	Medium-weight
MH-484U "Juki"	Low	Differential	Chainstitch	Medium-weight
LZ-228N-7WB "Juki"	Low	Differential	Lockstitch	Light-weight
DDL-8100eH "Juki"	Low	Differential	Lockstitch	Heavy-weight
DDL-8700L"Juki"	Low	Differential	Lockstitch	Medium-weight
DDL-5600-NL-7 "Juki"	Low	Differential	Lockstitch	Heavy-weight
MH - 380 FU "Juki"	High	Needle	Lockstitch	Light-weight
MS-1261 "Juki"	High	Differential	Chainstitch	Light-weight
MS - 1190 "Juki"	High	Differential	Chainstitch	Heavy-weight
DDL-7000A "Juki"	High	Needle	Lockstitch	Heavy-weight
DDL-900-BSNBN Juki	High	Differential	Lockstitch	Light-weight
LH-3568ASF "Juki"	High	Differential	Lockstitch	Medium-weight
DU - 1181 N "Juki"	High	Differential	Lockstitch	Heavy-weight
AEC-112 "Juki"	Low	Needle	Lockstitch	Heavy-weight
DDL-5550 "Juki"	Low	Needle	Chainstitch	Heavy-weight
ECS-154-470/ES-31/ET-5 "Juki"	Low	Needle	Lockstitch	Light-weight

a



b

Fig. 2. Database fragment: *a* — Table "Sewing machines"; *b* — adding a sewing machine to the table "Sewing machines"

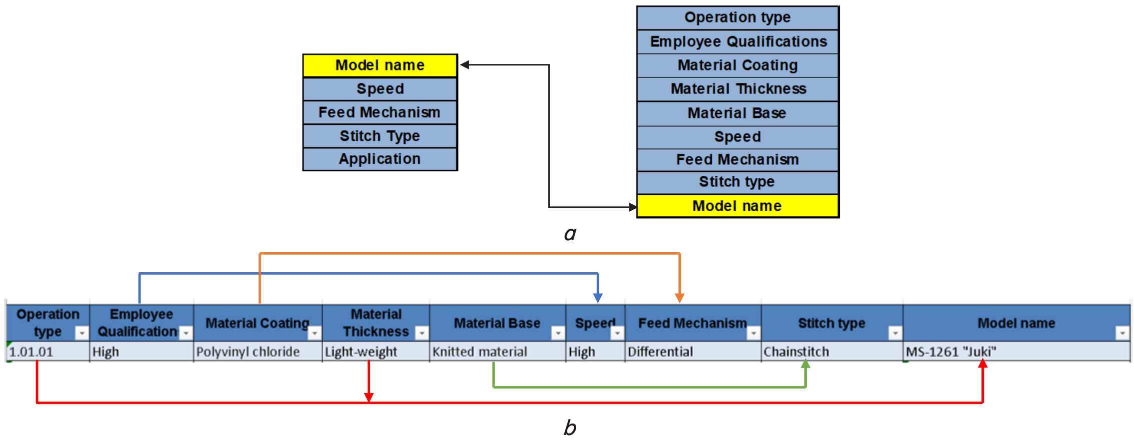


Fig. 3. Structure of the database "Sewing machine selection":
a — interrelation between tables; *b* — interrelation between factors and characteristics of sewing machines

Table 1

Role of the database (simulator) in ensuring the implementation of PLOs for EP "Light Industry Technologies" (Master's level)

PLO	Formulation of the result	Database implementation
PLO 1 (standard)	To have specialized conceptual knowledge in the field of production and technologies of light industry	The database accumulates scientifically based equipment selection parameters and transforms complex algorithms into a practical tool that integrates modern research into production practice
PLO 2 (standard)	Plan and conduct scientific and applied research	Database design includes structure planning, parameter formation and analysis of test results, which reflects research skills
PLO 6 (standard)	Design and implement innovative projects	The database is an example of an innovative project in the field of digitalization of light industry, aimed at implementing automated equipment selection
PLO 7 (standard)	Work with scientific literature, patents, databases	When forming the database, standards (ISO 4916:1991), technical catalogs and scientific sources were used to build a system of selection parameters
PLO 10 (standard)	Use modern methods and equipment for experimental research	Testing the database in educational and production conditions ensured its approval as a tool for modeling and optimizing technological processes
PLO 12 (standard)	Independently master new knowledge and help others	The representation level of the database has the function of a training simulator, which allows students and technologists to interactively master new approaches to equipment selection
PLO 14 (characteristic only for this EP)	Organize design and technological processes using IT	The database integrates information technologies into the process of selecting sewing equipment, thereby facilitating the organization of design and technological solutions in production

The PLOs and the corresponding database properties listed in Table 1 confirm our assumption regarding the possibility of its use as a multifunctional "simulator" for training specialists in the sewing industry.

5. 2. Substantiating the functioning logic of the "Sewing Machine Selection" database

The matrix structure of the sewing equipment selection parameters database (Fig. 4) is the basis for the technological advancement of a user interface for selecting sewing equipment for the needs in a specific sewing industry.

Otype	A				
	A_1	A_2	A_3	A_4	A_5
$Otype_1$	1	0	0	0	0
$Otype_2$	1	0	0	0	0
$Otype_3$	1	0	0	0	0
$Otype_4$	1	0	0	0	0
$Otype_5$	1	1	0	0	0
$Otype_6$	1	0	0	0	0

EQ	Mspeed	
	$Mspeed_1$	$Mspeed_2$
EQ_1	0	1
EQ_2	1	0

Mbase	Stype	
	$Stype_1$	$Stype_2$
$Mbase_1$	1	0
$Mbase_2$	0	1
$Mbase_3$	1	1
$Mbase_4$	1	1

MTh	Mpurpose		
	$Mpurpose_1$	$Mpurpose_2$	$Mpurpose_3$
MTh_1	1	0	0
MTh_2	0	1	0
MTh_3	0	0	1

P	F	
	F_1	F_2
P_1	1	0
P_2	0	1
P_3	0	1

Fig. 4. Matrix structure of the database of parameters for selecting sewing equipment: $Otype_i$ — type of operation; A_i — types of sewing machines; P_j — properties of the material coating; F_i — feed mechanism; MTh_j — material thickness; $Mpurpose_i$ — purpose of the machine; $Mbase_j$ — properties of the base materials; $Stype_i$ — types of seams; EQ_j — qualification of the worker; $Mspeed_i$ — machine speed parameters, as described in [12]

The selected database structure makes it possible to form the highest quality technology for manufacturing a product using the minimum required amount of machinery at its full load. This optimization technology consists of different sets of methods for processing individual product nodes, which, in turn, involve technological operations. The technological sequence of manufacturing products is usually represented in the form of a graph.

At the first stage, it is necessary to build a binary closure matrix for the transitivity of the relation, which stores information about the existence of paths between the vertices of the directed graph which is defined as follows:

$$cl_i = \begin{cases} 1, \text{ if vertex } K_0 \text{ is reachable from } K_i, \\ 0, \text{ if the vertex is unreachable,} \end{cases} \quad (1)$$

where K_0 is the solution to the problem, K_i is the solution element.

Variants that lead to unacceptable solutions are immediately rejected.

Nodes of the graph are methods for achieving the necessary requirements at each stage. Edges of the graph are combinations that make it possible to implement a specific method. The beginning of the solution to the problem is the lower level of the problem decomposition.

Therefore, the graph consists of decision branches – a set of nodes $Cl(k_i)$ of the graph, reachable from vertex K_0, for which, according to reachability matrix Cl, each element K_i is equal to 1.

Since the vertex of graph K_0, the path to which from K_i, is determined by the distance of 1, 2, ..., m stages, then the set of solution options for the problem can be represented in the form

$$Cl(k_i)=\Lambda\{K_i\}\cup\Lambda^2\{K_i\}\cup\ldots$$
$$\ldots\cup\Lambda^{m-1}\{K_i\}\cup\Lambda^m\{K_i\}, \qquad (2)$$

where $\Lambda\{K_i\}$ is the set of graph vertices that form bridges between (K_i, K_0).

In addition, a necessary condition for the formation of the set is the relation

$$\{K_0\}=\cup\{K(j)|K(j)\} \text{ – hanging graph vertice.} \qquad (3)$$

The search for solutions is completed when all hanging vertices are considered. The ranking of solution options is done depending on the length of the path (number of stages).

Optimization involves obtaining the smallest number of methods (operations)

$$K_0^{opt}=\lim_{m\to 1}\{K_0\}. \qquad (4)$$

Subject to the requirements for the type of functionality of the operation

$$P=extr\{h_0(x,y)|x\in D\}, \qquad (5)$$

where P is the functionality function, $h_0(x, y)$ is the optimization criterion, x is the control parameter, y is a constant process parameter, D is the domain of rational values of x.

Since the cost of fabric and the cost of machines fluctuate greatly, in this case it is better to use a directed technology selection graph with the n-th number of implementation methods: TO is the initial state of the technology; RP is the resulting product (finished product); M1...Mn is the technological processing methods (graph levels); V1...Vs is the technological processes of implementing the methods on a specific machine; TM1...TMm is the type of material (graph vertices); N1...Nl is the number of emissions (graph edges) (Fig. 5).

The matrix is a hyper prism, the planes of which correspond to the methods for achieving a productive product (methods for processing the nodes of a sewing product), and the planes themselves are matrices of types of sewing machines (by purpose) and the corresponding types of materials and technological operations performed (Fig. 6).

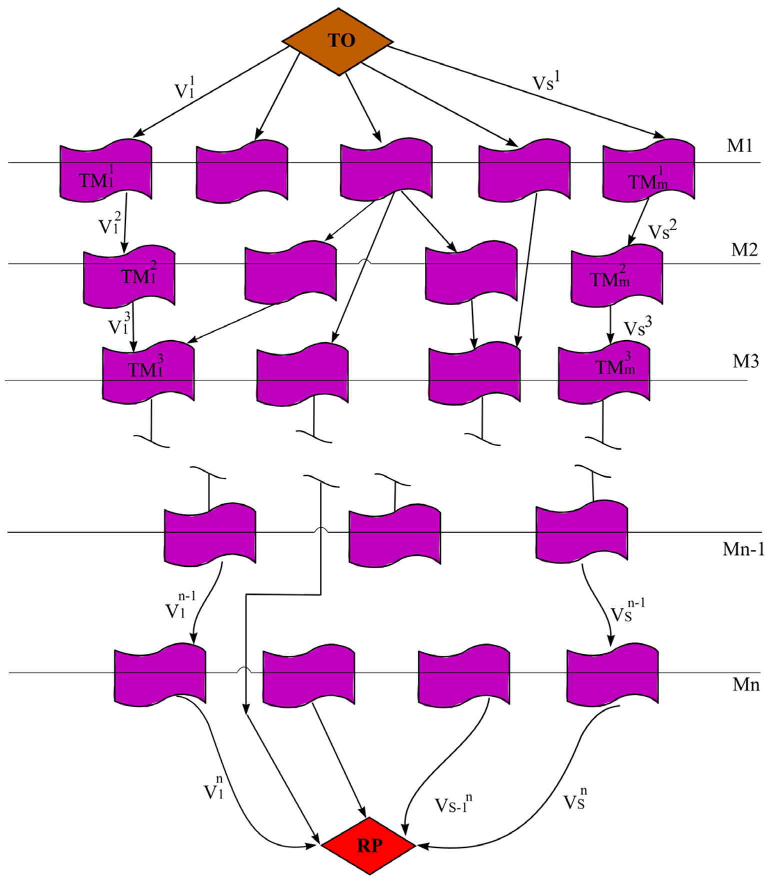
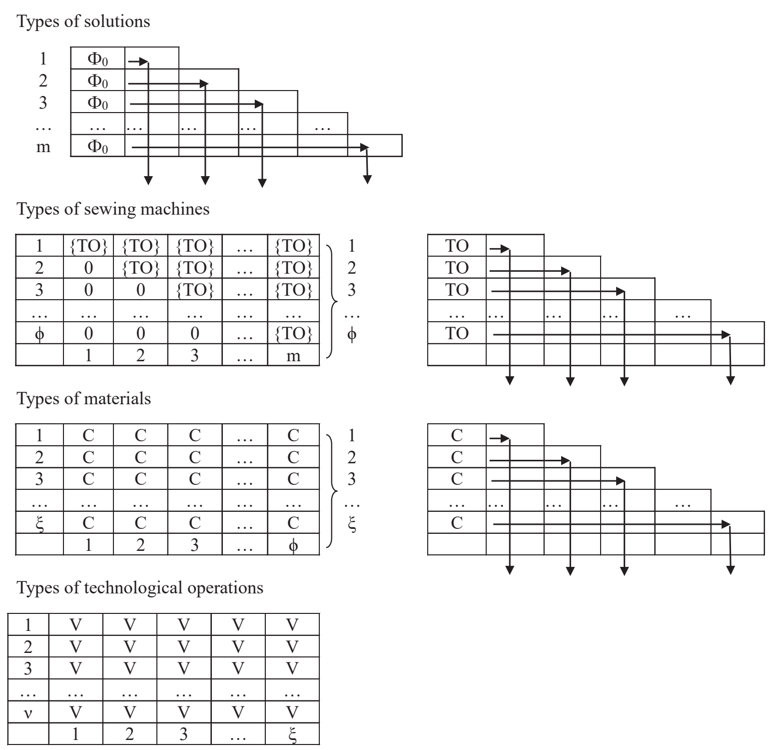


Fig. 5. Implementation graph for the most optimal effective product



Types of solutions

1	Φ_0
2	Φ_0
3	Φ_0
…	…
m	Φ_0

Types of sewing machines

1	{TO}	{TO}	{TO}	…	{TO}
2	0	{TO}	{TO}	…	{TO}
3	0	0	{TO}	…	{TO}
…	…	…	…	…	…
ϕ	0	0	0	…	{TO}
	1	2	3	…	m

Types of materials

1	C	C	C	…	C
2	C	C	C	…	C
3	C	C	C	…	C
…	…	…	…	…	…
ξ	C	C	C	…	C
	1	2	3	…	ϕ

Types of technological operations

1	V	V	V	V	V
2	V	V	V	V	V
3	V	V	V	V	V
…	…	…	…	…	…
ν	V	V	V	V	V
	1	2	3	…	ξ

Fig. 6. Table for selecting the optimal technology for sewing an article

The adjacency matrix of methods $T = [t_{i,j}]$ (Fig. 7), where $t_{i,j} = 1$: there is a connection between technological operations for the specified sewing machine; $t_{i,j} = 0$: there is no connection.

A=

0	0	0	1	0	…	0	1
0	0	1	0	0	…	0	2
0	1	0	0	0	…	0	3
0	0	0	0	0	…	0	4
0	0	0	0	0	…	1	5
…	…	…	…	…	…	…	…
0	1	0	0	0	…	0	m
TO_1	TO_1	TO_1	TO_1	TO_1	…	TO_n	

Fig. 7. Proportionality matrix of methods for obtaining a quality product

The matrix has a size of $m \times n$ according to the number of analyzed methods for processing the product and the complexity of its manufacture. The matrix is filled horizontally. According to the graph of the implementation of this problem (Fig. 5), the row of the matrix corresponds to the set of methods for processing nodes, and the column determines the complexity of the problem (the number of nodes processed, and therefore the processing methods used and the technological operations that make them up). For each branch of the graph with a hanging vertex, a matrix of adjacency of methods is constructed. The last row with "1" corresponds to the lowest level of decomposition of the problem.

Using the adjacency matrices, we build a network model for the selection of equipment $\rho_\xi(s)$ (Fig. 8). The nodes of the network are processing methods, and the path segments correspond to the types of technological operations and types of machines.

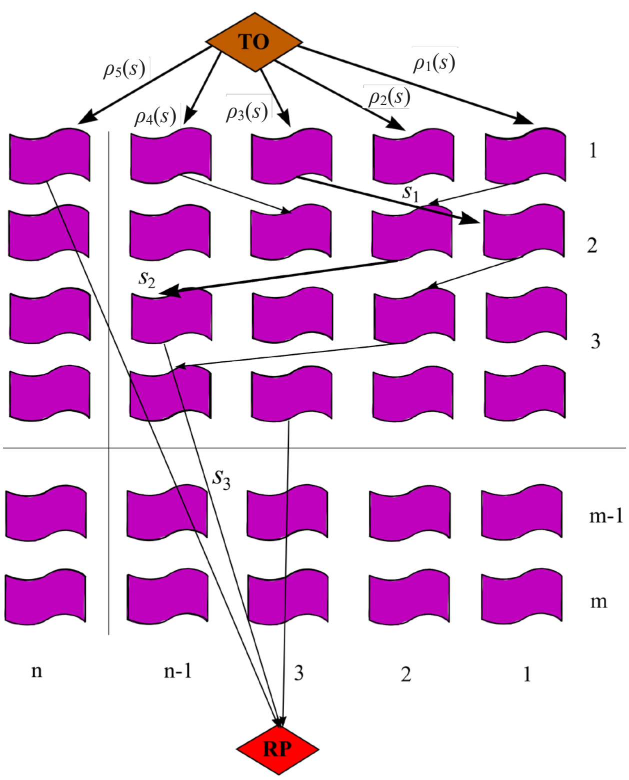


Fig. 8. Network model of equipment selection

The directed selection of machinery involves determining the shortest path of this network model. If we take as the weight function (ρ) the optimal machine that reflects the weights on the network segments, then the entire path $s = \langle s_0, s_1, \ldots, s_k \rangle$ is equal to the sum of the edges contained in it

$$\rho(s) = \sum_{i=1}^{k} \rho(s_{i-1}, s_i). \tag{6}$$

In this case, the weight of the shortest path from TO to RP_s will be determined by the ratio

$$\Delta(TO, RP) = \begin{cases} \min\left\{\rho(s) : TO \xrightarrow{s} RP_s\right\}, \text{if there are paths } TO, RP, \\ \infty, \text{otherwise.} \end{cases} \tag{7}$$

We solve the linear programming problem. The following optimization criterion is taken into account

$$\rho = h(\alpha, \beta), \tag{8}$$

where α is a parameter that depends on the processing method when choosing a particular sewing machine; β is a set of constraints.

A necessary condition for the existence of a technological process

$$\underset{\varepsilon\in\theta}{\exists} K_{0\varepsilon} = \bigcap_{\psi=1}^{m} \Lambda^{\psi}\{K_i\} \vee \underset{\phi=1}{\overset{\phi}{}}\exists M_\varphi \vee \underset{\xi=1}{\overset{\chi}{}}\exists C_\xi \vee \underset{\nu=1}{\overset{s}{}}\exists \underset{\nu=1\div s}{\exists} V_\nu, \tag{9}$$

where $\underset{\varepsilon\in\theta}{\exists} K_{0\varepsilon}$ is the existing solution to the problem; $\bigcap_{\psi=1}^{m} \Lambda^{\psi}\{K_i\}$ is the set of stages in solving the problem; $\underset{\phi=1\div\varphi}{\exists} M_\varphi$ – availability of methods for solving the problem at each stage with the specified qualification of workers; $\underset{\xi=1\div x}{\exists} C_\xi$ – type of material that corresponds to this method; $\underset{\nu=1\div s}{\exists} V_\nu$ – number and quality of products that are produced under the operating conditions of the specified sewing machines.

In this case, the set of solutions at the qualitative level will satisfy the sufficient condition

$$\underset{k\in X}{\forall} K_{0k} = \left\{K_0 \middle| \beta_{K_0}^{\min} \le \beta_{K_0} \le \beta_{K_0}^{\max}\right\}, \tag{10}$$

That is, for all existing solutions to the problem, the process quality criteria must be within the range of permissible values of the worker's qualification, type of material, type of operation, and type of sewing machine.

Taking into account the necessary and sufficient conditions, the solution set takes the form

$$\left\{Solv_{K_0}\right\} = \\ = \left\{Solv_{K_0}(k)\right\} \left| \begin{array}{l} \underset{\varepsilon\in\theta}{\exists} K_{0\varepsilon} = \bigcap\limits_{\psi=1}^{m} \Lambda^{\psi}\{K_i\} \vee \\ \vee \underset{\phi=1\div\varphi}{\exists} M_\varphi \vee \underset{\xi=1\div\chi}{\exists} F_\xi \vee \underset{\nu=1\div s}{\exists} V_\nu, \\ \underset{k\in X}{\forall} K_{0k} = \left\{K_0 \middle| \beta_{K_0}^{\min} \le \beta_{K_0} \le \beta_{K_0}^{\max}\right\}. \end{array} \right. \tag{11}$$

Then

$$K_0^{opt} = \lim_{solv\to\min} K_0 \middle| Solv \in \left\{F_{K_0}\right\}. \tag{12}$$

Thus, the optimal option is the one that meets the criteria of the shortest path of the network model.

The directed selection algorithm consists of the following stages:

– rejection of unacceptable solution options;

– ranking the complexity of finding solutions in stages;

– search for possible methods of solving the problem at each step;

– search for means for implementing each method;

– calculation of rational operating modes of machines;

– checking the correspondence of the solution option and quality parameters;

– calculation of the cost;

– determination of the rational technology according to the criterion of minimum cost.

If the technologies have the same cost, then they are chosen according to the least complexity of the work.

5. 3. Representation level of the database "Sewing machine selection"

The process of interaction with the designed tool, which performs the function of an interactive simulator, occurs in several main stages. The user's task is to sequentially specify the input parameters to initiate the equipment selection algorithm.

First, the user needs to open a file that contains the software implementation of the simulator database (hereinafter referred to as the simulator). After that, the user is taken to the main tab where the control elements for data entry are located. The representation level, which displays data in a user-accessible form and provides an interface for interaction with the logic, is shown in Fig. 9.

Input parameters are selected by simply clicking on the buttons with the appropriate names, which enables standardization of the entered data and eliminates the possibility of errors. The parameters to be selected include the type of seam, worker qualification, properties and thickness of the material.

After determining all the necessary criteria, the selection algorithm is launched by activating the appropriate button. The system automatically performs a multifactor analysis of the database corresponding to the matrix model and generates a list of recommended equipment. The results, represented in the form of a table, contain the key characteristics of machines that meet the specified criteria. This stage makes it possible to visualize the relationship between technological requirements and specific equipment models, which is especially valuable for training.

Fig. 10 shows the results of selecting sewing equipment for the following query: seam type "stitched" (1.01.01); worker qualification – "high"; material coating – "caproacetate"; material thickness "heavy"; material base – "faux fur".

An example of using the designed interface and database is available at the link: https://youtu.be/spCSFOFHSn8.

The user is given the opportunity not only to work with existing data but also to supplement the database with information about new equipment. For this purpose, a separate tab is provided that makes it possible to enter data about the manufacturer, model, purpose, and other parameters of the machines. This function enables the scalability of the tool and its relevance for various industrial conditions. Upon completion of work with the simulator, it is possible to clear the fields for data entry.

5. 4. Verifying the results in the database "Sewing Machine Selection"

The study was attended by 30 people, among whom are representatives of the academic environment (graduate students, associate professors, professors and students) predominate, as well as representatives of the business sector. In general, 86.7% of the participants represent the academic environment and 13.3% – the business sector. By position, the sample combines scientific and pedagogical workers, students of various levels of education and production practitioners.

Analysis of user responses (Table 2) reveals that the designed database-simulator for the selection of equipment for the production of leather and fur clothing generally received a positive assessment, especially in terms of speed of work, convenience, and practicality of use. 93.3% of respondents noted high speed of work, 86.7% – ease of use, and 90.0% – practicality. Many respondents noted that process automation and multi-factor search options significantly reduce the time it takes to find the right information, and the clear interface makes work intuitively simple. Users also see the simulator as a tool for optimizing production processes and increasing the efficiency of enterprises.

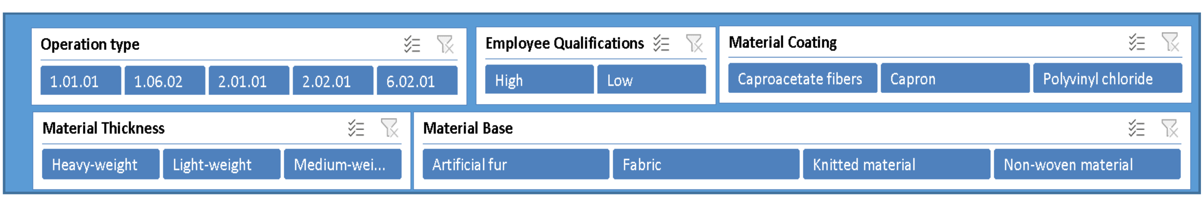


Fig. 9. Database representation layer

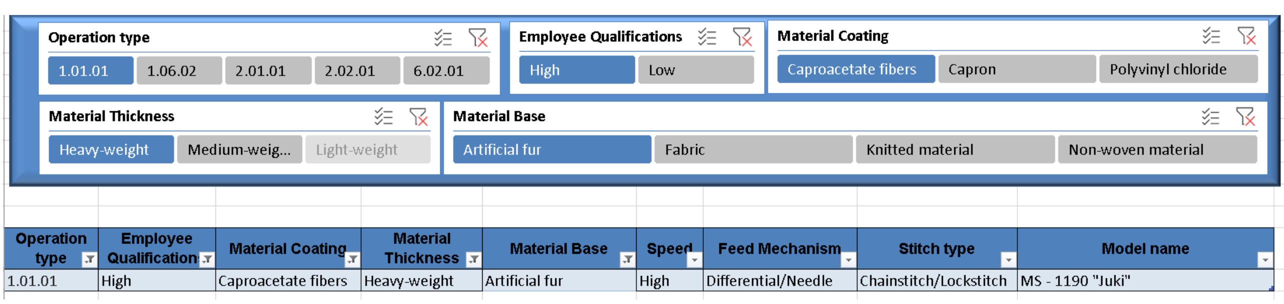


Fig. 10. Example of selection results

Table 2

Analysis of respondents' answers

Evaluation criteria	Answer options	Number of responses	Frequency of occurrence, %
Advantage	Speed of work, reduction of search time	22	73.3%
	Automation, multifactor search	9	30.0%
	Convenience/versatility	10	33.3%
	Practicality/usefulness	8	26.7%
	Optimization of production processes	5	16.7%
Disadvantage	Need for a Ukrainian version	4	13.3%
	Lack of detailed instructions/explanations	3	10.0%
	Control of entered data	2	6.7%
	Link to tables	1	3.3%
	General precautions for operation	2	6.7%
	No shortcomings (not noted by users)	12	40.0%
Suggestion	Database expansion (equipment, materials)	8	26.7%
	Add Ukrainian version	4	13.3%
	Interface modernization (expansion, search, filters)	5	16.7%
	Add instructions/explanations	3	10.0%
	Creating a mobile application	2	6.7%
	No options/uncertain	4	13.3%

However, certain shortcomings were also noted. In particular, 13.3% of respondents emphasized the need to implement a full-fledged Ukrainian-language version of the interface (currently the interface is in English) and instructions. In addition, 10.0% indicated that new users lack clear step-by-step explanations or video instructions, which complicates the first acquaintance with the simulator. In addition, 26.7% of respondents expressed the need to expand the database – both in terms of equipment (in particular, modern models) and in terms of the description of raw materials, its characteristics and compatibility parameters. Separately, respondents drew attention to the importance of controlling the correctness of the entered data (6.7%) and the need to modernize the interface (16.7%) – adding quick search, filters, the ability to save settings, and export selection results. The results of evaluating the simulator (database) according to three criteria (ease of use, practicality of development and clarity of use) are shown in Fig. 11.

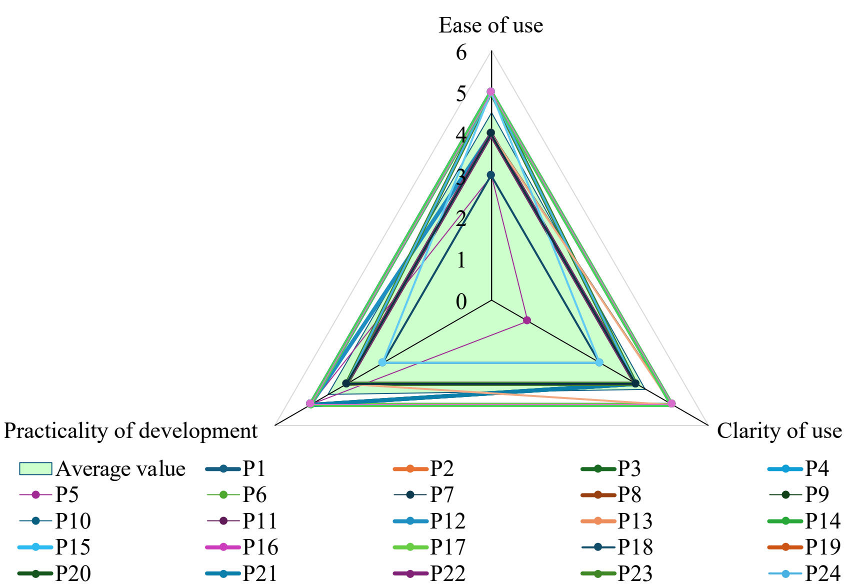


Fig. 11. Results of evaluating the simulator (database) according to three criteria

The usability criterion focuses on the ergonomics and intuitiveness of the interface. It analyzes how easily and quickly the user can perform basic tasks, such as entering selection criteria and obtaining results. The assessment is based on the minimum number of actions required for work, as well as on the logical arrangement of control elements. The speed of data processing and output of results is also a key indicator that determines the overall efficiency of interaction with the tool. The use of standardized drop-down lists simplifies the data entry process and reduces the likelihood of errors, which is also an important aspect of usability. The understandability criterion evaluates the extent to which the user is able to understand the logic of the simulator and interpret the results of its work without additional explanations. It includes an assessment of the clarity of the terminology used in the interface and database. In addition, it analyzes whether the output data, presented in the form of a table of results, is easily readable and understandable. Another important aspect is the correspondence of the results produced by the algorithm to the user's expectations, which indicates the correctness of the underlying logic. Although the interface may lack additional prompts, the assessment may reflect the need for their implementation.

The practicality criterion assesses the real usefulness and potential for the application of the designed tool. It analyzes the extent to which the simulator solves the real problem of multifactorial equipment selection in the garment industry, as well as its economic feasibility compared to existing methods. The adaptability of the system is assessed, that is, the possibility of its further scaling by adding new data on equipment, materials and technological operations. In addition, it is important to assess the possibility of using the simulator in the educational process as a teaching tool, allowing students and specialists to interactively master new approaches. The availability of the MS Excel platform is also an important indicator, indicating a high potential for the tool to be implemented at enterprises without additional costs.

Representatives from the academic sector (graduate students, professors, associate professors, students) generally demonstrated a high assessment of the simulator in all parameters. The average score for convenience, understandability and practicality in this group was 4.73; 4.45; 4.82, respectively. They more often emphasized the speed of work, automation, and multifactor selection as key advantages, and also suggested improvements in the form of expanding the database, improving the interface and adding a Ukrainian-language version. They assessed the shortcomings mainly from the point of view of functionality and system development opportunities.

The ratings from the business sector were lower, especially in terms of convenience (3 points) and understandability (the lowest score in this group is 1 point). At the same time, practicality was rated at the highest level (83.3% of business representatives rated it at 5 points). This group noted that the simulator is new, so there is a need for detailed instructions and explanations on how to use it. Among the advantages, optimization of work was mentioned but no specific suggestions for improvement were received at the familiarization stage.

Thus, it can be concluded that the academic sector is more familiar with such tools and evaluates them more positively, while representatives of the business sector need additional support in the form of training and step-by-step explanations.

Scientific and pedagogical workers gave maximum or close to maximum marks for all criteria (convenience – 5 or 4, clarity – 5 or 4, practicality – 5). They noted the speed of work, convenience, usefulness, as well as multi-factor selection. Their suggestions concerned expanding the base of equipment and materials, adding a Ukrainian-language version, and improving the interface.

Students showed slightly lower but still high scores (convenience – 4 or 5, clarity – 4, practicality – 4 or 5). They emphasized automation and convenience, but the suggestions were less detailed – for example, expanding the interface or controlling the entered information.

Thus, academics are more focused on strategic improvements to the database and functionality, while students are focused on ease of use and improving the user experience.

6. Results from investigating the database "Sewing Machine Selection": discussion

The designed interactive interface of the database "Sewing Machine Selection" (Fig. 9) performs the function of visualizing the matrix structure of the database (Fig. 4) and interacting with the algorithm (1) to (12) (Fig. 5–8). This allows us to implement in practice the work of the decision support system (DSS) in the process of forming a technological sequence for the manufacture of leather and fur products.

Known DSS solutions described in the scientific literature [36, 37] are aimed at optimizing internal technological parameters (such as machine learning for process control [38] or optimizing textile ozonation [39]). In contrast, the decision support system based on the database "Sewing Machine Selection" is directly aimed at solving the real problem of equipment selection.

Published solutions for the selection of sewing equipment are limited to the technological advancement of algorithms [11], mathematical description of the logic of choice [20, 21] or factor analysis [12]. The designed solution is distinguished by the presence of practical implementation, which makes it possible to overcome the main barrier to the digitalization of the sewing industry – the reluctance to use complex theoretical models.

The implementation of the tool in the format of an interactive simulator based on MS Excel turns an abstract algorithm into an intuitive manual. Such a tool allows technologists and students without special knowledge in the field of programming and Data Science to effectively use it for training and decision-making (Table 1, Fig. 11).

The use of digital tools that can be used both in the training process and directly in the sewing industry is described in [18, 19]. The solutions reported in them are aimed at supporting the designer's work, while the constructed database "Sewing Machine Selection" (Fig. 3) focuses on technological preparation of production.

Recommendations for improving the database and the simulator include expanding language support with the introduction of a Ukrainian-language interface, compiling understandable training materials, improving the interface through filters (Table 2). It is also necessary to expand the equipment and raw material database, add step-by-step selection logic, as well as implement automatic data verification and integration with manufacturer catalogs. It will be additionally useful to create the ability to export results into convenient formats and supplement the simulator with calculation modules that will make it possible to assess the economic efficiency of the proposed solutions.

The current simulator database is limited to equipment from specific manufacturers specializing in the manufacture of leather and fur products (according to [11]). This narrows the scope of its application. To expand its use as a decision support system and a simulator, it is necessary to fill the database with new categories of recommended equipment (Fig. 2) and the corresponding technological operations.

In addition, the database tables use only a list of equipment that is already available at a hypothetical enterprise. Price, weight, availability, popularity, or other parameters related to the purchase of equipment are quite widely described in the scientific literature [30–34]; therefore. they are considered to be taken into account at the preliminary stage of forming the technological flow. These criteria are not part of the selection process in the designed system.

To transform the simulator into an automated tool for equipment selection, it is necessary to integrate information about the equipment available at the enterprises and the technological operations performed on it into the database. It is also desirable to supplement the list of data by integrating with catalogs of machine manufacturers.

At the current stage of development, the database operates exclusively with a limited set of parameters for which all search criteria have counterparts (Fig. 10). Cases when certain user criteria remain unmet are not currently implemented. Overcoming this gap requires further research, in particular, determining the importance of each factor involved in the equipment selection process. This will make it possible in the future to offer a mechanism for searching for alternative solutions in cases where the optimal option is absent and will also provide the possibility of gradually expanding and filling the database with new materials and criteria.

At this stage, the system does not implement a ranking mechanism in cases where several equipment samples meet the same set of criteria. At the same time, in the future it is planned to develop an algorithm that will be based on the principles of multifactor analysis and determining the relative importance of each criterion. This will make it possible to build the order of representation of results from the most to the least relevant, taking into account, for example, the type of material, the complexity of the operation, or the qualification of the worker. Thus, future modifications of the system will provide for more flexible and intelligent support for the decision-making process.

7. Conclusions

1. In the course of our work, a database of sewing equipment selection parameters was successfully built. The proposed matrix structure of the database enables the preservation and consistency of information about technological operations ($Otype_i$), materials (P_j, $Mbase_j$, MTh_j), and key characteristics of machines ($Mspeed_i$, $Mpurpose_i$, etc.).

2. The functioning logic of the database "Sewing Machine Selection" that implements multifactor data analysis has been substantiated. The application of the principles of graph theory and the binary matrix of closure by transitivity of the relation allowed us to implement logic that effectively analyzes the input criteria. The optimization problem was solved by the linear programming method, which enables the selection of the optimal sewing machine model for specific industrial conditions.

3. An interactive interface based on MS Excel has been designed, which performs the function of visualization and interaction with the algorithm. This tool allows the user, by selecting parameters such as the type of seam, worker qualification, material properties, and material thickness, to directly interact with the selection algorithm. The interface displays the results of the logical level in a user-friendly form and serves as an effective educational and practical tool. The implementation of the database in the educational process for educational programs in the field of "Light Industry Technologies" will contribute to the achievement of a number of program learning outcomes.

4. Our tests have confirmed the effectiveness and practical significance of the devised method. 30 respondents representing the academic environment and the business sector took part in the experiment (86.7% and 13.3%, respectively). The vast majority of users noted its speed of work (93.3%), convenience (86.7%), and practicality (90.0%). Among the respondents, 26.7% expressed a need to expand the database, 13.3% – to introduce a Ukrainian-language version of the interface, 10.0% – to provide instructions, 16.7% – to modernize the interface. Participants from the academic environment rated the simulator the highest in terms of convenience, clarity, and practicality: 4.73; 4.45; 4.82, respectively.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors used artificial intelligence technologies within acceptable limits to provide their own verified data, which is described in the research methodology section.

References

1. Meyer, M., Dietrich, S., Schulz, H., Mondschein, A. (2021). Comparison of the Technical Performance of Leather, Artificial Leather, and Trendy Alternatives. Coatings, 11 (2), 226. https://doi.org/10.3390/coatings11020226
2. Tokuda, F., Murakami, R., Seino, A., Kobayashi, A., Hayashibe, M., Kosuge, K. (2025). Fixture-Free 2D Sewing Using a Dual-Arm Manipulator System. IEEE Transactions on Automation Science and Engineering, 22, 7927–7940. https://doi.org/10.1109/tase.2024.3474914
3. Kong, R. W. M. (2025). Innovative Automated Stretch Elastic Waistband Sewing Machine for Garment Manufacturing. International Research Journal of Modernization in Engineering Technology and Science. https://doi.org/10.56726/irjmets70275
4. Jindal, H., Kaur, S. (2021). Robotics and Automation in Textile Industry. International Journal of Scientific Research in Science, Engineering and Technology, 8 (3), 40–45. https://doi.org/10.32628/ijsrset21839
5. Forlini, M., Ciccarelli, M., Carbonari, L., Papetti, A., Palmieri, G. (2024). Smart automation in luxury leather shoe polishing: a human centric robotic approach. International Journal of Computer Integrated Manufacturing, 38 (9), 1329–1343. https://doi.org/10.1080/0951192x.2024.2421313
6. Huan, Y., Ren, G., Sun, J., Jin, G., Ding, X., Du, W. (2024). Efficient leather spreading operations by dual-arm robotic systems. Scientific Reports, 14 (1). https://doi.org/10.1038/s41598-024-66904-2
7. Seino, A., Terayama, J., Tokuda, F., Kobayashi, A., Kosuge, K. (2022). Robot End-effector for Fabric Folding. https://doi.org/10.36227/techrxiv.21283725.v1
8. Boz, S., Birkocak, D. T., Necef, Ö. K., Kiliç, A., Öndoğan, Z. (2022). Investigation of sewing parameters caused fabric damages. W: AUTEX 2022: 21st World Textile Conference AUTEX 2022 – AUTEX Conference Proceedings. Lodz, 40–44. https://doi.org/10.34658/9788366741751.9
9. Tang, K., Tokuda, F., Seino, A., Kobayashi, A., Tien, N. C., Kosuge, K. (2024). Time-Scaling Modeling and Control of Robotic Sewing System. IEEE/ASME Transactions on Mechatronics, 29 (4), 3166–3174. https://doi.org/10.1109/tmech.2024.3398713

10. Martínez-Peral, F. J., Migallón, H., Borrell-Méndez, J., Martínez-Rach, M., Pérez-Vidal, C. (2024). Manipulation order optimization in industrial pick-and-place operations: application to textile and leather industry. The International Journal of Advanced Manufacturing Technology, 133 (1-2), 987–1010. https://doi.org/10.1007/s00170-024-13436-8
11. Zakharkevich, O., Zhylenko, T., Koshevko, J., Shvets, G. (2023). Development of an algorithm for the reasoned selection of machines for leather garments manufacturing. Eastern-European Journal of Enterprise Technologies, 5 (3 (125)), 86–94. https://doi.org/10.15587/1729-4061.2023.287482
12. Shahriar, M. M., Parvez, M. S., Talapatra, S. (2022). Hierarchizing the Product Characteristics of Industrial Plain Sewing Machine for Making Best Purchase Decision. Mathematical Problems in Engineering, 2022, 1–17. https://doi.org/10.1155/2022/2578875
13. Kalwar, M. A., Khan, M. A., Wassan, A. N., Phul, Z., Shaikh, S. A., Marri, H. B. (2023). Automation of Post-Order Costing Analysis By Using Visual Basic For Applications In Microsoft Excel: A Case Study. WPOM-Working Papers on Operations Management, 14 (2), 101–136. https://doi.org/10.4995/wpom.18697
14. Swaminathan, V., Saffiudeen, M. F., Gupta, S., Alamri, Y. A. (2024). Review of semiconductor laser diode technologies for sustainable energy in leather machining. Clean Technologies and Environmental Policy, 27 (2), 577–606. https://doi.org/10.1007/s10098-024-02976-y
15. Werheid, J., Melnychuk, O., Zhou, H., Huber, M., Rippe, C., Joosten, D. et al. (2024). Designing an LLM-Based Copilot for Manufacturing Equipment Selection. arXiv. https://doi.org/10.48550/arXiv.2412.13774
16. Kefale, G. Y., Bizuneh, B., Getachew, L., Karthikeyan, R. (2025). Innovative Pathways in Leather Industry: A Comprehensive Review of Sustainable Technologies and Strategies. Journal of Scientific & Industrial Research, 84 (6). https://doi.org/10.56042/jsir.v84i6.10781
17. Kim, M., Ahn, J., Kang, J., Kim, S. (2020). A Systematic Review on Smart Manufacturing in the Garment Industry. Fashion & Textile Research Journal, 22 (5), 660–675. https://doi.org/10.5805/sfti.2020.22.5.660
18. Zakharkevich, O., Poluchovich, I., Kuleshova, S., Koshevko, J., Shvets, G., Shvets, A. (2021). "CloStyler" – mobile application to calculate the parameters of clothing blocks. IOP Conference Series: Materials Science and Engineering, 1031 (1), 012031. https://doi.org/10.1088/1757-899x/1031/1/012031
19. Zakharkevich, O., Koshevko, J., Shvets, G., Kuleshova, S., Bazyliuk, E., Paraska, O., Kazlacheva, Z. (2022). Development of the Mobile Application to Calculate Parameters of Underwear Patterns. Terotechnology XII, 24, 309–315. https://doi.org/10.21741/9781644902059-45
20. Karakiş, E. (2021). Machine Selection for a Textile Company with CRITIC and MAUT Methods. European Journal of Science and Technology. https://doi.org/10.31590/ejosat.994697
21. Ulutaş, A. (2020). New Grey Integrated Model to Solve Machine Selection Problem for a Textile Company. Fibres and Textiles in Eastern Europe, 28 (1 (139)), 20–25. https://doi.org/10.5604/01.3001.0013.5853
22. Tama Birkocak, D. (2022). Effects of Needle Size and Sewing Thread on Seam Quality of Traditional Fabrics. Tekstil ve Konfeksiyon, 32 (3), 277–287. https://doi.org/10.32710/tekstilvekonfeksiyon.1088043
23. Syabani, Muh. W., Devi, C., Hermiyati, I., Angkasa, A. D. (2020). The effect of PVC's resin K-value on the mechanical properties of the artificial leather. Majalah Kulit, Karet, Dan Plastik, 35 (2), 75. https://doi.org/10.20543/mkkp.v35i2.5639
24. Watanabe, S., Tominaga, S., Horiuchi, T. (2020). The Difference in Impression between Genuine and Artificial Leather: Quantifying the Feeling of Authenticity. Journal of Perceptual Imaging, 3 (2), 020501-1-020501–020511. https://doi.org/10.2352/j.percept.imaging.2020.3.2.020501
25. Ersöz, T., Tenbeli, R., Ersöz, F. (2021). Visual analysis of turkey's textile sector with Gephi complex network. Proceding of 11th International Symposium on Intelligent Manufacturing and Service System. Sakarya, 519–529. https://doi.org/10.5281/zenodo.16411310
26. Angeli. Available at: https://angeli.net.ua/uk/juki
27. Amtex. Available at: https://amtex.com.ua/brands/shvejnoe_oborydovanie_juki/
28. Lapka.com.ua. Available at: https://www.lapka.com.ua/ua/brand-juki.aspx
29. Sewtech. Available at: https://sewtech.com.ua/uk/promislovi-shvejni-mashini/brand-juki/
30. What is an Industrial Sewing Machine? Juki. Available at: https://www.juki.co.jp/en/products/industrial/
31. How to Analyze Data in Excel? Quick and Easy Steps. Available at: https://techbii.com/how-to-analyze-data-in-excel-quick-and-easy-steps/
32. Zakharkevich, O., Paraska, O., Koshevko, J., Shvets, G., Shvets, A., Zhylenko, T. (2023). Development of a Mobile Application to Study Sewing Techniques for Manufacturing Fur and Leather Clothes. Fibres & Textiles in Eastern Europe, 31 (2), 1–10. https://doi.org/10.2478/ftee-2023-0011
33. TechLab. Available at: https://play.google.com/store/apps/details?id=appinventor.ai_zbirvukladach.TL1&hl=uk&gl=US
34. ISO 4916:1991 (1991). Textiles – Seam types – Classification and terminology. Printed in Switzerland/lmprime en Suisse, 64.
35. Osvitnia prohrama "Tekhnolohiyi lehkoi promyslovosti" (riven mahistr) (2025). Available at: https://khmnu.edu.ua/wp-content/op/m/g15-ktshv-2025.pdf
36. Poluda, S. N., Koval, T. V., Boksha, N. I. (2016). Tekhnolohiya shveinoho vyrobnytstva ta osnastka. Mukachevo: MDU, 93.
37. Tran, K. P. (2022). Machine Learning and Probabilistic Graphical Models for Decision Support Systems. CRC Press. https://doi.org/10.1201/9781003189886
38. He, Z., Tran, K.-P., Thomassey, S., Zeng, X., Xu, J., Yi, C. (2021). A deep reinforcement learning based multi-criteria decision support system for optimizing textile chemical process. Computers in Industry, 125, 103373. https://doi.org/10.1016/j.compind.2020.103373
39. Di Domenico, A. (2023). Entanglement, CPT, and Neutral Kaons. CPT and Lorentz Symmetry, 74–78. https://doi.org/10.1142/9789811275388_0016