Evaluation of the expert system as a stage of the life cycle model ESDLC on the example of WIKex

M. FURMANKIEWICZ, J. FURMANKIEWICZ, P. ZIUZIAŃSKI
malgorzata.furmankiewicz@gmail.com

University of Economics in Katowice
Koło Naukowe Scientia Ingenium
ul. 1 Maja 50, 40-287 Katowice, Poland

The purpose of the article is to present the Expert System Development Life Cycle (ESDLC) and – in particular – the ESDLC's evaluation stage. The essence of expert systems has been briefly described in the Artificial Intelligence (AI) context. Authors concentrated on the WIKex expert system, which was a practical part of the master's thesis submitted by one of the authors of the University of Economics in Katowice. Moreover, the results of WIKex evaluation have been presented as a the last stage of the life cycle of the expert system.

Keywords: expert system, ESDLC, WIKex.

1. Introduction

Constructing information systems, including expert systems, should be a process that takes into account many aspects of software design.

This article presents the theoretical considerations regarding the Expert System Development Life Cycle (ESDLC) comprising the following elements: planning, knowledge definition, knowledge design, encoding and testing, knowledge validation and the system evaluation. The authors particularly focused on the last component. The article presents the results of the WIKex expert system evaluation. The system provides consultancy in choosing specialization at the Informatics and Communications Department of the University of Economics in Katowice.

2. Expert Systems

The popularization of information technology has contributed to the start in thinking of using computers in the decision-making process. One of the disciplines developed in this area is artificial intelligence (AI), which originated in the 1940s [13]. It is assumed that the term "artificial intelligence" was suggested by John McCarthy in 1958. He defined AI as follows: "(...) the construction of machines, whose activities may be described as similar to human manifestations of intelligence" [19]. The subsequent definitions of AI differentiate this term in two dimensions. The first one encompasses the thinking processes and reasoning together with acting, the second one leads from measures of success to the ideal concept of intelligence, which is understood as thinking and rational action [3, 5].

The expert systems are considered to be the most visible result of research on artificial intelligence [9, 17]. The term expert system is understood as the IT program that generates a solution to a given problem and explains it at the level of a domain expert, using logic by applying explicitly represented knowledge and reasoning methods [2, 8, 10, 16]. An expert is a person who has specialist knowledge of a specific, narrow field and is able to use it to solve the problems in this field [13]. Expert systems are created by knowledge engineers, who are specialists in the field of knowledge representation methods. Knowledge engineers are responsible for acquiring knowledge from experts, collecting it in a knowledge base, as well as for the verification of knowledge [19].

Expert systems are used in areas such as: business, medicine, agriculture, education, telecommunications, mathematics, chemistry, geology, environment, law, transportation, and military. The broadest and most frequently used group of expert systems are consultancy systems, whose result of acting is a method of solving a problem [4, 12].

3. Implementation of expert systems – Expert System Development Life Cycle (ESDLC)

There is a variety of different design and implementation models of expert systems. The starting point for deliberations on the subject are methods that are developed within the software engineering discipline. The basis of ESDLC constitutes a waterfall model [6]. This model takes into account the specifics of the design of expert systems and highlights the phase associated with the preparation and design of the knowledge base. This cycle is characterized by a waterfall model's features, such as: [1]:

- division into sequential steps and phases
- need for completion of each stage before proceeding to the next one
- preparation of documentation and summaries at the end of each stage.

This model consists of six major steps, as presented in Figure 1. Within the stages already mentioned, one can distinguish a few phases. The knowledge defining stage comprises a phase identification, selection and acquisition of sources, as well as their analysis and extraction. The design stage includes the defining phase and detailed design. In the case of the knowledge validation stage, formal tests and an analysis of tests are carried out.

The key decision that needs to be made before the process of the expert system project is executed, is connected with the choice of the implementation environment. This choice greatly influences the choice of the system life-cycle model, which the implemented project will be based on. Table 1 shows the stages and phases distinguished in ESDCL, as well as their tasks and objectives.

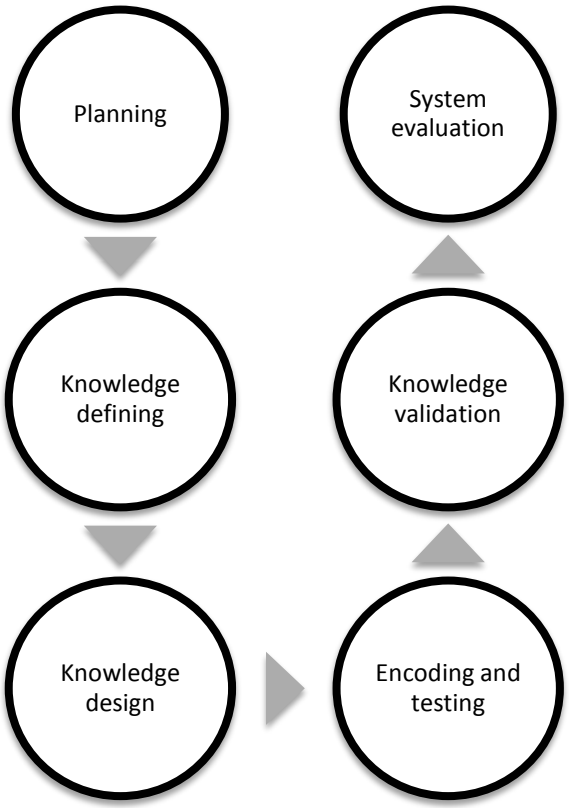

Fig. 1. ESDLC Model
Source: Own work based on [1]

Table 1. Stages, phases, tasks and their objectives in the Expert System Development Life-Cycle model
Source: Own work based on [1]

Stage	Phase	Task	Objective
Planning	–	Feasibility study	Assessment of the merits of creating an expert system with an indication of the technology that will be used to build the system.
		Resource management	Assessment and management of human resources, budget, time, software and hardware that are indispensable to implement the project.
		The division of tasks	Specifying tasks and their meanings in subsequent stages of the project.
		Scheduling	Setting commence dates and deadlines for the next tasks.
		Preliminary functional system	Definition of the tasks performed by the expert system.
		High level demands	Definition of functions to be performed at the user level.
Defining knowledge	Identification and selection of sources	Identification of sources	Defining who or what will be the source of knowledge.
		Meaning of sources	Importance assessment of particular sources for the project execution.

		Availability of sources	Preparation of a list of sources according to the availability criteria.
		Choosing the sources	Choosing the knowledge sources in terms of their availability and importance for the project.
	Acquisition and analysis of knowledge	Knowledge acquisition strategy	Determining how to acquire knowledge, through the definition of methods, e.g. review of documents or interviews with experts.
		Identification of the elements of knowledge	Defining the suitability of specific knowledge at the various stages of the system's life.
		Knowledge classification system	Classification and organization of knowledge in order to support its verification and understanding by the designers.
		Detailed functional layout	Exact specification of the system's functional abilities (at the technical level).
		Initial flow of controlling	Defining the main phases in which the system will be run.
		Preliminary User's Manual	Characterization of the expert system from the perspective of the end user. This stage is often ignored, but it is crucial for the design of the system. It is especially important to take into account assessments of end users in the context of the expert system's functionality.
		Requirements' specification	Detailed definition of the purpose of the expert system. Determination of what is to be implemented through the system.
		The baseline for knowledge	Closure of all previous tasks, implementation of any necessary changes.
Knowledge design	Knowledge definition	Knowledge representation	Determining how the knowledge will be represented (e.g. rules, frames).
		Detailed knowledge structure	Determining the control structures (such as a method of inducing an expert system during the execution of the code, metalevel of the structure controlling the rules).
		Internal structure of the facts	Specification of the internal structure of the facts in a coherent and comprehensible manner.
		The initial user interface	Specifying the initial appearance of the interface, taking into account its assessment of the potential end-users.
		Internal test plan	Determining the testing of the system and the way the results are to be analyzed.
	Detailed knowledge design	Design structure	Determining the scope of the knowledge base.
		Implementation strategy	Determining the way knowledge will be executed.
		Detailed user interface	Specifying a detailed appearance of the interface taking into account the remarks of users that have been reported in the task "initial user interface".
		Design specification and reports	The aim is to document the design process.
		Detailed test plan	Determination of the method of testing and verifying the code.
Encoding and checking	–	Encoding	Implementation of the expert system's code.
		Testing	Testing the expert system's code.
		Source listings (of the code)	Preparation of the described and documented code.
		User's Manual	Preparation of the user's manual that will allow experts and end users to provide remarks on the system.
		Installation/operation guide	The aim is to prepare the installation and operational system documentation, which will be made available to users.
		Description of the system	Preparation of documentation, which will contain a description of the system's functionality, as well as its limitations and problems.

Verification (validation) of knowledge	Formal testing	Testing procedure	The aim is to implement procedures for formal testing.
		Reports of tests	Preparation of documentation of the results of the carried out tests.
	Analysis of tests	Evaluation of the results	Analysis of the results of carried out tests.
		Recommendations	Preparation of documents with recommendations and a summary of tests.
Evaluation of the system	–	Evaluation of the results	Summary of the test results and verification.
		Recommendations	Indicating the recommendations for possible changes in the system.
		Validation	Examining the correctness of the system designed (after taking into account the needs and requirements of users).
		An interim report or a final report	Preparing a final report (when the system is complete) or an interim report.

One should note that the final decision on the system's transfer for use should be taken after the system is accepted by end users and when their requirements are met. The transfer of the system for use and its regulations covering aspects such as its adaptation to needs, removal of faults and errors, and the completion of what it lacks constitute the final stage in the implementation of the expert system. Due to the fact that commencing use of the system is often associated with migration to a new working environment, it must be agreed upon with end users. It is indispensable to indicate the deadlines that will allow for potential changes, without generating too many negative effects (e.g. delays in the production process).

It is essential that a smooth functioning of all its components is ensured before the system's start-up. Therefore it is important to check, among others, the hardware platforms, and servers and to verify the aspect of the network system performance. It is also necessary to confirm both data sets, as well as communication interfaces that are required by the implemented system. It should be emphasized that these operations must be undertaken in a standard working environment of the system, and not in the testing environment.

The next, crucial step is the preparation of documentation for the user that will contain a description of system functionality but not its technical aspects. This differentiates the user's documentation from the project documentation. An important phase is to conduct training for users. In the initial period of using the system, the system users need to make comments and suggestions, which should be considered for the modification of the system.

Maintaining the efficiency of each system, and therefore also of the expert system, is associated with defining groups of people who will be involved in its maintenance process. The main task of the group should be to maintain the knowledge base at the level that corresponds to the current state of knowledge. Periodically, it is also significant to check the correct operations of the expert system, as well as ongoing evaluation of the economic benefits that arise from carrying out the implementation.

4. WIKex system as an example of an expert system

The WIKex system has been elaborated upon in a practical part of the master's thesis by one of the authors in the University of Economics in Katowice [7]. In order to build the system, eXpertise2Go, a free web-based expert system shell, was used [14]. The task of WIKex, the created expert system, is to help the students of the Department of Communications Engineering and Informatics of the University of Economics in Katowice in the decision-making process on choosing their further educational path, i.e. specialization. An expert system was created taking into account the faculties and specializations which could be conducted at the Department of Communications Engineering and Informatics in 2013. Table 1 shows the synthetic approach to faculties and specializations that are considered in the WIKex expert system.

Table 2. Specializations conducted at the Department of Communications Engineering and Informatics of the University of Economics in Katowice in 2013
Source: Own work based on [7]

	Specialization	Detailed specialization	First degree. Full-time studies/ Part-time studies	Second degree. Full-time studies/ Part-time studies
Department of Communications Engineering and Informatics	Informatics and Econometrics	E-Business	x	
		Economic Informatics	x	
		Engineering of information systems management	x	
		Knowledge Engineering	x	
		Methods and systems for decision--making support	x	
		Project management		x
	Informatics	Databases and data warehouses	x	
		Mobile games and applications programming	x	
		Integrated informatics management systems	x	
	Journalism and Social Communication	New media and electronic communications in organizations	x	
		Economic Journalism and Public Relations	x	
		Culture and intercultural communication	x	

To build a system, a special software eXpertise2Go was chosen due to the number of its advantages, including the most important for the designer of the system – availability through thte website and possibility to integrate it with the webpage. Due to the fact that the system can be integrated with the website, which is the most popular service that provides hypertext documents which can be viewed using the browser, a website http://knsi.ue.katowice.pl/wikex/ was created, using, among others, CSS and JavaScript. The created website operates four tabs: Home, WIKex system, System evaluation, and Information. Home tab serves as the main page, which displays basic information about its contents (Figure 2). The WIKex system tab contains an expert system built in the eXpertise2Go environment, which can benefit the user with access to the Internet and a browser. The page also integrates LimeSurvey, an open research management of the survey results. This is a free, multilingual, and an intuitive software providing an opportunity to create a questionnaire with many types of questions (e.g. single and multiple choice questions, yes / no questions with a defined mask, and panel questions). The System evaluation bar enables the user to fill in an online questionnaire regarding the WIKex system. The last bar, namely Information bar provides a note about the creator of the system.

Fig. 2. The WIKex system
Source: Own work

5. Evaluation of the WIKex system on the basis of a survey

WIKex system was evaluated by end users, namely by the first- and second-degree students of Informatics and Econometrics, as well as by first-degree students of Informatics and Journalism and Social Communication. The study was conducted using Computer Assisted Web Interview method (CAWI), which used the Internet in the process of data collection [11]. Among the advantages of the CAWI method, one can enumerate low cost, availability and the ability to reach respondents in a relatively short period of time. Another advantage of conducting research via the Internet is a reduction of errors by eliminating the influence of interviewers on respondents [15].

The survey was successfully completed by 51 people. The rejection rate accounted for about 32%, the majority of whom were people who opened the survey, but did not respond to any question. The structure of the sample is presented in Table 3.

Table 3. The structure of the sample
Source: Own work

	Specialization			**Total**
Degree	**Informatics and Econometrics**	**Informatics**	**Journalism and Social Communication**	
First-degree studies	12	19	3	34
Second-degree studies	17	–	–	17
Total	29	19	3	51

The first part of the questions concerned the WIKex graphical interface. The users evaluated the interface's particular features using a five-point scale. Table 4 presents the users' notes and the average value of a given feature (results are listed according to the average value of a given feature).

Table 4. The results of questions concerning the graphical interface of the WIKex system
Source: Own work

Rating (1 – *lowest rating*; 5 – *highest rating*) / **The interface's feature**	**1**	**2**	**3**	**4**	**5**	**Average value**
Promptness of learning how to use the interface	0	2	6	13	30	4,39
Font readability	1	2	3	17	28	4,35
Easiness of navigation and tasks performance	1	1	10	14	25	4,20
Transparency of the interface	0	3	6	21	21	4,18
Layout and size of the buttons	0	3	8	25	15	4,02
Color scheme	2	6	10	18	15	3,75
Total:	**4**	**17**	**43**	**108**	**134**	**4,15** **306**

The data shows that the highest rated feature of the graphical interface of the WIKex system is "Promptness of learning how to use the interface" – achieving an average rating of 4.39. Only a slightly lower rating was ascribed to "font readability" (rating at the level of 4.35). Respondents liked the color scheme least. This feature was rated 3.75. It is worth noting that the lowest rating was given only 4 times out of 306 total ratings.

Moreover, the respondents evaluated the intuitiveness of the WIKex system. More than 84% of respondents rated the system as intuitive. The messages that were displayed to users are

comprehensible to more than 90% of the users. The second set of questions related to the value of the expertise provided by the WIKex system. More than 72% of respondents received the expertise corresponding to the reality, which means that the WIKex expert system indicated the specialization they study. Also, more than 70% of respondents are currently studying a specialization they wanted. The fact that almost 75% of respondents claim that the specialization they wanted to study was opened is also thought-provoking. This ratio is higher than the previous one (ratio of students studying their dream specialization), which presumably means that, despite the fact that the specialty the students desired to study was opened, the students do not study it. The respondents also answered a question about the time that they spent using the WIKex system in order to obtain an expert opinion. Around 61% of respondents achieved the expertise in less than 3 minutes, 33% of respondents needed from 3 up to 5 minutes, and just 6% of the respondents answered that obtaining the expertise took them more than 5 minutes.

The third set of questions comprised four general questions about the WIKex system. The first question consisted of six statements that the respondents evaluated using the so-called Likert scale. It is a bipolar interval scale measuring attitudes and beliefs. The term "bipolar" refers to the fact that at the opposite edges of the scale there are contrary beliefs. Additionally, the term "Interval" means that the subsequent points on the scale are aligned to maintain an equal distance between them. The comparison of the results is shown in Table 5.

Table 5. The results of questions concerning the graphical interface of a user of the WIKex system
Source: Own work

Answers / **Statement**	I strongly agree	I rather agree	I do not know	I rather disagree	I strongly disagree
The WIKex system inspired my trust	16%	41%	21%	14%	8%
I would use the WIKex system again	16%	35%	19%	18%	12%
I would recommend the WIKex system to my friends	21%	33%	20%	18%	8%
The WIKex system can be considered innovative	19%	41%	18%	12%	10%
The name of the system is corresponding to its functions	18%	31%	23%	18%	10%
I would like to the WIKex system to be freely available	26%	37%	27%	4%	6%

The presented data shows that 55% of the respondents trust the WIKex system. Also, more than half of the respondents (51%) considered that they would use the system again. As many as 21% of respondents strongly agreed with the statement that they would recommend the system to their friends. As many as 60% of respondents recognized it as an innovative, while 63% of the surveyed would like the system to be widely available (27% of respondents had no opinion on this subject).

Respondents also answered the question regarding the advantages of the WIKex system. This was a multiple choice, with the restriction that the respondent could indicate no more than three features. In addition, respondents could indicate a different characteristic feature to those listed in the question. Figure 3 presents the results.

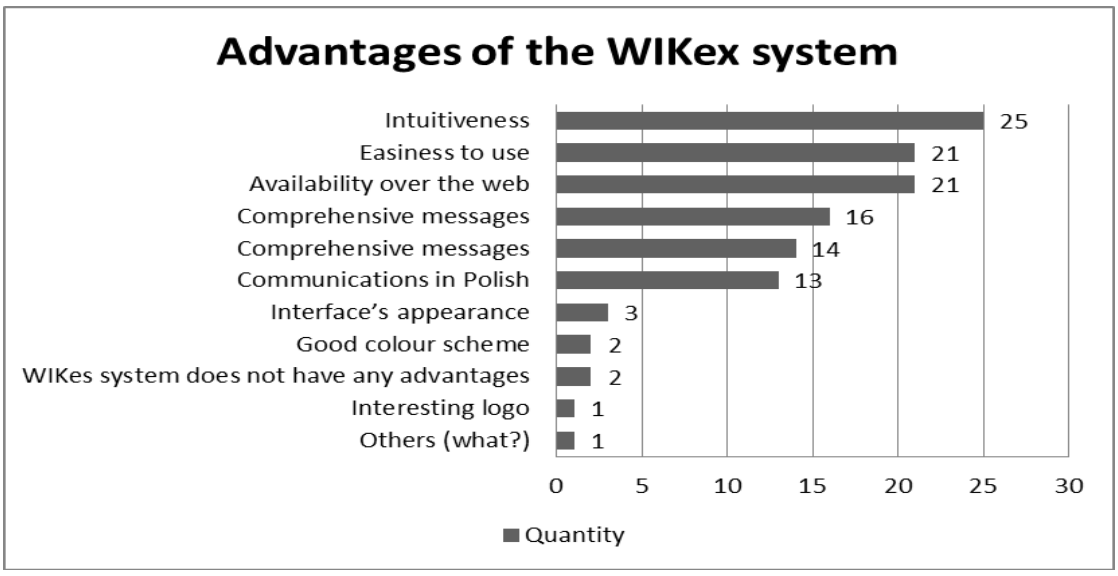

Fig. 3. Advantages of the WIKex system
Source: Own work

The most commonly noted advantage of the WIKex system was its intuitiveness. This feature has been pointed out by almost 50% of respondents. Easiness of use and availability over the web were similarly evaluated and indicated as the most important features of the WIKex system by 21 respondents. Comprehensive messages, the appropriate expertise and communications in Polish were analogically indicated by the respondents, respectively by 16, 14 and 13 respondents. Respondents indicated the interface design, color scheme and logo least frequently; 2 respondents indicated that the system does not have advantages. Only 1 respondent additionally pointed out that an important advantage of the WIKex system is its promptness.

Respondents also answered the question regarding the disadvantages of the WIKex system. The question was constructed in an analogical way to question about the advantages of WIKex, i.e. respondents could choose up to three features. In addition, respondents could indicate a different disadvantage to those listed in the question. The results are shown in Figure 4.

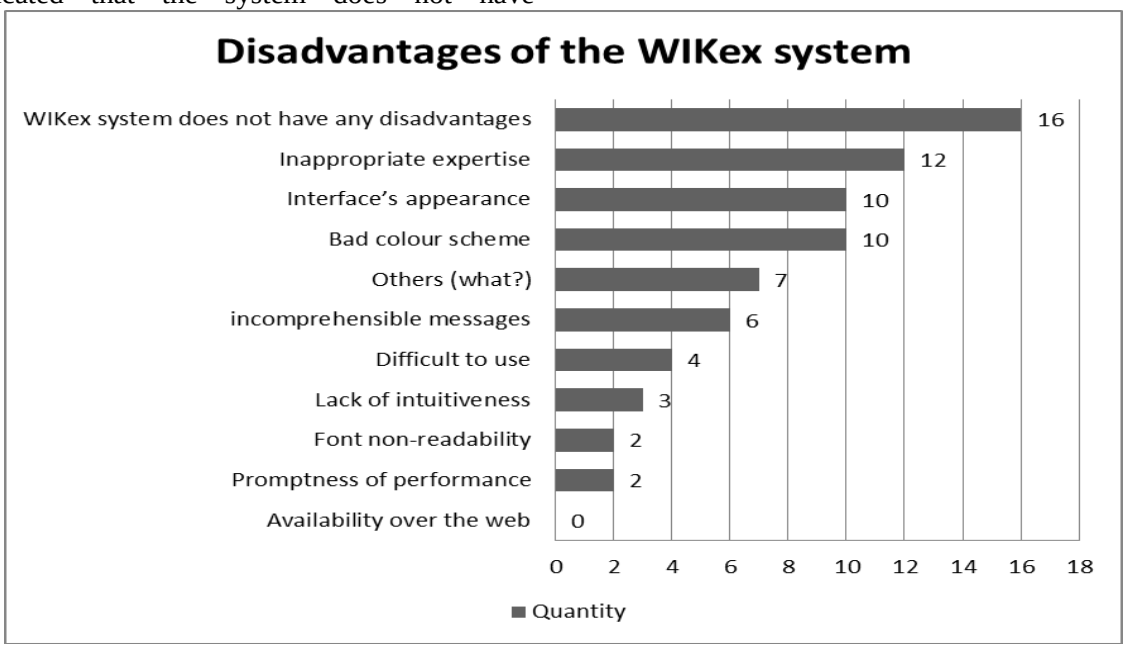

Fig. 4. Disadvantages of the WIKex system
Source: Own work

Most often, the respondents indicated that the system has no disadvantages. About 23% of respondents, i.e. 12 respondents indicated that the most important disadvantage of the system is delivering an incorrect expertise. The interface's appearance and the applied colors were disliked by approximately 20% of the respondents. The users pointed out that a major drawback is also the need to accept Java software. It is worth mentioning that respondents pointed out the system's flaws only 56 times. The advantages were indicated around two times more often (117 times) than the disadvantages.

6. Summary

The evaluation of an expert system, which is the last stage of the life cycle (ESDLC), also accounts for its extremely important element. One of the purposes of assessing the expert system is validation of the system design. A possible way to verify whether the objective has been achieved is to enable its users to assess it. The study demonstrated that the WIKex system can be considered innovative, intuitive and easy to operate. Users have also identified a need to create such systems by agreeing with the statement that the system should be freely available. Noteworthy is the fact that the majority of respondents would recommend the WIKex system to their friends. One of the major defects pointed out by the respondents is the need to accept Java software. The users specified the direction of possible changes in the system, e.g. by incorporating an internal mechanism making the eXpertise2Go independent from Java.

To conclude, the results of the study on the WIKex system indicate that there is a need for this type of solutions, which, despite time, are considered to be uprated. It is extremely important that the rule-based systems are equipped with the completeness of the knowledge base, while ensuring a minimum amount of rules [18]. The system should also be web-based, preferably without having to install any additional components.

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Ocena systemu ekspertowego jako etap modelu cyklu życia ESDLC na przykładzie systemu WIKex

M. FURMANKIEWICZ, J. FURMANKIEWICZ, P. ZIUZIAŃSKI

Celem artykułu jest prezentacja cyklu życia systemu ekspertowego, a w szczególności etapu oceny systemu ekspertowego. W artykule przedstawiono istotę systemów ekspertowych w kontekście systemów sztucznej inteligencji. Autorzy zaprezentowali WIKex – system ekspertowy, którego opracowanie stanowiło przedmiot części praktycznej pracy magisterskiej jednego z autorów na Uniwersytecie Ekonomicznym w Katowicach. Przedstawiono wyniki oceny systemu WIKex jako ostatniego etapu cyklu życia systemu ekspertowego.

Słowa kluczowe: system ekspertowy, ESDLC, WIKex.