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SYSTEM SUPPORTING THE ASSESSMENT OF THE DEGREE OF IMPLEMENTATION MATURITY OF TECHNICAL INNOVATIONS

Key words

Assessment system, degree of implementation maturity (SDW), SDW assessment algorithm, technological innovations, technology transfer.

Abstract

The paper presents a supporting system for assessing the degree of implementation maturity (SDW) of innovative technical solutions, developed under the Strategic Programme: “Innovative technical support system for sustainable economic development.” The system was verified in the course of the assessment of more than 170 innovative solutions arising as a result of Strategic Plan: “Innovative technical support system for sustainable economic development” executed at the Institute for Sustainable Technologies – National Research Institute in Radom. The developed tool is an important element supporting the processes of the transformation of knowledge and transfer of advanced process and products technologies in the area of production and operation of machines and equipment. The verification confirmed the usefulness of the method and system for evaluating the application potential at various stages of the development of innovative solutions. The use of the method allows more effective control of the implementation of research results into practical

applications contributing to a boost of innovation and competitiveness of the economy. The effectiveness of SDW assessment system was confirmed in subsequent applications, including an application for the assessment of innovative solutions for SMEs and innovative activities undertaken by industrial and technological parks.

Introduction

The reasons for the low efficiency of the practical application of research results may be due to imperfections of mechanisms supporting the phases of implementation and commercialization, and a low degree of implementation maturity of the developed innovative solutions [1]. Among the measures taken to enable the conversion of research results into innovative products [2], it is also important to consider to some extent the degree of the technical advancement of the solutions as well as readiness of the products for industrial and commercial implementation in the models of the transformation of knowledge into practical applications and the transfer of technology into economy. Application efficiency of technological innovations can be significantly increased when a realistic assessment of the degree of technological development is introduced and some activities focused on their practical implementation are proposed [3–4].

Therefore, in order to assess the maturity of solutions, the methodologies modelled on Technology Readiness Levels (TRL) [5–7], adapted for specialized applications are more widely used at the further stages of technology development. The use of the TRL method is currently a common practice of innovative economies, especially in high-tech and complex terms of organization endeavours. Recently, this method has been also introduced in the National Research and Development Centre for assessment of research projects [8].

Using general assumptions of the TRL method [9], [10] and the previous effects of the its applications for specialized purposes all over the world [11–13], the Institute for Sustainable Technologies – National Research Institute developed an original methodology for assessing the degree of implementation maturity (SDW) of products arising as a results of the Strategic Programme “Innovative technical support systems for sustainable economic development”^{1, 2}. The methodology takes into account both types of the assessed solutions and the degree of the advancement of the innovation development process.

¹ A. Mazurkiewicz, T. Giesko, W. Karsznia, B. Belina: Metodyka oceny stopnia dojrzałości wdrożeniowej innowacji technicznych. *Problemy Eksploatacji* 1/2010, s. 5–20.

² A. Mazurkiewicz, T. Giesko, W. Karsznia, B. Belina: System operacyjny oceny stopnia dojrzałości wdrożeniowej innowacyjnych rozwiązań w zakresie usług. *Problemy Eksploatacji* 3/2011, s. 61–73.

The developed SDW method is used to identify the advancement of a phase and precisely to assess of the level of innovation and the implementation readiness of a particular solution. This assessment relates to technical aspects and the advancement of R&D works. SDW assessment allows one to rationally plan (in terms of risk, time and cost) further actions to be taken regarding the innovative solution. It is performed by a team of peer experts in a particular field as well as specialists in the developed methodology.

The method uses two coupled algorithms for the initial assessment and the detailed assessment of innovative solutions containing specially adjusted sets of control questions. The overall assessment (Fig. 1) is the expert methodology enabling quick determination of the degree of innovative solution readiness for the implementation and the initial determination of one of the 10 levels of advancement of a given solution. The basis for the assessment is the description of the level of technical development as well as general expert knowledge on a given assessed solution and its real adaptation to economically applicable operational activities. The answers to the questions of detailed assessment algorithm allow effective assessment of the phase at which is the research and development project. Therefore, they are the basis for the precise assessment of whether the current level of development of the innovative solution provides for its practical use. The main objective of the assessment is to minimize the risk associated with the selection of underdeveloped solutions that require additional research and obtaining commissioning certificates, etc.

The described assessment mechanism was implemented in the original, self-developed, computer system, the core of which is a database and software for data processing and user interaction. The system operates according to the algorithm for the DIM assessment method.

1. Algorithmic model for assessing implementation maturity

Based on the documentation of the method for assessing the implementation maturity of innovative solutions, the algorithm was developed which is presented in Figure 1. It was then implemented in a computer system for supporting the process of performing SDW assessments.

Figure 1 Legend. Abbreviations and symbols are as follows:

- The following are in terms of categorization of innovative solutions: M – Materials, T – Technologies, U – Equipment; S – Systems, Z – Services, x – subcategory number (e.g. T2 – Technologies of Surface Engineering).
- The following are in terms of the importance of criteria: Opc. – Optional criterion. Crit. – Critical criterion.
- Other symbols include the following: n – the number of SDW level, i – the next number of the assessment criterion for the n level, k – number of assessment criteria at the n level.

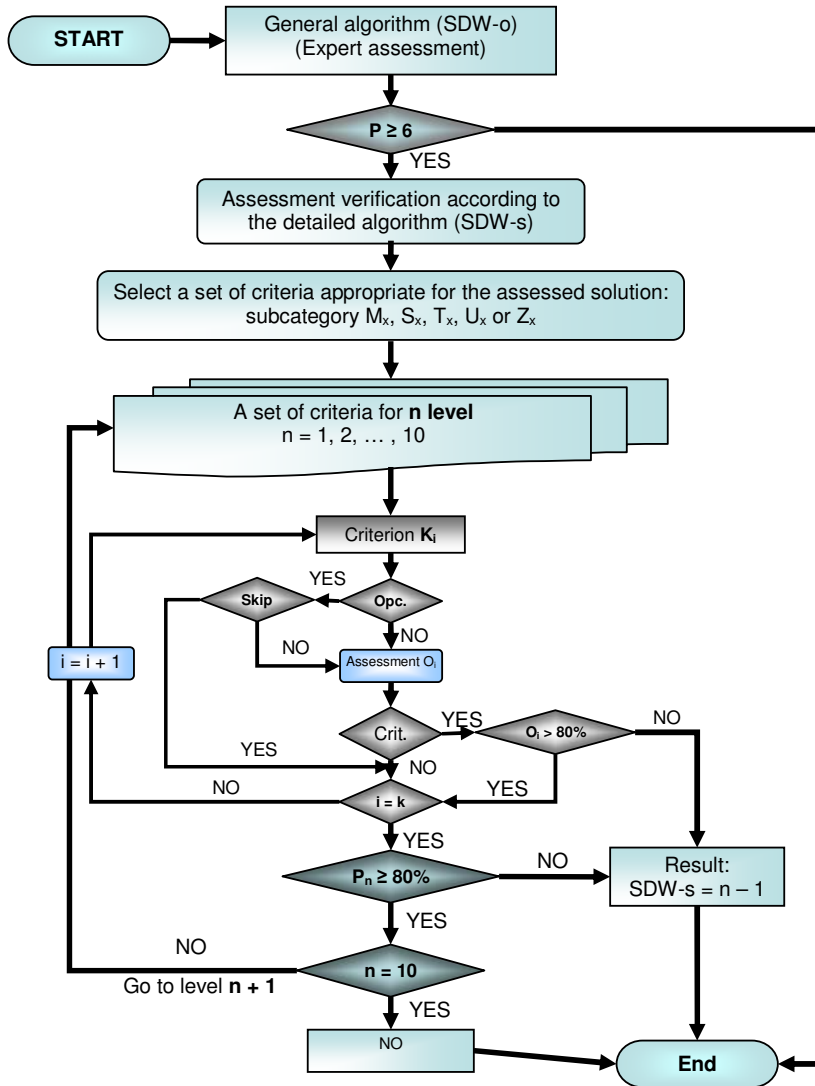


Fig. 1. Algorithm for assessing the maturity of implementation
 Source: own elaboration.

The criteria are assessed on a scale of 0 to 100%. The presented algorithm of detailed assessment includes mandatory, optional, and critical criteria. The criteria of critical importance must obtain at least 80%, otherwise, regardless of advancement index on the n level, they are disqualified, and the final result is $n - 1$ level. In the case of the optional criteria, if an expert selects the “skip” option, the criterion is not taken into account when assessing and does not affect the result.

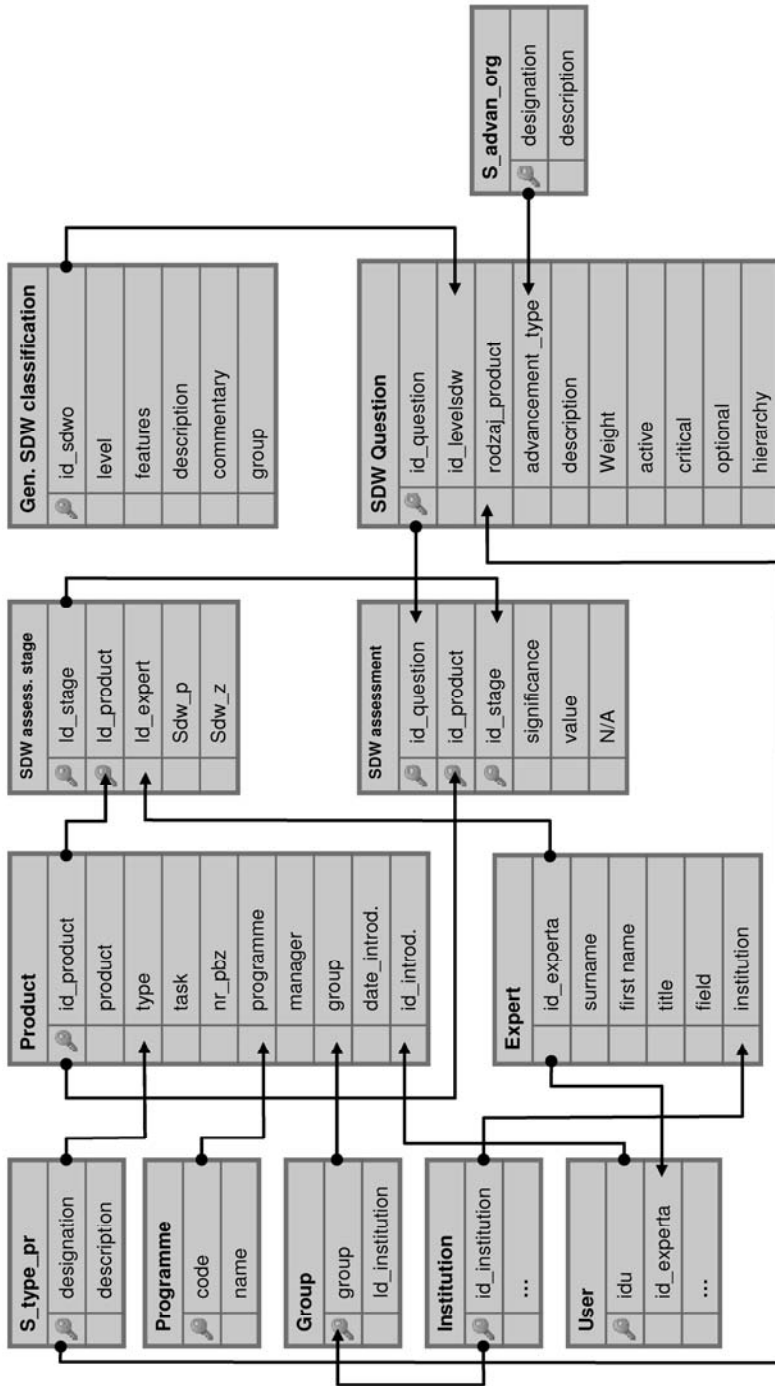


Fig. 2. Diagram of data relations for the module of assessment of implementation maturity
Source: own elaboration.

The 6th implementation maturity level adopted at the beginning of the algorithm by expert judgment is a threshold level at which the verification through the detailed algorithm method is mandatory and should be periodically updated. This does not block the possibility of carrying out a detailed assessment for a lower advancement level of a particular solution, which enables the verification of the conception phase and early stages of prototype development and can significantly improve the project management.

2. The database structure

The developed IT system collects and processes the data connected with assessments of products according to the devised method. Therefore, the structure of the database ensures storing all the information entered by experts in the assessment process. However, due to the need of full identification of solutions and assessment process, it is necessary to collect additional information, such as information about institutions, experts, users, etc. As a result, in order to ensure the required functionality and integrity of the data, 14 tables are used in the system.

The data integrity is ensured by relations between particular tables in the database, which are presented in Figure 2 as a diagram. Attributes with a key symbol define primary keys in tables, whereas connectors define the relations between tables that are of one-to-many type.

3. The application for the assessment of implementation capacity

The computer system for the SDW assessment of innovative solutions is a part of a modular application whose task is, among others, supporting the processes of implementation maturity assessment of solutions (another module is developed to evaluate the commercial potential), which are the result of research or development work. The system enables the users to conduct assessments in accordance with the developed methodology, to archive and process the results, and to generate printouts containing assessment sheets and basic combinations.

The developed system meets the assumptions made at the design stage, including the following:

- It enables the collection and processing of information about innovative solutions and the assessments of solutions in accordance with the devised assessment method.
- It gives the possibility to create multiple assessments of the same product for the selected method (multi-stage assessment).

- It is divided into functional modules with the possibility to extend with new modules without significant interference in the structure of existing modules or with minor changes.
- The database is located on a relational database server which supports simultaneous work of multiple users.
- It is developed in a three-tier architecture shown in Figure 3: client – application server – database server; the solutions, which are already in operation at the Institute, i.e. GlassFish 3.1 (application server) and Oracle 11g R1 (relational database server), were used for the implementation of the system. Regarding the RDBMS server, the system can cooperate with both the Oracle 11 g database and Microsoft SQL Server 2012.
- The client communicates with the system via the HTTP protocol (through the web browser).
- Access to the system requires authorization. The users have various permissions to access available modules, to edit the data, and to generate assessment sheets.

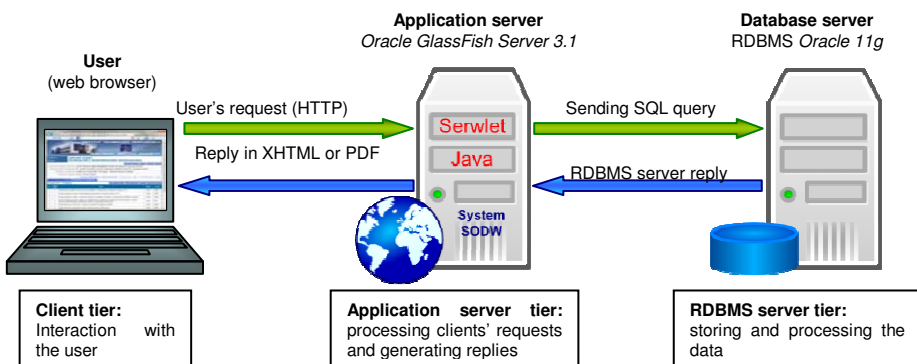


Fig. 3. Three-tier system architecture

Source: authors.

The core of the developed system is Java servlets, which process the user's requests. The essence of the solution used in the developed application is a division of performed procedures into separate packages of Java classes having specific functionalities, including the following:

- The packages of data models – mapping the structure of the rows of individual database tables;
- The packages of data providers – a set of classes for downloading and saving data in the database; and,
- Servlet packages – a set of classes with the HTTP protocol support for processing requests and creating the presentation layer.

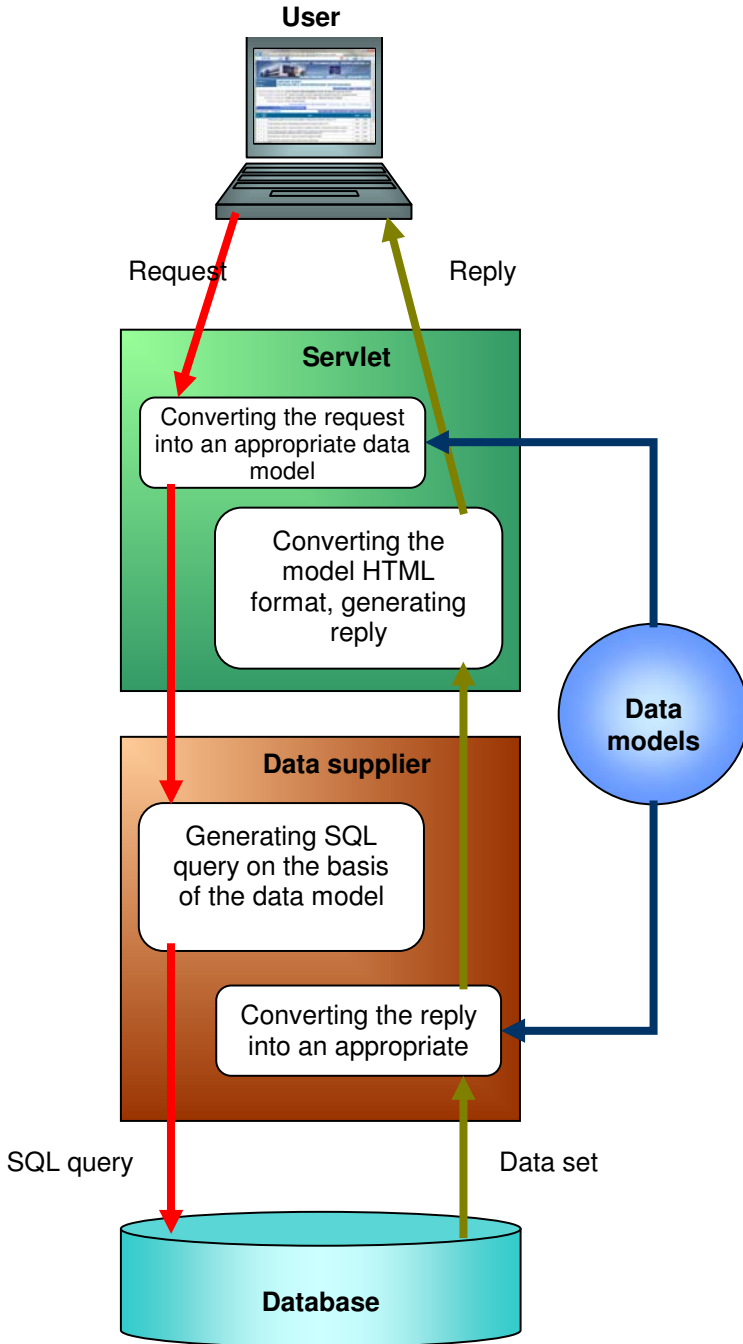


Fig. 4. General scheme of requests processing in the computer system for assessing SDW
Source: authors.

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PAŃSTWOWY INSTYTUT BADAWCZY

MODUŁOWY SYSTEM OCENY ROZWIĄZAŃ INNOWACYJNYCH

Wejście do systemu wymaga uwierzytelnienia.
 Wprowadź swoje parametry logowania a następnie wybierz polecenie przejścia do odpowiedniego modułu.

Użytkownik: Hasło:

Przejdź do modułu:

- Moduł oceny dojrzałości wdrożeniowej
- Moduł oceny potencjału komercyjnego
- Moduł oceny konkurencyjności
- Moduł oceny innowacyjności

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Fig. 5. Window for logging into the system

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System Oceny Rozwiązań Innowacyjnych
EDYCJA DANYCH PRODUKTU

Nazwa produktu/rozwiązania: Modelowy moduł pomiarowy dla czujników cyfrowych i impulsowych

Rodzaj produktu/rozwiązania: U1 - Urządzenia z zaawansowanymi systemami sterowania

Właściciele rozwiązania: Instytut Technologii Eksploatacji - Państwowy Instytut Badawczy

Program/projekt badawczy: Program Strategiczny POIG.01.01.02-14-034
 V.3.2 Inteligentne systemy monitorowania zużycia mediów energetycznych i technologicznych

Nazwa zadania: V.3.2 Inteligentne systemy monitorowania zużycia mediów energetycznych i technologicznych w obiektach technicznych

Kod produktu: V.3.2_U_1_1

Osoba prowadząca: dr inż. Jacek Wojutyński Data rejestracji: 2012-04-11

Cofnij Zapisz Zapisz i powrót Powrót Wyloguj

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Fig. 6. Window for editing the data of a product

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PAŃSTWOWY INSTYTUT BADAWCZY

Przejdź do ...
System Oceny Rozwiązań Innowacyjnych.
Moduł oceny dojrzałości wdrożeniowej.

Wyloguj
LISTA ZAREJESTROWANYCH PRODUKTÓW

Statystyki
Drukuj do pliku PDF ...
Dodaj produkt
Filtruj
Usuń filtr

Strona: 1
Idź z 3
Pokazuj wierszy: 20
Liczba produktów: 41

Lp.	Produkt	Rodzaj	Kierownik	Poziom dojrzałości wdrożeniowej		
				Algorytm ogólny	Algorytm szczegółowy	
1.	III.1.1_U_3_1: Aparatura badawcza do monitorowania procesów destrukcji materiałów Usuń produkt Ocena 1 z dnia 17.03.2012 r. Usuń Ocena 2 z dnia 18.10.2012 r. Usuń Ocena 3 z dnia 27.02.2013 r. Usuń Ocena 4 z dnia 18.09.2013 r. Usuń Dodaj nową ocenę	U ₃	dr inż. Tomasz Giesko	8	8	
2.	III.1.1_U_3_2: System kalibracji kamer (28.10.2013 r.) Usuń ocenę Usuń produkt Dodaj nową ocenę	U ₃	dr inż. Tomasz Giesko	8	8	
3.	III.1.2_U_3_1: Urządzenie badawcze do łącznego wyznaczenia odporności na zużycie ściernie i kruche pękanie nowoczesnych materiałów Usuń produkt Ocena 1 z dnia 30.03.2012 r. Usuń Ocena 2 z dnia 05.11.2012 r. Usuń Ocena 3 z dnia 01.03.2013 r. Usuń Ocena 4 z dnia 24.09.2013 r. Usuń Dodaj nową ocenę	U ₃	mgr inż. Jan Wulczyński	8	7	
4.	III.2.1_U_3_1: Urządzenie do badania przekładni zębatych walcowych. Usuń produkt Ocena 1 z dnia 26.03.2012 r. Usuń Ocena 2 z dnia 31.10.2012 r. Usuń Ocena 3 z dnia 02.04.2013 r. Usuń Ocena 4 z dnia 18.09.2013 r. Usuń Dodaj nową ocenę	U ₃	dr hab inż. Waldemar Tuszyński, prof. ITeE-PIB	8	8	
5.	III.2.2_U_3_1: Urządzenie do badania tribologicznych własności smarów plastycznych Usuń produkt Ocena 1 z dnia 27.03.2012 r. Usuń Ocena 2 z dnia 09.11.2012 r. Usuń Ocena 3 z dnia 05.04.2013 r. Usuń Dodaj nową ocenę	U ₃	dr hab. inż. Witold Piękoszewski, prof. ITeE-PIB	7	7	

Fig. 7. Fragment of the main window of the module for the assessment of implementation maturity

The first two packages contain application logic, whereas the servlet packages comprise both application logic and presentation layer. In addition to the division by function, the adopted internal structure of the application also provides for easy separation of the methods implemented in the system of the assessment of innovative solutions into autonomous modules, such as a module for assessment of implementation maturity or a module for assessment of commercial potential. Each module of the system has its own models' packages, data providers, and servlets, and all modules can use the common packages independent from any module (e.g. in relation to the product or user's authorisation).

The user's requests are handled using HTML Forms and JavaScript. The scheme of requests processing is demonstrated in Figure 4. The application does not use cookies, except for the user's session ID. All parameters necessary for the proper display of the requested page are entered in the URL or are taken from the parameters of the user session; every user has his own collection of session parameters, stored and supported by the application server. As the data displayed in the browser are retrieved from the database, the templates of websites are implemented directly in the servlet code so that the application dynamically generates the appropriate pages in xhtml or html format. The information from the system (e.g. assessment sheets, collective assessment sheets, statistics, etc.) can be exported to a file saved on the user's computer. They are generated "on the fly," mostly in PDF format, but also according to the user's choice, in Word 2007 (*Open XML*).

In the developed IT system, the module for the assessment of implementation maturity has been labelled with the code "SODW" (the Implementation Maturity Assessment System). In Figures 5 to 9, sample screenshots of some exemplary windows of the application for users with the highest privileges, i.e. administrator privileges are presented.

The list of registered products is the first window that is sent to the user after logging into the system. By the use of the window of products, the user possessing the appropriate privileges can add, edit, and delete products from the database, add, edit and delete the assessment sheets of products, export the selected assessment sheets and the cumulative assessment sheets to PDF files, and navigate to other windows of the module or other modules.

The window for filtering data shown in Figure 8 is common to the entire system. It allows the user to filter the list of products, which is the main window of the SODW module, and it is used when generating some aggregate reports (PDF files), such as the results of assessments of products. Demonstrated in Figure 8, filtering capabilities relate to the characteristics of the products. The second card ("Assessment results") provides for the search of solutions that meet the requirements entered by the user within the scope of assessment results.

The window shown in Figure 9 enables adding or editing the product assessment sheet. From this window, it is possible to navigate to all stages of the assessment of the product, and to export the assessment sheet to PDF. With the use of JavaScript, the process of completing the assessment form can be improved by automation, which can be applied to extreme results (0 or 100%). JavaScript also provides for the possibility of on-line checking the assessment results (the user receives a message with aggregate results of the assessment at all levels). An important improvement of the assessment process is also "rewriting" the results of the last SDW assessment (if it was carried out) to the assessment sheet when adding a new stage.

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PAŃSTWOWY INSTYTUT BADAWCZY

Przejdź do ... Modułowy System Oceny Rozwiązań Innowacyjnych
 Wyloguj **FILTR PRODUKTÓW**

Właściwości produktu Wyniki ocen

Nazwa produktu/rozwiązania uwzględnij zawiera znaki oraz lub

Program/projekt badawczy uwzględnij

Program Inwestycyjny POIG.02.01.00-14-173
 Program Strategiczny POIG.01.01.02-14-034

Tylko: I ob. problemowy II ob. problemowy III ob. problemowy IV ob. problemowy V ob. problemowy

Program Wieloletni PW-004
 Projekt celowy
 Projekt rozwojowy
 Services concerning the assessment of innovative products
 Usługi w zakresie oceny innowacyjnych rozwiązań

Rodzaj produktu/rozwiązania uwzględnij oraz lub

Nazwa zadania uwzględnij zawiera znaki oraz lub

Kierownik projektu uwzględnij zawiera znaki oraz lub

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Fig. 8. Window for filtering the products

The usefulness and effectiveness of the IT system for SDW assessment was subject to the practical verification within the framework of four stages of assessment of more than 170 innovative products that are the outcome of the Strategic Programme "Innovative technical support systems for sustainable economic development." As a result of the tests, the necessary modifications to the application source code were made to eliminate the errors and increase the functionality of the system. One of the most important changes was an introduction of a new functionality that is a multi-stage assessment that required reorganization of both the structure of the database and application.

An important advantage of the SODW module is the possibility to both modify the existing information and add new categories of solutions, in relation to the assessment criteria of the detailed algorithm. It also gives the possibility of deactivation of a criterion without affecting the assessment carried out earlier. Moreover, the flexible structure of the software enables its modification

within the framework of system improvement and adaptation to applications for special purposes.

INSTYTUT TECHNOLOGII EKSPLOATACJI
PAŃSTWOWY INSTYTUT BADAWCZY

Przejdź do ... **System Oceny Rozwiązań Innowacyjnych.** Moduł oceny dojrzałości wdrożeniowej.

Wyloguj **ARKUSZ OCENY PRODUKTU**

Wycofaj zmiany Zapisz Drukuj Powrót

Nazwa produktu/rozwiązania: **Aparatura badawcza do monitorowania procesów destrukcji materiałów**

Rodzaj produktu/rozwiązania: **U3 - Aparatura badawcza i testowa**

Właściele rozwiązania: **Instytut Technologii Eksploatacji - Państwowy Instytut Badawczy**

Osoba prowadząca: **dr inż. Tomasz Giesko**

Ocena 1 z dnia 2012-03-17 Ocena 2 z dnia 2012-10-18 **Ocena 3 z dnia 2013-02-27**

Poziom dojrzałości wdrożeniowej: Szacowany 8 Zweryfikowany 8 Zespół oceniający ↑

▼

Algorytm ogólny Algorytm szczegółowy

◀ ▶ Poziom 7 z 10 ▶ ▶ ▶ Wszystkie 100% Wszystkie 0% Drukuj Sprawdź wynik

Prototyp produktu sprawdzono w rzeczywistych warunkach eksploatacji

Lp.	Zaaw. org.	Opis	Pomiń	Waga	Ocena
1.	M	Wykonano prototyp urządzenia z wykorzystaniem zaadaptowanego oprzyrządowania	X (K)	100%	100%
2.	T	Prototyp sprawdzono w rzeczywistych warunkach eksploatacji	X (K)	100%	90%
3.	T	Sprawdzono funkcjonowanie algorytmów w środowisku pracy	<input type="checkbox"/>	100%	100%
4.	T	Przetestowano interfejsy systemu w warunkach eksploatacji o podwyższonych wymaganiach	<input checked="" type="checkbox"/>	X	X
5.	P	Opracowano wersję testową (beta) oprogramowania	<input type="checkbox"/>	100%	100%
6.	P	Przeprowadzono weryfikację oprogramowania	<input type="checkbox"/>	100%	100%
7.	T	Potwierdzono osiągnięcie docelowego poziomu rozwiązania dla elementów produktu	X	100%	90%
8.	P	Zakończono opracowanie dokumentacji projektowej w wersji wstępnej	X	100%	100%
9.	M	Sprawdzono działanie maszyn, oprzyrządowania i wyposażenia do kontroli jakości w warunkach przemysłowych	X	100%	100%
10.	M	Sprawdzono i zaakceptowano materiały do wytworzenia produktu, zweryfikowano procesy produkcyjne i procedury organizacyjne w procesie produkcji	X	100%	100%

Fig. 9. Window of the sheet for the assessment of the implementation maturity of the product with exemplary assessment criteria for Level 7

Source: authors.

Figure 10 shows a fragment of aggregate results of four completed and one ongoing stage of the assessment of solutions developed within the Strategic Programme which were generated by the SODW module.

Nr oceny	Poziom dojrzałości wdrożeniowej										Liczba ocenianych produktów
	1	2	3	4	5	6	7	8	9	10	
1	23	32	50	25	44	33	52	62	10	40	371
2	6	11	17	26	28	18	22	21	2	5	156
3	0	7	9	18	24	20	20	40	7	1	146
4	1	0	4	10	18	26	18	32	7	2	118
5	0	0	0	0	0	4	1	0	1	0	6
Stan na 19.02.2014 ^[A] [B]	8	9	27	17	43	57	57	100	17	47	382

Fig. 10. The results of the four stages of SDW assessment of solutions that are the outcome of SP
Source: authors.

In the periods between assessments, based on the feedback on the functionality of the procedures for assessment implemented in the SODW module, significant changes and improvements in the assessment methodology were made, for example, the classification of different advancement levels was modified and sets of criteria for the various assessment algorithms were verified. As a result of these changes, the SODW module was modified. The consequence was the original method for the assessment of implementation maturity (SDW) of innovation solutions within the scope of defined categories, and IT system supporting SDW assessment.

Summary

The developed system supporting SDW assessment significantly improves the process of assessment, facilitates in-depth analysis and comprehensive assessment of solutions, and helps in comparing and archiving the results, and using the collected information about particular solutions. The utilization of the system in procedures for the assessment of innovative solutions saves time and labour resources necessary for performing assessments. It also enables one to assess the methodology of assessment. In addition, the data collected in the system, in particular the results of the assessments, can be used in assessments at higher levels, such as the evaluation of projects or research programmes.

Scientific work executed within the Strategic Programme “Innovative Systems of Technical Support for Sustainable Development of Economy” within Innovative Economy Operational Programme.

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System wspomagający ocenę stopnia dojrzałości wdrożeniowej innowacji technicznych

Słowa kluczowe

System oceny, Stopień Dojrzałości Wdrożeniowej SDW, algorytm oceny SDW, innowacje techniczne, transfer technologii.

Streszczenie

W artykule zaprezentowano system wspomagający ocenę stopnia dojrzałości wdrożeniowej (SDW) innowacyjnych rozwiązań technicznych, opracowany w ramach Programu Strategicznego pn. „Innowacyjne systemy wspomagania technicznego zrównoważonego rozwoju gospodarki”. Działanie systemu zweryfikowano w trakcie oceny ponad 170 innowacyjnych rozwiązań będących rezultatem Programu Strategicznego pn. „Innowacyjne systemy wspomagania technicznego zrównoważonego rozwoju gospodarki” realizowanego w Instytucie Technologii Eksploatacji – Państwowym Instytucie Badawczym w Radomiu. Opracowane narzędzie stanowi istotny element wspomagania procesów transformacji wiedzy i transferu zaawansowanych technologii procesowych i produktowych w obszarze wytwarzania oraz eksploatacji maszyn i urządzeń technicznych. Weryfikacja potwierdziła przydatność metody i systemu do ewaluacji potencjału aplikacyjnego na poszczególnych etapach opracowywania innowacyjnych rozwiązań. Wykorzystanie metody umożliwia bardziej efektywną kontrolę procesu wdrażania wyników badań naukowych do zastosowań praktycznych, przyczyniając się do wzrostu innowacyjności i konkurencyjności gospodarki. Walory systemu oceny SDW zostały potwierdzone w kolejnych aplikacjach, m.in. do oceny rozwiązań innowacyjnych MŚP oraz innowacyjnych przedsięwzięć podejmowanych w ramach parków przemysłowo-technologicznych.