Beata POTERALSKA
Institute for Sustainable Technologies – National Research Institute
beata.poteralska@itee.radom.pl

TECHNOLOGY ASSESSMENT SYSTEMS

Key words

Technology assessment, technological innovative solutions, complex technology assessment system, implementation maturity level assessment, commercial potential assessment, innovativeness level assessment, implementation risk assessment.

Abstract

Technology assessment is one of key challenges in innovation management concerning support for the decision-making processes with regard to the importance, development, and implementation of technologies.

The article presents a literature review concerning the term "technology assessment" and methods and models applied in this field. Against this background, an original complex technology assessment system that was developed and verified at the Institute for Sustainable Technologies – National Research Institute in Radom, Poland is presented.

Introduction

An unquestionable need, resulting from the macroeconomic expectations of increasing the level of the innovativeness and competitiveness of national economies, is to develop products, technologies, and conduct projects that are innovative and comply with market needs. Technological innovation is acknowledged at a macro level as a driver of the economic and social development of a country and at a micro level. This provides a source of the

competitive advantage of firms applying innovative technological solutions as well as of research organisations involved in their development and implementation. The importance of technology influences the need for technology assessment (TA), which is one of the core challenges in innovation management. In plays an increasingly important role for firms as well as for private and public institutions [1].

1. State of the art

1.1. Definitions

The origins of technology assessment can be seen in technology forecasting studies conducted in the 1950s. The term "technology assessment" seems to have been used for the first time in mid-1960s [2]. It has been defined in many different ways and has greatly evolved with respect to its focuses and approaches [3, 4]. The discussion on the definition of TA remains unsettled, thus more study of this field should be conducted [4, 5].

Traditionally, the discipline has focused on forecasting, impact assessment, and policy studies [1, 3], and its initial intention was to have an early warning system about the potential unfavourable consequences of applying a new technology [2]. The dominant actors in the field have been parliamentary and policy-making bodies; however, the subject was later also picked up by researchers from academics and industry [4]. At the time, when the first stream, and in fact still the mainstream, of technology assessment research was developed, it was focused on social aspects and was applied in public decision-making. Within this stream, technology assessment is understood as "a scientific, interactive, and communicative process with the aim to contribute to the public and political opinion forming on societal aspects of science and technology" [6]. It is "designed to better understand the consequences across society of the extension of the existing technology or the introduction of a new technology with emphasis on the effects that would normally be unplanned and unanticipated" [2].

In the traditional understanding of technology assessment, two aspects are stressed: the usefulness of TA in the decision-making process and the impact on the society of the introduction of a new technology or the expansion of an already existing technology [7].

The non-mainstream of TA research emerged in business, industry, and non-governmental circles in the early 1980s and developed during the 1990s and the turn of the present century [4]. This unconventional approach will probably develop and expand in the future.

The non-mainstream of TA originated from acknowledging the need to conduct technology assessment or technology evaluation to serve its strategic planning. This stream is connected mainly with economic evaluation, decision

making, and technology measurement methods [4]. In general, the public TA looked at technologies from a social perspective; whereas, the business and non-governmental TA concerned mainly an economic or technical point of view.

The non-mainstream adopted the term technology assessment; however, it had a completely different meaning that pertained mainly to technological readiness. Within it, apart from technological readiness, aspects of other dimensions connected with technology development are taken into account.

This new understanding of technology assessment refers to different applications for the needs of business and non-governmental research institutions, such as the economic and performance evaluation of technology alternatives, the selection and acquisition of strategic technologies, strategic technological planning, and so on.

Within this paper, technology assessment refers to the non-mainstream definition and concerns support for the process of technological development.

1.2. Methodology

Technology assessment applies different approaches and methods [3]. Although it has been developing since 1960s, there is still a strong need to introduce more effective methods [4]. Furthermore, there are no universal methods and tools that can be applied for all disciplines. Thus, different technology assessment methods and systems are still created and applied.

Within early public TA research, traditional methods such as impact analysis and system analysis were applied [4]. However, toward the end of the 1990s, non-traditional methods emerged. Within the non-mainstream, the economic evaluation methods applied reflected the economic point of view of the corporate decision makers; whereas, decision analysis and technology measurement techniques tended to represent the technical people's angle, particularly the academics and technologists [4].

In general, within both the mainstream and non-mainstream of technology assessment, apart from the application of methods that are well established in management literature, there were introduced methods and tools that have not been well documented.

The majority of methods applied in technology assessment concern the assessment of incremental technologies; however, some approaches to assess emerging technologies have been initiated [8, 9].

Apart from single methods, models for technology assessment are applied. There can be distinguished models focused on one homogenous group of assessment factors and complex models comprising other distinctive factors. Models focused on a single group of factors comprise the following:

– The implementation maturity assessment (i.e. *Technology Readiness Levels* (TRL) [10] or more advanced – *Engineering Manufacturing Readiness Levels* (EMRL) by NASA, and the implementation maturity level

assessment (SDW) method developed and used at the Institute for Sustainable Technologies – National Research Institute in Radom (ITeE – PIB), Poland;
- The commercial potential assessment (i.e. the *QFD* technique developed by the Korean Han Nam University and the Electronics and Telecommunications Research Institute (ETRI); *Commercial Potential Index* by NASA [11]; and, the commercial potential assessment method by ITeE – PIB) [12];
- The industrialisation potential assessment of new or emerging technologies [9];
- The Cost Benefit Analysis (e.g. Strategic Technology Assessment Review (STAR) [13], System Wide Benefits Value Analysis (SWBVA) [14];
- The assessment of ecological aspects of a technology (i.e., a set of criteria enabling the comparison of environmentally friendly technologies); and
- The ethical technology assessment (i.e. "eTA" model) [15].

With time, complex technology assessment models have been developed that simultaneously take into account various aspects of technology development. The complex technology assessment model used by the French Sophia-Antipolis Science Park can serve as an example here [16]. It focuses on two basic issues, including the company's technological competitiveness and the technology attractiveness determinants. Simultaneously some methods and models for technology selection [17, 18] have been developed. Technology selection enables one to identify the best amongst the analysed options and all the considered technologies and to create their ranking [19]. Technology selection is often preceded by technology assessment. This article is not aimed at discussing the similarities and differences of technology assessment and technology selection. It covers the problem of technology assessment as a tool supporting the process of technology development.

2. Complex technology assessment system developed at ITeE – PIB

A complex technology assessment system [12, 20] has been developed, verified, and experimentally implemented at the Institute for Sustainable Technologies – National Research Institute (ITeE – PIB). The genesis for the creation of the system was from participation by its authors – scientific workers at ITeE – PIB in the realisation and management of a few strategic, multi-year, national, and international programmes, which indicated a severe lack of such an operational system. This experience was a stimulus to start the development of the complex technology assessment system already several years ago. The system has been designed for the assessment of incremental innovations from the area of technical support for sustainable development. It is composed of the following three main modules:

– The implementation maturity level assessment module comprising detailed assessment procedures depending on the type of an innovative solution (product, technology, system, service) (SDW);
– The commercial potential assessment module (PK); and,
– The innovativeness level assessment module (PI) (Fig. 1).

The forth module concerning risk assessment is currently designed.

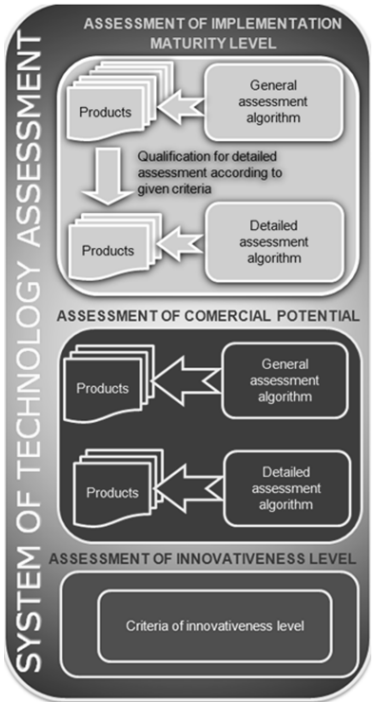

Fig. 1. Complex technology assessment system [20]

Firstly, the implementation maturity level assessment module has been developed with its origins based on NASA's TRL [10]. However, its characteristic features in comparison to this and other existing maturity assessment systems consist, among others, in applying individual sets of assessment criteria for different types of innovations (material, system, apparatus, technology, service) at two stages – general and detailed. Furthermore, it can be applied for the assessment of technological solutions at consecutive stages of their development. The implementation maturity level assessment aims at the identification of the level of the advancement of R&D activities and a precise assessment of the implementation readiness of an innovative technical solution [21].

Next, taking into account the importance of generating and developing technological solutions that have the greatest marketability opportunities, the modules for the assessment of the commercial potential and the innovativeness level were developed. The commercial potential assessment is used to evaluate the market need for a particular technological solution [22]. The innovativeness level assessment enables the identification of the level of the innovativeness of a technological solution expressed by the solution's added value for potential buyers. At present, they are at the phase of final verification. The next planned module concerns the implementation risk assessment.

Thus, each technological solution can undergo a complex assessment with regard to all the mentioned aspects or be subjected to the assessment of any selected individual aspect.

In order to facilitate the assessment of innovative solutions, a computer system, available by the Internet, supporting the implementation maturity, the commercial potential, and the innovativeness level assessments was designed. The modules of this computer system are autonomous and can be used independently. They enable the user to trace the assessment characteristics in time functions.

3. Discussion

The executed work contributes to technology assessment research concerning the stream corresponding with the needs of business and industry.

The proposed original complex technology assessment system developed at ITeE – PIB enables the assessment of the most essential aspects connected with the development of new technological solutions of incremental character. Its main advantage comprises the possibility to assess innovative products at any stage of a project execution, including ex-ante, ongoing, ex-post, and follow-up, and to compare the assessments results at different stages of a product development (from the concept stage, through the development stage, to the final technology stage).

Another advantage compared to other TA systems consists in the development of a set of the assessment criteria within the module for the implementation maturity level assessment proposed for particular categories of products (material, system, apparatus, technology, and service) at two stages, general and detailed.

The results of any or all aspects – the implementation maturity, the commercial potential and the innovativeness level – can be compared for one solution at consecutive stages of its development; and, in this way, give the possibility of monitoring the progress of the product development and control over the implementation stage.

Applying the results of the system supports the decision-making process concerning technology development. The results provide information about

individual technological solutions with regard to their technological readiness, meeting market needs and the innovativeness level. This information is of crucial importance for the managers in the decision-making process concerning particular technological solutions. For example when the solution is at the concept stage or is being developed the decisions made concern the future of the solution – whether the development process should be continued, supported by additional staff or financial means or should be terminated, e.g. in case of a very low commercial potential or the lack of it as well as they concern the selection of appropriate tools enabling innovation commercialisation.

Information obtained from the system is also of help in the course of evaluating research projects and programmes, e.g. it enables one to monitor the programme and see a moment when its further continuation is not reasonable or effective. On the other hand, all the results of a project can be compared, e.g. with regard to their implementation maturity, and in this way, the progress of the whole project execution can be assessed. Thus, the system is a tool supporting decision making not only with regard to individual technological solutions, but also whole programmes.

There are obviously also some limitations to the system. The most important one relates to the fact that the effectiveness of its application strongly relies on the selection of experts involved in technology assessment. In the case of highly advanced and complex technological solutions subjectivity of the assessment may occur, resulting from the necessity of participation of the solution's author in technology assessment.

Conclusions

Technology assessment within the non-mainstream of TA research is applied for the support of the technology development process. In this field, various approaches, methods, and systems are still being developed. One of the proposed set of methods comprises the complex technology assessment system developed and applied at the Institute for Sustainable Technologies – National Research Institute. It is a useful tool for those developing and financing new technological solutions, supporting the technology transfer process, and applying new technologies, such as research institutions, technological parks, technology transfer offices, or entrepreneurs.

The practical value of the system has been proven by its use for the assessment of several hundred technological solutions for the needs of research organisations, business support institutions, and enterprises in Poland. Among others, with the use of the system, approximately 170 innovative technological solutions developed within a strategic research programme "Innovative Systems of Technical Support for Sustainable Development of Economy," co-financed from EU structural funds are assessed every half a year at consecutive stages of their development. They are subject to the implementation maturity

assessment (4 rounds of assessment already), commercial potential assessment (3 rounds), and the innovativeness level assessment (3 rounds) [12].

References

1. Azzone G., Manzinib R.: Quick and dirty technology assessment: The case of an Italian Research Centre, Technological Forecasting and Social Change, Volume 75, Issue 8, October 2008, pp. 1324–1338.
2. Coates J.: A 21st Century Agenda for Technology Assessment, Technological Forecasting and Social Change 67, 303–308 (2001), Elsevier Science, Inc.
3. Van Den Ende J., Mulder K., Knot M., Moors E., Vergragt P.: Traditional and Modern Technology Assessment: Toward a Toolkit, Technological Forecasting and Social Change, Volume 58, Issues 1–2, May–June 1998, pp. 5–21.
4. Tran T., Daim T.: A taxonomic review of methods and tools applied in technology assessment. Technological Forecasting & Social Change 75, 2008, pp. 1396–1405.
5. Jong-Hyun H.: Exploratory study for integrated green technology assessment: focusing on renewable energy and photovoltaic data, Department of Management Engineering, KAIST, 2013, http://library.kaist.ac.kr/thesis02/2013/2013M020113684_S1Ver2.pdf, acc. 20.01.2014.
6. Decker M., Ladikas M. (eds.): Bridges between Science, Society and Policy. Technology Assessment – Methods and Impacts. Springer, Germany 2004.
7. Coates J.: Future and Technology Assessment Research for Business Clients, The inaugural meeting at the Center for Impact Assessment Studies and Forecasting, October 2001, www.josephcoates.com.
8. Fleischer T., Decker M., Fiedeler U.: Assessing emerging technologies – Methodological challenges and the case of nanotechnologies, Technological Forecasting and Social Change, Volume 72, Issue 9, November 2005, Pages 1112–1121, New Horizons and Challenges for Future-Oriented Technology Analysis: The 2004 EU-US Seminar.
9. Lucheng H., Xin L., Wenguang L., Research on emerging technology selection and assessment by technology foresight and fuzzy consistent matrix, Foresight, 2010, nr 12, 2.
10. Mankins, J.C.: Technology Readiness Levels: a white paper, NASA, Advanced Concepts Office, Office of Space Access and Technology, 1995.
11. NASA, Commercialization Readiness Level Assessment Index, Technology Commercialization Process, Change 1 (4/9/04), 2004.

12. Mazurkiewicz A., Poteralska B.: System of a complex assessment of technological innovative solutions. Problemy Eksploatacji, ITeE – PIB, Radom, No 4/2012.
13. McGrath R.G., MacMillan I.C.: Assessing technology projects using real options reasoning, Res. Technol. Manag, July-August 2000, pp. 35–49.
14. Ordoobadi S.M., Mulvaney N.J.: Development of a justification tool for advanced manufacturing technologies: system-wide benefits value analysis, Journal of Engineering and Technology Management, vol. 18, issue 2, 2001, pp. 157–184.
15. Palm E., Hansson S.O.: The case for ethical technology assessment (eTA), Technological Forecasting & Social Change, 2006, nr 73.
16. Jolly, D.R.: Chinese vs. European views regarding technology assessment: Convergent or divergent? Technovation, 2008, nr 28.
17. Shen Y.-Ch., Lin G.T.R., Tzeng G.-H.: Combined DEMATEL techniques with novel MCDM for the organic light emitting diode technology selection, Expert Systems with Applications, 2011, nr 38.
18. Chen, Ch.-J., Chung, M.-Ch., Wei, Ch.-H.: Government policy of technology selection for advanced traveler information systems, R&D Management, 2006, nr 36, 4, pp. 439–450.
19. Klincewicz K., Manikowski A.: Ocena, rankingowanie i selekcja technologii, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa, 2013, pp. 204.
20. Mazurkiewicz A., Poteralska B.: Problems of Development and Practical Implementation of Innovative Technological Solutions, The Proceedings of the 6th ISPIM Innovation Symposium – Innovation in the Asian Century, Melbourne, Australia, 2013.
21. Mazurkiewicz, A., Karsznia, W., Giesko, T., Belina, B.: Metodyka oceny stopnia dojrzałości wdrożeniowej innowacji technicznych, Problemy Eksploatacji, 1/2010, ITeE-PIB, Radom.
22. Belina B., Giesko T., Łopacińska L., Walasik M.: Setting of criteria in the commercial potential assessment method of innovative technological solutions, Problemy Eksploatacji 2/2013 pp. 221–234.

Systemy oceny technologii

Słowa kluczowe

Ocena technologii, innowacyjne rozwiązania techniczne, system kompleksowej oceny technologii, ocena poziomu dojrzałości wdrożeniowej, ocena potencjału komercyjnego, ocena poziomu innowacyjności, ocena ryzyka wdrożeniowego.

Streszczenie

Ocena technologii stanowi jedno z kluczowych wyzwań zarządzania innowacjami w zakresie wspomagania procesów decyzyjnych dotyczących znaczenia i rozwoju technologii.

W artykule przeprowadzono analizę pojęciową terminu „ocena technologii" oraz zaprezentowano przegląd stosowanych w tym zakresie metod i modeli. Na tym tle przedstawiono oryginalny system kompleksowej oceny technologii opracowany i zweryfikowany w Instytucie Technologii Eksploatacji – Państwowym Instytucie Badawczym w Radomiu.