# Decision support systems in waste management – a review of selected tools

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# DECISION SUPPORT SYSTEMS IN WASTE MANAGEMENT - A REVIEW OF SELECTED TOOLS.

## INTRODUCTION

The necessity of decision making in the field of uncertainty forms an integral part of its traders, managers or analysts. Seemingly, this is an intuitive process that applies to every human being, however, in a professional resource management it requires appropriate procedures and preparation. Tracing the definition of W.T. Bielecki [5] decision making is preceded by the identification of the problem, collection of the relevant information, compilation of expert knowledge and finally the elaboration of solutions which will allow to make the best choices as far as evaluation and selection are concerned. Business practice has caused computerization of these activities, creating foundations of decision support systems for all sectors of enterprises' activity.

Waste Management due to its multifaceted nature, also went through a number of support systems which will allow to implement effective decision-making processes of a varying complexity effectively. A wide range of information and data, including the logistic, technological, environmental, social and legal issues makes it possible to process using multi-criteria analysis and specialist support systems.
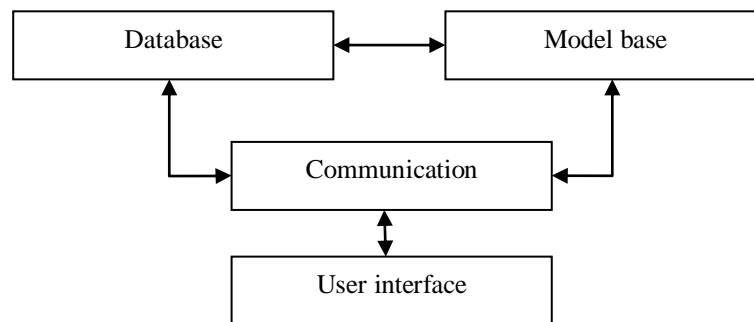
## THE ESSENCE OF DECISION SUPPORT SYSTEMS

Decision support systems have been known for decades, and more specifically from the time when the information technology development has enabled automation of the selected decision-making areas[5]. In connection with these issues, DSS (Decision Support) were defined as information solutions that support business and organizational decision-making activities, enabling setting an optimal solution.

A wide range of applications and benefits of DDS resulted in the rapid development of all kinds of tools which denominator is defined by S. Alter requirements, that also constitutes the essence of support systems. These include [3]:

a)The DDS are designed for support the decision-making process,

b)The DDS should support, not automate the decision-making process,

c)The DDS should be flexible enough to smoothly adapt to the constantly changing requirements by decision makers.

During the design process of decision support tools it is necessary to prepare specified conditions including an analysis of its application. Systems should be mostly adequate, which means compatible with operational needs which contained data and if–then rules. DSS also requires availability, which is associated with the correct process of communication and unambiguous interpretation of the results.

An unequivocal purpose of DDS application has a graphical representation of its structure (Figure 1), which in the most transparent way introduces the main elements of its architecture, and verifies which information systems are a decision support system.



**Figure 1 Decision support system structure**
**Source: [3, p.19]**

According to the graphic representation of DDS, a composition of separate elements affects the advisability of the system. The basic division of the structure covering the core of the system, highlights the DDS focus on data and DDS focused on decision support models. Depending on the demands, the classification can be extended to DDS focused on communication, documents or knowledge - as a purposely dominant part of the system architecture.

Each system consists of a database (DB), which collects, provides and stores relevant data. Therefore, DB is a selected information unit that has been extracted from a comprehensive set of data and are a main power source of DDS [3]. Analyses, forecasts, current transactions - these are the actions faced by all users of information systems. A well-ordered and thematically selected data source allows you to quickly and efficiently process an extensive database that is stored on storage media and allows to satisfy the information needs at any time.

The user interface of DDS is considered to be a web page or text, image or software part responsible for interaction with the user. Due to the diversity of DDS, the issue of the designed interfaces is widely considered with the functional and operational requirements. Creating an interface in accordance with the C.M. Olszak [5] recommendations, in addition to an accurate analysis of the tasks and systems objectives should be taken into account during the implementation of lexical and semantic level. The results of these analyzes are a description of the communication language with the decision-maker, a choice of interface standard, and the environment of its implementation [3]. Due to a high level of details in interface design and the impact of its effects on the system functionality, it is suggested to prototype which allows to evaluate preliminary designs.

In order to reduce costs and eliminate the risk of the decision-making process errors, various methods for simulating potential solutions are used. All processes and phenomena occurring in reality can be described using the interrelationships between components, that create a special collection and aim to achieve a particular purpose. This reflection of reality by a set is called a model, on the basis of which DDS examine and predict options of analyzed alternatives.

Modeling is a separate and complex chapter in the issues of DDS. The versatility of the system application determines the need of models elaboration with an adequate level of detail. In a study of phenomena and processes advanced mathematical models are often applied which clearly identify the most important factors. The logical decomposition and selection of the most important parameters allow for adequate processing of data and execute analyzes that can be the basis of optimization methods.

In literature the application of conceptual models can also be found, as well as object-oriented models, models of multi-criteria analysis or specialist models including i.a. integrated waste management systems. The extensive use of DDS and the possibility of setting up models, have formed a new trend in the application of artificial intelligence in the process of decision-making. Their use is most common in resolving the complex decision-making processes which require pattern recognition and classification, learning or effective risk management.

Economic development encourages the development of specialized information systems, including decision support systems. Their application can be found in many industries and sectors, where companies implement their processes under conditions of uncertainty and risk. Due to market demands, DDS is characterized by complex and hybrid structure, which includes the use of i.a. spatial information systems.

Simulations and interpretations carried out on a visual representation of solutions allow to understand the effects better and take a final decision. The use of this type of hybrid systems, in particular, is known in environmental management and waste management. DDS is based on complex models of waste management systems and it is often used by public and private entities that process the collected data for analysis, forecasting and simulation.

**SUPPORT SYSTEMS IN THE WASTE MANAGEMENT**

The use of decision support systems in waste management have been intensified along with the need for analysis of additional issues, including costs, spatial planning, legal requirements, environmental protection and technologies used.

The first attempt to use web-based tools within Waste Management Systems Data Management was included in basic data management. Recording and reporting - are the basic activities related to the management of waste flowing from the manufacturers to waste processing entities. Standard data sheets have enabled to implement these basic requirements, but they have significantly limited more complex actions. Along with the need of process simulation, forecasting and reporting the results of alternative solutions - a need to develop web-based tools using spreadsheets, mathematical optimization and simulation models, including Geographic Information Systems has emerged [4].

The increasing interest in spatial data analysis is resulted in widening of the decision support systems properties by GIS (ang. Geographic Information System) with the result of developing technology SDSS (ang. Spartial Decision Support System). The dynamic development of GIS-based software currently supports local governments in the spatial planning management, water, sewage and waste management, enabling to build spatial information infrastructure at different administrative levels [4]. In this perspective, GIS is a valuable component of DDS during the flows planning and determining the location of waste recovery facilities and waste disposal. Multi-criteria analyses related to this issue were enriched through geographical analysis, allowing to specify the best solution for complex decision-making processes.

Table 1 shows some examples of decision support systems in waste management designed to meet specific targets like determining the location of landfills and assessment of technology collection or waste treatment and its disposal. You may have noticed all kinds of widely used methods to support decision-making in waste management. In addition to using approaches like LCA, AHP or spreadsheets, an increasing interest in the application of spatial

information - GIS is observed, which enables the presentation of the position of important objects related to waste management.

Literature describes many of the systems used for locating landfills. Their detailed analysis based on a multi-criteria decision-making process, also using geographic information systems, enables to select the best solution. In the current situation, according to new regulations and requirements of the EU, storage is an ultimate form of recycling, which should be kept to a minimum, and building new landfills should be eliminated from waste management plans. Law enforcement and rational waste management require the elaboration of integrated tools that could meet the growing expectations.

The current state of waste management in Poland, is interested in the possibility of energy recovery from waste that could support the enforcement of EU requirements, including reducing waste deposited in landfills, and thus affecting their increasing level of recovery. The realization of these assumptions requires detailed logistics and technology analysis in the context of local waste management systems, where it would be possible to use waste energy. One of DDS examples implemented for this purpose is W2E Software [15] , which supports the best choice in selecting energy recovery technology from sewage sludge. Other systems briefly treat these issues as one of the waste processing capabilities, without detailed analysis of the possibility of waste incineration.

A specialized use of DDS to separate the waste management processes is increasingly appreciated by the users from the public level of administration as well as private entrepreneurs and investors. In the context of the waste streams management, these kinds of tools undoubtedly etched into the framework of the waste management system as an integral part of planning, monitoring, simulation and evaluation.

Table 1 Examples of decision support systems in waste management

| Lp. | Name of the system | Country of origin/ Authors | Approaches to support decision-making process | Application | Source |
|---|---|---|---|---|---|
| 1 | Municipal Solid Waste Management System Planning [DSS] | Canada, Winnipeg | Knowledge based, Spreadsheet, Optimization and simulation models | Forecasting the quantity and quality of generated municipal waste, technology collection assessment, treatment and disposal of waste, estimating the cost of planned solutions, forecasting volumes and time of investment associated with waste management. | [5] |
| 2 | Spatial Decision Support System [SDSS] | Greece | AHP GIS | Determining the location of a landfill on the Lesbos island. | [5] |

| 3 | Spatial Decision Support System [SDSS] | Thailand | AHP GIS Fuzzy logic | Determining the initial location of landfills in Thailand. | [5] |
|---|---|---|---|---|---|
| 4 | DSS for Landfill Design, Evaluation and Monitoring LDEM-DSS | No data | GIS Expert system Simulation model | Design, evaluation and monitoring of landfills. | [5] |
| 5 | SIGOP | Poland, Katowice | Knowledge base, | SIGOP's database is used during the development of waste management programs for planning the industrial and service waste management, plans for municipalities, counties, provinces and also in ecological assessments of waste in particular to define ways of dealing with waste. On the basis of collected information in the database the standard reports are issued . | [5] |
| 6 | EcoSolver IP-SSK | Switzerland | LCA model Dynamic model Simulation model | Separation of plastic waste streams planning with regard to the facilities of recycling, treatment and recovery of mechanical energy for selected regions. | [14] |
| 7 | W2E Software | No data | Mathematical model Simulation model | Analysis and evaluation of the possibility of disposing of sewage sludge in the process of energy recovery - choosing the best solution . | [15] |
| 8 | ReFlows | Greece | Mathematical model Simulation model | Simulation of physical and financial flows in various scenarios in waste management system based on maximizing the recovery and recycling of municipal solid waste. | [1] |
| 9 | Spatial Decision Support System [SDSS] | Chang,2008 | GIS Fuzzy logic, multi-criteria decision-making methods | Landfills location, taking into account factors: transport , ecological , environmental, economic , social and historical indicators. | [6] |

**Source: author's own elaboration**

**INFORMATION SYSTEMS USED IN THE WASTE MANAGEMENT**

Amendments to the Act on maintaining cleanliness and order in municipalities imposed on local governments a duty of development and implementation of the waste management system which will effectively realize flows of municipal waste streams from inhabitants to the places of their processing. The new responsibilities of municipalities and related cooperation reorganization of entities responsible for waste transport and utilization, have provoked a range of decision problems that require detailed analysis. Application of modern software in waste management is aimed at supporting system's processes, starting with the register of residents and calculating charges and monitoring the waste flows to the places of their processing.

Table 2 presents an attempt to fit the different levels of decision-making waste management system to types of information systems executing separate tasks. The essence of this division focuses on the use of structured data sets (databases), as a part of defined system's needs.

The lowest level of decision-making related to current operations includes all applications that use the data for everyday system operation. Their main purpose is to store data and their basic processing at the operational level of waste management. Selected data are the basis of support for the analytical and reporting systems in waste management, which usage allows to execute complex actions. The results (both the and tactical level) are the basis of decision support system's functions at a strategic level of waste management.

It should be noted that only an integrated system that already has registration-transaction and analytical data in its structure, might include the waste management system functioning at the regional level. Current solutions realize tasks associated with selected elements of the systems, avoiding the complex connections and correlations.

**Table 2 Position of different types of information systems at waste management decision-making levels**

| System types | | Decision levels | Issues |
|---|---|---|---|
| Integrated information system in waste management | Decision support systems | Strategic | • Options Planning for the waste management systems of different groups , <br> • forecasting changes in processes , parameters , manufacturing waste streams . <br> • investment decisions |
| | Analytical and reporting systems | Taktical | • Identification of the data structures describing the elements of the system and process, <br> • data, process and environmental hazards classification <br> • studying the correlation between the different parts and processes , <br> • component process analysis (e.g. migration of pollutants from waste treatment facilities) <br> • process modeling, elementary objects |
| | Transactional and registration systems | Operating | • management and control of processes , systems and subsystems including calculating the costs of waste management , recording the mass of generated waste different groups, financial operations , |

Municipal waste management system, which is in pursuance of new rules is organized and coordinated by municipalities, it requires detailed records of data processing and analysis. According to these requirements and the need to elaborate tools to help residents' service as part of the system, the market formed a dedicated software for municipalities, as well as waste management sector companies. Examples of such solutions are shown in Table 3.

The offered applications are characterized by standards that apply information systems in modules that let to waste recording, preparing of aggregated data or process monitoring and reporting. Qualified tools for systems support require distinguishing the clear specialization structure and functions of the operating system in decision-making processes. It is important to separate the models which allow to ensure the solution of complex decision problems in the context of i.a. forecasts or simulations. The management system " odpadywgminie.com " and Ulysses ODPADY, provides additional functions associated with the process modeling to the greatest degree as compared to other tools.

**Table 3 Selected information applications supporting waste management**

| No. | Software name | Authors | Recipient | The module of declarations and financial settlements | The module of logistic | The module of reporting | Analisis and process monitoring module | Modeling / Forecasting | Source |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Management system „odpadywgminie.com" | Profeko Sp. z o.o. | Municipalities | YES | YES | YES | YES | YES<br>- Creation of a "knowledge base" of waste management<br>- Simulation model of the costs and logistics of waste management in the municipality<br>- Creation of budgetary forecasts for the entire waste management system | [11] |
| 2 | ecoSANIT | Logic Synergy | Municipalities | YES | NO | YES | YES | NO | [10] |
| 3 | Ulisses ODPADY | ULISSES | Municipalities | YES | YES | YES | YES | YES<br>- forecasting local government incomings from waste management | [13] |
| 4 | Waste records 2015 | darsoft.pl | Industrial companies | YES | YES | YES | YES | NO | [9] |
| 5 | Waste Management Informatic Sytem (SIGO) | Solvena Management Systems Sp. z o.o. | Companies engaging in complex municipal and industrial waste management. | YES | YES | YES | YES | NO | [12] |
| 6 | Municipal waste monitoring system | Solvena Management Systems Sp. z o.o. | Municipalities | YES | YES | YES | YES | NO | [12] |

**Source: Author's own elaboration**

The ones proposed as the market tools, in particular are based on the database processing operation level, and above all, on waste quantity and morphology recording, and number of entities of their processing. The generated reports and reports for basic operation of the system, rarely planning and modeling new solutions. The exception is the management system called "odpadywgminie.com " , which supports waste management and prognostic simulation models of logistics processes and economic analyzes. The results of these additional features undoubtedly

constitute a value-added analysis and make it possible to try to improve the system and achieve better results with the waste recovery and recycling.

**CONCLUSION**

The review of literature and applications to support waste management system available on the market, strengthen the conviction about the benefits of the decision support systems used in practice. Unquestionable advantages associated with the implementation of the systems that are reflected into efficiency of implemented actions include e.g. .:

- Multi-criterial - decisions can be examined from the point of view of any number of criteria;
- flexibility - the ability to input any number of decision variables, parameters, constraints, goals. DDS flexible structure makes it be prepared to changing user needs;
- the possibility of a hybrid approach - combining the use of several methods to solve the decision-making problem (np. SDSS);
- interdisciplinary approach - decision-making problems can be solved from the point of view of a variety of criteria such as technological, logistic, economic, social;
- low cost of ownership - the ability to acquire knowledge and to identify the best solution at the lowest cost;
- integration - the ability to quickly analyze and processing different (distributed) databases.

The presented examples of information systems included in this article enable to support processes in various areas of waste management and realize its targets. The weakness of the designed and implemented software solutions is the lack of a comprehensive approach. Each additional module to support separate areas could improve the efficiency of the decision-making processes at every level of waste management. Their extended properties can significantly contribute to a comprehensive approach within the different groups of waste flows, identifying the most ecologically and economically beneficial possibilities of their development. In addition, the compatibility of information systems at the local and regional level lacks errors at the registration stage. Therefore, a thorough analysis taking into account the needs of DDS application is recommended, for example :

- analysis of the current state of waste management problems and modeling purposes;
- choice of methods and tools for solving defined decision-making problems;

- determination of evaluation criteria, variables and parameters along with their preferred values;
- verification of the ability to integrate existing resources of data and knowledge base with the designed system.

Despite the widespread use of DSS there are still many areas of waste management to implement such solutions. Unlimited possibilities that provide information technology enable the development of models using multi-criteria decision-making methods of analysis and evaluation. Waste management is one of those areas that the management and planning need to take into account the many complex aspects of both quantitative and qualitative, that is why all the applications are enabled to faster and more efficient work.

To conclude, designing the support systems for waste management requires a flexible approach that takes into account the problems of generation, transportation and various kinds of waste processing technology. As it is used for the structure of DDS models and databases, it should form an integrated waste management system, taking into account the legal, social, environmental and economic aspects.

**REFERENCES**

[1] Abeliotis K. et al.: "Decision support systems in solid waste management: A case study at the national and local level in Greece, [w:] Global NEST Journal, vol. 11, no 2, 2009, s.117-126.

[2] Bieda B.: "Decision support systems based on the Life Cycle Inventory (LCI) - part of a Life Cycle Assesment (LCA) for Municipal Solid Waste (MSW). Management Case Study, [w:] Archiwum Gospodarki Odpadami i Ochrony Środowiska, vol. 4, 2006, s.13-32.

[3] Bojar W., Rostek K., Knopik L.: "Systemy wspomagania decyzji", PWE, Warszawa 2014.

[4] Gaska K., Generowicz A.: "Wykorzystanie systemów GIS oraz aplikacji sieciowych i dedykowanych w zarządzaniu gospodarką odpadami", [w:] Archiwum Gospodarki Odpadami i Ochrony Środowiska, vol. 16 issue 3, 2014, s. 53-72.

[5] Górniak-Zimroz J.: "Wykorzystanie systemów wspomagania decyzji w gospodarce odpadami, [w:] Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej, Nr 33(118), 2007, s.25-41.

[6] Kadafa A.A. et al..: "Applications of System Analysis Techniques in Solid Waste Management Assesment", [w:] Pol. J. Environ. Stud. Vol. 23, No. 4 (2014), s. 1061-1070.

[7] Khan D., Samadder S.R.: "Municipal solid waste management using Geographical Information System aided methods: A mini review, [w:] Waste Management & Research 32(11), 2014, s. 1049-1062.

[8] Łatuszyńska A.: "Przestrzenne systemy wspomagania decyzji", [w:] Zeszyty naukowe Uniwersytetu Szczecińskiego, Studia Informatica nr 26, 2010, s.89-103.

[9] Strona internetowa przedsiębiorstwa darsoft.pl: www.darsoft.pl, dostęp: 07.04.2015r.

[10] Strona internetowa przedsiębiorstwa LogicSynergy: www.systemecosanit.pl, dostęp: 07.04.2015r.

[11] Strona internetowa przedsiębiorstwa Profeko Sp. z o.o.: www.odpadywgminie.com, dostęp: 07.04.2015r.

[12] Strona internetowa przedsiębiorstwa Solvena Management Systems Sp. z o.o.: www.solvena.pl, dostęp: 07.04.2015r

[13] Strona internetowa przedsiębiorstwa ULISSES: www.ulisses.pl, dostęp: 07.04.2015r.

[14] Wager P.A., Hilty L.M.: "A simulation system for waste management - from system dynamics modelling to decision support", [w:] Rizzoli, A.E. Jakeman A.J. (red.) Proc. iEMSs 2002, Integrated Assessment and Decision Support, Lugano 2002, s.174-179.

[15] Pavlas M. et al, "Waste-to-Energy Systems Modelling Using In-House Developed Software, Institute of Prcess Environmental Engineering, Brno University of Technology, non-published.

**SYSTEMY WSPOMAGANIA DECYZJI W GOSPODARCE ODPADAMI – PRZEGLĄD WYBRANYCH NARZĘDZI.**

*Streszczenie: W artykule przedstawiono przegląd rozwiązań informatycznych w gospodarce odpadami ze szczególnym uwzględnieniem systemów wspomagania decyzji (SWD). Wskazano zasadnicze komponenty architektury systemów oraz ich wpływ na realizacje zadań z zakresu gospodarki odpadami. Analiza projektowanych i wdrażanych rozwiązań aplikacyjnych umożliwiła przyporządkowanie poszczególnych typów systemów informatycznych do poziomów decyzyjnych regionalnych i gminnych systemów gospodarki odpadami.*

*Słowa kluczowe: system wspomagania decyzji, system gospodarki odpadami*

# DECISION SUPPORT SYSTEMS IN WASTE MANAGEMENT - A REVIEW OF SELECTED TOOLS.

**Abstract:** *The article presents a review of information solutions in waste management with special regard to decision support systems (DSS). Basic components of system's architecture and their influence on waste management assignments have been described. An analysis of designed and implemented software solutions has enabled the ordering of various types of information systems for decision-making levels of regional and municipal waste management systems.*

**Key words:** *decision support system, waste management system*

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