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DECISION SUPPORT SYSTEMS IN WASTE MANAGEMENT – A REVIEW OF SELECTED TOOLS

3.1 INTRODUCTION

The necessity of decision making in the field of uncertainty, forms an integral part of is traders, managers or analysts workers. Seemingly, this is an intuitive process that applies to every human being, but in a professional resource management requires appropriate procedures and preparation. Tracing the definition of W.T. Bielecki [6] decision making is preceded by the identification of the problem, collection of the relevant information, expert knowledge gathering and finally the elaboration of solutions which under evaluation and selection will allow to make the best choices. Business practice has caused computerization of these activities, creating the 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 effective implementation of the decision-making processes with varying complexity. A wide range of information and data, including the logistical, technological, environmental, social and legal issues it is possible to process using multi-criteria analysis and specialist support systems.

3.2 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[6]. In connection with these issues, DSS (Decision Support) were defined as information solutions that support business and organizational decision-making activities, enabling setting the optimal solution.

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

- the DDS are designed for support the decision-making process,
- the DDS should support, not automate decision-making,
- 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 is necessary to prepare detailed conditions including an analysis of its application. Systems should be mostly adequate, which means compatibility of the operational needs with contained data and if-then rules. DSS is required also availability, which is associated with the correct process of communication and unambiguous interpretation of the results.

Unequivocal purpose of application DDS has a graphical representation of its structure (Fig. 3.1), which in the most transparent way to introduce the main elements of its architecture, and to verify which information systems are a decision support system.

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

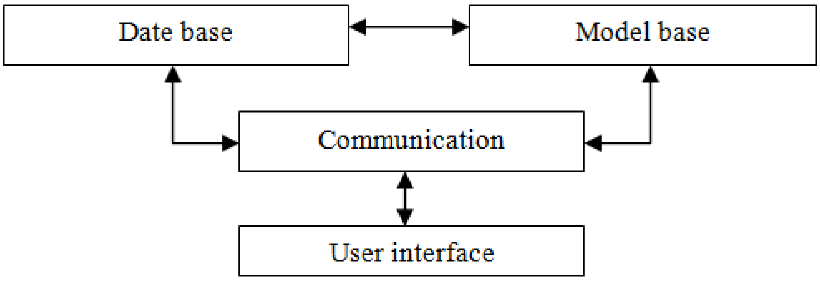

Fig. 3.1 Decision support system structure

Source: [3] p.19

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

The user interface of DDS is considered as 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 [6] recommendations, in addition to an accurate analysis of the tasks and systems objectives should be took into account the implementation of lexical and semantic level. The results of these analyzes are the description of the communication language with the decision-maker, a choice of interface standard, and the environment of its implementation [3]. Due to the high level of details in interface design and its effects impact on the system functionality, it is proposed to prototype which allows evaluating preliminary designs.

In order to reduce costs and eliminate the risk of decision-making process errors, there are used a various methods for simulating potential solutions. All processes and phenomena occurring in reality can be described using the interrelationships between components, which create a special collection and aim to achieve a particular purpose.

This reflection of reality by a set is called a model, on which DDS examine and predict options of analyzed alternatives.

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

In the literature can also be found the application of conceptual models, object-oriented models, models of multi-criteria analysis or specialist models including i.a. integrated waste management systems. Extensive use of DDS and the possibility of setting up models, have been 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 a better understanding of the effects 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 is often used by public and private entities that process the collected data for analysis, forecasting and simulation.

3.3 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 the informatics tools within Waste Management Systems Data Management was included basic data management. Recording and reporting – are the basic activities related to the management of waste flows from the manufacturers to waste processing entities. Standard data sheets have enabled to implement these basic requirements, but have limited significantly more complex actions. Along with the need of process simulation, forecasting and reporting the results of alternative solutions – has been being grown a need to develop informatics tools using spreadsheets, mathematical optimization and simulation models, including Geographic Information Systems [5].

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 [5]. In this perspective, GIS is a valuable component of DDS during the flows planning and determining location of waste recovery facilities and waste disposal. Multi-criteria analysis related to this issue enriched through geographical analysis, allow to specify the best solution for complex decision-making processes.

Tab. 3.1 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 widely used of all kinds of methods to support decision-making in waste management. In addition to using approaches like LCA, AHP or spreadsheets, is observed increasing interest in the application of spatial information – GIS, which allows the presentation of the position of important objects related to waste management.

The literature describes many of the systems used for locating landfills. Their detailed analysis based on multi-criteria decision-making process also using geographic information systems, is enable to selection the best solution. In the current situation, according to new regulations and requirements of the EU, storage is the ultimate form of recycling, which should be kept to a minimum, and building a 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 [11], 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.

Specialized use of DDS to separate the waste management processes is increasingly appreciated by the users from 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.

Tab. 3.1 Examples of decision support systems in waste management

No.	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 base, Spreadsheet, Optimization and simulation models	Forecasting the quantity and quality of generated municipal waste, techno-logy collection assessment, treatment and disposal of waste, estimating the cost of planned solutions, forecasting volumes and time of investment asso-ciated with waste management	6
2	Spatial Decision Support System [SDSS]	Greece	AHP, GIS	Determining the location of a landfill on the Lesbos island.	6
3	Spatial Decision Support System [SDSS]	Thailand	AHP, GIS, Fuzzy logic	Determining the initial location of landfills in Thailand.	6
4	DSS for Landfill Design, Evaluation and Monitoring LDEM-DSS	No data	GIS, Expert system Simulation model	Design, evaluation and monitoring of landfills.	6
5	SIGOP	Poland, Katowice	Knowledge base,	SIGOP's database is used during the de-velopment of waste management pro-grams 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	6
6	EcoSolver IP-SSK	Switzerland	LCA model, Dynamic model, Simulation model	Separation of plastic waste streams plan-ning with regard to the facilities of recycling, treatment and recovery of mechanical energy for selected re-gions	13
7	W2E Software	No data	Mathematical model, Simulation model	Analysis and evaluation of the possibility of disposing of sewage sludge in the pro-cess of energy recovery - choosing the best solution	11
8	ReFlows	Greece	Mathematical model, Simulation model	Simulation of physical and financial flows in various scenarios in waste ma-nagement 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, environ-mental, economic, social and historical indicators.	7

Source: Own elaboration

3.4 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 a waste management system which will effectively realized 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.

Tab. 3.2 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 a 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 that usage allows to execute complex actions. The results (both operational 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 systems that in theirs structure already have registration-transaction and analytical data, might include the waste management system functioning at the regional level. Currently solutions realize tasks associated with selected elements of the systems, avoiding the complex connections and correlations.

Tab. 3.2 Position of the different types of information systems in waste management decision-making levels

Type systems		Decision levels	Issues
Integrated information system in waste management	Decision support systems	Strategic	Options planning for the waste management systems of different groups , forecasting changes in processes, parameters , anufacturing waste streams. investment decisions
	Analytical and reporting systems	Taktical	identification data structures describing the elements of the system and process, data, process and environmental hazards classification study the correlation between the different parts and processes, component process analysis (eg migration of pollutants from waste treatment facilities), 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

Source: Own elaboration based on: [3], [5]

Municipal waste management system, which one in pursuance of the new rules is organized and coordinated by municipalities, 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 dedicated software for municipalities, as well as waste management sector companies. Examples of such solutions are shown in Tab. 3.3.

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 ensuring the solution of complex decision problems in the context of i.a. forecasts or simulations. The management system „odpadywgminie.com" and Ulysses ODPADY, to the greatest degree, compared to other tools provides additional functions associated with process modeling.

Tab. 3.3 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 „odpady wgminie.com"	Profeko Sp z o.o.	Municipalities	Yes	Yes	Yes	Yes	Yes /*	12
2	ecoSANIT	Logic Synergy	Municipalities	Yes	No	Yes	Yes	No	9
3	Ulisses ODPADY	ULISSES	Municipalities	Yes	Yes	Yes	Yes	Yes/**	15
4	Waste records 2015	darsoft.pl	Industrial companies	Yes	Yes	Yes	Yes	No	4
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	14
6	Municipal waste monitoring system	Solvena Management Systems Sp. z o.o.	Municipalities	Yes	Yes	Yes	Yes	No	14

/* Creation of a „knowledge base" of waste management, simulation model of the costs and logistics of waste management in the municipality, creation of budgetary forecasts for the entire waste management system.
/** Forecasting local government incomings from waste management,
Source: Own elaboration

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

CONCLUSION

Review of the literature and available on the market applications to support waste management system, strengthens the conviction about the benefits of the decision support systems used in practice. Unquestionable advantages associated with the implementation of systems that translate into efficiency implemented actions include eg.:

- multicriterial – 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 prepared to changing user needs;
- the possibility of 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 in this article information system enable to support processes in various areas of waste management and realizing 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 local and regional level avoids errors at registration. Therefore it is recommended a thorough analysis taking into account the needs of application DDS, 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;
- verify 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. Used for the structure of DDS models and databases should form an integrated waste management system, taking into account the legal, social, environmental and economic aspects.

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DECISION SUPPORT SYSTEMS IN WASTE MANAGEMENT – A REVIEW OF SELECTED TOOLS

Abstract: *The article presents review of information solutions in waste management with special regard to decision support systems (DSS). There was indicated basic components of system's architecture and their influence on waste management assignments. 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*

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*

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Date of submission of the article to the Editor: 04/08/2015
Date of acceptance of the article by the Editor: 04/24/2015