

The Development of Decision Support System for Waste Management; a Review

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Abstract—Most Decision Support Systems (DSS) for waste management (WM) constructed are not widely marketed and lack practical applications. This is due to the number of variables and complexity of the mathematical models which include the assumptions and constraints required in decision making. The approach made by many researchers in DSS modelling is to isolate a few key factors that have a significant influence to the DSS. This segmented approach does not provide a thorough understanding of the complex relationships of the many elements involved. The various elements in constructing the DSS must be integrated and optimized in order to produce a viable model that is marketable and has practical application. The DSS model used in assisting decision makers should be integrated with GIS, able to give robust prediction despite the inherent uncertainties of waste generation and the plethora of waste characteristics, and gives optimal allocation of waste stream for recycling, incineration, landfill and composting.

Keywords—Review, decision support system, GIS and waste management.

I. INTRODUCTION

SOLID waste management is a high priority issue for all societies around the world and owing to major problem nowadays. Increasing the solid waste generation rates and disposal cost, environmental and health concern, limited landfill space, legislative changes, political climate, and social attitudes have significant on waste management efforts [5].

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Finding acceptable strategies to cope such a problem cause the development of strategic waste management, pollution control technologies, and to more rigorous legislation on waste handling and disposal, to minimize the environmental impact associated with solid waste [6]. Without the proper management and the better technology, waste cannot be treating efficiently and can damage the environmental or habitat and harm the human. Also, the legislation and policy regarding waste management must be changed to improve the effectiveness of waste management and strengthen the rules and regulation of environmental issue.

All this issue owing to development and application of decision support system (DSS) in overall waste management and environmental issues from both economic and environmental standpoints. DSS as a computer integrated tools systems is capable to assist the planner or decision makers in various steps of design procedures [11]. The application of DSS nowadays becomes widely implemented in many applications proportional with growing study and research of DSS and resulted in the development of variety of scientific problem-solving and model based methods for many decision problems. Initially, DSS acknowledge as interactive computer based systems, which help decision makers, utilize data and model to solve unstructured problem [19]. Diaz et al. (2005) defines the DSS as a new generation of information system, the goal of which is to try to discover what would happen if a series of decision are taken, or going further, by automatically providing the decision or suggestions that assist the users [15].

II. STRUCTURE OF DECISION SUPPORT SYSTEM

To develop the DSS for waste management, the DSS architecture proposed by Sprague and Watson (1996) have been applied in this field and also has been used by Chang (1996), MacDonald (1996), Bhargava (1997), Hasstrup et al. (1998), Boyle and Baetz (1998), Diaz et al. (2005), and Simonetto & Brenstein (2007). The important basic of this structure was supported by Pearson (1995) [36]. Fig. 1 shows the structure of DSS which basically consists of three components; database management, model base management, and user interface or dialogue [1, 7, 13, 19, 30, 32].

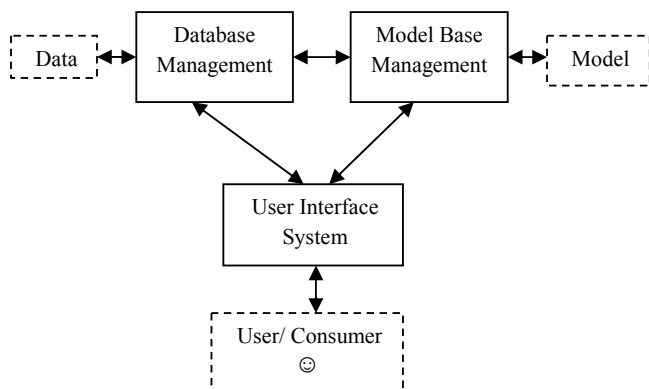


Fig. 1 The basic structure of Decision Support System for waste management [19]

The architecture of DSS must show two interactions among all subsystem to able passing any data. To build a complete model of waste management system, a wide knowledge and deep analysis must be done on all aspects such as possible treatment processes of the waste, characteristic of waste, cost economic, prediction, analyzing recovery versus disposal of waste, and possible to produce energy from waste. Usually, planner and decision makers do not have a thorough understanding of the whole waste management cycle and its implications to environment and health such as contamination to soil, air, and water.

Chang & Wang (1996), MacDonald (1996), Bhargava & Tettelbach (1997), Hastrup et al. (1998), Cheng et al.(2003), Diaz et al.(2005), Eugenio & Denis(2007), Chang et al.(2007), and Paraskevopoulos et al.(2008) had used GIS in the system [1,2,7,15,16,19,20,32]. GIS based software is used to display the geographical information associated to a territory, resorting also the thematic views displaying homogenous data, routing network, point sources of air and water pollution, and can present and store population and demographic information about the region and facilities being studies [36]. The developed software which integrated with GIS can assists the users such as planners, policy makers, decision makers, investors, enforcers, environment consultant and etc in analyzing and comparing different waste management and collection alternatives in order to select the best and most cost effective one, complying with legislative, technical and economic constraints.

III. CHRONOLOGY OF DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR SOLID WASTE MANAGEMENT

The attribute and characteristic of waste produced by waste generators is different and each of them has constraints itself. Solid waste management is complex, multidisciplinary problem involving economic and technical aspects, normative constraint about the minimum requirement for the recycling and sustainable development issues [6]. Many researchers have stride toward the development of economic based optimization model for solid waste management flow allocation.

A review has focus on objective of DSS, constraints that take account, and loop hole of the DSS in solid waste management. In early 1996, Chang & Wang (1996) had produced paper of development of an environmental decision support system for municipal solid waste management [7]. Increasing of closing landfill has motivated various recycling and incineration process. But inherent complexity of composition waste and various prices of recyclables owing to the difficulties in waste management. These problems owing to use the intelligent system to overcome that problems and find the compatible of recycling and incineration process in metropolitan region. This research represent the first effort to introduce the development of an innovative decision support system as a graphical, interactive, problem structuring tool for the management planning of solid waste collection, recycling and incineration system. The DSS developed by Chang and Wang (1996) can predict an optimal solid waste distribution regarding on waste collection capability, prices of recyclables, waste generation and composition, transportation cost, and construction and operating costs for these solid waste processing facilities [7]. This DSS provides a user-friendly interface to establish statistical and optimization analysis (the allocation of stream waste for recycling and incineration, selecting the best allocation between recycling and incineration facilities, and confronts uncertainty in waste management) and to communicate with the decision makers or planner, who may not be able to memorize all the message to integrate all the necessary factors or to learn how to write a complicated computer program [7]. Chang & Wang (1996) used linear programming in optimization analysis and used SAS software to constitute with the DSS for data presentation, graphic display, statistic, and modeling analysis [7]. However, this model doest not take account the possibility of production of refuse-derived fuel (RDF) and the best tradeoff between monetary payoff and travel time. It also not includes the distance between the waste generators to the transfer stations or plant treatment. The system has a less information and awareness to recycling and incineration program. It also used one incinerator as a case study and owing to inefficient optimization.

In the same year, MacDonald (1996) has developed spatial decision support system (SDSS); the interactive, computerized tool, and user friendly to assist municipal solid waste planner in the solid waste planning [32]. SDSS is develops in parallel with concept of DSS. Solid waste planning constitutes a variety factor and must be considered such as economic costs, legislative requirement, land and water use, air and water pollution, resources usage and equity in the number and demographic effected by a plan. All of this large amount data owing to information that must be organized and analyzed. Peoples have limited ability to store all the enormous data and recalling it back. Thus, this DSS used to handle a large amount of background information which may be need to be collected, rearranged and analyzed before the decision making is performed [7,32]. The DSS provided with Geographical Information System (GIS) to help planners understand the spatial nature of particular programs and how they may impact the public and the environment. The system included mathematical programming model to suggest scenarios or to make optimization analysis (recycling and trash systems from

collection to transportation and disposal). Multicriteria decision-making was used to integrate with SDSS to choose an alternative from a set of options. This system can give thorough understanding of the whole waste solid waste management cycle and its potential implications to planners or decision makers and solve the problem due to lack of communication between various group involved in solid waste planning [32]. The problem may arise in this system is the participation and awareness of public in this planning (recycling), and in case if these issues were not addressed accurately, the plan or system will not operate as designed. This SDSS makes management science technique more accessible to solid waste and can provide significant insight into many trade-offs involved in solid waste planning such as between economic cost and environmental degradation or between economic efficiency and labor relations.

Bhargava and Tettelbach (1997) have adopted a new approach for decision support system to be equipped with standard Web browsers [19]. The authors presents a computerized decision support system (DSS) that assist and educated consumers by giving better access to information and decision model that maximize their economic incentives for recycling and waste disposal. The idea for researchers to develop this DSS is based on insufficient recycling of household and industrial waste, which has led to increase fullness and losses in landfill. The authors created a model (for optimizing delivery of waste to transfer station) and describe its implementation within DSS in which it is install on World Wide Web server and stored detail data and decision models. The system contain integer programming model that capture the objectives and constraints in developing a recycling plan; the model is combined with suitable solution algorithm to develop an optimal recycling plan for each consumer. The constraint in this research is the different important attribute of transfer station; the item that they accept, the payoffs that they offer for each item, and their distance from consumers. Then, travel cost cannot be determined until the list of stations to be visited is established. Bhargava (1997) used mathematical programming to solve the problem, which is to balance payoff and travel costs [19]. The model used to optimize recycle plan, determine the transfer station that are to be visited, item that are to be dropped at station visited, and the travel route between stations and makes the best tradeoff between monetary payoff and travel times by using a complex mathematical optimization model[19]. The weakness of this system is the computer used cannot support complex function, the complexity inherent in all environmental management, and cannot load a lot of data and software. The software to be run with DSS is not compatible and a few potential users are expertise with this system. The system included one station for recycled and eliminated the sub tours to make the system run faster and not complexity and assumed sufficient vehicle capacity to carry all item during one trips and assumed linear tradeoff between travel cost and payoff.

In Italy, Hasstrup et al. (1998) has developed a DSS for urban waste management to be used for evaluating general policies for service organization of the collection and for identifying the suitable location for locating waste treatment and disposal plants and rank them from the best to the worst [2]. The structure of this system is composed of three

elements; database system (geographical data, treatment or disposal data, and waste production data), model system (construction scenario, evaluation scenario, and NAIAD), and user interface. The set of facilities associated with a scenario must meet these two constraints: a) combination between location of disposal and treatment facilities must be able to treat and dispose the waste production at the interest region b) all location must comply with an existing regional list of feasible location for waste disposal and treatment facilities [2]. The DSS includes a map concerning waste treatment sites, and four assessment models (the site risk, the environmental impact, the costs, and the transportation risk model). Hasstrup et al. (1998) focused to generate alternatives for the sitting of new waste facilities to satisfy the requirements of self-sufficiency in the area of solid urban waste treatment and disposal and to divide the territory into user basin, each delivering waste to a specific site [2]. The problems arise in this system same as system present by Bhargava and Tettelbach (1997) [19].

At the same years, Boyle and Baetz (1998) have developed a prototype knowledge-based decision support system for industrial waste management [13]. This system would assist and educate managers in determining the waste management option for all type of waste from industrial plant and determine the potentials for reuse and recycling of waste materials, to select the treatment facilities for recycle, to determine the potentials for co-treatment of wastes, and giving priority to minimize cost and environmental impact [13]. By providing DSS for waste management, it possibly can encourage the industries to identify and recognize the potential markets for their waste material. Moreover, the manager of industries can compare the suitability of the current waste treatment system to treat the waste from a new industry. The output of the system will identify the optimum treatment necessary to treat all the waste produced by considering the optimum cost, environmental impact, and the priority for recycling. But the system has a limitation due on number of treatment and synthesis of chemical reactions. This system only provided 10 treatments, which mean that some material may not be treated within that limit. Besides that, the system doesn't consider the possibility of complex chemical reaction that may occurs and doesn't match the desired input. The other factor is the parameters that characterize waste are only few in this system and this system are not providing economic data and analysis for final result.

Amouzegarn & Jacobsen (1998) has done a research of decision support system for regional hazardous waste management alternatives [25]. The DSS used as a tool for regional planning, incorporates information on the hazardous waste generation, treatment capacity and the costs of waste treatment alternatives into an optimization problem of finding relationships between agency and the toxic waste producing firms. This idea formerly comes from the regional planner, which did not take, account the relationship between treatment capacity, treatment prices and hazardous waste generation. In this system, Amouzegarn & Jacobsen (1998) has introduced two important agents in the economy: the central authority (CA) and the firms to solve that matters [25]. The CA is any agent who has the authority to regulate the other agent's activity and the firm is any organization that through its

activity produces some goods. The objective of this research is to aid policy makers in developing a sound managerial decision regarding an important issue facing many industrialized nations. Issues such as social welfare, risk assessment and cooperation with firms are also addressed. After few years, Amouzegar and Moshirvarziri, (2001) was present a strategic management decision support system: an analysis of the environment policy issue to tackle environmental problem and this is ideally come from the previous research of DSS for regional hazardous waste management alternatives [10]. Amouzegar et al., (2001) were attempting to use bilevel technique and derived a solution to help decision makers to cope with environmental issue [25]. The developed system has implemented a optimization model based on consumer's surplus, profit loss, and changes in tax revenue; and concluded that, when information costs are too high, it is most efficient to tax solid waste directly rather than tax the goods that produced waste [25,10]. But this model only limited a set of waste stream and the whole class of waste.

Fiorucci et al. (2003) and Costi et al. (2004) have developed an application of decision support system for solid waste management in urban areas at municipal scale to assist decision makers or planner of municipality in SWM [6,17]. Ideally, the system focused on municipal solid waste management based on minimum requirement for recycling, incineration, sanitary landfill conservation and mass balance [6,17]. A mathematical model used in this system based on minimization overall cost in which taking into account transportation, treatment, maintenance and recycling cost and possible benefits for electric energy sales whereas constraints arise from technical, normative, and environmental issue. Fiorucci et al. (2003) and Costi et al. (2004) proposed the future development and application of the DSS for solid waste management [6,17]. The first one is extending the proposed model in order to allow it to include an analytical representation of environmental impact. Another possible future development is refinement of the analysis of recycling, transportation, and maintenance cost. In this connection, a deeper correlation with the territorial system should be taken into account.

In the middle 2003, a different approach is adopted by Cheng et al. (2003) who apply an integrated multi-criteria decision analysis (MCDA) and inexact mixed integer linear programming (IMILP) approach to tackle the problem of solid waste management [16]. This method was used to support selection of an optimal landfill site and a waste flow allocation pattern such that the total system cost can be minimized [16]. Cheng et al. (2003) present a paper which are consider the risk of groundwater pollution as well as other environmental and socio economic factors which are important in selection of landfill location, and change in allocation pattern of waste flows required by construction of a new landfill. Other researcher deeply doing the landfill assessment are Kirkeby et al. (2007) and Liamsanguan et al. (2008) in important aspect such as leachate, emission gas, and energy recovery [37,38]. The five MCDA methods that are applied in this system are adopted to evaluate the landfill site alternative considered in solid waste management problem [16]. An integrated IMILP-MCDA was adopted in this system, which IMILP is used to

determine the municipal waste flow at minimal total cost for each potential landfill site. But this system only focuses on landfill site selection and build new site location, which is not suit with the world trend in waste management, [18, 39]. However, this gives idea toward the integration of solid waste management in term of prevention, recovery treatment, incineration, and disposal landfill by using integrated IMILP/MCDA method. Hokkanen et al. (1997), Chung & Poon (1996), Hasstrup et al. (1998), and Cheng et al. (2003) was used multiple criteria decision to evaluate alternatives when the uncertainties involved and ignore qualitative and often subjective consideration in waste management [2, 16, 27, 29].

Another decision support system approach has been formulated for the management solid waste flow by Simonetto & Brenstein in 2007 [1]. This paper present the conception, modeling, and implementation of decision support system to the operational planning solid waste collection system called SCOLDSS. The main used of this system is the generation of alternatives to decision concerning: 1) the allocation of separate collection vehicle as well as the determination of their routes 2) the determination of the daily amount of solid waste to be sent to each sorting facilities [1]. Simonetto et al. (2007) focused in these two matters for the reason that to determine their routes and avoid waste of labor force and reduce the amount of waste to sent to landfills. The DSS tool also used to prevail over this two problem; a) high cost of solid waste collection for municipalities and b) lack of a system correctly design and operated in term of storage capacity and waste processing at the sorting unit[1]. This system also comprises graphic, interactive facilities, and menu data driven dialogue that offer a friendly environment for the user to define data to run. For the development of computerized system, a combination of quantitative technique was used such as discrete-events simulation and heuristics to optimize this task: 1) reducing the amount of solid waste destined to the landfill, 2) assuring a waste input percentage at each sorting unit, 3) assigning vehicles to collection trips, 4) defining their routes, and 5) estimating the work capacity of sorting units [1].

Repousis et al. (2007) have presented an article of a web-based Decision Support System that enables scheduler to tackle reverse supply chain management problem interactively and focal on the efficient and effective management of waste lube oils collection and recycling operation [20]. Repousis et al. (2007) has identified four major query that the DSS must tackle which are 1) how much Waste Lube Oil (WLO) must be available at the central accumulation point in order to allow smooth production; 2) how to effectively schedule the collection process preformed by heterogeneous vehicle fleets, considering all operational constraints; 3) how to continuously monitor collection operations and accumulation rates to ensure full WLO retrieval; and 4) to provide the appropriate decision making tools for the effective and efficient distribution of lubricant products to customers[20]. The system has provided with Geographical Information System (GIS) to support a graphical display, routing network, and collection points. Repousis et al. (2007) and Bhargava (1997) has developed a decision support system for waste management via standard web browser to make user easier access the system and can query the database [19, 20]. The movement toward web-based

DSS allows planning or optimization tool to be distributed more widely, since all decision support related operations are performed on network servers. The capabilities of using web is enable sharing information and algorithm among multiple sites, include platform independence, shorter learning curves for users already familiar with web tools, lower software distribution costs and ease for system updates. Bhargava & Tettelbach (1997) created a model (for optimizing delivery of waste to transfer station) and describe its implementation within DSS in which it is install on World Wide Web server and stored detail data and decision models [19]. Using net, the information stored or database can be updated by providers of recycling services easily. The standard web browser serves as the graphical user interface, accommodating both textual and multimedia information.

Gomes et al. (2008) has developed multi-criteria decision making applied to waste recycling in Brazil. The paper presents two cases where the decision maker faced the problem [4]. The first case is social agents required an evaluation of different disposal alternatives for plastic waste and the second case is existing construction and demolition waste recycling facilities required performance evaluation. Multiple-criteria decision has making establish preferences for evaluating, prioritizing or selecting the available alternative. For each of alternatives, a group of criteria given by decision makers (government, manager, consumer, and integrated) were considers: 1) investments, 2) operating cost, 3) disposal/treatment costs, 4) CO₂ emissions, 5) corporate image, and 6) benefits. In this paper, the researchers also apply and study product life cycle in their research. The DSS was help by (multi-criteria decision aiding hybrid algorithm) THOR, which is used to arrange the alternatives identified according to the criteria established previously by each decision maker. THOR generates a comparison of ranking suggestion from best to the worst alternatives for each criterion considered in the analysis. Gomes et al. (2008) identified this model can be used to find the best solutions for the planning of a reverse network, including the location of recycling facilities and the reduction of the costs incurred with waste transport and collection [4]. Chang et al. (2008) has developed spatial decision support system, which employed a two stages analysis; 1) geographic information system (GIS) and 2) fuzzy multi-criteria decision analysis (FMCDCA) for the selection of landfill sites and developed a ranking of the potential areas based on variety criteria [12]. But it does differ from the conventional method in which Chang et al. (2008) approach two sequential steps rather than a full-integrated scheme. The purpose of GIS in this paper is to perform an initial screening process to eliminate unsuitable land followed by utilization of FMCDM method to identify the most suitable site using the information provided by the regional experts with reference to five chosen criteria. Table 1 shows the summary of decision support system for waste management from 1996 to 2008.

IV. DISCUSSION AND CONCLUSION

By the year 1996, a rapid growth of decision support systems for waste management was observed which were successfully established to overcome the critical problems of

rising waste generation, insufficiency of waste management, management of landfill sites, etc. The main objective of developed decision support system for waste management depends on the critical problems faced by the region, country, industry or societies in the world. Many researchers have applied and adopted the Waste Management Hierarchy (Prevention, material recovery/recycling/reuse, incineration, and landfill), which was introduced by Sakai *et al.* (1996), Nicholas (2003), Ekvall (2005) and Bhatia (2007) as the main approach for developing waste management decision support system [31,24,23,18].

In 1996, the system presented by Chang (1996) did not take into account the RDF and distances among waste generators and transfer stations or plant treatment. In addition, this system applied only one incinerator as a case study and lacked the information pertaining to recycling program [28]. This results in adverse impact to optimization and efficiency of the system. Fiorucci (2003) overcame the weaknesses in Chang's (1996) and Hastrup (1998) systems in which it included the transportation and maintenance costs, and the core production in recycling program-RDF [7,6,2]. The DSS proposed by Macdonald (1996) has a problem cause by human factor, which contributed a significant effect to recycling program. As stated by Wiedemann (1993), the public participation gives a large impact to recycling program. The cooperation and participation of the public in the program are required for the success of the system [3]. The legislation and policy in waste management are required to encourage the public participation in recycling implementation [34]. Lavee (2007) stated that recycling becomes more economically when factors such as unavailability of landfill sites and scarcity of raw material, LCA are taken into account [28]. Nevertheless, Bhargava (1997) solved the problem of Chang (1996) in transportation and collection. It provided the distances among WG to transfer stations [19,7]. The problem encountered in Hastrup's system (1998) is the same as in Bhargava (1997) where utilization of the computer is restricted due to the complexity of the optimizing function, limited expertise on software application, the inclusion of many assumptions, and limited use of GIS [2, 35]. The evolution of software and capability of computer technology lead to the integration of DSS with mathematical modeling, data, software and advanced GIS. The importance of GIS in waste management has been proven by other researchers such as Ghose et al. (2006), Caputo et al.(2002), Chang et al. (1997) and Macdonald (1996) [35,14,26]. Currently, coupled with the higher capability of GIS, almost all of the problems faced by researchers 20 years ago can be solved. Thus, the DSS can be improved by integrating GIS in the existing model such as Boyle (1998), Cheng et al. (2003), Gomes at al. (2008) and Simonetto (2007) [13,16,4,1].

The system presented by Boyle & Baetz (1998) is to assist managers to determine the waste management options for all type of waste from industrial plants [13]. It can only be used for industrial type of waste and cannot be used for household and clinical waste. The other limitations are the exclusion of treatment facilities, chemical reactions and economic data resulting in a worthless system. The system must be extended to include the availability of treatment and economic analysis to make it more compatible with the real situation and

marketable. Amouzegar (1998) proposed two important agents in the economy of hazardous waste management [25]. One agent is used to regulate the tasks of the other agents under his supervision. However, the system is limited to a set of stream and cannot be implemented in other countries. In addition, the researchers discovered that the DSS in application today are still not viable in terms of functional model from region to other region or from country to country due to the heterogeneous characteristic of the waste, weather, lifestyle of the community, industrial activities, and the country's policies legislatures. This is consistent with the claims made by Bhargava et al. (1997) that the waste characteristics affect the structuring of waste management model [19]. Therefore, to create a workable DSS model, considerations must be made for all of the factors stated above and alternatives for waste management. This is consistent with the statements based on review of DSS for municipal solid waste management by Barlishen & Baetz (1996) [33]. Formalizing the decision problem in a dynamical setting is the other possibility in the development of DSS in DSS model [6,17]. Hence, there is still a need for the improvement of the DSS to encompass all aspects of waste management. This is to give the best optimization and options of waste management strategies regardless of the uncertainties, constraints, complexities and number of options involved in decision making. Currently, no research or studies on DSS that covers all aspects of waste management have been done.

In conclusion, the future research or study must consider all of the possibilities in order for the DSS to be an effective decision making tool in spite of the uncertainties, problems of waste generation, prediction and optimal allocation of waste stream for recycling, incineration, landfill and composting. The model should also include direct interaction with data and analysis of data, and also overcome the problems associated with the previous DSS models explained before. It is the author's opinion that with the greater capabilities of computing power and software application, the DSS can be used in various areas, be more practical and marketable, and can be easily extended to meet current situations. In order to ensure the success of waste management, all of the functional elements must be integrated and taken into consideration *viz.* waste generation, sources of waste, collection, transfer stations, transportation, waste treatment i.e. separation & processing, and final disposal of the waste.

TABLE I
FEATURE INVOLVED IN DECISION SUPPORT SYSTEM FOR WASTE MANAGEMENT

Name of the system	Name of the establishment	Available since	Recycling	Incineration	Landfill	Collection	GIS	MCDA	Application	References
DSS	N.B. Chang & S.F. Wang	1996	Yes	Yes	No	Yes	No	No	Municipal Solid Waste Management	Compt., Environ., and Urban Systems, Vol.20, No.3, pp.201-212, 1996
SDSS	M.L. MacDonald	1996	Yes	No	Yes	Yes	Yes	Yes	Solid Waste management	Compt., Environ., and Urban Systems, Vol.20, No.1, pp.1-17, 1996
Web-DSS	Hermant & Tettelbach	1997	Yes	No	No	No	Yes	No	Waste Disposal & Recycling	Compt., Environ., and Urban Systems, Vol.21, No.1, pp.47-65, 1997
DSS	Mahyar & Jacobsen	1998	Yes	Yes	Yes	No	No	No	Hazardous Waste Management	Journal of Applied Mathematics & Decision Sciences, 2(1), 23-50 (1998)
DSS	C.A. Boyle & B.W. Baetz	1998	Yes*	Yes*	Yes*	No	No	No	Industrial Waste Management	Waste Management 18 (1998) 87-97
DSS	P. Haastrup et al.	1998	Yes	Yes	Yes	Yes	Yes	Yes	Urban Waste Management	European Journal of Operational Research 109 (1998) 330-341
IMILP/MCDA	S. Cheng et al.	2003	No	No	Yes	No	Yes	Yes	Solid Waste Management	Engineering Application of Artificial Intelligence 16 (2003) 543-554
DSS	Paolo Fiorucci et al.	2003	Yes	Yes	Yes	Yes	No	No	Solid Waste Management	Resources, Conservation and Recycling (2003) 301-328
DSS	P. Costi et al.	2004	Yes	Yes	Yes	No	No	No	Solid Waste Management	Waste Management 24 (2004) 277-295
DSS	Eugenio & Denis	2007	Yes	No	No	Yes	Yes	Yes	Solid Waste Collection	Waste Management 27 (2007) 1286-1297
Web-DSS	Paraskevopoulos et al.	2007	Yes	No	No	Yes	Yes	No	Waste Lube Oil Collection & Recycling	European Journal of Operational Research (2007)
SDSS	N.B. Chang et al.	2008	No	No	Yes	No	Yes	Yes	Landfill sitting in fast-growing urban region; solid waste management	Journal of Environmental Management (2008) 139-153
DSS	C.F.S. Gomes et al.	2008	Yes	No	No	Yes	No	Yes	Waste Recycling	Omega 36(2008) 395-404
Intelligent DSS	N. Musee et al.	2008	No	No	No	No	No	No	Hazardous Waste Classification	Journal of hazardous material xxx (2008) xxx-xxx.

*not included costs.

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