DECONRCM: A WEB-BASED TOOL FOR THE OPTIMAL MANAGEMENT OF WASTE FROM CONSTRUCTION ACTIVITIES

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***Abstract**: Construction and demolition waste (CDW) constitute the largest by quantity fraction of solid wastes, especially in urban areas. It is also widely accepted that the particular waste stream contain hazardous materials, such as insulating materials, plastic frames of doors and windows etc. Uncontrolled disposal of waste from construction activities result to long-term pollution costs, resource overuse and wasted energy. Towards environmental-friendly management of CDW, a web-based Decision Support System (DSS) has been developed, namely DeconRCM, which aims towards the identification of the optimal degree of buildings' deconstruction or demolition in order to minimise constructions' end-of-life costs (including logistics costs for the transportation of end-of-life building materials to certified recycling/disposal companies) and maximise recovery of salvaged building materials. This paper addresses both technical and functional structure of the developed web application, while also presents the software's results for a number of buildings in the Greater Thessaloniki Area, Greece.*

***Keywords:** Construction and demolition waste, demolition, deconstruction, DeconRCM.*

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1. INTRODUCTION

As concerns the environment, the construction industry has proven as one of the most pressing sectors, both for the consumption of natural resources, as well as for the release of pollutants to the natural environment. Construction and Demolition Waste (CDW) stream, accounts to an estimated 30 – 35% of the overall municipal solid waste (MSW) stream internationally [11]. Construction and demolition waste (CDW) include a wide range of materials depending on the source of the waste [7], namely:

- excavation materials (e.g. earth, sand, gravel, rocks and clay),
- road building and maintenance materials (e.g. asphalt, sand, gravel and metals),
- demolition materials (e.g. debris including earth, gravel, sand, blocks of concrete, bricks, gypsum, porcelain and lime-cast),
- other worksite waste materials (e.g. wood, plastic, paper, glass, metal and pigments).

Despite the fact that this particular waste stream presents the third largest in quantities, only following waste from the mining and farming industry [5], up to recently, common practice was to discard CDW materials and debris in landfills, most often the same ones built for the disposal of MSW [8]. Moreover, it is often reported that large quantities of CDW end up in uncontrolled open dumps, which presents a significant burden for the environment.

Environmental impacts of such practices include soil and water contamination, air pollution as a result of resulting fires, reduced land and property values, destruction of open spaces, aesthetic degradation and landscape blight [6]. In addition, CDW may include asbestos waste, which poses a significant health risk, especially in building sites which are later converted into residential areas or playgrounds [9].

In order to assist construction companies, public bodies, engineers and individuals towards environmental-friendly sound management of CDW, a web-based Decision Support System (DSS) has been developed, namely DeconRCM. A beta version of DeconRCM can be visited at: http://pandora.meng.auth.gr/deconrcm. Currently, the application is built for the case of the Region of Central Macedonia, Greece, but can be easily expanded to other areas with the necessary adjustments [4]. In this paper, functional specifications of DeconRCM are provided, together with a brief description of its technical aspects.

2. DEVELOPMENT OF "DeconRCM" DECISION SUPPORT SYSTEM

DeconRCM addresses the needs of specific target groups such as, contractors, engineers and public stakeholders. In brief, DeconRCM provides an accurate estimation of the generated quantities of 21 different waste streams produced by two main processes (renovation and demolition - R&D) of four building types (residential, office, commercial and industrial), based on the typical construction practice in Greece [2]. Furthermore, DeconRCM provides the user with the optimal management of each generated R&D waste stream regarding both economic and environmental criteria.

DeconRCM's structure and data flow are depicted in Figure 1.The basic scope of DeconRCM is to provide the end user with an easy to use tool for:

a. the total volume of the CDW produced either from a demolition or renovation constructional process,
b. the optimal CDW management,
c. the optimal route from the construction sites to the deposition sites, and
d. the overall CDW management cost.

DeconRCM is built with the use of a web mapping via Google Maps API (free web mapping service application and technology provided by Google that powers many map-based services, including the Google Maps website via Google Maps API). A database with all the adequate information regarding the disposal sites of the Region of Central Macedonia, Greece is embodied in the application. The database, which is based on MySQL, can be accessed and edited only by the administrator of the portal. Feedback forms, based on php 5.0 scripting language, are developed for gathering data as regards the source site (demolished or renovated building). Additionally, an algorithmical model, built with the use of excel spreadsheets, is constructed and embodied in the DSS tool for the estimation of the generated quantities of R&D wastes from a building. The output of quantity estimation model is stored in databases, also developed with MySQL. Finally, optimisation of the integrated CDW management of end-of-life buildings is solved with the use of a mixed-integer linear programming model (MILP). The full description of the tool's technical and functional specifications are provided in [3].

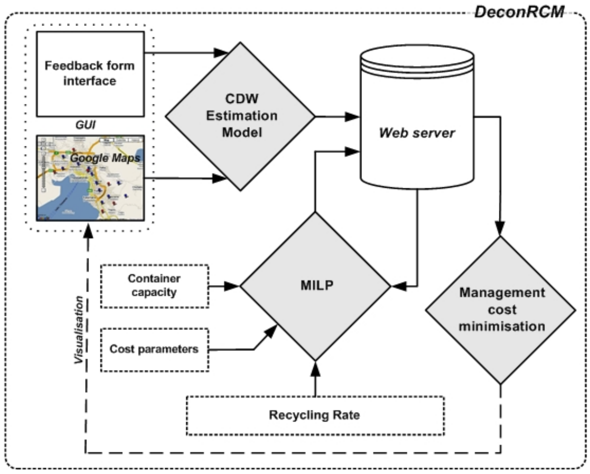

Figure 1. Structural components of DeconRCM

On top of the above, DeconRCM's user is required to insert a series of data that is essential in order to define the abovementioned parameters. In detail, by accessing DeconRCM the user has to determine the exact position of the case under review in the map. At the same time, the user must, both choose the constructional activity (demolition/renovation) that takes place and to define the kind of each building category (detached house/block of flats, office building and industrial building) (Figure 2).

Figure 2. DeconRCM's interface of building and construction determination

Moreover, the user has to set in the feedback forms the technical characteristics and/or details of each building type. In case of a residence building demolition (whether it is a detached house or a block of flats) the user should be in position to set the following characteristics concerning the building (Figure 3):

- construction year,
- building dimensions and number of floors,
- ground floor usage (residence, parking or pilotis),
- roof type,
- existence of basement and elevator,
- total balcony surface,
- heating type system and number of radiators per floor,
- number of apartments and WCs per floor,
- total number of windows per floor,
- type and number of frames (aluminum, timber, plastic),
- number of internal walls.

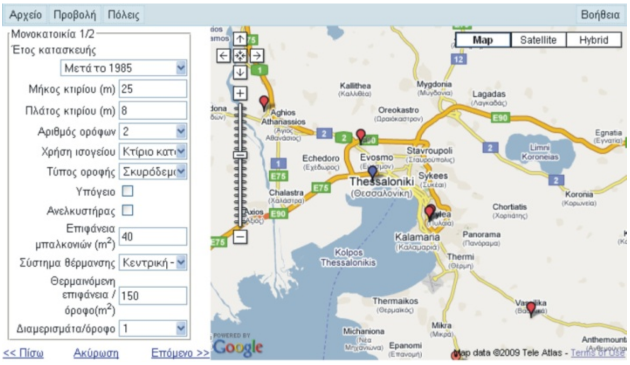

Figure 3. DeconRCM's interface of building and construction characteristics

Figure 4 depicts the information and result management interface which include the "Information" and "Calculation" tabs. By clicking the field "CDW quantities" the total amount of produced waste is presented.

Data input, as it was fully described above in the DeconRCM application forms, allows the user to depict the total CDW volume produced by the selected constructional activity. More specifically, finding and choosing the building that was defined in the map leads to the window with the tabs entitled "Information" and "Calculation" (Figure 5).

Optimisation of the integrated CDW management is solved with the use of a mixed-integer linear programming (MIPL) model [1]. Cost parameters that are included are:

i. the fixed deconstruction process cost,
ii. the fixed cost of demolishing the entire building,
iii. the fixed demolition process cost,
iv. the variable cost of deconstructing the building (€/t),
v. the variable cost of separating CDW, plus loading cost in container for each material,
vi. the fixed cost of using/renting a container and
vii. the variable cost of a container to a disposal site (€/container).

Revenues from secondary materials' sales are also considered [1].

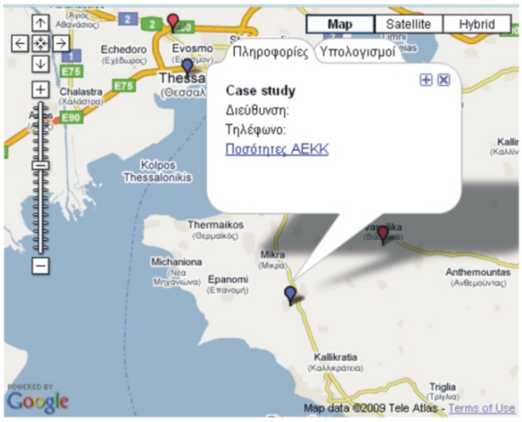

Figure 4. DeconRCM's information and result management interface

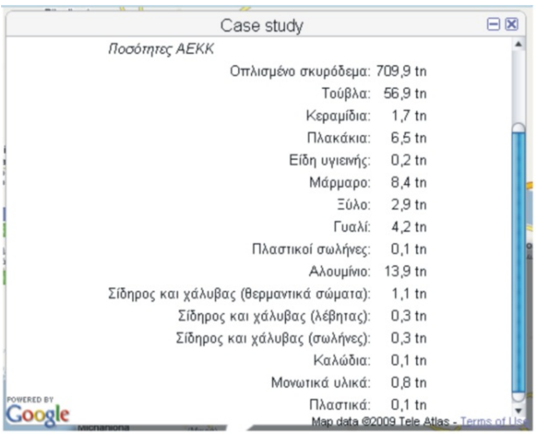

Figure 5. DeconRCM's CDW quantities interface

3. APPLICATION AND MANAGERIAL INSIGHTS

The applicability of DeconRCM has been demonstrated and its results have been validated elsewhere [4]. In the framework of the present work additional applications of the DSS are presented and statistically analyzed in order to obtain useful managerial insights as regards CDW management. More specifically, DeconRCM was used in order to assess CDW quantities and management cost for twenty seven residential buildings in the Greater Thessaloniki Area. More information about the specific case studies is reported in the work of [10].

Table 1. CDW quantities and managerial cost for thirty residential buildings in the Greater Thessaloniki Area

Building id	Concrete	Brick	Tile	Porcelain	Marble	Timber	Glass	Plastic	Aluminium	Metal	Management cost
(#)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(€)
1	814.3	80.8	1.3	0.9	37.8	0.1	1.3	0.1	4.3	0	19,034
2	814.3	71.1	1.3	0.9	37.8	0.1	1.3	0.1	4.3	0	18,825
3	1760	92.5	1.8	1.1	102.8	0.1	3.9	0.3	12.8	4.4	27,136
4	395.7	33.3	-	0.2	-	2.1	1.5	0.1	5	0.7	2,906
5	255.2	16.6	0.8	-	-	0.1	0.5	0	1.6	0.5	4,294
6	2196.4	118.5	1.9	1	90.7	0.1	4.6	0.2	15.4	2.5	36,714
7	1040.4	77.9	1	0.8	37.6	2.8	2	0.2	6.9	1.8	16,970
8	4254.4	299.6	-	3.4	254	0.1	6.5	0.6	21.7	11.7	80,744
9	3662.1	200.3	3.7	1.4	181.4	0.1	2.6	0.3	8.8	4.2	91,569
10	1859	78.9	2.3	0.8	90.7	0.1	3.7	0.2	12.3	1.9	33,883
11	4704.4	328.5	-	3.4	302.4	0.1	2.4	0.6	9.7	11.4	114,545
12	464.4	39.2	0.8	0.2	14.8	0.1	1.2	0.1	3.8	0.7	7,053
13	1571.6	71.9	1.3	1.4	64.7	0.1	3.5	0.3	11.8	4	22,598
14	218.1	10.2	-	-	-	0.1	0.5	0	1.6	0.6	3,028
15	2489.7	124.8	2.3	1.9	113.4	0.1	6	0.4	20	6.1	34,826
16	1971.7	103.9	1.7	1	109.2	-	2.4	0.1	6.3	1.6	48,416
17	1702.9	103.8	1	1.1	60.5	4.9	4.9	0.2	11.2	2.1	31.055
18	1519.5	79.1	1.7	0.8	67.2	4.4	2.4	0.2	7.9	1.9	31.456
19	645.7	73.5	1.7	0.6	33.6	8.2	1.4	0.2	4.9	2	10,109
20	3722.2	123.5	3.2	1.4	157.5	10	5.1	0.3	17.1	4.1	78,377
21	1818.8	99.6	1.9	1.1	74.3	11.1	3.7	0.2	11.6	2.5	33,229
22	2653.1	98.6	1.9	1.7	108.9	12	6.1	0.3	20.6	5	39,480
23	530	61.9	0.8	0.3	24.2	4.4	0.9	0.1	2.4	1	11,627
24	6148.7	323.5	-	2.3	349.4	27.7	3.9	0.4	10.3	7.7	162,239
25	3473	149.6	2.6	1.1	151.2	5.7	3	0.2	10	2.5	84,879
26	2500.4	154.3	3.5	1.1	134.4	17.7	2.5	0.2	8.3	2.7	60,232
27	2308.8	90	3.1	0.8	93.1	9.2	2.3	0.2	-	2.3	65,857
avg	2271.6	119.7	2.0	1.3	132.7	4.5	3.2	0.2	10.6	3.5	101,145

It should be noted that all figures in Table 1 are calculated for a recycling rate of 50%. The average percentage of the different CDW streams are illustrated in Figure 6.

Figure 7 illustrates the relevance between CDW quantities and its management cost for the cases under consideration.

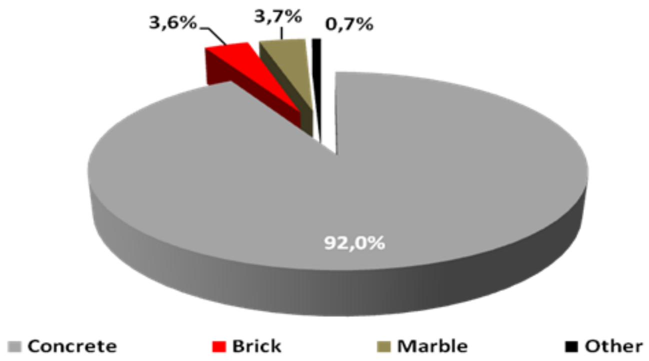

Figure 6. CDW streams' percentages

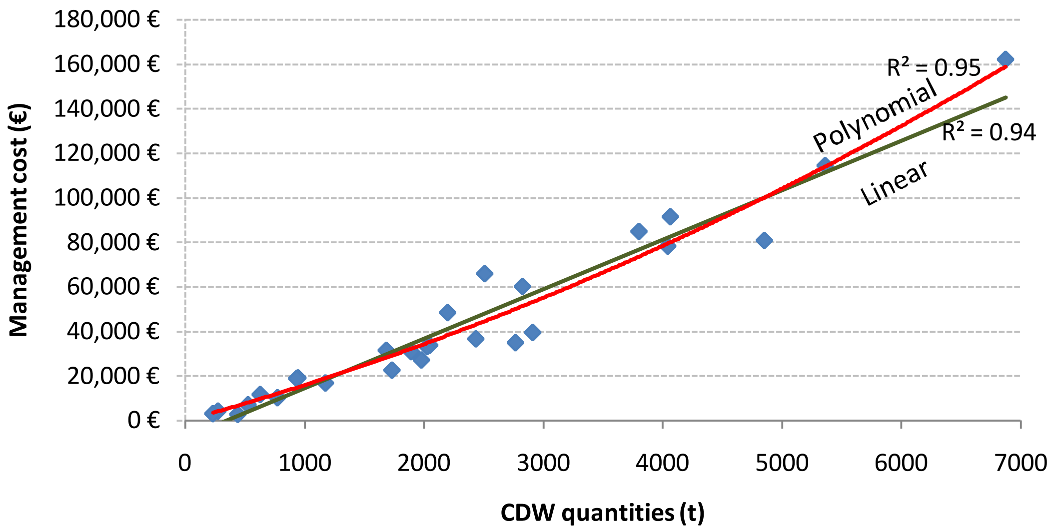

Figure 7. CDW quantities and management cost

4. CONCLUSIONS

CDW is a "priority" waste stream for the European Union, mainly due to its rapid growth over the last years. In this paper the technical and functional characteristics for the development of a web-based DSS application, namely DeconRCM are presented. Moreover, the software's results for a number of buildings in the Greater Thessaloniki Area, Greece are presented.

DeconRCM's major advantage lies in its web-based technology. There are several reasons in favour of a web-based DSS, e.g. raise of awareness, enhancement of detailed knowledge and encouragement of specific target groups' commitment towards sustainable CDW management. In addition, DeconRCM's "look-and-feel" user interface enables users -who do not always have the adequate scientific background- to retrieve information and navigate through data interactively.

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