

# Impact of Capital and Current Costs Changes of the Incineration Process of the Medical Waste on System Management Cost

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**Abstract.** The article describes optimization studies aimed at analysing the impact of capital and current costs changes of medical waste incineration on the cost of the system management and its structure. The study was conducted on the example of an analysis of the system of medical waste management in the Podlaskie Province, in north-eastern Poland. The scope of operational research carried out under the optimization study was divided into two stages of optimization calculations with assumed technical and economic parameters of the system. In the first stage, the lowest cost of functioning of the analysed system was generated, whereas in the second one the influence of the input parameter of the system, i.e. capital and current costs of medical waste incineration on economic efficiency index (E) and the spatial structure of the system was determined. Optimization studies were conducted for the following cases: with a 25% increase in capital and current costs of incineration process, followed by 50%, 75% and 100% increase. As a result of the calculations, the highest cost of system operation was achieved at the level of 3143.70 PLN/t with the assumption of 100% increase in capital and current costs of incineration process. There was an increase in the economic efficiency index (E) by about 97% in relation to run 1.

## 1. Introduction

Many decision problems arising in medical waste management system can be represented by an appropriate decision making model [1, 2] and consequently, solved through operational research. The final decision does not necessarily coincide with the decision resulting from modelling, which is only to help in the decision making process. At this period of time and regarding the complexities in the integrated solid waste management, decision-makers should distinguish between optimal, good, and fortuitous decision-making. In the optimal decision-making, one can solve the optimal problem using the techniques available in other fields [3, 4, 5]. In this solution method, generally some constraints (criteria) are considered, where the function(s) is to be optimized through applying some methods. Good decision-making is done based on experience, trial and error or comparison between different options of the integrated model of waste management.

The use of computational systems, due to absorption of a large number of resources and having great impacts on the environment, one can help decision-makers to achieve significant savings in costs and improve waste management [6].



Various economic optimization models for waste treatment have been developed which focus on different parameters. Models focusing on transport are one example but models focusing on energy production have also been developed as well as models which take into account the plants economies of scale, environmental impact, material recovery and social costs. Finally, models combining different criteria for selection of waste treatment methods in multi criteria analysis have been developed [6, 7].

In this paper, the optimization model of the export and disposal of medical waste is presented in the dynamic version, taking into account expected changes of input and output parameters of the waste management system as well as its status in given periods of time. The aim of the study was to analyse the impact of the parameter describing capital and current costs of medical waste incineration on the value of the economic efficiency index (E). With the assumed technical and economical parameters of the system the operating range of tests, performed as part of the optimization study was divided into two stages. In the first stage, the lowest cost of operation of the system was calculated, while the second stage resulted in describing the impact of input parameters of the system, i.e. capital and current costs of medical waste incineration on the economic efficiency index and spatial structure of the system (set of system facilities and related transportation network).

## 2. Case study

In this paper, the optimization model of the export and disposal of medical waste is presented in the dynamic version, taking into account expected changes of input and output parameters of the waste management system as well as its status in given periods of time.

A model region in north-eastern Poland, i.e. the Podlaskie Province, which can be considered representative for other regions, was chosen for the optimization research. The input data, necessary to describe the proposed variations in medical waste management system, has been collected and compiled in the course of analytical and factual study. Optimization study which was based on real data for both technical parameters and economic quantities, allows generalise the results and their implication for other similar regions.

18 sources of waste generation and accumulation (hospitals) within the studied area of the Podlaskie Province were selected for the analysis after taking into account the above mentioned assumptions and environmental conditions. The study also included: four intermediate objects (medical waste incinerators), respectively: IF1 (Suwalki), IF2 (Lomza), IF3 (Bialystok) and IF4 (Hajnowka), where pyrolytic decomposition process of waste will take place, and four end objects (respectively FF1, FF2, FF3, FF4) - areas for temporary storage of post-process waste from the incineration process located in the area of waste incineration facility. The model did not include restrictions on the capacity of intermediate and end objects.

The scope of operational research carried out in the framework of the optimization study was divided into successive stages in order to present options of the proposed model: Stage I - includes optimization calculations, assuming fixed technical and economic parameters. Sequence 1, made in this stage, was also a comparative course - a benchmark for other solutions and obtained results to compare.

Stage II - included a number of additional runs aimed at determining the impact of the model input parameters of the system on the indicator of expenses of economic efficiency (E) and the spatial structure of the system (system location of objects and their associated waste disposal routes). The following input data were taken into account:

- economic parameters describing the system (waste transport unitary costs, inflation and discount rate),
- economic parameters describing the objects of the system (capital and operating costs),
- the size reduction of medical waste in the system of indirect objects expressed in the form of the output factor of the process – wwp [%],
- the planned time horizon [t], (duration of model process).

The data relating to the costs of transport, investments and operation of the system objects, necessary for optimisation calculations, derived from existing plants, located in the model region. The calculation was performed by the unit cost of the work presented in Biedugnis et al. [8] taking into account the current prices and fees. The cost of medical waste removal from the source unit to the disposal site, with the adopted technical and operational conditions is  $K_{ij} = \text{PLN } 9.57$ , and when expressed in unit cost of 1 ton of transport per 1 minute ( $k$ ) = PLN 1.33/t/min.

The economic efficiency calculations of the method were presented in the work by Biedugnis et al. [8] whose dynamic model related to inflation and discounting of the annual capital and operating costs in each model period. Transport costs are also discounted and adjusted for inflation. Finding the best solution from the point of view of economic efficiency indicator was set as a priority. The above mentioned criterion takes into account both the selection of waste treatment technologies, as well as search for the best relationship between the location of objects used and the associated waste transport route network, depending on the amount of waste transported in each model periods.

### 3. Results and discussion

Calculations were carried out in the following runs:

Stage I - run 1 - the run like in the solution with the following parameters: duration of model period, respectively  $t_1 = 5$  and  $t_2 = 15$  years, the unitary cost of transportation of medical waste in the first and second model period, respectively, 1.33 and 0.44 PLN/t/min, the level of reduction of medical waste in the intermediate facilities expressed as a coefficient of the process output,  $wwp=10\%$ .

Stage II - in runs 2-5 - the impact of changes in capital and current costs of waste incineration process on the cost of the system and its structure was investigated: respectively for run 2 - with a 25% increase in capital and current costs; For run 3 - with a 50% increase in capital and current costs; For run 4 - with a 75% increase in capital and current costs and for run 5 - with a 100% increase in capital and current costs.

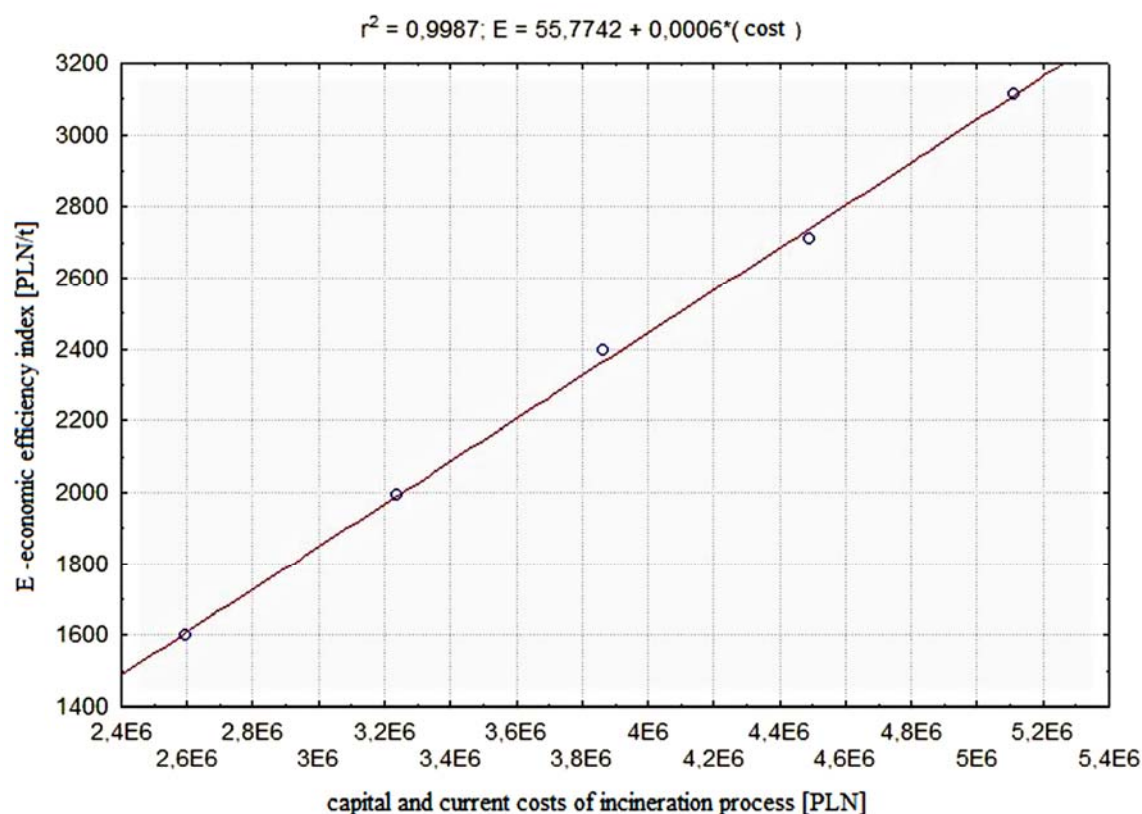
As a result of optimization calculations for the course 1 (Stage I) of the pre-established model system of the 26 facilities (18 - the source of the medical waste, 4 - incineration, 4 - storage of hazardous waste, 55 - possible routes for waste transport), there was a number of facilities selected in model periods I and II: 3/3 incinerators, 3/3 of the landfills and 21/21 waste transport routes, in consequence minimizing the cost of the system. Process levels in intermediate and final facilities in each model period for Stage I are presented in Table 1.

**Table 1.** The level of processing activities of intermediate and final objects for the 1<sup>st</sup> run [ton/year]

System facilities	Process	Processing activity level	Duration of model studies
		[t/year]	I=5 years, II=15 years
<b>IF1</b>	incineration	140.400	I
<b>IF1</b>	incineration	148.800	II
<b>IF2</b>	incineration	210.400	I
<b>IF2</b>	incineration	222.400	II
<b>IF3</b>	incineration	434.400	I
<b>IF3</b>	incineration	450.900	II
<b>FF1</b>	storage	14.040	I
<b>FF1</b>	storage	14.880	II
<b>FF2</b>	storage	21.040	I
<b>FF2</b>	storage	22.240	II
<b>FF3</b>	storage	43.440	I
<b>FF3</b>	storage	45.090	II

In subsequent runs 2, 3, 4 and 5 the impact of changes in capital and current costs of waste incineration process on the cost of the system and its structure was investigated: respectively for run 2 - with a 25% increase in capital and current costs; For run 3 - with a 50% increase in capital and current costs; For run 4 - with a 75% increase in capital and current costs and for run 5 - with a 100% increase in capital and current costs.

The highest economic efficiency index  $E = 3143.70$  PLN/t and was achieved with a 100% increase in capital and current costs. This index (E) increased by approx. 97% in relation to run 1. Figure 1 shows the values of the economic efficiency index (E) for runs 2-5, depending on the capital and current costs of the incineration process.



**Figure 1.** Correlation of economic efficiency index (E) and capital and current costs of incineration process

#### 4. Conclusions

Capital and current (running) costs of the waste incineration process cause a significant change in the system's operating costs and consequently a change in the economic efficiency index (E). It does not, however change the structure of the system.

Both capital and current costs of the incineration process have a significant impact on the cost of operating the system, as medical waste incinerators are part of capital-intensive facilities compared to other alternative methods of disposal of medical waste. However, it should be pointed out that incineration is a method which, despite high costs, ensures the highest ecological and epidemiological safety. Optimization studies yielded the highest economic efficiency index  $(E) = 3143.70$  PLN/t with the assumed 100% increase in capital and current costs. The economic efficiency index (E) increased by ca. 97%. The increase in capital and current costs is accompanied by an increase in the economic efficiency ratio (E):

$$E(\text{cost of incineration}) = 55.7742 + 0.0006 \cdot (\text{cost}) \text{ [PLN/t]}$$

Due to high accuracy of the method of computing the correctness of the optimisation test results depends on the accuracy of input data, i.e. technical-technological and economic data relating to individual system objects. Creating a database describing individual objects of the system is crucial for updating and verification of existing, or newly designed systems. The possibility of implications of the model presented in this work for other regions.

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