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## MONTE CARLO SIMULATION ON INTEGRATED WASTE MANAGEMENT SYSTEMS – SMID – APPLICATION

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**Abstract:** Commitments agreed to join the EU waste management sector is a difficult, long-term. Therefore, to achieve those goals, Romania needs the longest transition period (until 2017). Theoretical approaches related to waste management are numerous. We believe that the waste management practices requires several improvements, which entails better management, which will have positive consequences on both environmental and financial effort of every citizen. The paper presents an application of Monte Carlo simulation in waste management.

**Key words:** Waste management system, Monte Carlo simulation, Statistics on waste, probability theory, distribution (Student).

### 1. INTRODUCTION

From research we found that most companies/operators are conducting a management that could be improved by using the existing volume of data in the firm itself. Applying a better management can have serious long-term positive economic and organizations effect on both the urban and rural population. Within the organization that collects municipal waste a number of special vehicles for waste collection have been received. These, depending on the route, agents skill and quality of the waste collected allows for different delivery of concrete results. Number of waste containers collected per day of various teams and various routes was checked by sampling. The results were recorded for 100 cases. All teams used the same special vehicles for waste collection.

### 2. INFORMATION

Collection routes remained unchanged, but the teams were sent on different tracks in rotation. So that while monitoring it can be said that all teams were on all routes. Also,

collection frequencies remained unchanged, order not to intervene situations that require a much different volume of waste collection from the normal work. It can be said that during the test period working conditions were similar for all work teams. The results obtained were centralized in a table and are presented in Table nr. 1.

Table 1.

**Statistic data collected related on work teams performance.**

Number of waste containers collected per day [pieces]	Number of cases
120	2
200	5
220	11
280	15
320	20
410	15
450	12
490	13
520	5
590	2

The organization wants to know the performance over time in order to properly size the number of special vehicles required and the number of workers (work teams) and to

appreciate the work rules. In this way, in the future will be able to assess the effectiveness of work teams and will be able to identify abnormal situations occurring during activity. In this way the quality of management will increase significantly. When changing working conditions or other variables change, procedure can be repeated for the correct estimation of the

average and extreme values the normal range of variation (normal maximum amplitude). These can be determined by the Monte Carlo simulation method. Performance evaluation is done based on concrete observation.

We calculate the probability and cumulative probability. Calculations are summarized in Table 2.

Table 2

**Centralization probability calculations of statistical data collected**

Nr.crt.	Number of waste containers collected per day [pieces]	Probability of occurrence	Cumulated probability
1	120	0,02	0,02
2	200	0,05	0,07
3	220	0,11	0,18
4	280	0,15	0,33
5	320	0,20	0,53
6	410	0,15	0,68
7	450	0,12	0,80
8	490	0,13	0,93
9	520	0,05	0,98
10	590	0,02	1,00

### 3. APPLYING THE MONTE CARLO SIMULATION

Remove 20 random numbers between 0 and 1. This can be done one non-random number table or by mathematical methods (random number generators). We calculate the average ( $\bar{X}$ ) standard deviation ( $\sigma^2$ ), deviation coefficient of variation Cv and the confidence interval ( $1-\alpha$ ). In concrete cases of

business / industry we can extract a larger number of random numbers.

In the Monte Carlo method, number of attempts varies inversely with the probability. Monte Carlo method is not adapted for studies processes with very small probability. For an integrated waste management system (Smid) this method can be successfully applied. Calculation based on simulation evolution studied phenomenon is centralized in Table 3.

Table 3

**Table 3. Calculation of studied phenomenon in basis of simulation with random numbers**

Nr.crt.	Random number	Number of waste containers collected per day [pieces]	$x_i - \bar{X}$	$(x_i - \bar{X})^2$
1	0,0317	200	-174,5	30.450,25
2	0,9369	520	145,5	21.170,25
3	0,3406	320	-54,5	2.970,25
4	0,0200	120	-254,5	64.770,25
5	0,9650	520	145,5	21.170,25
6	0,6568	410	35,5	1.260,25
7	0,7571	450	75,5	5.700,25
8	0,6174	410	35,5	1.260,25
9	0,1511	220	-154,5	23.870,25
10	0,0306	100	-174,5	30.450,25
11	0,2333	280	-94,5	8.930,25
12	0,6603	410	35,5	1.260,25
13	0,5447	410	35,5	1.260,25
14	0,9134	490	115,5	13.340,25

15	0,7861	450	75,5	5.700,25
16	0,6969	450	75,5	5.700,25
17	0,9277	490	115,5	13.340,25
18	0,2388	280	-94,5	8.930,25
19	0,5773	410	35,5	1.260,25
20	0,6971	450	75,5	5.700,25
		7.490		268.495,00

Our calculations indicates following values for the main statistical indicators needed in calculation:

$$\text{the average, } \bar{X} = \frac{7.490}{20} = 374.5 \quad (1)$$

$$\text{deviation } \sigma^2 = \frac{268.495}{20} = 13.424,75 \quad (2)$$

$$(\sigma = 115,86)$$

Coefficient of variation

$$C_v = \frac{115,86}{374,5} = 0,309 \quad (3)$$

N = 20 (number of experiments considered);

G = N-1 ; g= 19 (degrees of freedom);

$\alpha = 0,05$  (significance level or tolerable error);

$(1 - \alpha) = 0,95$  (confidence level);

To check the hypothesis on the average number of waste containers collected is used t-distribution (Student).

Limits that indicates the amount of waste containers that can be collect in a day is given by the expression:

$$\bar{X} \mp t_{\alpha/2, N-1} * \frac{\sigma}{\sqrt{N}} \quad (4)$$

Value  $t_{\alpha/2, 19} = 2,093$  was taken from the table

Student (distribution of the values of the degrees of freedom). Substituting the above expression we obtain the value limits 320 and 428.

#### 4. CONCLUSION

With the new special vehicles for waste collection, teams will work and normally collect between 320 and 428 waste containers per day. This statement is made with a probability of 95%. Situations where work teams will register values that are not in this

range represents a 95% probability of abnormal, will be investigated. In this way management activities will be improved or at least maintained at a certain level.

Probability theory suggests that the average will be more accurate if it is based on the results of a larger number of simulation experiments.

Our proposed method is relatively simple and can be easily integrated into procedures of a Integrated Waste System Management.

Similarly, Monte Carlo simulation method may be applied to other activities related to waste management that includes:

- amount of waste processed manually sort within sorting stations;
- final volume of land filled waste;
- percentage of various waste materials composition;
- time of making in/out documents of amount of waste arriving at the storage;
- time needed for customer service (special vehicles entering the deposit, are weighed, conducted on a particular route, waiting to unload, then comes the cleaning operation, return to weighing after leaving the deposit to make a new transport etc.

#### 5. REFERENCES

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**Simularea Monte Carlo în sisteme de management integrat a deșeurilor  
SMID – aplicație**

**Rezumat:** Îndeplinirea angajamentelor asumate la aderarea în UE în sectorul de management al deșeurilor este o sarcină dificilă, pe termen lung. Nu întâmplător pentru realizarea respectivelor obiective sunt cele mai lungi perioade de tranziție (până în 2017). Abordările teoretice referitoare la managementul deșeurilor sunt numeroase. Considerăm că la nivelul practicilor de gestionare a deșeurilor este nevoie de mai multe îmbunătățiri, care să atragă după sine un management mai performant, care va avea consecințe pozitive atât asupra mediului cât și asupra efortului financiar a fiecărui cetățean. Articolul prezintă o aplicație a simulării Monte Carlo în managementul deșeurilor.

**Cuvinte cheie:** Sistem de management al deșeurilor, simulare Monte Carlo, gestiunea deșeurilor, managementul deșeurilor

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