Response Surfaces Model For Optimization of Solid Waste Management

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***Abstract*—In this paper a response surface model (RSM) was established and numerical simulations were performed to study the impact factor for optimization of solid waste management. The effects of three parameters such as fuel consumption, total workforce, and volume of transport were investigated. According to the statistics presented, municipality of Sari's expenditure for workers' salary and fuel for vehicles to transport the waste was US$71,680 in fall 2009. In addition, the value of machinery used in this period was US$197,050. According to the predictions done, generation of solid waste will be 25147 ton in spring 2011. By using the response surface 2FI model, the cost of labor and fuel for machinery will decrease to US$55606 and also the capital value of machinery used in this section will be US$136,615.**

***Index Terms*—response surfaces model, optimization cost, municipal solid waste management, Two factor integration.**

I. Introduction

Municipal solid waste management (MSWM) is one of the critical environmental challenges of quick urban development that developing countries, including Iran, face.

One of the most complicated problems of human society is the production of solid waste materials in different quantities and of varied quality. Establishing a management system of collecting and disposing the solid waste materials is of remarkable importance for the purpose of control of production and consumption, and the process of garbage collection and disposal. The collection and transportation of solid waste in urban areas is a very hard and complicated problem. Collection and transportation of solid waste often accounts for a substantial percentage of the total waste management budget (including labor costs). Therefore, even a small improvement in the collection operation can result in an important saving in the overall cost. The total cost of the solid waste management system included the transportation cost of the waste to different facilities such as transfer stations, landfills, and incinerators and also the operational and fixed costs of these facilities.

II. Methodology And Data Analysis

Response surface methods (RSMs) display the statistical plan of experiment (DOE) tools that direct to peak at procedure performance. RSM produces precise maps based on the mathematical pattern. The initial task in analyzing the response surface is the approximation of the parameters of the model by the least-squares regression and to acquire information about the fit in the form of ANOVA. Of specific importance are the values of Fisher variance ratio (F-ratio) and the coefficient of determination (R^2). In many RSM mechanisms it is suitable to transform the normal variables to coded variables, x_1x_2, x_3… x_k which are more often than not defined to be dimensionless with signify zero and the same standard deviation. In conditions of the coded variables, the response function will be written as:

$$Y = f(x_1, x_2, x_3, \ldots, x) \quad (2.1)$$

This is the first-order model with mutual action. Addition the interaction term introduces curvature into the response function. Frequently, the curvature in the factual response surface is strong enough that the first-order model (even with the interaction term included) is insufficient. A second-order model will likely be necessary in these situations. For the case of two variables, the second-order model is:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

This model would likely be helpful as an approximation to the factual response surface in a relatively small region. The second-order model is extremely supple. It can receive a broad variety of functional forms, so it will frequently work well as an estimate to the true response surface. It is also simple to approximate the parameters (theβ's) in the second-order model. The method of the least-squares model can be used for this purpose. The effect of four independent variables, x_1(personnel), x_2 (4 ton van) and x_3 (7 ton lorry) and x_4 (10 ton lorry) on one response variables (Y_1, solid waste in the seasonal) and (Y_2, cost of collection and transfer solid waste) was evaluated by using the response surface methodology. Experiments were randomized in arrangement to minimize the effects of unexplained variability in the actual responses due to extraneous factors.

III. Results And Discussions

In this research, multiple regression analyses were carried out using response surface analysis to fit mathematical models to the experimental data aiming at an optimal region for the response variables studied and to define the relationship between four independent variables and the criteria of two response variables. The response surface analysis allowed the development of an empirical relationship where each response variable (Y_1 and Y_2) was assessed as a function of x_1(personnel), x_2 (4 ton van), x_3 (7

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ton lorry), and x_4 (10 ton lorry), and predicted as the sum of constant (β0), four first-order effects (interactive terms in X_1, X_2, X_3, X_4, $X_1 X_4$, $X_2 X_3$, $X_2 X_4$ and $X_3 X_4$). The obtained results were analyzed by ANOVA to assess the "goodness of fit" .Only terms found statistically significant ($p<0.05$) were included in the reduced model. As shown in Equation 4.1, the obtained model for predicting the response variables explained the main quadratic and interaction effects of factors affecting the response variables.

Values of "Prob > F" less than 0.0500 indicated model terms are significant. In this case X_1, X_2, X_3, X_4, $X_1 X_4$, $X_2 X_3$, $X_2 X_4$ and $X_3 X_4$ are significant model terms.

Values greater than 0.1000 indicate the model terms are not significant.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

The probability (p) values of all regression models were less than 0.05, which had no indication of lack of fit. The $-R^2$ values for these response variables were higher than 0.80 (0.9297), thus ensuring a satisfactory fitness of the regression models to the experimental data. The following response surface models (Equation 4.1) were fitted to the response variable ($Y1$) four independent variables (X_1, X_2, X_3 , X_4, and six interaction effects interactive terms in X_1X_2, X_1X_3, $X_1 X_4$, $X_2 X_3$, $X_2 X_4$ and $X_3 X_4$).

Y_1= -7239.46 + 5911.56 - 4176.22 + 29247.42 -7171.18 + 19258.19 -56014.68 + 4250.32 + 4707.90 + 29566.96
(3.1)

The observed points on these plots reveal that the actual values are distributed relatively near the straight line in this case ($R^2 = 0.9297$). So far, based on the existing facilities and other parameters that were mentioned and according to 2FI model, the best use of machinery and manpower for displaying the minimum price in collection management and transport waste is presented in Table 3-1.

TABLE 3-1 NUMBER OPTIMIZATION-SET GOALS FOR EACH RESPONSE

Number	Personal	Van 4 Tone	Lorry7 Ton	Lorry10 Ton	Solid Waste	Cost US.$	Desirability
1	1334	1416	1065	481	25147	58702	1
2	1442	1132	1280	626	25193	62628	1
3	1194	672	1486	964	25179	63525	1
4	1252	1911	500	1198	25198	67526	0.840395

IV. CONCLUSION

The most significant and unique part of this model is that for the first time cost optimization of solid waste management has been done by the statistical analysis of response surface two-factor integration model and also combining the amount of generated waste, fuel consumption, total labor force and quantity and quality of transport as input data.

According to statistics presented, the amount that the municipality of Sari spent for workers salary, fuel and vehicles for transporting waste was US$71,680 in fall 2009. In addition, the value of machinery used in this section is equivalent to US$197,050. According to prediction done, generation of solid waste will be 25,147 ton in spring 2011. Using response surface 2FI model, the costs of labor, machinery, and fuel consumption can be decreased to US$55,606 and the capital value of machinery used in this section will be US$136,615.

REFERENCES

[1] A.M El-Hamouz,. Logistical management and private sector involvement in reducing the cost of municipal solid waste collection service in the Tubas are of the West Bank. Waste Management, 28, 2008,260–271.
[2] E Ericsson,., H.Larsson, , K.Brundell-Freij,. Optimizing route choice for lowest fuel consumption – potential effects of a new driver support tool. Transportation Research Part C: Emerging Technologies 14 (6), 2006,369–383.
[3] O.M Johansson. The effect of dynamic scheduling and routing in a solid waste management system. Waste Management 26, ., 2006,875–885.
[4] N.Karadimas, , K.Papatzelou, & V.Loumos, Optimal solid waste collection routes identified by the ant colony system algorithm. Waste Management & Research, 25, 2007 ,139–147.
[5] B-In Kim, , S.Kim, , S.Sahoo,. Waste collection vehicle routing problems with time windows. Computers and Operations Research 33, 2006, 3624–3642.
[6] J.V. Lopez, M.Aguilar, S.Fernández-Carrión, & A.Jiménez del Valle, Optimizing the collection of used paper from small businesses through GIS techniques: the Leganés case (Madrid, Spain). Waste Management, 28, 2008,282–293.
[7] A.Magrinho, , V.Semiao, ,. On the effect of MSW moisture content on meeting target recycling rates. Waste Management 28, 2008,310–317.
[8] H.Mirhosseini, , C. P.Tan, , N. S. A.Hamid, , & S.Yusof,. Solidphase microextraction for determining twelve orange flavour compounds in a model beverage emulsion. Phytochemical Analysis, 105, 2007,1659–1670.
[9] B.Mrayyan, , M.R.Hamdi, Management approach to integrated solid waste in industrialized zones in Jordan: a case of Zarqa City. Waste Management 26, 2006,195–205.
[10] B,Nadi ,A.Rodzi , A. Sharif, A.Noordin Use of geospatial technology for landfill site selection. Journal of Environment and engineering .volume 3 .no 9.USA(2009).