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JUNK CAR PROBLEM

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1. Background

Worn-out and unusable trash automobiles, trucks, and miscellaneous other powered vehicles, henceforth called „Junk Cars“, have been collecting throughout the Czech Republic for some years, becoming both a public nuisance and an eyesore. It is appropriate to consider organized methods to control, if not outright eliminate, this situation.

2. Solution

An appealing possibility is the establishment, at suitable locations, of facilities devoted to the dismantling of Junk Cars and preparation of their salvageable components and materials for recycling; this could include salable used parts as well as raw materials such as steel, copper, glass, and rubber. It might be expected that in due course of time a profit/centered industry would develop independently to address these ends. Even so, a case can be advanced for the formal study of this problem, with the objective of outlining a system with less overall grief and total expense ... than might be expected if the job is left to market forces alone.

3. Elements

The overall Junk Car problem is perceived to consist of the following elements.

- a) Identify the location for potential recycling facilities, henceforth called Recycling Centers. This will involve economic, engineering, and environmental impact studies of the possible locations, as well as the differing setup costs which may be expected to be involved.

- b) Asses the quantity of Junk Cars in inventory at all Junk Car accumulation sites ... both large and small ... throughout the country, as well as econometric assessment of the accumulation-rate of Junk Cars into the future. In addition, a determination should be made of the unit cost of transporting Junk Cars from the various sites to each of the proposed recycling centres. This determination (in naive form) could involve no more than a table of the distances involved; compounding such a table could range from a practical "common sense" approach to the solution of a formal mathematical problem.
- c) Determination of the "production horizon " for the recycling centres. This will necessitate the specification of a target date when the recycling process should reach statistical equilibrium, and will (of necessity) include a schedule for the processing of Junk Cars accumulated to date. (Mathematical models developed for epidemiological purposes may be helpful to this latter and.)
- d) Determine which of the potential sites for the construction of recycling centres should (in fact) be established, and develop a schedule for the construction sequence. The first problem is solvable via Mathematical Programming Techniques, while the second could involve similar methodology, together with addressing the financial and legalistic issues which attend all construction tasks.

4. A small problem of "Junk car" form

Let there be $S=7$ „source site“ of junk cars and $R = 3$ potential locations for their dismantlement, which we term „processing centres“. Table 1 lists these sites and the cost of transporting one car from each to the different processing centres, as well as the supply of junk cars at each source location.

Table 1

Source	Cost to site			Supply
	1	2	3	
1	1	2	3	10
2	2	2	6	15
3	4	2	5	12
4	5	1	2	22
5	6	3	2	29
6	6	4	1	18
7	2	4	3	16

Table 2 lists the 3 processing centres, together with their costs of set up (or establishment), and their processing capacities if established.

Table 2

Processing Centre	Setup Cost	Capacity
1	150	50
2	160	60
3	170	70

For $i=1$ to 7 and $j=1$ to 3 let x_{ij} denote the number of junk cars which are directed from Source Site i to Processing Centre j . For $j=1$ to 3 let $y_j=1$ indicates that Processing centre j is established and $y_j=0$ indicates that Centre j is not established. Then the algebraic form of the

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problem of transporting the junk cars at the various sources to the processing centres at minimum total cost can be expressed as the following fixed/cost integer/programming problem.

Minimize:

$$150y_1 + 160y_2 + 170y_3 + x_{11} + 2x_{12} + 3x_{13} + 2x_{21} + 2x_{22} + 6x_{23} + 4x_{31} + 2x_{32} + 5x_{33} + 5x_{41} + x_{42} + 2x_{43} + 6x_{51} + 3x_{52} + 2x_{53} + 6x_{61} + 4x_{62} + x_{63} + 2x_{71} + 4x_{72} + 3x_{73}$$

subject to the conditions that all of the junk cars are processed:

$$\begin{aligned} x_{11} + x_{12} + x_{13} &= 10 & x_{21} + x_{22} + x_{23} &= 15 \\ x_{31} + x_{32} + x_{33} &= 12 & x_{41} + x_{42} + x_{43} &= 22 \\ x_{51} + x_{52} + x_{53} &= 29 & x_{61} + x_{62} + x_{63} &= 18 \\ x_{71} + x_{72} + x_{73} &= 16 \end{aligned}$$

and no processing capacity is exceeded:

$$\begin{aligned} 50y_1 - x_{11} - x_{21} - x_{31} - x_{41} - x_{51} - x_{61} - x_{71} &\geq 0 \\ 60y_2 - x_{12} - x_{22} - x_{32} - x_{42} - x_{52} - x_{62} - x_{72} &\geq 0 \\ 70y_3 - x_{13} - x_{23} - x_{33} - x_{43} - x_{53} - x_{63} - x_{73} &\geq 0 \end{aligned}$$

together with all $x_{ij} \geq 0$ and integer and all $y_j = 0$ or 1.

5. Solution

The solution to this problem, expressed in terms of the nonzero variables (only), is:

$$\begin{aligned} y_2 &= 1, y_3 = 1 \\ x_{12} &= 10, x_{22} = 15, x_{32} = 12, x_{42} = 22, x_{53} = 29, x_{63} = 18, \\ &\text{and } x_{73} = 16. \end{aligned}$$

All other variables equal zero. This solution achieves minimum Cost, at the value 550.

To the solution of the problem was used Linear, Interactive and Discrete Optimizer - LINDO, which enables to solve linear, integer, and quadratic programming models. Given the explicit algebraic formulation of the problem the commands GIN 24 and INTEGER 3 (in this order) set the integer requirements. An automatic solution needs to transfer the algebraic statements into MPS Format. The above problem in MPS format is given on the next page, and is printed for brevity in double columns. Also, certain trailing zeros have been provided for cosmetic effect. Comparison of the MPS format with algebraic statement of the problem shows how a larger problem can be prepared by program and/or word processor for importation into LINDO and automatic solution.

Junk Car Problem solution by LINDO

NAME LINDO GENERATED MPS FILE (MIN)

ROWS						
N1				X41	1	5.00
E2				X41	1	5.00
E3				X42	1	1.00
E4				X42	5	1.00
E5				X42	10	-1.00
E6				X43	1	2.00
E7				X43	5	1.00
E8				X43	11	2.00
G9				X51	1	6.00
G10				X51	6	1.00
G11				X51	9	-1.00
COLUMNS				X52	1	3.00
INTEGER1 'MARKER' 'INTROG'				X52	6	1.00
Y1	1	150.0		X52	10	-1.00
Y1	9	50.0		X53	1	2.00
Y2	1	160.0		X53	6	1.00
Y2	10	60.0		X53	11	-1.00
Y3	1	170.0		X61	1	6.00
Y3	11	70.0		X61	7	1.00
INTEGER2 'MARKER' 'INTROG'				X61	0	-1.00
X11	1	1.00		X62	1	4.00
X11	2	1.00		X62	7	1.00
X11	9	-1.00		X62	10	-1.00
X12	1	2.00		X63	1	1.00
X12	2	1.00		X63	7	1.00
X12	10	-1.00		X63	11	-1.00
X13	1	3.00		X71	1	2.00
X13	2	1.00		X71	8	1.00
X13	11	-1.00		X71	9	-1.00
X21	1	2.00		X72	1	4.00
X21	3	1.00		X72	8	1.00
X21	9	-1.00		X72	10	-1.00
X22	1	2.00		X73	1	3.00
X22	3	1.00		X73	8	1.00
X22	10	-1.00		X73	11	-1.00
X23	1	6.00		RHS		
X23	3	1.00		RHS	2	10.00
X23	11	-1.00			3	15.00
X31	1	4.00			4	12.00
X31	4	1.00			5	22.00
X31	9	-1.00			6	29.00
X32	1	2.00			7	18.00
X32	4	1.00			8	16.00
X32	10	-1.00		BOUNDS		
X33	1	5.00		UP LINBOBD	Y1	1.00
X33	4	1.00			Y2	1.00
X33	11	-1.00			Y3	1.00
X41	1	5.00				

References

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Resumé

PROBLÉM OJETÝCH VOZŮ

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Přístupy k řešení problému alokace a lokace recyklačních center pro „ojetá“ vozidla v prostoru České republiky vycházejí z aktuálního stavu, předpokládaného vývoje a zamýšleného cílového stavu. Současný stav likvidace opotřebovaných vozidel v ČR není příliš povzbuzující. Článek je příspěvkem k diskusi o možnostech analytického řešení lokalizace recyklačních středisek a modelování systému likvidace ojetých osobních i nákladních automobilů.

Summary

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The approach to the allocation/location problem solution of the recycling centres of used cars in the Czech Republic issues from the actual state, presumed development and designed target state. The actual state of used cars treatment in the CR is not very encouraging. The article presents the contribution to the discussion of analytical possibilities of recycling centres location and used personal cars and lorries treatment system modelling.

Zusammenfassung

DAS PROBLEM ABGEFAHRENE FHRZEUGE

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Die Einstellungen zur Lösung des Allokationsproblems und die Verteilung der Recyclingzentren für abgefahrne Fahrzeuge in Tschechischen Republik gehen von Zustand, voraussetzene Entwicklung und gedankte Zielstand aus. Der Zustand von Liquidierung abgefahrenen Fahrzeuge in CR ist nicht anregend. Der Artikel ist ein Beitrag zur Diskussion über Möglichkeiten der analytischen Lösungen von Verteilung Recyclingzentren und Modellierung des Liquidierungssystems der abgefahrenen PKW und LKW.