Scheduling the Tour of a Marketing Executive

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Abstract

This paper addresses the problem of scheduling the tour of a marketing executive (ME) of a large electronics manufacturing company in India. Based on our observations of this problem in the company and the various personnel scheduling problems addressed in the literature, we realize that the scheduling (a personnel scheduling) problem taken up in this study seems to be quite different from the various personnel scheduling problems addressed in the literature. In this paper the tour scheduling problem of the ME is modeled using (0-1) goal programming (GP). The (0-1) GP model for the data provided from the company for one month has 802 constraints and 1167 binary variables. The model is solved using LINDO software package. The model takes less than a minute (on a 1.50 MHz Pentium machine with 128 MB RAM) to get a solution of the non-pre-emptive version and about 6 days for the pre-emptive version. The main contribution is in problem identification and development of the mathematical model for scheduling the tour of a marketing executive.

1. Introduction

In this paper, we consider the problem of scheduling the tour of a marketing executive of a large electronics manufacturing company in India. Based on our observations of this problem in the company and the various personnel scheduling problems addressed in the literature, we felt that this problem differs significantly compared with many other personnel scheduling problems addressed so far in the literature. This type of personnel scheduling problem can be observed in many other situations such as periodical visits of inspection officers, tour of politicians during election campaigns, schedule of mobile courts, schedule of mobile stalls in various areas, etc.

The paper is organized as follows: Section 2 presents the problem statement and assumptions. Section 3 provides a related review for the problem. Section 4 describes the development of a mathematical model for the problem stated in section 2. Section 5 presents an application of the model to the data from the company. Finally section 6 presents some concluding remarks and directions for future work.

2. Problem Statement

The problem of tour scheduling of a marketing executive (ME) of a company may be stated as follows. We are given a set of regions $\boldsymbol{R} = \{r_1, r_2, \ldots. r_m\}$ having a number of customers in a city. Each region $\boldsymbol{r_i}$ is covered by one marketing executive. The ME assigned to each region has to visit all the customers clustered in the region periodically for continuously increasing the business interactions between the customers and the company. The number of effective working days for ME in a given planning period is accounted after excluding the holidays of the company and the days in which the ME has to make full-day visits to head-office. For each ME, the head-office visit-days vary, except the last visit, in the planning period. All the marketing executives assemble at the head-office during their last head-office visit towards the end of planning period for a common discussion on the business strategy. Accordingly, for every planning period and for every ME, the set of days not scheduled for customer visits is $\boldsymbol{M}$ = {holidays for the company, holidays for individual customers, days for full-day visits to head-office}.

Each region has a set of customers $\boldsymbol{C} = \{c_1, c_2, \ldots. c_n\}$ and each customer has different level of business transactions with the company. Accordingly, based on the business transactions with the company, the customers are classified as A-type, B-type and C-type, which is similar to ABC-inventory classification. Thus class A customers have a highest level of business transaction in the company, followed by Class B and C customers. As per the policy of the company, the number of visits made by the ME to a customer is directly proportional to the customer's level of business transaction. That is, the ME should visit class A customer more number of times in a given planning period compared to the number of visits to class B and C customers. Thus, if ME has to visit each A-type customers $\boldsymbol{N_A}$ times, each B-type customers $\boldsymbol{N_B}$ times and each C-type customers $\boldsymbol{N_C}$ times in the planning period then $\boldsymbol{N_A} > \boldsymbol{N_B} > \boldsymbol{N_C}$. As per the policy on each customer's number-of-visits, the company puts a condition that the ME has to maintain an appropriate time-interval between the consecutive visits of any customer in the planning period. The time-interval between the consecutive visits is a function of effective number of working days available for the ME in the planning period and number of required visits to a customer. In addition to the time-interval condition, the company specifies upper and lower bounds on the number of customer to be visited per day.

As the company divides logistically their customers in the city into a multiple regions and one ME is assigned to each region for the continuous and efficient development of their business with customers, in this paper, we are addressing the scheduling of the tour of a single ME.

Assumptions

- There are no restrictions/limitations in moving from one customer to another.
- The time and cost of traveling from one customer to another is not explicitly incorporated.
- The working hours and pattern (if any) remain the same for both customer and ME of the company.
- The emergency requirement of any customer is not addressed.
- The policy decisions of the management of the customers such as type of customer, number of visits of a customer, etc., do not change during the planning period.
- Natural calamities are not accounted for in the solution development.
- The model specifies the customers to be visited by the ME on any working

day, but does not specify the sequencing of the customers.

- The total number of visits required by all the customers in the planning period should be less than or equal to the total number of trips expected to be made by the ME in the planning period.

3. Related Work

Personnel or staff or tour scheduling problems have been studied for many years (Alfares, 2004). These scheduling problems cover many areas, such as the tour scheduling problem in a post office setting (Bard et al. 2003), scheduling personnel in a newspaper publishing environment (Gopalakrishnan et al. 1993), the transportation staff scheduling (Wren and Wren, 1995), scheduling of cashiers in a supermarket (Melachrinoudis and Olafsson, 1995), nurse rostering problem (Burke et al, 2001;), audit staff scheduling (Dodin et al. 1998), educational institute staff scheduling (Schaerf, 1999), airline crew-scheduling (Emden-Weinert and Proksch, 1999), scheduling a sales summit (Cowling et al., 2000), scheduling of laboratory personnel (Boyd and Savory, 2001) and scheduling pharmaceutical sales representatives (Hertel and Gautam, 2004). However, the scheduling of the visits of a ME (a tour scheduling) problem taken up in this study seems to be significantly different from the various personnel scheduling problems addressed in the literature.

Goal programming (GP) has received a great deal of attention among optimization techniques in personnel scheduling as it attempts to address multiple objectives simultaneously such as maximizing utilization of full-time staff, minimizing understaffing and overstaffing costs, minimizing payroll costs, as well as minimizing deviations from desired staffing requirements, customer special requests, staff preferences, and staff special requests [example: Azaiez and Sharif (2005)]. Thus, the problem of designing the schedule of visits of a ME is formulated as a (0-1) goal programming.

4. Goal Programming Model for Scheduling the Visits of a ME

Notation

i stands for Customer i

j stands for Day j, $j = 1, 2, \ldots, N$.

N = Number of days in the planning period

I = Maximum number of customers in the cluster (Without loss of generality, let us assume that the first I_A customers are Class A customers, the next I_B customers are Class B customers, and the next I_C customers are Class C customers. Thus, $I_A + I_B + I_C = I$.)

N_A = Number of days the ME should visit Class A customer in a given period

N_B = Number of days the ME should visit Class B customer in a given period

N_C = Number of days the ME should visit Class C customer in a given period

T_A = Time-interval between consecutive visits by the ME to Class A customers
= Integer value of the ratio (N/N_A)

T_B = Time-interval between consecutive visits by the ME to Class B customers
= Integer value of the ratio (N/N_B)

T_C = Time-interval between consecutive visits by the ME to Class C customers
= Integer value of the ratio (N/N_C)

M = {Holidays for the company, Holidays for the individual customers, Days in which the ME has to make a full-day visits to head-office}

$MinVisit$ = Minimum number of Customers the ME should visit every day

MaxVisit = Maximum number of Customers the ME should visit every day

Decision variable: x_{ij} = 1 if the ME visits Customer *i* on Day *j*; 0 otherwise

Soft Constraints

As per the policies of the Company, the ME is required to visit different classes of customers at a certain frequency (constraints 1-3).

$$\sum_{k=0}^{T_A} x_{i,j+k} \approx 1, i = 1,2,\cdots I_A, j = 1,2,\cdots N - T_A, j \notin \mathrm{M} \qquad (1)$$

$$\sum_{k=0}^{T_B} x_{i,j+k} \approx 1, i = I_A + 1, I_A + 2,\cdots I_B, j = 1,2, \cdots N - T_B, j \notin \mathrm{M} \qquad (2)$$

$$\sum_{k=0}^{T_C} x_{i,j+k} \approx 1, i = I_B + 1, I_B + 2,\cdots I_C, j = 1,2, \cdots N - T_C, j \notin \mathrm{M} \qquad (3)$$

Hard Constraints

Constraints 4-6 below are used to ensure that the ME makes the required number of visits per planning period for different classes of customers as specified by the Company.

$$x_{i,1} + x_{i,2} + \cdots + x_{i,N} = N_A, i = 1,2,\cdots I_A \qquad (4)$$

$$x_{i,1} + x_{i,2} + \cdots + x_{i,N} = N_B, i = I_A + 1, I_A + 2,\cdots I_B \qquad (5)$$

$$x_{i,1} + x_{i,2} + \cdots + x_{i,N} = N_B, i = I_A + 1, I_A + 2, \cdots I_B \qquad (6)$$

The ME should visit a minimum number of customers on any single working day (Constraint 7)

$$\sum_{i=1}^{I} x_{i,j} \geq MinVisit,\ j = 1,2,\cdots N, j \notin M \qquad (7)$$

The ME should not visit more than a maximum number of customers on any single working day (Constraint 8)

$$\sum_{i=1}^{I} x_{i,j} \leq MaxVisit,\ j = 1,2,\cdots N, j \notin M \qquad (8)$$

Because of the approximate nature of the constraints (1-3), there is a possibility that the visits by the ME to the same customer may be scheduled frequently (for example on two consecutive days), and hard constraints (9-11) are written to overcome this possibility.

$$\sum_{k=0}^{T_A - 1} x_{i,j+k} \leq 1, i = 1,2,\cdots I_A, j = 1,2,\cdots N - T_A + 1 \qquad (9)$$

$$\sum_{k=0}^{T_B - 1} x_{i,j+k} \leq 1, i = I_A + 1, I_A + 2,\cdots I_B, j = 1,2, \cdots N - T_B + 1 \qquad (10)$$

$$\sum_{k=0}^{T_C - 1} x_{i,j+k} \leq 1, i = I_B + 1, I_B + 2,\cdots I_C, j = 1,2, \cdots N - T_C + 1 \qquad (11)$$

Formulating Goals

Goal 1: It minimizes the sum of deviational variables corresponding to the soft Constraint 1 (approximately one visit to Class *A* customers for every L_A +1 working days).

$$\sum_{k=0}^{T_A} x_{i,j+k} + d_{i,j}^{+} - d_{i,j}^{-} = 1, i = 1,2,\cdots I_A, j = 1,2, \cdots N - T_A, j \notin \mathrm{M} \qquad (12)$$

Goal 2: It minimizes the sum of deviational variables corresponding to the soft Constraint 2 (Class *B* customers).

$$\sum_{k=0}^{T_B} x_{i,j+k} + d_{i,j}^{+} - d_{i,j}^{-} = 1, i = I_A + 1, I_A + 2,\cdots I_B, j = 1,2,\cdots N - T_B, j \notin \mathrm{M} \qquad (13)$$

Goal 3: It minimizes the sum of deviational variables corresponding to the soft Constraint 3 (Class *C* customers).

$$\sum_{k=0}^{T_C} x_{i,j+k} + d^{+}_{i,j} - d^{-}_{i,j} = 1,\ i = I_B + 1, I_B + 2, \cdots I_C,\ j = 1,2,\cdots N - T_C,\ j \notin \mathrm{M} \qquad (14)$$

Assigning Importance Weights: Importance levels of Goals 1, 2 and 3 can be assigned as per the company policy. As stated earlier, Class A customers are the most important and hence Goal 1 should have the highest level of importance. Importance level decreases to Class B and to Class C customers.

GP objective function: In GP for the problem addressed here, two different ways of specifying importance level are available – pre-emptive and non-preemptive [13]. Both the ways have been attempted in this study.

*Pre-emptive GP**:*** In pre-emptive GP, priority levels P_1, P_2 and P_3 are assigned to Goals 1, 2 and 3 respectively with $P_1 >>> P_2$, and $P_2 >>> P_3$. Accordingly, the objective function minimizes the weighted sum of deviational variables corresponding to the goals.

$$\text{Minimize} \quad P_1\left(\sum_{i=1}^{I_A}\sum_{j=1}^{N-T_A}\left(d^{+}_{i,j} + d^{-}_{i,j}\right)\right) + P_2\left(\sum_{i=I_A+1}^{I_B}\sum_{j=1}^{N-T_B}\left(d^{+}_{i,j} + d^{-}_{i,j}\right)\right) + P_3\left(\sum_{i=I_B+1}^{I_C}\sum_{j=1}^{N-T_C}\left(d^{+}_{i,j} + d^{-}_{i,j}\right)\right) \qquad (15)$$

*Non-pre-emptive GP**:*** In non-pre-emptive GP, the importance levels of the goals are not pre-emptive but comparable to each other. Their magnitude gives implicit trade-off information about the achievements in terms of different goals. With the importance weights w_1, w_2 and w_3, the GP objective function can be written as follows.

$$\text{Minimize}\left(w_1 \times \sum_{i=1}^{I_A}\sum_{j=1}^{N-T_A}\left(d^{+}_{i,j} + d^{-}_{i,j}\right)\right) + \left(w_2 \times \sum_{i=I_A+1}^{I_B}\sum_{j=1}^{N-T_B}\left(d^{+}_{i,j} + d^{-}_{i,j}\right)\right) + \left(w_3 \times \sum_{i=I_B+1}^{I_C}\sum_{j=1}^{N-T_C}\left(d^{+}_{i,j} + d^{-}_{i,j}\right)\right) \qquad (16)$$

The full goal programming model: The pre-emptive GP model has Objective Function (14) and 11 Constraints (4-14). The non-preemptive GP model has Objective Function (16) and 11 Constraints (4-14).

5. Application and Results

In this section, the (0-1) GP model proposed in the previous section is solved based on the data from the company. The following data, shown in Table 1, are used in the (0-1) GP model.

- *Customer data*: customer code and the number of visits required by the customer
- *Planning horizon data*: number of days in the planning period (= one month), name and starting day of the month
- *Set of days in which the ME is not scheduled to visit customers*: {{Holidays for the company}, {Holidays for individual customers}, {General holidays}, {Days in which the ME has to make a full-day visit to head-office}}
- *Constraints on number of customers to be visited by ME per day*: minimum and/or maximum number of expected visits by the ME

For data presented in Table 1, the planning horizon is one month, the name of the month is January, the starting day of the month is 2, the set of days in which the ME is not scheduled to visit customers, M = {{2, 9, 16, 23, 30} (holidays for the company), {14} (general holidays), {4, 11, 18, 29} (days in which the ME has to make a full-day visit to head-office)}, and the minimum and maximum customers to be visited per day by the ME is 4 and 6 respectively. Note that holidays for individual customers vary depending upon the customer and is specified in Table 1.

The software LINDO [14] has been used to solve the (0-1) GP model developed in this paper in a 1.50 MHz Pentium IV Machine with 128 MB RAM. The (0-1) GP model for the data provided from the company for one month has 802 constraints and 1167 (0-1) variables.

The comparison of the solution based on the four versions of the (0-1) GP model for the company data in terms of (a) number violations of time-interval between consecutive visits of each type of customers and (b) computational time are obtained and presented in Table 2. The non-preemptive version with weights close to each other resulted in more violations for B type customers and lesser violations for C type customers (first row of the table) compared to the other non-preemptive weighting scheme (second row) and the preemptive version (third row). For the company data, the weighting scheme, “$w_1 = 25$, $w_2 = 10$ and $w_3 = 1$” in the (0-1) GP model resulted the same scheduling of the tour of a ME as resulted in preemptive version of (0-1) GP. It can be observed form Table 2 that computationally the non-preemptive (0-1) GP is simpler to solve than preemptive version.

Table 1. Customer’s Details

Customer		Number of Visits	Customer’s closure-day
Type	Code		
A	C10	8	Nil
	C11	8	{3,10,17,24,31}
	C09	8	Nil
B	C01	6	{5,12,19,26}
	C03	6	Nil
	C25	6	Nil
	C31	6	Nil
	C24	6	Nil
	C23	6	Nil
	C32	6	Nil
	C27	6	Nil
	C05	6	Nil
C	C26	4	Nil
	C02	4	Nil
	C21	4	Nil
	C22	4	Nil
	C06	4	Nil
	C07	4	Nil
	C39	4	Nil
	C08	4	Nil
	C30	4	Nil

Table 2. Computational Complexity

GP version	Customer type wise the Number of Violations in “Time-interval between consecutive visits”			Computational Complexity (Optimal solution : 1.50 MHz P4 with 128 MB RAM)	
	A	B	C	Time	Number of Iterations[#]
1	4	12	24	About 2 minutes	3606
2	4	11	26	About 2 minutes	101117
3	4	11	26	About 6 days	About 3 millions[#]
4	Even allowing the computer to run for 15 days, the model has not resulted the final optimal solution				

GP version: **1** – Non-preemptive with weights 3, 2, 1 respectively for A, B and C type customers; **2** - Non-preemptive with weights 25, 10, 1 respectively for A, B and C type customers; **3** –Preemptive without using the LINDO option GLEX; and **4** – Preemptive by using the LINDO option GLEX.

[#] This is approximate as LINDO does not print the number of iterations beyond 7 digits.

6. Conclusion

The main contribution of this paper is in problem identification and development of an appropriate mathematical model for scheduling the tour of a marketing executive. Furthermore, the company data used for demonstrating the proposed (0-1) GP model indicated that an appropriate weighting scheme for non-preemptive version is computationally simpler compared to the preemptive version in obtaining an efficient and fast solution for scheduling the tour of the ME.

An immediate extension of this problem is to explore the possibility to develop other solution approaches such as simple heuristics or meta-heuristics, to tackle the problem, as solving a very large size problem using (0-1) GP may become computationally intractable.

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7. References

[1] Azaiez, M.N., Al Sharif, S.S., (2005). "A 0-1 Goal Programming Model for Nurse Scheduling". *Computes and Operations Research, 32, 491-507.*

[2] Alfares, H. K., (2004). "Survey, Categorization, and Comparison of Recent Tour Scheduling Literature". *Annals of Operations Research, 127, 145-175.*

[3] Bard, J.F., Binici, C., deSilva, A.H. (2003). "Staff Schedulingt at the United States Postal Service". *Computers and Operations Research, 30, 745-771.*

[4] Boyd, J.C., Savory, J., (2001). "Genetic Algorithm for Scheduling of Laboratory Personnel". *Clinical Chemistry, 47(1), 118-123.*

[5] Burke, E. K., Cowling, P. I., De Causmaecker, P., Vanden Berghe, G., (2001). "A Memetic Approach to the Nurse Rostering Problem". *Applied Intelligence, 15, 199-214.*

[6] Cowling, P.I., Kendall, G., Soubeiga, E. (2000). "Hyperheuristic Approach to Scheduling a Sales Summit". *Springer LNCS vol. 2079, 176-190.*

[7] Dodin, b., Elimam, A. A., Rolland, E., (1998). "Tabu Search in Audit Scheduling". *European Journal of Operational Research, 106, 373-392.*

[8] Emden-Weinert, T., Proksch, M., (1999). "Best Practice Simulated Annealing for the Airline Crew Scheduling Problem", *Journal of Heuristics, 5, 419-436.*

[9] Gopalakrishnan, M., Gopalakrishnan, S., Miller, D.M. (1993). "A Decision Support System for Scheduling Personnel in Newspaper Publishing Environment". *Interfaces 23(4), 104-115.*

[10] Hertel, L., Gautam, N., (2004). "A Mathematical Programming Model for Scheduling Pharmaceutical Sales Representatives". *Proceedings of the Annual Industrial Engineering Research Conference,* Houston. http://www.ie.psu.edu/Faculty/Gautam/papers/lauren.pdf

[11] Melachrinoudis, E., Olafsson, M. (1995). "A Microcomputer Cashier Scheduling System for Supermarket Stores".

International Journal of Physical Distribution and Logistics, 25(1), 34-50.

[12] Schaerf, A., (1999). “Local Search Techniques for Large High School Timetabling Problems”. *IEEE Transactions on Systems, Man and Cybernetics Part A: systems and human, 29(1), 368-377.*

[13] Schniederjans, M. J., (1995). *Goal Program-Ming Methodology and Applications*, Kluwer Academic Publishers, Boston.

[14] Schrage, L., (1991). *LINDO – User’s Manual: Release 5.0.* The Scientific Press, CA, USA.

[15] Wren, A., Wren, D.O., (1995). “A Genetic Algorithm for Public Transport Driver Scheduling”. *Computers and Operations Research*, 22, 101-110.