A Multi-Objective Programming to Increase Labor Efficiency of a Truck Hub: A Case Study

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KEYWORDS	ABSTRACT
Staff Scheduling, Multi-Objective Programming, Labor Efficiency, Goal Programming	*The problem of staff scheduling at a truck hub for loading and stripping of the trucks is an important and difficult problem to optimize the labor efficiency and cost. The trucks enter the hub at different hours a day, in different known time schedules and operating hours. In this paper, we propose a goal programming to maximize the labor efficiency via minimizing the allocation cost. The proposed model of this paper is implemented for a real-world of a case study and the results are analyzed.*

1. Introduction[*]

Increasing need to planning and optimizing production and service delivery resource, assure organizations to optimum use of these resources. Human resource is one of the most important sources of production and service delivery, which influences the productivity of organizations, significantly. A relatively efficient and productive human resource schedule program could reduce total cost of production, substantially.

Scheduling the staffs in any organization is necessary, because it helps determine the timing and scope of working times as well as the number of people who are needed. An optimum use of work force capabilities increases the organizations' outputs and labor productivity.

In this study, we discuss staff scheduling in logistic management, and we study the truck hub to achieve the minimum assignment cost and the maximum level of labor efficiency. As mentioned, manpower is the most essential resources of the organization, which uses the biggest portion of the cost components in many organizations. We present a description on various aspects of human resources scheduling we provide a mathematical model based on goal programming for a case study of truck hub.

The organization of this paper first presents the related literature review in section 2. Section 3 presents the necessary notations and the proposed mathematical model. Section 4 is devoted for the proposed goal programming approach and section 5 explains the implementation of the proposed model for a real-world case study. Finally concluding remarks are given in the last section to summarize the contribution of the paper.

2. Literature Review

Several classifications for the preparation of list of tasks and staff scheduling is presented, among them the following three categories are more important. In each of these categories a framework is presented. Tine [1] noted that the issue of manpower scheduling problems generally is based on the following five factors: temporary manpower requirements, manpower requirements for permanent, recreation and vacation, work scheduling and shift scheduling.

Arabeyre et al [2] and Caprara [3] in other studies with a three-step approach created an appropriate combination of human resources, manpower combination optimization and staff scheduling [2, 3]. Bailey (1985) offered a staff scheduling classification based on three factors of holidays, shifts and shift rotation schedule [4, 5].

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Staff scheduling problems in different fields of work each one with its own conditions have been investigated, but there are three fundamental differences among these various issues and models that include schedule days correlation degree, work structure and work allocation, fields that need to perform scheduling and the type of demand for basic constituent units of work structure [6].

Edie in the traffic area first discussed staff scheduling, and then the idea was developed in various areas such as transportation systems such as airline and railway systems, health, emergency services like police, ambulance and fire fighting organizations, call centers, and many other services such as hotel, restaurant and or retail centers were used. Chu and Zhu studied scheduling the delivery staff at the airport and considered the payment based on unemployment hours and limiting the maximum changes in working hours and reduced the shift length using goal programming [7].

Detienne [8] used Lagrangian lower bound and heuristic methods, Integer programming and multi-choice multi-dimensional to formulate a newly formed Knapsack problem. Matta and Peters [9] used mathematical programming method to decrease cost, using less number of manpower, increase job satisfaction and flexible work combination [9]. Andersen et al. discussed some issues such as employee classification, types of fleet, network structures, laws and regulations and the cost structure. Lasry et al [10] discussed human resources combination, optimization of these compounds and the staff scheduling in the airline industry.

Ernst and Jiang [11] and Caprara et al. [11] integrated an approach to prepare a crew schedule and time table. There is other work, which focuses on transportation problem for hubs [12].

In the area of phone centers Robbins [13] considered uncertainty state and random demand and its impact on the scheduling, and studied the scheduling costs and shortage fines using queuing theory to schedule steady state Erlangen C model and integrated stochastic scheduling model. He also considered missed calls in his model that others did not regard to it and it lead some errors in theirs scheduling [13].

There are some other works, which focus on the scheduling on health care system such as nurse scheduling and sometimes in intensive care, in the hospital guards [6].

Usually the goal in this sector is to provide better health care and reduce costs. Topaloglu [14] studied different skill levels among nurses used multi-objective models and hierarchical modeling, and divided the constraints to two hard constraints (rules) and software constraints (working conditions). Massey [15] performed scheduling by taking into account the variable number of clients, absenteeism, increased staff training and scheduling flexibility [15]. Vanhoucke and Maenhout (2009) considered the increase service quality in their scheduling [16]. Tsai and Li [17] considered the desirability and autonomy in determining the time tabling, and did scheduling based on existing laws and programs received from the nurses. Their time tabling was based on the maximum days of unemployment and tried to minimize the maximum consecutive working days. Also, they considered the number of equality between day and night shift among all employees, and to achieve these objectives they used the genetic algorithm and two-stage mathematical modeling [17]. Beliën (2007) considered total demand and healthcare operation stochastic, and used heuristic algorithm, analysis tasks approach, heuristic search procedures and heuristic column generation, integer programming and dynamic programming [18].

In logistic management field, An and D. Subramanian [19] considered skill levels of employees, hired and fired, training, and minimizing costs by using the integer linear programming [19]. Mason et al. on airport staffs, Alvarez et al. On the aircraft and stoker staffs and Dowling et al. did some researches on human resources in this field [6].

In dynamic manufacturing environment, decision variables are to determine production levels for various items in order to meet the demand in periods of time and storage products are made in an acceptable level. Critical problems because of the balance between supply and demand decisions about the manpower requirements in different periods of production occurs, this increases the costs of the organizations. Also in production field Sabar et al. [20] used linear programming to discuss on problems such as wage costs, operator labor allocation, unemployment, and displacement between the parts, fine operators in the unauthorized displacement and operators dissatisfaction.

According to studies in human resources scheduling gaps in various areas of research in the field of logistic management are: to consider the increased labor efficiency objective, considering the state of transfer of some activities to later days, considering a fine in doing jobs with delay, considering the uncertainty of demand and employee satisfaction. According to the gaps identified above in this study we focus on the first and the most important objective, increasing labor efficiency - as one of the most essential resources in the organization - along with the lowest cost of this allocation.

3. Problem Description

Issue examined in this study is associated with truck hub, where trucks come to the center in different hours a day, and after the loading operation by operators, they go out. Each truck has an especial arrival and operation time. The scheduling for this problem is performed separately for different days. All of the operators are the same and there is no skill level

defined for them. Here, we have some prescriptions for operators, trucks and the operation, which are performed in this center.

Trucks are arranged for scheduling and allocation in chronological entry order in the center. Each operator at the same time can only work on one truck and also, only one truck at the same time can be assign to an operator. Interruption in operations is not permitted on the trucks loading operation. The operators can have unemployment during normal shift time. During the shift, operators are always available, and any required time during the work shift and overtime are ready to work. All trucks have equal value and the all of the loadings must be done during the day. All model parameters are determined.

3-1. Notation

Desired goals in this modeling are cost minimization and labor efficiency maximization. Constraints discussed in this model include: per job scheduled exactly once and each position on each operators timetable is occupied by only one job. A truck assigned to one operator if that operator is active on certain day. Start time for each operation on a truck is bigger than or equal to its arrival time to the center. Other constraints that we have are shift length, operator allocation requirement in overtime work, and the maximum amount of overtime.

Innovation introduced in this issue considers the maximization of the labor efficiency as objective function along with the cost minimization as another objective function.

Although most of the scheduling issues are indissoluble because of their uncontrolled complexity, using integer programming is to be substantial. On the other hand, increasing development of integer programming already suggests promising future for these issues.

3-1-1. Parameters

The parameters that we used in this modeling are as follow:

m	The number of trucks
n	The number of operators
i	The index on the trucks, $i = 1, 2, \dots , m$
j	The index on the operators, $j = 1, 2, \dots , n$
k	The index on the position of scheduling, $k = 1, 2, \dots , m$
p_i	Truck i operation time
r_i	Arrival time for truck i
G	Total time available for regular work every day (during normal shift)
M	A big number

ε	A small number
A	Wage costs per hour of a normal working day
B	Wage costs per hour worked during overtime work
f	Maximum amount of overtime work

m and n are indicate the number of trucks and operators that we have in especial day during the planning horizon, i, j and k are the indexes that count this numbers for each parameter or variable.

3-1-2. Decision Variables

The decision variables that we used in our modeling are as follow:

$x_{ijk} = 1$ if truck i in position k assigned to operator j; otherwise $x_{ijk} = 0$.

$y_j = 1$ if operator j assigned; otherwise $y_j = 0$.

$o_j = 1$ if operator j assigned in added time; otherwise $o_j = 0$.

t_i = Start Time of operation on truck i.

s_i = number of added time for operator j.

we define three variables x_{ijk}, y_j , and o_j as binary variables, and t_i and s_i as positive variables.

3-2. Mathematical Formulation

We formulate our problem as a mathematical model with two objective function, which is as follow:

$$\max z = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{m} p_i . x_{ijk}}{\sum \left(G.y_j + s_j.o_j \right)} \tag{1}$$

$$\min z = \sum_{j=1}^{n}\left(A.y_j + B.s_j.o_j \right) \tag{2}$$

$$\sum_{i=1}^{m} x_{ijk} \le 1 \qquad ;\forall j = 1,...,n, k = 1,...,m \tag{3}$$

$$\sum_{j=1}^{n}\sum_{k=1}^{m} x_{ijk} = 1 \qquad ;\forall i = 1,...,m \tag{4}$$

$$\varepsilon.y_j \le \sum_{i=1}^{m}\sum_{k=1}^{m} x_{ijk} \le M.y_j \qquad \forall j = 1,...,n \tag{5}$$

$$t_i \le r_i \qquad ;\forall i = 1,...,m \tag{6}$$

$$\sum_{i=1}^{m}\sum_{k=1}^{m} p_i . x_{ijk} \le G.y_j + s_j.o_j \qquad ;\forall j = 1,...,n \tag{7}$$

$$s_j \le f \qquad ;\forall j = 1,...,n \tag{8}$$

$$o_j \le y_j \qquad ;\forall j = 1,...,n \tag{9}$$

$$x_{ijk}, y_j, o_j = 0 or 1 \qquad ;\forall i = 1,...,m, \forall j = 1,...,n, k = 1,...,m$$

$$t_i, s_j \ge 0$$

Know we explain each of the above equations one by one;

$$\max z = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{m} p_i . x_{ijk}}{\sum \left(G.y_j + s_j.o_j\right)} \qquad (1)$$

Eq. (1), the first issue of the objective function and the purpose of it is labor efficiency maximization. The Numerator of fraction is the total amount of time that is deducted per day for operators operate on the trucks, and the denominator are mere fraction of the total time available during regular and overtime per day.

$$\min z = \sum_{j=1}^{n}\left(A.y_j + B.s_j.o_j\right) \qquad (2)$$

In Eq. (2), the goal is to minimize the amount of costs for normal and overtime wages per day. That the first part is associated with the wage cost for normal hours and it compute for each day, and the second part related to overtime work and it compute for each hour work in overtime, if the operator assign is this time.

$$\sum_{i=1}^{m} x_{ijk} \le 1 \qquad ; \forall j = 1,...,n, k = 1,...,m \qquad (3)$$

$$\sum_{j=1}^{n}\sum_{k=1}^{m} x_{ijk} = 1 \qquad ; \forall i = 1,...,m \qquad (4)$$

Eq. (3 and 4), represent this constraint that it is required any work to be scheduled exactly once, and every working position by an operator occupied by up to one job.

$$\varepsilon.y_j \le \sum_{i=1}^{m}\sum_{k=1}^{m} x_{ijk} \le M.y_j \qquad \forall j = 1,...,n \qquad (5)$$

Eq. (5) provides conditions that limit the allocation of one truck to one operator, until that operator is active on the special day.

$$t_i \le r_i \qquad ; \forall i = 1,...,m \qquad (6)$$

Eq. (6) indicates that starting time being equal or bigger than the truck's arrival time to the center.

$$\sum_{i=1}^{m}\sum_{k=1}^{m} p_i . x_{ijk} \le G.y_j + s_j.o_j \qquad ; \forall j = 1,...,n \qquad (7)$$

Eq. (7) is for shift length, and it indicates that the total operation time that the operators do in a day must be less than the total available time that they have in a day (in normal or overtime if each of them allocate at it).

$$s_j \le f \qquad ; \forall j = 1,...,n \qquad (8)$$

Eq. (8) indicates the maximum time allowed for overtime in each day that each person can operate on it if necessary.

$$o_j \le y_j \qquad ; \forall j = 1,...,n \qquad (9)$$

Eq. (9) indicate that only the person that work in normal time can work in overtime (if it is necessary, that the objective function indicate this and make decision about it).

4. Formulation of Staff Scheduling Problem using a Goal Programming Approach

In this study we use goal programming method to solve the proposed model of this paper. We apply the following changes for conversion this model to goal programming model.

$$\min z = \left(\left(d_1^- + d_1^+\right)^2 + \left(d_2^- + d_2^+\right)^2\right)^{1/2} \qquad (10)$$

We consider Eq. (10) as goal programming problem objective function, and rewrite the Eq. (1) and (2) that are the objective functions of the previous model as the Eq. (11) and (12), and use them as constraints.

$$\max z = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{m} p_i . x_{ijk}}{\sum \left(G.y_j + s_j.o_j\right)} + d_1^- - d_1^+ = 0 \qquad (11)$$

$$\sum_{j=1}^{n}\left(A.y_j + B.s_j.o_j\right) + d_2^- - d_2^+ = 0 \qquad (12)$$

Also the following constraints are added to the model.

$$d_1^- . d_1^+ = 0 \qquad (13)$$

$$d_2^- . d_2^+ = 0 \qquad (14)$$

$$d_1^-, d_1^+, d_2^-, d_2^+ \ge 0$$

The variables d_1^-, d_1^+, d_2^- and d_2^+ respectively negative and positive deviation of the goals of objective functions defined for increasing labor efficiency and decreasing the cost.

5. Computational Results

The data that we use in this study was from a truck hub that work in 8 hours shifts, and do loading services. In Table 1, we show 5 day's data of this hub.
We solve this model using GAMS software and computer system Pentium Dual-core CPU and 2.70 GHz.

Tab. 1. 5 day's data from the hub

Truck no.	Day 1 Arrival time	Day 1 Operating time	Day 2 Arrival time	Day 2 Operating time	Day 3 Arrival time	Day 3 Operating time	Day 4 Arrival time	Day 4 Operating time	Day 5 Arrival time	Day 5 Operating time
1	0.00	2.17	0.00	1.25	0.00	0.67	0.00	2.80	0.00	1.58
2	0.00	0.67	0.00	1.47	0.00	0.82	0.00	1.42	0.00	0.62
3	0.00	0.30	0.00	1.10	0.00	1.67	0.00	0.62	0.00	0.58
4	0.00	1.23	0.00	0.57	0.00	1.12	0.00	1.27	0.00	0.40
5	0.00	0.45	0.00	0.60	0.00	0.57	0.00	0.82	0.00	0.53
6	0.00	0.53	0.00	1.18	0.00	0.82	0.00	0.92	0.00	1.05
7	0.00	0.73	0.00	0.82	0.00	1.55	0.00	0.47	0.00	1.70
8	0.50	0.47	0.00	2.23	0.00	0.82	0.00	1.73	0.00	1.55
9	0.50	0.95	0.00	0.60	0.00	0.70	0.00	1.87	0.25	0.65
10	0.50	2.00	0.00	1.50	0.00	1.02	0.00	1.27	0.50	1.40
11	0.75	0.37	0.00	1.07	0.00	1.20	0.00	1.45	0.50	1.42
12	1.00	1.30	0.00	1.30	0.00	0.53	0.00	0.60	0.50	1.42
13	1.00	1.12	0.00	1.48	0.00	0.83	0.50	1.17	0.50	0.96
14	1.75	1.67	0.00	0.15	0.00	0.73	0.50	1.57	0.50	1.72
15	2.00	0.97	0.00	1.03	0.00	0.55	1.00	0.87	0.50	1.23
16	2.25	2.30	0.50	0.58	0.00	0.50	1.00	0.48	1.00	0.50
17	2.50	1.47	0.50	2.13	0.00	0.73	1.50	0.65	1.00	2.42
18			0.50	0.45	0.50	1.60	1.50	2.05	1.50	1.62
19			0.80	0.83	1.00	1.47	3.50	1.18	1.75	2.05
20			1.00	0.67	3.00	0.62	4.00	0.67	2.50	1.10
21			1.00	2.00	4.50	0.42			2.75	0.43
22			1.50	2.77					3.75	1.60
23			1.50	1.50					3.75	0.77
24			2.00	2.32					4.50	1.13
25			4.50	1.08					4.75	1.03

Tab. 2. Results of goal programming model

Day	x	y	o	s (h)	Cost	Efficiency	Time (min)
1	17	3	-	-	24	0.779	00:22.625
2	25	4	-	-	32	0.959	02:15.750
3	21	3	-	-	24	0.789	00:19.719
4	20	3	-	-	24	0.995	00:46.469
5	25	4	-	-	32	0.905	01:34.531
6	23	3	3	1,2,1	30	0.897	16:40.937
7	17	3	-	-	24	0.875	00:14.500
8	17	4	-	-	32	0.844	00:25.094
9	16	3	-	-	24	0.915	00:04.641
10	23	3	2	2,2	30	0.884	16:41.157
11	20	4	-	-	32	0.963	02:55.046
12	21	4	-	-	32	0.937	01:19.313
13	22	3	3	2,1,1	30	0.974	16:42.672
14	21	4	-	-	32	0.996	05:56.094
15	19	3	-	-	24	0.926	00:58.062

Day	x	y	o	s (h)	Cost	Efficiency	Time (min)
16	17	3	-	-	24	0.984	00:08.969
17	16	2	-	-	16	0.923	00:07.328
18	19	3	3	2,2,2	33	0.900	16:42.719
19	18	3	-	-	24	0.850	00:32.422
20	16	4	-	-	32	0.840	00:22.234
21	25	4	-	-	32	0.943	00:59.063
22	17	3	-	-	24	0.932	00:22.578
23	22	4	-	-	32	0.976	00:34.484
24	20	3	3	2,2,2	33	0.822	16:41.546
25	21	4	-	-	32	0.966	00:46.468
26	19	3	-	-	24	0.941	00:14.359
27	25	4	-	-	32	0.970	02:35.875
28	22	3	3	1,1,1	28.5	0.951	16:40.640
29	15	2	2	2,1	19	0.979	16:40.938

In Table 2, the first column represents different days, and the second column shows the number of arrival trucks in each day. The third column shows the number of operators assigned on each day. Forth column shows the number of operators in overtime work per day, and the fifth column shows the amount of overtime work assigned to each operator. Sixth column is for wage cost, and the next column shows the labor efficiency on any given day. Finally, the last column represents the solution time for each day with GAMS software and computer system Pentium Dual-core CPU, E5400 and 2.70 GHz.

For example, for 13th day there are 22 trucks that enter to the center in different hours of the day, and the model solution for this amount and its operation and arrival time is: 3 operators are assign, and all of them were used in overtime, but two of them used for 1 hour and another one was used for 2 hours. The minimum allocation cost via labor efficiency 0.974 was 30$, and this solution spent 16:42.672 minute to solve.

6. Sensitivity Analyses

In order to do more analyses on data, we decided to change salary cost for working in normal work shift and analyze its effect on the objectives, assignment cost and labor efficiency.

We apply this change by increasing/decreasing 25 percent up in salary cost, and analyze the results of this change. Table 3 and Table 4 show the changes on efficiencies.

In Table3 when there is a 25% decrease in salary cost, column 3 shows the information of operators who are assigned to works on specific day. In addition, column 4 shows the operators who work on added time on that day, column 5 shows the hours of added time work for each operator, column 6 shows the assignment and column 7 shows labor efficiency. First column is counter of days and second one is number of truck in each day.

Tab. 3. Results of goal programming model for 25% decrease in salary cost

Day	x	y	o	s (h)	Cost	Efficiency
1	17	2	2	2,2	18	0.935
2	25	4	-	-	24	0.959
3	21	3	-	-	18	0.789
4	20	3	-	-	18	0.995
5	25	4	-	-	24	0.905
6	23	3	3	1,2,1	24	0.897
7	17	3	-	-	18	0.875
8	17	3	3	1,2,1	24	0.965
9	16	3	-	-	18	0.915
10	23	3	2	2,2	24	0.884
11	20	4	-	-	24	0.963
12	21	4	-	-	24	0.937
13	22	4	-	-	24	0.937
14	21	3	3	2,2,1	25.5	0.940
15	19	4	-	-	24	0.996
16	17	3	-	-	18	0.926
17	16	3	-	-	18	0.984
18	19	2	-	-	12	0.923
19	18	3	3	2,2,1	25.5	0.931
20	16	3	-	-	18	0.850
21	25	3	3	2,1,1	24	0.960
22	17	3	-	-	18	0.932
23	22	4	-	-	24	0.976
24	20	3	3	2,2,1	25.5	0.850
25	21	4	-	-	24	0.966
26	19	3	-	-	18	0.941
27	25	4	-	-	24	0.970
28	22	3	3	2,2,1	25.5	0.886
29	15	2	1	2	15	0.979

Table 4 shows the impact of 25% increase in salary cost and the information on this table are similar to what we presented in Table 3.

**Tab. 4. Results of goal programming model for 25% increase in salary cost**

Day	x	y	o	s (h)	Cost	Efficiency
1	17	3	-	-	30	0.779
2	25	4	-	-	40	0.959
3	21	3	-	-	30	0.789
4	20	3	-	-	30	0.995
5	25	3	3	1.5,1.5,1.5	37.5	0.999
6	23	3	3	1,1,2	36	0.897
7	17	3	-	-	30	0.875
8	17	4	-	-	40	0.844
9	16	3	-	-	30	0.915
10	23	3	3	1,1,2	36	0.884
11	20	4	-	-	40	0.963
12	21	4	-	-	40	0.937
13	22	3	3	2,1,1	36	0.974
14	21	4	-	-	40	0.996
15	19	3	-	-	30	0.926
16	17	3	-	-	30	0.984
17	16	2	-	-	20	0.923
18	19	3	2	2,2	36	0.965
19	18	3	-	-	30	0.850
20	16	4	-	-	40	0.840
21	25	4	-	-	40	0.943
22	17	3	-	-	30	0.932
23	22	4	-	-	40	0.976
24	20	3	2	1,2	34	0.913
25	21	4	-	-	40	0.996
26	19	3	-	-	30	0.941
27	25	4	1	2	43	0.913
28	22	3	3	1,1,1	34.5	0.951
29	15	2	2	2,2	26	0.881

As we can see from the results of Table 3 and Table 4, there are some differences in the results, which are different from the results given in Table 2. As we can see the changes on the salary cost can change the efficiency, very significantly. Table 5 shows the average of these factors (assignment cost and labor efficiency) for 29 day of research. As we can observe from the results of Table 5, when a 25% change on the cost could change the efficiency only two percent, in average.

Tab. 5. Average of cost and efficiency in three statuses

	- 25% change	0 % change	+ 25% change
Cost	21.41	27.98	34.45
Efficiency	0.930	0.918	0.922

We illustrate these changes in two diagrams. In Diagram1, we show the trend of cost in three statuses. First, 25% decrease of salary cost status. Second, normal status and third 25% increase in salary cost.
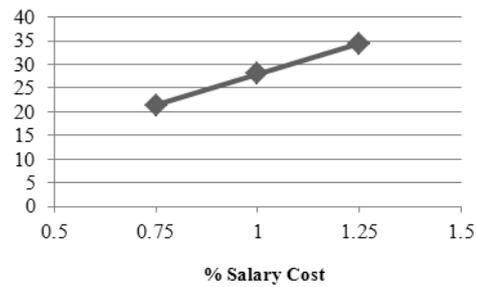
Diag. 1. Assignment cost trend

In Diagram2, we show the trend of labor efficiency in three scenarios of decrease, normal and increase, respectively.
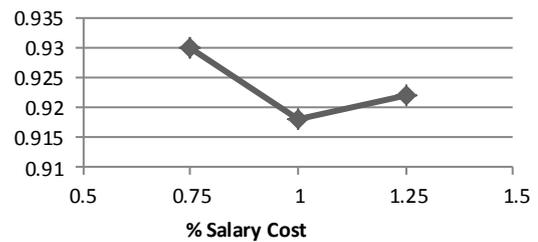
Diag. 2. Labor efficiency trend

As we can see in Diagram1 assignment cost decrease when the salary cost decreases and it rises when assignment cost increases. On the other hand, in Diagram2 we cannot do exact deduction for the results. As seen, by decreasing and increasing salary cost we have increase in labor efficiency.

7. Conclusion and Further Study

In this paper, we have offered multi-objective mathematical model for a real staff scheduling problem, and solve it with goal programming method, which is one of the most popular methods to solve such problems. In this study, the company that we got data offers services up to 500 trucks in 29 days, where they enter to the company in different times of a day. We offered a mixed integer non-linear programming model to achieve two goals, maximum labor efficiency and minimum cost. In some solutions the solution time is too long, so, we proposed to use other methods to modeling and solve it with lower time. Also, we propose that use of linear form of model to solve it easier with each solver.

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