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THE SECURITY STAFF SCHEDULING PROBLEM WITH GOAL PROGRAMMING APPROACH

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ABSTRACT
The proper operation of security personnel is one of the major problems in public institutions. By assigning the security personnel to the most appropriate duty areas, security service can be provided in the best conceivable way. From this point of view, the problem of assigning the most appropriate security personnel to determined places is handled in this study. As a place of application, a big scale university campus where the 158 security personnel serve 24 hours with a total of 10 points is considered. A monthly schedule is obtained for this group by solving the identified problem by a goal programming model which is solved by ILOG CPLEX Studio IDE Optimization tool. As a result of solving this proposed model is shown that the intended goals are achieved, and better results are obtained from the existing schedule.
Keywords: Staff Scheduling, Personnel Assignment, Goal Programming, Personnel Scheduling

1. INTRODUCTION
Scheduling problems have become one of the most studied types of problems in recent years by researchers. Personnel scheduling problems, a specific type of scheduling problems, are confronted as one of the most studied scheduling problems when they are examined to date. Organizations need to focus on many parameters to reach top-level goals such as satisfaction at the top level, maximization of profit and system efficiency and cost minimization. Considering the significant effect of the staff employed in the production of goods and services, achieving the distribution of a fair work among the employees, the importance of staff scheduling which serves to increase the motivation and performance by ensuring that they work in safety in works suited to the sufficiency, desire and needs of the employees arises. Staff scheduling plays an important role on production and service industries. Staff Scheduling is a widely studying area which is a process that plays an important role in manufacturing and service industries. In this study, a monthly schedule is proposed for personnel involved in security at a university, using the goal programming method. 158 security personnel serve 24 hours with a total of 10 points in a university campus.

2. STAFF SCHEDULING

Arrangement of work plans and assignment of staff planning and staff scheduling in order to meet the demand for resources that vary according to time. These problems occur in service industries, such as call center operators, hospital nurses, police officers, transportation personnel (aircraft crews, bus drivers) and so on. It is very important topic for personnel scheduling. These environments are often prolonged and unsteady, and staff requirements fluctuate over time. Schedules typically include equipment requirements, trade union rules, etc. It is the subject of various restrictions dictated by. The problems that arise tend to be combinatorically difficult. Staff scheduling problem's structure can be divided into several categories. General solution method is with integer programming. This method contains a large class of personnel scheduling problem solutions. Besides, there is a special class of integer programming problems, namely cyclical personnel problems. This problem can be used in terms of class and a combinatorial viewpoint. Apart from these, crew and operator scheduling problems have a different model structure.

3. GOAL PROGRAMMING

In goal programming; minimization or maximization of objective measures cannot be done directly. Rather, deviations between the goals are sought to minimize. The objective function is constructed only from deviant variables [1-3]. Since both positive and negative deviations cannot occur at the same time, at least one or both variable deviations must be zero. After the determination of the unwanted variables, the deviation goal programming formulation was made. It is desirable that only one of these variables be deducted by the decision maker [4-8].

4. APPLICATION

The problem of assigning the most appropriate security personnel to the designated locations has been addressed in this study. As a place of application, a large-scale university campus with 158 security personnel serving 24 hours is evaluated with a total of 10 points. The number of personnel required in each region and each shift is given below.

Personnel requirements for each shift are as follows: 32 personnel - shift 1, 20 personnel - shift 2, 10 personnel - shift 3. There are 10 areas for the staff for being ready.

For this group, a monthly program is obtained by solving the problem defined by a goal programming model.

CONSTRAINTS

Constraint 1: Number of personnel needed for each shift every day.

Constraint 2: A staff working any day at night should not work in the morning and evening shifts the next day.

Constraint 3: A person working on any day of the evening should not work the next morning in the morning.

Constraint 4: Every staff member should not work more than 6 days.

Constraint 5: Every staff member should not work on his/her the day off.

These constraints are for the number of night shifts each staff should work at least according to their seniority level.

Constraint 6: Every staff member should be assigned one shift per day. To overcome the excesses.

Constraint 7: In the Evening Shift, the staff cannot be operated more than 9 days.

Parameters

i: Personnel index,	$i=1,2,...,e$	(1)
j: Day index,	$j=1,2,...,m$	(2)
k: Shift index	$k=1,2,...,n$	(3)
l: Area index	$l= 1,2,\ldots v$	(4)
e: Number of Personnel	$e=158$	(5)
m: Number of Day	$m=30$	(6)
n: Number of Shifts	$n=3$	(7)
v: Number of area	$v=10$	(8)

MATHEMATICAL MODEL
Decision Variables

$$X_{ijkl} = \begin{cases} 1, & \text{If personnel } i \text{ is assigned to day } j \text{ on shift } k \text{ to the area } l \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

$$h_{ij} = \begin{cases} 1, & \text{If the personnel } i \text{ is on leave in day } j \\ 0, & \text{otherwise} \end{cases} \quad (10)$$

CONSTRAINTS:

Constraint 1: The constraint that indicating the number of personnel assigned to each shift:

a. Number of personnel needed for shift 1.

$$\sum_{i=1}^{70} X_{ij1l} = 32 \qquad j=1,2,...,m \quad k=1,2,3 \quad l=1,2,\dots 10 \qquad (11)$$

b. Number of personnel needed for shift 2.

$$\sum_{i=71}^{110} X_{ij2l} = 20 \qquad j=1,2,...,m \quad k=1,2,3 \quad l=1,2,\dots 10 \qquad (12)$$

c. Number of personnel needed for shift 3.

$$\sum_{i=111}^{158} X_{ij3l} = 10 \qquad j=1,2,...,m \quad k=1,2,3 \quad l=1,2,\dots 10 \qquad (13)$$

Constraint 2: The constraint that indicating if a staff working any day at night should not work in the morning and evening shifts the next day:

$$X_{ij3} + X_{i(j+1)1} + X_{i(j+1)2} \leq 1 \quad i=1,2,3,\dots,l \quad j=1,2,...,29 \quad l=1,2,\dots 10 \qquad (14)$$

Constraint 3: The constraint that indicating if a person working on any day of the evening should not work the next morning in the morning:

$$X_{ij2l} + X_{i(j+1)1l} \leq 1 \qquad i=1,2,3,\dots,l \quad j=1,2,...,29 \quad l=1,2,\dots 10 \qquad (15)$$

Constraint 4: The constraint that indicating every staff member should not work more than 6 days:

$$\sum_{i=1}^{24} h_{ij} + h_{i(j+1)} + h_{i(j+2)} + h_{i(j+3)} + h_{i(j+4)} + h_{i(j+5)} + h_{i(j+6)} >= 1 \quad i=1,2,...,l \ (16)$$

Constraint 5: The constraint that indicating every staff member should not work on his/her the day off:

$$\sum_{k=1}^{3} X_{ijkl} + h_{ij} = 1 \quad i=1,2,3,\dots,l \quad j=1,2,...,m \quad l=1,2,\dots 10 \qquad (17)$$

Constraint 6: The constraint that indicating every staff member should be assigned one shift per day. To overcome the excesses:

$$\sum_{k=1}^{n} X_{ijkl} \leq 1 \qquad i=1,2,3,\dots,l \quad j=1,2,...,m \quad l=1,2,\dots 10 \qquad (18)$$

Constraint 7: The constraint that indicating in the Evening Shift, the staff cannot be operated more than 9 days:

$$X_{ij3l} + X_{i(j+1)3l} + X_{i(j+2)3l} + X_{i(j+3)3l} + X_{i(j+4)3l} + X_{i(j+5)3l} + X_{i(j+6)3l} + X_{i(j+7)3l} + X_{i(j+8)3l} \leq 9$$

$$i=1,2,3,...,l \quad j=1,2,...,21 \qquad (19)$$

GOAL CONSTRAINTS

The total number of shifts assigned to each staff should be as equal as possible.

$$\sum_{i=1}^{158} X_{ijkl} - d1_i^+ + d1_i^- = 1 \quad j=1,2,3,\dots,30 \quad k=1,2,3 \quad l=1,2,\dots 10 \qquad (20)$$

OBJECTIVE FUNCTION

$$\min Z = \sum_{i=1}^{158} (d1_i^+ + d1_i^-) \qquad (21)$$

The proposed model, ILOG CPLEX Studio IDE is written in the program and is solved with the CPLEX solvent.

5. RESULTS AND DISCUSSION

In this study, work schedules of the security personnel of a university are planned. Scheduling includes one month of staff work. Before this work is done, once the current work scheduling is done by hand, the benefit of working is revealed once more. In Table 1, final schedule of the job is given.

Table.1 The final schedule

		DAYS														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Area 1	Shift 1	46, 89, 99, 119	59, 146, 151, 109	11, 127, 152, 114	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	46, 86, 109, 110	59, 1, 141, 142	2, 3, 4, 5	1, 88, 89, 90	1, 2, 3, 4	5, 10, 11, 12	1 ,2, 3, 4	43, 44, 45,46
	Shift 2	58, 109	60, 155	12, 128	25, 5	10, 5	5, 6	5, 6	48, 111	60, 2	6, 9	6, 91	5, 16	8, 13	5, 7	47, 48
	Shift 3	60	70	38	28	16	9	7	49	63	10	22	18	15	13	49
Area 2	Shift 1	61, 90, 100, 120	87, 156, 158	40, 134, 153, 125	32, 6, 7, 8	21, 6, 7, 8	7, 8, 10, 18	8, 9, 10, 11	51, 112, 113, 114	64, 3, 4, 5	7, 8, 11, 13	25, 92, 93, 94	6, 7, 8, 23	17, 14, 16, 17	8, 9, 10, 14	50, 51, 52, 53
	Shift 2	62, 110	90, 100	45, 136	37, 9	26, 9	11, 19	12, 13	58, 115	66, 6	12, 14	26, 95	9, 41	19, 18	11, 20	54, 58
	Shift 3	63	98	52	43	34	23	14	60	78	21	28	44	29	24	60
Area 3	Shift 1	64, 91, 101	99, 145, 153	53, 137, 154	49, 10, 11	35, 11, 17	12, 13, 29	15, 16, 17	61, 116, 117	83, 7, 8	15, 16, 36	32, 96, 97	10, 11, 56	20, 21, 30	12, 15, 27	10, 11, 61
	Shift 2	65, 111	116, 1	67, 150	65, 12	41, 12	14, 36	18, 19	62, 118	90, 9	17, 38	34, 98	12, 71	32, 33	16, 31	12, 62
	Shift 3	66	119	71	68	42	50	20	63	92	40	35	81	39	47	63
Area 4	Shift 1	67, 92, 102	121, 2, 3	75, 157, 132	69, 13, 14	56, 13, 14	15, 16, 51	21, 22, 23	64, 119, 120	93, 10, 11	18, 19, 43	37, 99, 100	13, 14, 85	34, 35, 54	32, 33, 55	13, 14, 64
	Shift 2	68, 112	122, 4	92, 137	79, 15	70, 15	17, 66	24, 25	65, 121	98, 12	20, 45	42, 101	15, 101	36, 57	34, 65	15, 65
	Shift 3	69	123	94	91	73	76	26	66	100	52	50	107	61	67	66
Area 5	Shift 1	71, 93, 103	124, 5, 6	103, 1, 2	96, 16, 17	74, 18, 19	20, 21, 84	27, 28, 30	67, 122, 123	101, 13, 14	26, 22, 53	62, 102, 103	17, 19, 108	37, 38, 72	35, 36, 69	16, 17, 67
	Shift 2	72, 113	125, 7	106, 3	122, 18	78, 20	22, 85	31, 32	68, 124	102, 15	23, 68	79, 104	20, 109	40, 74	37, 70	18, 68
	Shift 3	73	126	108	123	80	86	33	69	103	73	87	110	80	75	69
Area 6	Shift 1	74, 94, 104	127, 8, 9	110, 4, 5	133, 19, 20	81, 22, 23	24, 25, 89	34, 35, 39	70, 125, 126	104, 16, 17	24, 25, 76	105, 106, 107	21, 22, 112	41, 42, 91	38, 39, 77	19, 20, 70
	Shift 2	75, 114	128, 10	111, 6	134, 21	83, 24	26, 95	36, 44	71, 127	105, 18	27, 86	117, 108	121, 119	43, 94	40, 82	21, 71
	Shift 3	76	129	112	135	93	97	47	72	106	88	121	120	95	84	72
Area 7	Shift 1	77, 95, 105	130, 11, 12	117, 7, 8	138, 22, 23	102, 25, 27	27, 28, 101	48, 49, 50	73, 128, 129	107, 19, 20	100, 101, 113	123, 109, 110	24, 25, 122	158, 44, 102	41, 42, 89	22, 23, 73
	Shift 2	78, 115	131, 13	118, 9	139, 24	105, 28	30, 104	51, 54	74, 130	108, 21	102, 118	126, 2	26, 124	45, 103	43, 96	24, 74
	Shift 3	79	132	120	140	107	124	55	75	128	127	131	130	104	97	75
Area 8	Shift 1	80, 96, 106	133, 14, 15	126, 10, 13	141, 26, 27	113, 29, 30	31, 32, 135	52, 53, 57	76, 131, 132	129, 22, 23	103, 104, 135	132, 3, 4	27, 28, 134	46, 47, 111	44, 45, 99	25, 26, 76
	Shift 2	81, 116	134, 16	130, 14	142, 29	115, 31	33, 139	56, 61	77, 133	140, 24	105, 136	139, 5	29, 143	48, 114	46, 106	27, 77
	Shift 3	82	135	131	143	121	140	62	78	145	137	141	144	116	115	78
Area 9	Shift 1	83, 97, 107	136, 17, 18	138, 15, 16	144, 30, 31	129, 32, 33	34, 35, 142	59, 58, 63	79, 134, 135	147, 25, 26	106, 107, 139	142, 12, 7	30, 31, 151	49, 50, 138	48, 49, 125	28, 29, 79
	Shift 2	84, 117	141, 19	148, 17	145, 33	140, 36	62, 147	60, 64	80, 136	153, 27	108, 140	143, 8	32, 152	51, 141	50, 133	30, 80
	Shift 3	85	150	149	146	143	148	72	82	154	144	144	155	154	145	81
Area 10	Shift 1	86, 98, 108	152, 20, 21	151, 18, 19	147, 34, 35	144, 37, 38	53, 54, 152	70, 71, 77	83, 137, 138	155, 28, 29	109, 110, 150	145, 9, 10	33, 34, 156	52, 53, 155	51, 52, 147	31, 32, 82
	Shift 2	87, 118	154, 22	155, 20	148, 36	156, 40	55, 153	73, 82	84, 139	156, 30	111, 157	146, 11	35, 157	54, 156	53, 148	33, 83
	Shift 3	88	157	158	149	157	158	88	85	157	158	147	158	157	149	84

		DAYS														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Area 1	Shift 1	20, 21, 22, 59	2, 5 ,7 ,8	1, 2, 3, 5	1, 2, 3, 8	3, 4, 6, 7	4, 5, 6, 7	1, 2, 3, 46	10, 11, 12, 53	2, 107, 108, 109	1, 139, 140, 141	5, 6, 7, 8	3, 4, 5, 6	1, 2, 3, 7	10, 11, 12, 46	10, 11, 12, 50
	Shift 2	23, 62	3, 9	4, 7	4, 16	5, 8	8, 14	4, 48	13, 59	6, 110	4, 142	17, 9	8, 13	4, 14	13, 48	13, 53
	Shift 3	70	10	6	18	13	20	49	60	9	8	33	19	20	49	59
Area 2	Shift 1	24, 25, 26, 71	11, 13, 14, 15	15, 8, 9, 10	5, 6, 7, 23	17, 14, 15, 16	9, 10, 11, 24	5, 6, 7, 51	14, 15, 16, 62	10, 111, 112, 116	15, 143, 144, 145	39, 10, 11, 12	9, 10, 11, 54	5, 6, 8, 24	14, 15, 16, 51	14, 15, 16, 60
	Shift 2	27, 75	12, 16	22, 11	9, 33	19, 18	21, 27	8, 52	17, 63	11, 113	16, 146	83, 13	20, 64	9, 27	17, 52	17, 61
	Shift 3	86	21	25	39	29	31	58	67	12	23	92	86	31	58	62
Area 3	Shift 1	28, 29, 87	30, 22, 23	26, 12, 13	10, 11, 41	20, 21, 54	15, 16, 47	10, 11, 61	18, 19, 70	18, 114, 115	25, 147, 148	93, 14, 15	21, 22, 87	10, 11, 47	18, 19, 60	18, 19, 63
	Shift 2	30, 88	34, 24	28, 14	12, 44	22, 61	17, 63	12, 69	20, 71	21, 117	35, 149	96, 16	23, 88	12, 60	20, 61	20, 64
	Shift 3	89	36	32	55	64	69	76	72	22	37	97	89	61	62	65
Area 4	Shift 1	31, 32, 90	38, 25, 26	35, 16, 17	45, 46, 66	23, 24, 74	28, 29, 82	13, 14, 80	21, 22, 73	26, 118, 119	44, 150, 151	18, 19, 101	24, 25, 90	13, 15, 62	21, 22, 63	21, 22, 66
	Shift 2	33, 91	40, 27	37, 18	47, 79	25, 76	30, 93	15, 82	23, 75	28, 120	50, 152	20, 102	26, 91	16, 63	23, 64	23, 67
	Shift 3	92	43	42	83	80	94	95	77	29	55	105	92	64	65	68
Area 5	Shift 1	34, 35, 93	45, 28, 29	50, 19, 20	48, 49, 87	30, 31, 97	70, 71, 98	16, 17, 98	24, 25, 81	30, 121, 122	65, 153, 154	21, 22, 109	26, 27, 93	17, 18, 65	24, 25, 66	24, 25, 69
	Shift 2	36, 94	52, 57	57, 21	50, 92	32, 105	72, 107	18, 104	26, 86	32, 123	66, 155	23, 117	29, 94	19, 66	26, 67	26, 71
	Shift 3	95	53	60	96	133	108	110	87	34	74	120	95	67	68	72
Area 6	Shift 1	37, 38, 96	56, 58, 59	65, 58, 59	51, 52, 101	33, 34, 134	73, 74, 109	19, 20, 114	27, 28, 88	36, 124, 125	78, 156, 157	24, 25, 143	30, 31, 96	68, 83, 84	27, 28, 69	27, 28, 73
	Shift 2	39, 97	67, 60	68, 61	53, 102	35, 136	75, 110	21, 123	29, 90	38, 126	89, 158	26, 145	32, 97	69, 85	29, 70	29, 74
	Shift 3	98	73	72	103	138	111	125	91	40	103	146	98	70	71	75
Area 7	Shift 1	40, 41, 99	81, 61, 62	77, 62, 63	54, 56, 106	36, 37, 139	76, 77, 112	22, 23, 129	30, 31, 94	41, 127, 128	67, 68, 108	27, 28, 147	33, 34, 99	71, 86, 87	30, 31, 72	30, 31, 76
	Shift 2	42, 100	85, 63	78, 64	57, 109	38, 143	78, 113	24, 137	32, 99	42, 129	69, 113	29, 148	35, 100	72, 88	32, 73	32, 77
	Shift 3	101	88	84	113	146	114	143	107	43	115	149	101	73	74	78
Area 8	Shift 1	43, 44, 102	90, 91, 92	89, 130, 131	58, 59, 117	39, 40, 150	80, 81, 116	25, 26, 149	33, 34, 126	45, 130, 131	70, 71, 119	30, 31, 150	36, 37, 102	74, 89, 90	33, 34, 75	33, 34, 79
	Shift 2	45, 104	100, 93	91, 132	60, 119	81, 151	83, 120	27, 150	35, 131	56, 132	72, 121	32, 151	38, 103	75, 91	35, 76	35, 80
	Shift 3	110	112	95	121	152	122	151	141	57	122	152	104	76	78	82
Area 9	Shift 1	46, 47, 123	114, 94, 95	99, 133, 134	61, 62, 128	82, 83, 153	84, 85, 124	28, 29, 152	36, 37, 142	68, 133, 134	73, 75, 127	121, 122, 153	39, 40, 105	77, 92, 93	36, 37, 79	36, 37, 83
	Shift 2	48, 126	118, 96	107, 135	63, 132	84, 154	86, 125	30, 153	38, 144	79, 135	128, 130	123, 154	41, 106	78, 94	38, 80	38, 84
	Shift 3	137	131	108	145	155	127	154	148	84	132	155	134	79	81	85
Area 10	Shift 1	49, 50, 142	146, 97, 98	111, 136, 137	64, 67, 150	85, 86, 156	128, 129, 130	31, 32, 155	39, 40, 151	85, 136, 137	129, 134, 133	124, 125, 156	42, 43, 136	80, 95, 96	39, 40, 83	39, 40, 86
	Shift 2	51, 144	151, 99	115, 138	68, 153	87, 157	131, 141	33, 156	41, 153	100, 138	135, 136	126, 157	44, 152	81, 97	41, 84	41, 87
	Shift 3	149	154	129	155	158	156	157	154	106	138	158	158	82	87	88

Given the large number of employees and the number of areas that need to be found, the large size of the problem makes scheduling very difficult to do manually. Moreover, the manual execution of this process subverts a risk to the justice of the job distribution. With these mathematical models used, both preparation of the charts is shortened, and quality charts are obtained. In the mathematical model developed in the study, the wishes of the employees were fulfilled. Goal programming model has been used to achieve the goals that need to be realized and the demands of the staff with the least deviation.

The assignment of employees to designated jobs has been a concern for many years in the service sector. In the service sector, more attention has been paid to staff appointments in recent years due to increased service lines, the importance given to customer satisfaction and the expectation of balanced work by employees. The models established in the following studies can be used not only in the university environment but also in many other sectors. In this study, wider schedules can be made by increasing all kinds of points such as the number of points of duty, number of staffs, staffs' desires and so on. Meta-heuristic methods can be used depending on the size of the models to be used.

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