Scheduling Technicians for System Monitoring

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1. INTRODUCTION:

Intel Corporation is a multinational corporation which focuses mainly on cloud computing, data centers, Internet of Things, and PC solutions which helps powering the smart and connected digital world we live in. Intel's headquarter is in Santa Clara, and has many campuses in US and all around the world. It is the world's largest and highest valued semiconductor chip maker in the market and supplies processors for computer system manufacturer such as Apple, Lenovo, HP, Dell etc.

The LIWS (Liquid Industrial Waste System) waste department helps monitors and treats the waste from different types of machines which serves its own valuable purpose respectively. The department consist of shifts which deals allocating required number of Operations Technicians and Engineering Technicians every week. The responsibility of these technicians are as follows

Operations Technicians: Assist in inspections, repairs, or preventive maintenance of equipment or units. Compile delivery and receipt data and submit it electronically. Perform tasks in the field or in the facility, and respond to emergency calls.

Engineering Technician: An engineering technician has understanding of engineering concepts. Helps assist engineers and technologist in projects and other development.

2. LITERATURE REVIEW:

Creating a staff scheduling is a challenging and time consuming task. It requires generating a schedule with respect to the constraints and objective of the organization. There are many techniques used for the staff scheduling such as genetic algorithms, linear programmings, integer linear programming, mixed integer linear programming, etc. Here we have implemented the solution using solver in excel and with the help of linear programming. Implementing techniques from other mathematical science, such as mathematical modeling, statistical analysis, and mathematical optimization, operation research arrives at optimal or near-optimal solution to complex decision-making problems. There is mathematical algorithm that guarantees an optimal solution in a reasonable optimal time. Scheduling problems occurs mostly when events are

competing for the same attention, that is, conflicting constraints. The occurrence of conflicts can be stressful and detrimental to productivity so it is very vital to focus on prevention of these problems and, when they occur, work on minimizing the impact of the disruption. The best way to prevent scheduling conflicts is to review the full schedule during and after making changes.

Scheduling is mostly done by various mathematical methods mostly to minimize the number of employees required to satisfy forecast demand. There are many mathematical algorithms to find a solution to generate an effective schedule. The mathematical algorithms are aimed at providing reliable solution in a short time and providing results that are better from the human point of view. Study shows that better qualities of rosters were provided and the users were most satisfied with the results. Genetic algorithms are search heuristics used to generate useful solutions as well as optimize and search problems. When implementing genetic algorithms for solving scheduling problems, however, there is a challenge handling the conflict between constraints and objectives which are prevalent in scheduling tasks.

M. Labidi and M. Mrad have proposed a solution for scheduling of IT staff in a bank by using a multiobjective programming method [1]. They used Lingo software to implement the solution and compared the result using manual method. Their work provided a step by step overview of how the various constraints apply on the model and the optimal integer solution schedule is generated. It also guided on how the objective and constraints should be formulated.

M. Krishnamoorthy and A. T. Ernst have proposed a review of application used for staff scheduling and roastering problems [2]. They have presented specific applications areas, models, algorithms, and methods used for solving them. M. J. Brusco and L.W. Jacobs have presented a simulated annealing heuristic for use in a continuously operating scheduling environment [3]. Their research is designed to minimize the number of employees required to satisfy forecast demand. From the results, in terms of solution quality, the simulated annealing based method dominates other heuristics and it also exhibits rapid convergence to a low-cost solution.

There are many techniques used for the staff scheduling such as genetic algorithms, Integer linear programming, etc. Here we are trying to minimize the number of headcounts and scheduling cost, this is an example of integer linear programing, in which the objective function and constraints all are integers. We have implemented the solution using solver in excel and with

the help of linear programming.

3. PROBLEM STATEMENT:

Intel is one of the biggest chips manufacturing company around the world. Apart from the chip manufacturing, it focuses on many fields for its market growth and environment protection. One of the areas Intel focuses on deals with improving the environment and company through its environment waste department. Many tools release hazardous chemicals which needs to be monitored to prevent any foreseeable damage to the environment. Each monitor deals with different hazardous chemicals monitoring.

The LIWS (Liquid Industrial Waste System) waste department in different Intel locations such as: Hillsboro, Arizona, Santa Clara, Folsom helps monitors and treats the waste from different types of machines which serves its own valuable purpose respectively. The department consist of shifts which deals allocating required number of Ops tech and Engineering Tech every week. There are two types of shifts in LIWS department and they are morning shift and night shift. The problem statement helps optimize the assignment of staff to its minimum requirement to minimize their overall expense per campus and the company as whole. Creating a staff scheduling is a challenging and time consuming task. There are some methods that can guarantee the optimal solution.

4. CURRENT APPROACH:

The table below provides the staff arrangement in their roles and location. The table also provides detailed understanding weekly expenditure currently.

Current Situation for Campuses

Hillsboro

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	8	3	4	1	8	3	4	1	
Cost($)/hr	192	108	80	30	192	108	80	30	820
Weekly	$9,216	$5,184	$3,840	$1,440	$9,216	$5,184	$3,840	$1,440	$39,360

Phoenix

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	7	3	5	1	7	3	5	1	
Cost($)	168	108	100	30	168	108	100	30	812
Weekly	$8,064	$5,184	$4,800	$1,440	$8,064	$5,184	$4,800	$1,440	$38,976

Santa Clara

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	10	4	6	2	10	4	6	2	
Cost($)	360	192	180	80	360	192	180	80	1624
Weekly	$17,280	$9,216	$8,640	$3,840	$17,280	$9,216	$8,640	$3,840	$77,952

Folsom

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	9	5	7	1	9	5	7	1	
Cost($)	324	240	210	30	324	240	210	30	1608
Weekly	$15,552	$11,520	$10,080	$1,440	$15,552	$11,520	$10,080	$1,440	$77,184

	Hillsboro	Phoenix	Santa Clara	Folsom	
Total Hourly Cost	$820	$800	$1,624	$1,708	$4,952
Weekly Cost	$39,360	$38,976	$77,952	$77,184	$233,472

5. OBJECTIVE:

There are basically two objectives of this project:

- Minimize number of headcounts
- Minimizing scheduling cost

For Hillsboro campus:

$$Min\ (z) = \sum_{i=1}^{4} CoiXoi + \sum_{i=1}^{4} CeiYei$$

- *Coi = Cost of Ops Tech at Shift i*
- *Cei = Cost of Eng Tech at Shift i*
- *Xoi = No. of Ops Tech in Shift i*
- *Yei = No. of Eng Tech in Shift i*

For Phoenix campus:

$$Min\ (z) = \sum_{i=1}^{4} CoiXoi + \sum_{i=1}^{4} CeiYei$$

- *Coi = Cost of Ops Tech at Shift i*
- *Cei = Cost of Eng Tech at Shift i*
- *Xoi = No. of Ops Tech in Shift i*
- *Yei = No. of Eng Tech in Shift i*

For Santa Clara campus:

$$Min\ (z) = \sum_{i=1}^{4} CoiXoi + \sum_{i=1}^{4} CeiYei$$

- *Coi = Cost of Ops Tech at Shift i*
- *Cei = Cost of Eng Tech at Shift i*
- *Xoi = No. of Ops Tech in Shift i*

- *Yei = No. of Eng Tech in Shift i*

For Folsom campus:

$$Min\ (z) = \sum_{i=1}^{4} CoiXoi + \sum_{i=1}^{4} CeiYei$$

- *Coi = Cost of Ops Tech at Shift i*
- *Cei = Cost of Eng Tech at Shift i*
- *Xoi = No. of Ops Tech in Shift i*
- *Yei = No. of Eng Tech in Shift i*

6. VARIABLES:

Number of headcounts (HC) at Intel campuses:

- Hillsboro, OR = 32
- Arizona = 32
- Santa Clara, California = 44
- Folsom, California = 44
- Total Technicians in all campuses = 152

For each location: X1+X2+X3+X4+Y1+Y2+Y3+Y4

Table below shows details on wages and shifts for Hillsboro and Phoenix

Wages for Ops Tech	Wages for Eng Tech	Time	Shift	Days
$24/hr.	$36/hr.	8 pm - 8 am	1	Sat - Tue
$20/hr.	$30/hr.	8 am - 8 pm	2	Sun - Wed
$24/hr.	$36/hr.	8 pm - 8 am	3	Thu - Sat
$20/hr.	$30/hr.	8 am - 8 pm	4	Wed - Fri
Total = $480/hr.	**Total = $264/hr.**			

Below table shows details on wages and shifts for Folsom and Santa Clara

Wages for Ops Tech	Wages for Eng Tech	Time	Shift	Days
$36/hr.	$48/hr.	8 pm - 8 am	1	Sat - Tue
$30/hr.	$40/hr.	8 am - 8 pm	2	Sun - Wed
$36/hr.	$48/hr.	8 pm - 8 am	3	Thu - Sat
$30/hr.	$40/hr.	8 am - 8 pm	4	Wed - Fri
Total = $996	**Total = $624/hr.**			

7. CONSTRAINTS AND REQUIREMENTS:

The LIWS department rules or constraints are to be considered while generating the schedule are as follow:

- A technician cannot be assigned more than one shift a day
- A technician assigned to night shift must not be assigned to the next day shift
- Maximum 2 staff needed as Engineering Tech in Hillsboro and Phoenix.
    - Maximum 5 staff needed as Ops Tech for Shift 1 and 3
    - Maximum 7 staff needed as Ops Tech for Shift 2 and 4
- Maximum 3 staff needed as Engineering Tech in Santa Clara and Folsom
    - Maximum 7 staff needed as Ops Tech for Shift 1 and 3
    - Maximum 9 staff needed as Ops Tech for Shift 2 and 4
- Minimize the total expenditure on technicians for all the campuses

Constraints LP:

Hillsboro and Phoenix

- Shift 1 and 3:
    - $Xoi \geq 5$; $Yei \geq 2$
- Shift 2 and 4
    - $Xoi \geq 7$; $Yei \geq 2$

Santa Clara and Folsom

- Shift 1 and 3:
    - $Xoi \geq 7$; $Yei \geq 3$
- Shift 2 and 4
    - $Xoi \geq 9$; $Yei \geq 3$

Where,

- Xoi = No. of Ops Tech in Shift i
- Yei = No. of Eng Tech in Shift i

8. DATA ANALYSIS:

Implementing the constraints and variables on the solver, the optimized results for all the location are as follows:

- **Hillsboro**

HILLSBRO CAMPUS

VARIABLES

	Shift 1		Shift 2		Shift 3		Shift 4	
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech
	5	2	7	2	5	2	7	2

OBJECTIVE

									Cost
	$24	$36	$20	$30	$24	$36	$20	$30	784

CONSTRAINTS:									LHS		RHS
Shift 1	1	1	0	0	0	0	0	0	7	>=	7
Shift 2	0	0	1	1	0	0	0	0	9	>=	9
Shift 3	0	0	0	0	1	1	0	0	7	>=	7
Shift 4	0	0	0	0	0	0	1	1	9	>=	9

- **Santa Clara**

SANTA CLARA CAMPUS

VARIABLES

	Shift 1		Shift 2		Shift 3		Shift 4	
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech
	7	3	9	3	7	3	9	3

OBJECTIVE

									Cost
	$36	$48	$30	$40	$36	$48	$30	$40	1572

CONSTRAINTS:									LHS		RHS
Shift 1	1	1	0	0	0	0	0	0	10	>=	10
Shift 2	0	0	1	1	0	0	0	0	12	>=	12
Shift 3	0	0	0	0	1	1	0	0	10	>=	10
Shift 4	0	0	0	0	0	0	1	1	12	>=	12

- **Folsom**

FOLSOM CAMPUS

VARIABLES

	Shift 1		Shift 2		Shift 3		Shift 4	
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech
	7	3	9	3	7	3	9	3

OBJECTIVE

								Cost
	$36	$48	$30	$40	$36	$48	$30	$40	1572

CONSTRAINTS:

									LHS		RHS
Shift 1	1	1	0	0	0	0	0	0	10	>=	10
Shift 2	0	0	1	1	0	0	0	0	12	>=	12
Shift 3	0	0	0	0	1	1	0	0	10	>=	10
Shift 4	0	0	0	0	0	0	1	1	12	>=	12

- **Phoenix**

PHOENIX CAMPUS

VARIABLES

	Shift 1		Shift 2		Shift 3		Shift 4	
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech
	5	2	7	2	5	2	7	2

OBJECTIVE

								Cost
	$24	$36	$20	$30	$24	$36	$20	$30	784

CONSTRAINTS:

									LHS		RHS
Shift 1	1	1	0	0	0	0	0	0	7	>=	7
Shift 2	0	0	1	1	0	0	0	0	9	>=	9
Shift 3	0	0	0	0	1	1	0	0	7	>=	7
Shift 4	0	0	0	0	0	0	1	1	9	>=	9

- **Overall Optimized Result for All Campuses**

Optimized Situation for Campuses

Hillsboro

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	5	2	7	2	5	2	7	2	
Cost($)	120	72	140	60	120	72	140	60	784
Weekly	$5,760	$3,456	$6,720	$2,880	$5,760	$3,456	$6,720	$2,880	$37,632

Phoenix

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	5	2	7	2	5	2	7	2	
Cost($)	120	72	140	60	120	72	140	60	784
Weekly	$5,760	$3,456	$6,720	$2,880	$5,760	$3,456	$6,720	$2,880	$37,632

Santa Clara

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	7	3	9	3	7	3	9	3	
Cost($)	252	144	270	120	252	144	270	120	1572
Weekly	$12,096	$6,912	$12,960	$5,760	$12,096	$6,912	$12,960	$5,760	$75,456

Folsom

	Shift 1		Shift 2		Shift 3		Shift 4		
	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	Ops Tech	Eng. Tech	
Staff	7	3	9	3	7	3	9	3	
Cost($)	252	144	270	120	252	144	270	120	1572
Weekly	$12,096	$6,912	$12,960	$5,760	$12,096	$6,912	$12,960	$5,760	$75,456

	Hillsboro	Phoenix	Santa Clara	Folsom	
Total Hourly Cost	784	784	1572	1572	4712
Weekly Cost	$37,632	$37,632	$75,456	$75,456	$226,176

9. SOLUTION/CONCLUSION:

As we look at the results from the current situation to optimized situation after implementing necessary constraints, the hourly cost for Hillsboro decreased by $36; Phoenix decreased by $16; Santa Clara decreased by $52 and Folsom campus decreased their hourly expense by $136 respectively. To further evaluate the scenario, and looking at the bigger picture, the optimization helped decrease overall expense by $240 hourly.

Future work can include implementing the solutions to provide flexibility in case of disruptions.

10. REFERENCES:

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