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Application of linear programming in employee allocation: A case study in emerging economy

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Abstract

Linear programming is widely used in numerous industries for allocating scarce resources to fulfill customers' demands. In this study, we use this mathematical technique in an automobile industry located in an emerging economy (Bangladesh). Given that, the emerging economy faces problems in implementing sophisticated technologies. Therefore, the key objective of this study is to show how linear programming applications are possible without sophisticated technologies, just by using a software, named GAM. Moreover, this study shows that the application of linear programming in the automobile industry in the emerging economy is also cost-effective and efficient in employee management. Based on the outcome of this study, we find that the company can save $26,174 in employee costs in eight weeks by implementing linear programming in the allocation of its employees. This study will contribute in many ways such as realizing policymakers, employees, and management how linear programming is beneficial for them in providing small efforts. Furthermore, this will add value to the existing literature that linear programming is also applicable in a specific industry in the emerging economy.

Keywords: Linear programming; Resource allocation; Emerging economy; Automobile industry; Employee/staff allocation; Optimization

1. Introduction

Mathematical techniques have been being used increasingly everywhere in the world in the last few decades. Linear programming is one of the renowned techniques that are used mostly in different industrial sections. Linear programming is an optimization mechanism, which is utilized in limited resource allocations with the target of fulfilling the demand of products or services [16]. Using optimization techniques, companies can gain economies of scale easily [13] [22]. Staff allocation is the most common form of linear programming applications [7] in numerous industries such as the hospitalized industry for allocating nurses [11] [15] [17] [19], hotel and banking sectors [4], and most importantly in airlines sector [6] [9]. Linear programming applications are as important as the Internet of Things (IoT) in business environments [8].

In our case study, we apply linear programming for allocating employees in the automobile industry from an emerging economy (Bangladesh) point of view. In Bangladesh, very few companies are using linear programming techniques. We posit that the application of linear programming benefits the industry in emerging economies. That is why our research question is "How does applying linear programming benefit financially in an emerging economy's automobile industry?".

We collect the relevant data from the respected company related to its employees. Subsequently, based on some assumptions, we apply linear programming in GAM software to the assembling of its two products only and find that

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the company would save $26,174 in employee costs in eight weeks of the assembling of those products. The study has numerous contributions to policymakers of companies, employees, and management. For example, using linear programming in the study, policymakers of companies can realize how it is cost-effective for their companies even though they are operating their businesses in not highly digitalized ways because there do not require too many sophisticated mechanisms to apply linear programming as it needs only good planning process and understanding how to operate GAM software. Moreover, management of the same type of company in an emerging economy can also realize how it is easy to operate their employee management in such manufacturing companies.

The study is presented as follows: Section 2 discusses the literature review. Section 3 and Section 4 discuss company background information and problem statements respectively. Following that, Section 5 presents assumptions and Section 6 discusses methodology. Section 7, Section 8, and Section 9 outline linear programming model, quantitative outcomes, and conclusion respectively.

2. Literature review

Employee scheduling through the utilization of linear programming is not new. Numerous researchers have conducted their research activities on it in various industries. Given by [18] & [21] regarding the roles of information and communication technology's roles in education, [23] provides that scheduling educational resources, classes, and courses is effective by applying linear programming because the number of faculties and classes are limited resources, and these resources need to be allocated in an efficient way so that all the classes can be taken in proper manner. Uncertainty is everywhere, and it is more so in business sectors because of uneven or inequality of supply and demand [25]. [14] posit that on-call shifts with the rotation of employees' schedules can be a good way of employee scheduling through linear programming.

Moreover, [24] uses of their research binary integer linear programming for staff force allocations. [2] utilize the mathematical techniques in a Nigerian power station company for manpower allocation, and find that linear programming enhances to obtain the highest efficiency in staff allocations. Further, linear programming is not only applied in full-time but also applied in part-time employee scheduling [1]. For example, [3] [5] [12] use the techniques in the construction industry for human resource allocations. This is also applicable to a company that operates its operation in multiple locations [20].

3. Company Background Information

XYZ Truck Assembly Company* (The company) runs its business in the automobile industry in Bangladesh by assembling different parts of its vehicle parts imported from abroad to produce its finished goods such as Human haulers, mini trucks, and trucks. Every month, it collects forecasted sales information from its dealers for the next month, which fluctuates from month to month, even sometimes varying significantly. The company needs to meet the dealers' demand every month as they are the ultimate key marketers to manage their customers to boost their sales. Although the company has a wide range of products, this study is conducted on two products those are human haulers and trucks.

**Due to the confidentiality issue, the actual name of the company cannot be disclosed.*

4. Problem statements

Currently, the company has full-time plant-level workers (Assembler, Helper, and Painter) for its production. As mentioned, the demand is varied, full-time workers need to overstay when their demands go up in a particular month; on the other hand, sometimes the workers are passing their time at their work premises just doing nothing if demand significantly decreases. When they have overtime work, they need to be paid a double working hourly rate. Moreover, when they stay at their workplace without doing anything or not working in a full phase, the company loses some opportunity costs as it cannot utilize its workers efficiently because they need to be paid their monthly basic wages as per their appointment contracts. Moreover, as human beings, employees sometimes tend to become opportunistic and try to take advantage of such situations by delaying some work and shifting it later to make a case for overtime hours and get double working rates. [10] suggests that employees working at different company ladders can use different scenarios in their workplace as an opportunity to commit something unethical if situations permit.

Now, the question is what if the company fires some full-time workers? As per the management of the company, this is not possible because of increasing demand in certain months, and the minimum number of employees cannot work more than 12 hours a day. Therefore, there is a chance of not meeting the company's dealer expectations which leads to being questionable in its existence in the long run. The company can go for contractual workers** without having any full-time workers as it can assess its monthly demand weekly almost one month earlier to avoid its excessive overtime payments and save the idle time of its full-time workers. However, the problem is that the company's management cannot instantly hire the required contractual employee a day or a week ago, but they can be hired one month earlier. The unfavorable side to implementing this is that the management cannot understand the minimum number of workers who will be hired and how they schedule the contractual workers in different weeks in the next month as a worker cannot work 7 days a week and the company needs to run production for seven days a week.

***The workers are hired on a weekly contractual basis although it is renewed as per the company's production requirements.*

5. Assumptions

- The company has contractual workers available for contractual work.
- There is no minimum payment for contractual employment. Contractual workers will be paid every week only for the working week they work in the company's plants.
- No overtime is required as the company can hire whatever it requires, and it has sufficient assembling plants.
- The company needs to contract workers for the next whole week, not for one day. If the company goes for one-day contract with workers, the management thinks that they may not get adequate workers as workers may be reluctant to work.

6. Methodology

The project develops linear programming equations to minimize worker numbers in the company. The linear programming is executed in GAMS software to get the output. Subsequently, it presents total wages as per the existing system and wages after implementing linear programming. In other words, it presents comparative wages in two options 1) full-time worker option and 2) contractual worker option by employing linear programming.

7. Linear programming model

The company has three types of workers (Assembler, Helper, and Painter) who are working 5 days and the operation runs for 7 days. Therefore, they need to schedule workers working hours, and setting starting day of the week for workers is the key to the workers' schedule.

7.1. Indices

$i = working\ days\ of\ a\ week$

$j = starting\ day\ of\ working\ of\ a\ week$

$k = week\ number\ with\ types\ of\ workers$

7.2. Decision variables

$x_{Jk} = number\ of\ workers\ who\ starts\ his/her\ working\ on\ j\ day\ of\ k\ week$

7.3. Objective function

Minimizing the number of workers:

$$\text{z} = \min \sum_{J=1}^{7} x_{Jk}$$

7.4. Constraints

$$\sum_{J}^{7} b_{iJ} x_{Jk} \geq a_{ik}\ \forall \text{i}$$

$b_{iJ} \sum_{0= otherwise}^{1= if\ workers\ working\ on\ i\ day\ that\ starts\ on\ j\ day\ of\ the\ week}$

$a_{ik} = minimum\ required\ number\ of\ k\ type\ workers\ working\ on\ i\ day$

$$x_{Jk} \geq 0$$

8. Quantitative outcomes

8.1. Historical numerical data in 2021

To evaluate the outcomes of the model, the project considers the first eight weeks of the year of 2021 data of the company. The total weekly wages payment (full-time basic wages and overtime) of the company for the first eight weeks in 2021 are as follows:

Table 1 Weekly data

Week number in 2021	Demand of products		Full-time workers	Amount paid to workers	
	Human hauler	Big truck		Basic wages payment in USD	Overtime payment in USD
1	35	20	121	9700	544
2	36	25	121	9700	3410
3	58	34	121	9700	9240
4	56	43	121	9700	12780
5	64	45	121	9700	6854
6	82	53	121	9700	9500
7	85	58	121	9700	7478
8	78	50	121	9700	4890
Total	494	328	121	77600	54696

8.2. Data related to Linear programming

The company needs the following standard number of workers during a week (7 days) to assemble every five human haulers and five big trucks if the workers work eight hours a day:

Table 2 Type-wise workers' demand

Types of workers	Workers needed per 5 goods productions in different products	
	Human hauler	Big trucks
Assembler	2	2
Helper	2	3
Painter	1	1
Total	5	6

Based on the above standard criteria, the minimum number of workers who must work at its plant is presented in annexure-A. Subsequently, the company can use the linear programming model and can calculate the number of workers who start their duty for consecutive five days in a week. Therefore, the summation of all workers who start their duty on different days in a week is the required number of workers for that week to meet the minimum number of workers in Annexure-A. The number of required workers is determined for every next four weeks by using linear programming mentioned below:

Table 3 Forecasted required workers based on linear programming

Week number	Number of workers		
	Assembler	Helper	Painter
1	28	33	14
2	35	41	19
3	48	58	26
4	54	65	27
5	61	71	31
6	73	87	37
7	80	96	41
8	69	83	35

The screenshot of GAMS output of the linear programming is in Annexure-B whose every column summation is the above numerical values against week number and worker types.

Based on the above numbers of workers, the weekly wage rate of each type of worker ($103, $80, and $69 for Assembler, Helper, and painter respectively), the total wages would be $104,734 for the first eight weeks in 2021 (presented in Annexure-C) if the company used the linear programming method; and the payment of the actual wages was $130,908 that was $26,174 higher in first eight weeks in 2021 than the proposed linear programming method. Because the company could reduce the minimum basic payment to its all-full-time workers (USD9700) as well as could not require paying wages to double the working hourly rate compared to the regular basic hourly rate.

Annexure A Minimum number of all workers required in a week

	1		2		3		4		5		6		7		8	
	Human hauler	Big truck	Human hauler	Big truck	Human hauler	Big truck	Human hauler	Big truck	Human hauler	Big truck	Human hauler	Big truck	Human hauler	Big truck	Human hauler	Big truck
Product demand	35	20	36	25	58	34	56	43	64	45	82	53	85	58	78	50
Assembler	12	8	15	10	21	13	22	16	25	18	32	20	35	22	30	19
Helper	12	11	15	14	21	20	22	24	25	26	32	30	35	33	30	29
Painter	6	4	8	5	11	7	11	8	13	9	16	10	18	11	15	10

Annexure B Screenshot of GAMS output

	w1A	w1H	w1P	w2A	w2H	w2P	w3A	w3H	w3P	w4A	w4H	w4P
monday	4.000	4.000	2.000	5.000	5.000	2.000	6.000	8.000	3.000	7.000	9.000	3.000
tuesday	4.000	4.000	2.000	5.000	6.000	2.000	7.000	8.000	3.000	7.000	9.000	4.000
wednesday	4.000	5.000	2.000	5.000	6.000	3.000	7.000	8.000	4.000	8.000	9.000	4.000
thursday	4.000	5.000	2.000	5.000	6.000	3.000	7.000	8.000	4.000	8.000	9.000	4.000
friday	4.000	5.000	2.000	5.000	6.000	3.000	7.000	9.000	4.000	8.000	10.000	4.000
saturday	4.000	5.000	2.000	5.000	6.000	3.000	7.000	8.000	4.000	8.000	9.000	4.000
sunday	4.000	5.000	2.000	5.000	6.000	3.000	7.000	9.000	4.000	8.000	10.000	4.000

	w5A	w5H	w5P	w6A	w6H	w6P	w7A	w7H	w7P	w8A	w8H	w8P
monday	8.000	10.000	4.000	11.000	13.000	5.000	12.000	13.000	5.000	9.000	11.000	5.000
tuesday	8.000	10.000	4.000	10.000	12.000	5.000	11.000	13.000	6.000	10.000	12.000	5.000
wednesday	9.000	10.000	5.000	11.000	13.000	5.000	12.000	14.000	6.000	10.000	12.000	5.000
thursday	9.000	10.000	4.000	10.000	12.000	5.000	11.000	14.000	6.000	10.000	12.000	5.000
friday	9.000	11.000	5.000	11.000	12.000	6.000	11.000	14.000	6.000	10.000	12.000	5.000
saturday	9.000	10.000	4.000	10.000	13.000	5.000	12.000	14.000	6.000	10.000	12.000	5.000
sunday	9.000	11.000	5.000	10.000	12.000	6.000	11.000	14.000	6.000	10.000	12.000	5.000

Annexure C Wages calculation

Week	Number of workers as per GAMS			Weekly payment rate			Weekly wages			Total wages in USD (G+H+I)
	Assembler (A)	**Helper (B)**	**Painter (C)**	**Assembler (D)**	**Helper (E)**	**Painter (F)**	**Assembler G=(A*D)**	**Helper H=(B*E)**	**Painter I=(C*F)**	
1	28	33	14	103	80	69	2884	2640	966	6490
2	35	41	19	103	80	69	3605	3280	1311	8196
3	48	58	26	103	80	69	4944	4640	1794	11378
4	54	65	27	103	80	69	5562	5200	1863	12625
5	61	71	31	103	80	69	6283	5680	2139	14102
6	73	87	37	103	80	69	7519	6960	2553	17032
7	80	96	41	103	80	69	8240	7680	2829	18749
8	69	83	35	103	80	69	7107	6640	2415	16162
									Total	104734

9. Conclusion

A company that has similar types of problems regarding employee scheduling can use the linear programming method with the help of GAMS or other related software to determine the minimum number of workers. Thus, it will be helpful for them to reduce unnecessary wages or salaries without hampering their production and business activities, leading to an increase in their profit margin.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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