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Trainees assignment problem in Information Technology (IT) service organizations

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Abstract. This paper addresses the trainees assignment problem of an IT service firm. A Linear Programming (LP) model is developed to assign trainees to projects as per the requirements, considering their skill set and location preferences. The resulting LP model is solved using the actual cost data from the firm. This paper also discusses the implications of human resource allocation policies on the total cost.

Keywords: workforce allocation; IT service; linear programming; human resource policy

Introduction

Large IT service organizations face challenges in workforce planning and assignment owing to their size and scale. For instance, every year, thousands of trainees join such an IT firm. The planning and execution of trainee allocation is the major area of work for a trainees' resource manager (RM) of an IT firm. Each trainee is trained primarily in one technology stream in addition to the general training after joining. The quarterly projections of trainees' requirements for different projects are collected and are consolidated based on the location and technology stream by the RM. The RM has to then assign these thousands of trainees to multiple projects at various locations to meet the project requirements.

This trainee's assignment problem is important due to several reasons. First, the recruitment and training expenses for an IT firm are high (~ 100-215 crore rupees, Tata 2011). Hence, multiple attributes of trainees such as domain expertise and skill sets need to be matched with the project requirements given by various projects during this assignment exercise to reduce re-training and additional recruitment costs. The re-training time and re-training cost is less if a trainee is allocated to a project requiring the same or similar skill set. For example, it would be beneficial to allocate a C++ candidate to a C++ or Java requirement than to Mainframe technology to reduce the cost of mismatch. Assignment mismatches also result in delay in project execution and may impact the quality of deliverables.

Second, an attrition rate in major IT services firms in India is very high (~ 12-15%, Infosys 2011). The mismatch in allocation causes employee dissatisfaction and increases work pressures, which results in rise in the attrition rate. Hence, at the end of the training programme, each trainee is asked to provide three location choices. If the trainee does not get the first location choice, the firm has to pay for his/her logistics (accommodation and travel) expenses for the initial few days as per the type of the city (Metro or Non-metro). Furthermore, the RM also has to consider a few human resource (HR) policies during the allocation exercise. For example, employees with similar joining dates must be spread proportionately across locations, because later at the time of promotions, each branch manager has an upper limit for the number of promotions from these similar joining date employee groups.

A number of workforce management (WFM) software products are available in the market, but they are generally suitable for industries where standardization of categorization of employees is relatively easy. But in IT services sector, each professional has varied skill sets; the implementation of WFM software seems less effective. Many firms handle their own workforce planning systems. These systems provide processes for managers and employees to update information about the project requirements and upgrading of skill sets. These systems provide a platform for data integration, but these systems are not capable of decision making. It becomes really challenging for resource managers to routinely perform this repetitive and tedious allocation process in an efficient way for such a large number of employees.

In this paper, we address this problem of allocation of trainees to projects in an IT service firm. We have developed a mathematical programming formulation that minimizes the total assignment costs by considering various types of constraints. In contrast to the earlier work, we consider policy constraints during the assignment and problem-specific direct cost structure instead of using artificial penalties. We then solve a representative allocation problem using the actual cost data collected from the firm and demonstrate various cost implications by performing the trainee allocation with and without policy constraints.

The next section describes the research work in workforce allocation and planning. Subsequent sections provide the mathematical formulation and current assignment method. The paper is concluded by discussing the managerial implications and implementation issues.

Literature review

Research in workforce allocation and planning in IT service sector is relatively new. The various issues addressed in IT workforce planning are: capacity planning (Chouhan and Goyal 2010 and Hargaden 2011b), workforce planning using manufacturing supply chain concepts (Gresh et al 2007 and Dixit et al 2009) and IT resource allocation. The primary goal of these research papers is to allocate workforce such that idle resources are minimized and revenue from new project opportunities is increased. Owusu et al (2006) developed an automated resource planning system for managing the resources of British Telecom. Santos et al (2009) presented a workforce planning and scheduling model for IT project delivery service center and solved using commercial solvers for mixed integer programming model. Dong et al (2008) and Naveh et al (2007) presented a constraint programming-based solution for solving workforce matching problem. Duggan et al (2004) proposed a multi-objective evolutionary algorithm to generate a set of optimal solutions to satisfy multiple objectives such as minimizing software defects, project completion time and cost; and maximize worker utilization and customer satisfaction. Gonsalves and Itoh (2010) proposed a skill-to-time based allocation model in which project time varies based on the level of the skill possessed by the personnel assigned to the task. The allocation model is solved using multi-objective Particle Swarm optimization algorithm. Otero et al (2009) proposed a linear programming assignment model to assign resources to tasks to reduce the training time. Barreto et al (2008) proposed several utility functions for the managers, such as most qualified team, cheapest team, faster team, etc. They provided a solution using constraint satisfaction and branch-and-bound technique. Hargaden and Ryan (2011a) developed workforce planning models for professional service organizations and provided strategic insights into different workforce planning policies by the numerical analysis of the model.

In this paper, we build upon the above research streams and model the trainee assignment problem of an Indian IT firm using linear programming to minimize total assignment costs. In contrast to the above papers, we consider policy constraints during the assignment and problem-specific direct cost structure, instead of using artificial penalties.

Current solution approach

Allocating such a large number of trainees and perfectly matching them to the project requirement is important and a non trivial job, as discussed in detail in the Introduction section. One standard way of allocation is to examine the full list of trainees in some predefined order and for each trainee, shortlist the best-fitting requirements, and then assign the trainee to one of those requirements. An equivalent option is to look at the full list of project requirements in a predefined order, shortlist the best-fitting trainees, and then assign the project requirement to one of those trainees. As a part of this procedure, the RM may use search tools to search for a trainee with characteristics needed by the project. However, the above procedure has some drawbacks. It is repetitive, time consuming, and tedious. The trainees who are at the top of the list are more likely to be assigned to the best-found requirement, which is a greedy policy, because trainees may be better suited to some other project requirements. This may lead to fewer perfect assignments to project requirements and other requirements may not be well matched. As a result, this approach leads to suboptimal solution.

Given the above drawbacks and consequences of mismatched allocations, there was a need for developing an automatic allocation tool, which would tackle the problem in a global way, provide solution in short period, suggest alternative solutions, demonstrate policy implications, and provide the RM with various analyses and full support for decision making.

Proposed mathematical formulation

The gap between the resource availability and requirement results in allocation mismatch. Also mismatch occurs due to the HR policy constraint, that trainees with similar joining date must be spread proportionately across locations. These trainees are put into different caterogies as per their joining date. The task is to allocate such that the total cost of mismatch in allocation is minimized. The notations are:

Index $i = 1, \dots, N$ *Number of trainees to be assigned*
Index $j = 1, \dots, M$ *Number of categories*
Index $k = 1, \dots, K$ *Number of skills*
Index $l = 1, \dots, L$ *Number of locations*

Decision Variable:
$X_{ikl} = 1$, *if* i^{th} *trainee is assigned to the* k^{th} *skill at the* l^{th} *location, otherwise* $X_{ikl} = 0$.

Parameters:
C_{ikl} = *Cost of assigning* i^{th} *employee to the* k^{th} *skill at* l^{th} *location*
$a_{ij} = 1$, *if* i^{th} *trainee belongs to* j^{th} *category, otherwise* $a_{ij} = 0$
D_l = *Demand requirement at* l^{th} *location*
U_k = *Demand requirement for* k^{th} *skill*

Objective:

$$Min \quad Z = \sum_{i=1}^{N} \sum_{k=1}^{K} \sum_{l=1}^{L} X_{ikl} C_{ikl} \tag{1}$$

Subject to:

$$\sum_{i=1}^{N} \sum_{l=1}^{L} X_{ikl} = U_k \qquad \forall k = 1, \dots, K \tag{2}$$

$$\sum_{i=1}^{N} \sum_{k=1}^{K} X_{ikl} = D_l \qquad \forall l = 1, \dots, L \tag{3}$$

$$\sum_{l=1}^{L} \sum_{k=1}^{K} X_{ikl} \leq 1 \qquad \forall i = 1, \dots, N \tag{4}$$

$$\sum_{i=1}^{N} \sum_{k=1}^{K} a_{ij} * X_{ikl} \leq \left\lceil \left(\sum_{i=1}^{N} a_{ij}\right) \frac{D_l}{\sum_{l=1}^{L} D_l} \right\rceil \qquad \begin{matrix} \forall j = 1, \dots, M \\ \forall l = 1, \dots, L \end{matrix} \tag{5}$$

$$X_{ikl} \in \{0, 1\} \qquad \forall\, i, k, l \tag{6}$$

Constraints 2 and 3, state that the project requirements for each skill and for each location must be met. Constraint 4 states that each trainee would be allocated, at most once to any requirement. We group trainees as per their date of joining and tag them with a category. Constraint 5 ensures that the trainees in each category are proportionately spread across all the locations. In this constraint, a_{ij} is a known parameter and takes value one, when i^{th} trainee belongs to j^{th} joining category, otherwise it is zero. This ensures that only the relevant subset of trainee's belonging to a particular joining category are selected in each constraint. We refer this constraint as the HR policy constraint. The resulting mathematical formulation is a linear binary programming model. Despite having the binary variables, the problem can be solved efficiently by simplex algorithm because of total unimodularity property followed by the constraint coefficient matrix. Due to this problem structure, the integrality constraint 6 is not required.

Numerical results and discussion

The cost of misallocations is computed using the actual cost data from the field. The cost for skill set mismatch is computed using the training time multiplied by the daily cost-to-company of a trainee. The training time varies depending on the skill which the trainee is migrated to. Thus, the cost of allocation is zero for a particular trainee when the trainee gets first location choice and is assigned to the skill in which he\she is trained. If the trainee does not get his/her first location choice then the company has to pay for three days logistics charges (hotel accommodation and travel expenses). All these details were provided by the RM of the firm.

In the illustration, we consider a situation where eight trainees need to be assigned to eight project requirements. Table 1 displays the consolidated project requirements for each location for each skill set. Table 2 displays the employee details with stream, location choices and month of joining. Trainees with the same month of joining are put in one category as per the HR policy. Table 3 displays the actual training cost if a trainee with a specific skill set is allocated to a project requirement with different skill set. The cost of mismatch in location for a non-metro city is Rs 2000 and for metro city is Rs 3000. We have used lp_solve (Berkelaar et al 2004) dynamic linked library (DLL) with an interface written in Visual Basic for Applications on the Microsoft Excel for solving linear programming problem. The Excel with lp_solve can handle linear or mixed integer programs of substantial size (on the order of 10,000 variables and 50,000 constraints) (Buttrey 2005).

Table 4 shows the cost of allocation, zero cost indicates a perfect match, while in some cases, cost is due to mismatch of location or skill set or due to mismatch of both the attributes. Further, it can be seen from Table 4 that the total cost of allocation and the number of improper allocations, with the removal of the policy constraint (5), is significantly lower than the model with policy constraint. This shows how some HR policy can impact the total cost to the firm by acting as a constraint in a planning exercise.

Table 1. Consolidated Project Requirements.

Location	*Unix/C++*	*Java/J2EE*	*.NET*
Bangalore	2	0	2
Pune	0	1	0
Delhi	1	0	2

Table 2. Trainees Skill and Location Choices.

Emp No	*Stream*	*Location*			
		Choice 1	*Choice 2*	*Choice 3*	*DOJ*
1	*Unix/C++*	Bangalore	Pune	Delhi	Jan
2	*Java/J2EE*	Bangalore	Delhi	Pune	Jan
3	*.NET*	Delhi	Bangalore	Bangalore	Feb
4	*Java/J2EE*	Pune	Bangalore	Delhi	Feb
5	*.NET*	Pune	Bangalore	Bangalore	Feb
6	*Unix/C++*	Bangalore	Pune	Delhi	Jan
7	*Unix/C++*	Bangalore	Pune	Delhi	Feb
8	*.NET*	Delhi	Bangalore	Pune	Feb

Table 3. Training Cost in Rs.

Trainee Skill	*Project Requirement*		
	Unix/C++	*Java/J2EE*	*.NET*
Unix/C++	0	1400	2800
Java/J2EE	1400	0	2800
.NET	2800	2800	0

Table 4. Total cost of allocation with and without HR policy constraint.

	Allocation without policy constraint					*Allocation with policy constraint*			
Emp No	*Allocation Details*				***Emp No***	*Allocation Details*			
	Location	*Choice*	*Skill*	*Cost*		*Location*	*Choice*	*Skill*	*Cost*
1	Bangalore	1	Unix/C++	0	***1***	Delhi	3	Unix/C++	3000
2	Bangalore	1	.NET	2800	***2***	Bangalore	1	.NET	2800

	Allocation without policy constraint					*Allocation with policy constraint*			
Emp No	*Allocation Details*				**Emp No**	*Allocation Details*			
	Location	*Choice*	*Skill*	*Cost*		*Location*	*Choice*	*Skill*	*Cost*
3	Delhi	1	.NET	0	***3***	Delhi	1	.NET	0
4	Bangalore	2	Java/J2EE	2000	***4***	Bangalore	2	.NET	2000
5	Pune	1	.NET	0	***5***	Pune	1	.NET	0
6	Bangalore	1	Unix/C++	0	***6***	Bangalore	1	Unix/C++	0
7	Bangalore	1	Unix/C++	0	***7***	Bangalore	1	Unix/C++	0
8	Delhi	1	.NET	0	***8***	Delhi	1	.NET	0
	Total Mismatch	*2*	*Total Cost*	*4800*		*Total Mismatch*	*3*	*Total Cost*	*7800*

Conclusion

In this paper, a mathematical programming based model is suggested to assign the trainees to the software projects in an IT firm. The implementation of this trainees allocation problem in the IT service firm was time consuming. It started with problem understanding, requirement gathering, developing a proof of concept, piloting, and training the managers. The RM of the IT service firm has been using this Microsoft Excel-based solver for assigning tens of thousands of trainees to projects. This has significantly saved time for RM during the allocation exercise. It has saved millions of rupees for the IT firm by reducing allocation mismatches. The HR constraint is helpful for HR department from trainee's career and promotion planning perspective. However, it increases the total cost to the firm during the assignment exercise. Clearly, the firm should evaluate the tradeoffs before strictly implementing HR policies.

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