Workforce Planning and Scheduling for the HP IT Services Business

Cipriano A. Santos, Alex Zhang, Maria Teresa Gonzalez, Shelen Jain

Abstract:
We present a system for workforce planning for HP's IT services business. For project-based services, we solve the problem of matching an employee's skills and other attributes to the project (job) requirements; our mixed integer program (MIP) model finds the minimal cost plans, including a fulfillment plan, a hiring plan, and a transformation plan, for staffing the projects. Our system also incorporates business rules such as project priorities and bench duration priorities, and computes the service levels for fulfilling projects that are currently in the funnel.

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1   Introduction

Our research aims at developing analytical models for workforce planning to support labor supply and demand matching in an uncertain environment while minimizing costs of service delivery. The research challenges lie in (a) developing a modeling framework that encompasses the vast diversity of the IT services business from project-based to annuity-based and many other variations in between; (b) forecasting the labor demand for thousands of skills but with sparse historical data and hidden structural changes in the data; (c) building tractable optimization models for demand and supply matching – when both are uncertain; (d) aligning employees' career paths with business needs; and lastly (e) addressing the sheer scale of the problem due to multiple geographies, hundreds of service offerings, thousands of skills and tens of thousands of people resources. Our focus in this paper is on workforce planning and scheduling at a single project-based service delivery center.

Workforce planning and scheduling has been studied in the Operations Research literature under the name of Manpower (Personnel) Planning since 1950s. In fact, one of the early applications of the linear programming method pioneered by George B. Dantzig is "program planning of interdependent activities" (Dantzig [1]). There are many papers particularly for the U.S. Armed Forces on Manpower Planning. Saul I. Gass, a leading researcher in the field, defines Manpower Planning as the problem to determine the number of personnel and their skills that best meet the future operational requirements of an enterprise, and proposes that Manpower Planning should be tackled by a hierarchical planning approach (Gass [2]). Gass proposes to use Markov chains and network flow models to explain and optimize workforce dynamics. Grinold and Marshall [4] give the mathematical treatment of Markov chains and network flow models for Manpower Planning. Few business organizations face the type of workforce planning and scheduling problem at HP Services in terms of labor skills variety, complexity, supply dynamics, demand uncertainty, and competitive marketplace. The work by Gresh et al [3] done at IBM TJ Watson Research Center for IBM Global Services is most relevant to our workforce planning and scheduling setting. There are a number of aspects which the IBM work does not address. IBM's tool does not assign work to individuals but to a group of people matching skills and attributes. People substitution (as a group) to

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allow flexible skill matching is part of the IBM tool. However, each employee is assumed to have only one skill. Training of employees so they can handle different jobs depending on the demand mix is not addressed; nor is future hiring allowed. Hiring plans are followed as part of the input, rather than optimized together with the master plan. Another aspect is that IBM tool does not model personnel attrition. Finally, demand and supply in the IBM tool are treated as deterministic.

2   Workforce planning and scheduling for project-based services

Workforce planning and scheduling entails anticipating supply availability and job requirements in order to have the right people, with the right skill, at the right time, in the right place, at the right cost. The problem of matching future availability of employees with future job requirements is quite complex since HP has hundred of thousands of employees in project delivery roles, with thousands of skills distributed in countries all over the world. The other challenge of matching future availability of employees with future job requirements is that supply and demand is uncertain. Finally, there are no clear costs when matching an employee to a job. For example, let's suppose we require Java programmer at the Expert level for the manufacturing industry (job j), and have an employee (e1) that is a Java programmer at the Intermediate level from the Aerospace Industry, and an employee (e2) that is a Java programmer at the Master level from the Telecom Industry, then it is not clear what is the cost of assigning e1 to j and e2 to j.   There is the problem of discriminating *good* matches from *bad* matches automatically when matching future availability of employees with future job requirements. In practice, first-line managers *know* their employees and can assign the right employee to the right job, a *good* match; however at a company like HP where we have hundred of thousands of employees and jobs we will like to formulate a business utility function that automates the discrimination of good matches from bad matches.

A typical Project Delivery Center (PDC) faces both demand and supply uncertainty in workforce management. A PDC has a pipeline of potential projects called the *funnel of opportunities*. The main sources of demand uncertainty are the uncertainty about winning a project opportunity and the uncertainty about when the project will start if won. The types and amounts of resources required by the project are also uncertain at the time of resource planning for the projects. On the other hand, the main sources of supply uncertainty are the uncertainty about workforce attrition and uncertainties around hiring. Hiring lead times can vary from a couple of weeks to several months; therefore we need to plan ahead of demand realization in order to make sure that demand is satisfied. Therefore the main objective of workforce planning and scheduling is to balance workforce utilization and availability to optimize demand fulfillment. We tackle the workforce planning and scheduling problem in two phases. Phase 1 is a demand and supply consolidation step to express demand and supply in terms of jobs. At Phase 2 we formulate a large scale mixed integer programming model to optimally match future available employees with future job requirements.

2.1   Supply and Demand Consolidation

During our initial research we discovered that workforce planning under uncertainty cannot be done at the detailed skill-set level; instead, we need to plan at a higher level of aggregation than detailed skill set of requirements. We call this high level skill *Skill-Group* (SG). Skill Groups allow mapping the demand (Funnel of project opportunities) into the language of the supply (employee skills). The key ideas to determine the Skill Groups is to first identify standard projects of a given IT technology. Then identify the standard jobs that each standard project requires. For each a standard job, we identify the main technical skills required, this set of skills constitutes a SG, i.e. the main technical skills required to perform a standard job defines the SG. The PDC identified five more job attributes required to properly allocate people to projects; therefore the final labor *nomenclature* considered includes the

following attributes: Skill Group – J2EE, dot net, ABAP, etc; Workforce Type – regular or contingent; Job Level – entry, intermediate, expert, master, etc; Business Domain – manufacturing, aerospace, finance, etc; Location Offshore –Bangalore, Chennai, etc; Location On site – USA, Germany, UK, etc.

The main function of the Supply and Demand Consolidation approach is to map job requirements of project opportunities in the Funnel into employees qualified to perform the job required, where a job is represented as a string of job attributes. Our approximate matching approach allows mapping employees to jobs at less than 100% match and provides a score for the matching. To tackle demand and supply uncertainty, we create a buffer capacity called *bench*. To explain how our approach builds a bench, we first need to describe how we parameterize demand and supply uncertainty. Each opportunity in the funnel has a win probability that measures the degree of confidence we have in winning such a project, a (forecasted) schedule of headcount requirements for each job required to deliver the project opportunity, and 3 points in time where the project can start – Earliest Starting Time, Expected Starting Time, and Latest Starting Time. To characterize supply uncertainty, we consider the attrition rates of employees at the various technologies of the PDC. We observe that winning projects in the Funnel are independent events, thus the headcount requirements for a job of a project defines a Bernoulli process. We assume that the attrition process can be modeled with a binomial distribution with probability of success equal to the attrition rate and the population of the distribution equal to the inventory of employees; this binomial distribution determines the number of employees than need to be replaced. Resource Managers (RM) at the PDC define a threshold of win probability such that opportunities with a win probability higher or equal to the threshold will get employee resources to satisfy headcount requirements schedule for each job required. For opportunities with a win probability less than the threshold and for resources that need to be replaced due to attrition, we compute the SG requirements cumulative distribution as the convolution of the Bernoulli and Binomial distributions. We interpret the threshold defined by the Resource Managers as the Service Level (SL) required at the PDC, then based on the SL we determine the number of headcount requirements for SG that we need to have as a buffer capacity – i.e. bench.

The main outputs of the Demand and Supply Consolidation phase are a *qualifications* table that determines which jobs required by opportunities in the Funnel and Bench an employee is 100% qualified for, and a *transitions* table that determines which jobs required by either opportunities or Bench an employee is partially qualified for. The transitions table defines the score of the employee-job matching and the type of workforce transformation (training, promotion/demotion, re-location) required to fully qualify the employee for the job.

2.2   Mixed integer programming model to determine a workforce plan and schedule

We have built a mixed integer programming model that balances the trade-off between workforce utilization and availability to optimize demand fulfillment. The MIP tool generates three plans: a fulfillment plan, an employee transformation plan, and a hiring plan. The fulfillment plan encompasses project-job-employee-period allocations and a planned *bench*. A particular use of bench is called *practice building* where new employees will be hired to build expertise in a new technology field. The employee transformation plan entails employees' training, promotions, and re-deployment; i.e. anything that changes the current status of an employee to satisfy job requirements. The employee transformation plan identifies opportunities to increase resource utilization and aligns employees' career paths with business need of satisfying project requirements. Remaining gaps that cannot be filled by the fulfillment plan and employee transformation plan are filled by hiring new employees considering hiring lead times. The pipeline of joinees (new hires) is considered part of the hiring plan. Remaining gaps need to be resolved manually by Practice Managers (PM) and RM. Considering the SG requirements cumulative distribution computed at the Demand and Supply Consolidation phase, we can determine the probability of satisfying SG requirements with the workforce plans generated by the MIP (fulfillment, transformation, and hiring plans). This *service level*

metric is particularly valuable when management imposes a hire freeze or limits the number of people to hire, allowing PM to negotiate hiring for critical SG requirements. In addition to the mathematical optimization logic, the MIP encodes business rules that reflect the preferences RM and PMs in allocating employee resources. For example, high-priority opportunities in the funnel (demands) are staffed before low priority ones; low priority opportunities are to be filled with pipeline joinees (new hires). Employees who have been "on the bench" for a longer duration will have a higher priority to be assigned to projects.

3   Conclusions and future research

The workforce planning and scheduling approach presented has been deployed at an HP Project Delivery Center (PDC). Our approach uses commercially available solvers to tackle the mixed integer programming model. Typical problem size is very large, however, we have observed that these MIP solvers reduces the original model size to less than 10% with their constraint programming algorithms used during pre-processing. In addition, we have observed that the underlying MIP formulation is tight, since most of the time the optimal solution of the LP relaxation of the reduced problem is integer-feasible. Therefore, we believe that there is an underlying network flow structure that can be exploited. As future research, we want to study the *Polyhedron* associated with the MIP formulation and derive efficient algorithms to solve the problem. Also, we are building a simulation tool that will help to evaluate directly the effects of demand and supply uncertainty in terms of metrics such as demand fulfillment and resources utilization.

References

1. Dantzig, G.B. Programming of Interdependent Activities, II: Mathematical Model, *Econometrica*, Vol.17, 200-211 (1951)
2. Gass, Saul I. Military manpower planning models, *Computers & Operations Research,* 18 (1), 65-73 (1991)
3. Gresh, D.L., D.P. Connors, J.P. Fasano, R.J. Wittrock. Applying Supply Chain Optimization Techniques to Workforce Planning Problems. *IBM Journal of Research & Development,* Vol.51 (2007), No.3/4, May/July 2007, pp.251-261 (2007)
4. Grinold, R.C. and K.T. Marshal. *Manpower Planning Models*, North-Holland, Amsterdam (1977)