In this paper, we study the problem of manpower planning – how should a business unit hire and promote its employees through its hierarchy in order to achieve a targeted productivity level, while constrained by budget, availability of manpower and managerial span of control? This problem is not new. There have been many approaches, but we shall focus on the mathematical programming approach in this paper.

The Markov paradigm is most popular; Bartholomew et al. (1991) provides a broad overview. This is usually done by setting up transition probabilities through the hierarchy. Two central questions are of concern here:

- **Attainability** – Is it possible to transit from one organization of work to another?
- **Sustainability** – What is the minimum cost to do so?

Subsequent improvements have incorporated learning effects (Gans and Zhou 2002) and inter-departmental flows (Song and Huang 2008) just to name a few extensions. Attainability is not always guaranteed (Gurrey and De Feyter 2012). As such, additional conditions (such as the proportionality assumption in Nilakantan and Raghavendra 2008) and approximate measures (such as fuzzy sets in Dimitriou et al. 2013) have been introduced.

More broadly, the problem has been approached via dynamic programming (as in Rao 1990). Goal programming has also been employed to compare organizational outcomes (Georgiou and Tsantas 2002). More recently, stochastic programming techniques, such as linearization and Bender's decomposition (Zhu and Sherali 2009) were utilized to tackle tractability issues.
Nonetheless, these methods often suffer from the curse of dimensionality, becoming rapidly unscalable with the number of input variables. In Zhu and Sherali's case, the stochastic model only solved three out of ten times in computational tests. In the age of analytics, taking as input individual-level predictions of flight risk and performance risk would likely exceed computational limits of these models. It is also not immediately apparent how to extend these models to be robust to uncertainty, especially resignations, which are known to fluctuate wildly.

Most critically, time spent by an employee in a grade (time-in-grade, for short) is often ignored, despite being a major determinant of employee behaviour, such as resignations. Incorporating this factor however poses challenges – the uncertainty at each time period depends on decisions in the previous period. The earliest attempt employed a linear goal programming model using time-in-organization as a factor (Bres et al. 1980). Subsequently, Kalamatianou (1987) leveraged the Markov framework, by dividing employees into yet-to-be and ready-to-be-promoted, and estimating the transition probabilities based on the age distribution. Nonetheless, this did not address the inter-dependence of decision and uncertainty and was a workaround. Finally, Nilakantan and Raghavendra (2008) proposed a Markov model using both time-in-grade and time-in-organization, but only under strict assumptions, and only presented simulation results.

In this paper, we break away from the usual literature and approach this problem from the angle of risk under a modern robust optimization lens. In the area of manpower planning, robust optimization has traditionally been applied to staffing and scheduling problems (for example, Lusby et al. 2012). However, to the best of our knowledge, we haven’t seen any literature on its application to longer term manpower planning, which we are interested in.

We propose a model that minimizes a risk parameter, which provides bounds on the probability of constraint violation. Despite inter-dependence between the uncertainty and decision space, the
model is made tractable by a novel technique that exploits the structure of this dependence, termed ‘pipeline invariance’. Additionally, our model can circumvent the \textit{a priori} prescription of trade-offs between outcomes and policies, and has the potential to remain tractable while incorporating data at the individualized level, taken as input from other independent predictive analytics models. Our model is illustrated on a dataset of a homogenous population of employees in the Singapore Civil Service. Insights from our analysis, such as the numerical substantiation for a time-based progression policy and the ramifications of a lack of organizational renewal are also presented.

References


