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Workforce planning and technology installation optimisation for utilities

Mark G. Jennings [a,*], Nilay Shah [b]

[a] Department of Civil and Environmental Engineering, Imperial College London, London SW7 2AZ, UK
[b] Department of Chemical Engineering, Imperial College London, London SW7 2AZ, UK

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ABSTRACT

With the advent of government mandates to upgrade technologies which are owned by utilities but used by customers, utilities are pressurised into planning future workforce requirements. The smart meter rollout in Great Britain provides such an example. Previous models of workforce planning are numerous, but extensions for large-scale technology installation schemes have been paid less attention.

This paper provides three contributions to the field: (i) a novel formulation of the aggregate planning model which accounts for learning rates of the workforce when executing a new task, (ii) an enhanced process of employing uncertainty analysis using Sobol sampling, and (iii) a numerical example supplying an illustrative instance of the modelling and uncertainty analysis in practice. The proposed modelling framework can be used as a tool to further the planning capabilities and strategic decision-making toolkits of the utility sector.

1. Introduction

Utilities are under increasing pressure to train, hire, or outsource their workforce in response to changing customer and government demands. Increasingly sophisticated metering technologies are one result of these changes. Gas, water, and electric utilities have to manage their workforce demands carefully, particularly in the face of government mandates for 'smart' metering. Utilities are seeking ways in which to actively manage their workforce costs, at both tactical and strategic timeframes (e.g. see Edge, 2012).

Traditional workforce planning models determine the size and experience levels of workforce required to support production. They are typically based upon the aggregate planning model, first presented as a linear programme by Hanssmann and Hess (1960). This framework maintains a workforce level sufficient to provide the services of the system under study. Maintaining a balanced workforce and minimising the use of overtime are commonly included in the objective function. Also, the aggregate planning model can incorporate the log-linear curve as a way of recognising that workforce performance typically improves with increased experience (Ebert, 1976). A more recent study provided a mixed integer linear programming (MILP) model which could determine the best mix of internal and external engineers and administrative staff by experience level (Gagnon & Sheu, 1993). Research is ongoing, for example with Fragnière, Gondzio, and Yang (2010) providing a new approach to assessing the back-office expertise required to deal with operation risks in the banking sector. Othman, Bhuiyan, and Gouw (2012) presents a new approach of integrating the personality attributes of workers with particular skill levels on machines towards optimum delivery of a production plan. Gagnon and Sheu (2003) and Othman et al. (2012) provide extensive reviews of the literature.

What has been paid less attention is the extension of the workforce planning problem to utilities' workfroce and installation strategies for large-scale technology deployment schemes. Aside from a workforce planning model focused on the plant department of a telephone company (Krajewski & Thompson, 1975), no studies have been identified which broach the problems of optimal installation strategic planning with workforce capacity. At the strategic level in power and gas utilities it is not usually workforce capacity that is being explicitly planned for, but rather the existing power-plant capacities and future demands (Sáenz, Celik, Asfour, & Son, 2012; Stoyan & Dessouky, 2011).

This study seeks to fill this gap by extending the traditional deterministic workforce planning model to strategies for large-scale technology installations. There are two further objectives: (i) employ pseudo-uniform sampling methods to give a more realistic sample to help analyse uncertainty post-optimisation, and (ii) to test the model and uncertainty analysis procedure by applying it to a real-life numerical example. The rest of the paper details the tasks completed to fulfil these aims. First the optimisation model is presented. Following this, uncertainty analysis using Sobol sampling is described. A numerical example for the smart meter rollout in Haringey Borough in north London is given, and results from the

* Corresponding author.
E-mail addresses: m.jennings09@imperial.ac.uk (M.G. Jennings), n.shah@imperial.ac.uk (N. Shah).

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Nomenclature

Indices

- s index of suppliers, $s = 1, 2, \ldots, S$
- t index of time-periods, $t = 1, 2, \ldots, T$
- w index of workforce category, $w = 1, 2, \ldots, W$
- m index of technology type, $m = 1, 2, \ldots, M$
- j, k indices of piecewise linear segments, $j = 1, 2, \ldots, J,\ k = 1, 2, \ldots, K$

Parameters

- $\alpha_{w,m,t}$ workforce costs for workforce category w employed for technology type m during time-period t
- $\beta_{w,m}$ hiring costs for workforce category w employed for technology type m during time-period t
- $\gamma_{w,m}$ training costs for workforce category w employed for technology type m during time-period t
- $\delta_{w,m}$ redundancy costs for workforce category w employed for technology type m during time-period t
- $\epsilon_{m,m'}$ effect of training on technology types m and m'
- ζ_t working hours per time-period t
- η_s technology installation target for supplier s
- κ_s initial travelling time prior to any new technology installations for supplier s
- λ_s maximum travelling time between customer premises for the workforce of supplier s when all technology installations have been completed
- ω_s increased travel time between customer premises for the workforce of supplier s due to any difficulties accessing customer premises
- μ effect of technology installations on the customer's costs
- v effect of technology installations on the costs of maintaining and servicing a technology
- $\tau_{s,w}$ costs of overtime for workforce category w employed by supplier s
- $\phi_{s,w}$ initial number of workforce category w employed by supplier s
- $a_{m,w}$ time lag between the initial time of hiring and when the new employee is fully trained in workforce category w for technology type m. This can also act as a time lag between the starting of a mass technology deployment scheme and the availability of a trained workforce in the labour market
- $b_{m,w}$ time lag between the initial time of internal training and when the new employee is fully trained in workforce category w for technology type m
- $c_{j,w}$ intercept of learning rate relationship represented by linear segments j for workforce category w
- $d_{j,w}$ coefficient of learning rate relationship represented by linear segments j for workforce category w
- e_k intercept of technology maintenance cost relationship represented by linear piecewise segments k
- f_k coefficient of technology maintenance cost relationship represented by linear piecewise segments k
- $xr^{s,w}_{m,t}$ number of retirements by technology type m and category w for supplier s during time-period t
- i interest rate

Variables

- $x^{s,w}_{m,t}$ number of workforce by technology type m and category w as employed by supplier s during time-period t
- $XH^{s,w}_{m,t}$ number of workforce hired for technology type m and category w as employed by supplier s during time-period t
- $XT^{s,w}_{m,t}$ number of workforce trained for technology type m and category w as employed by supplier s during time-period t
- $XF^{s,w}_{m,t}$ number of workforce made redundant by technology type m and category w as employed by supplier s during time-period t
- TC^s_t cost of maintaining and servicing a technology on a customer's premise for supplier s during time-period t
- CC_t cost associated with the technology for a customer during time-period t
- $N^{s,w}_t$ number of installations of a technology by workforce category w working for supplier s during time-period t
- $T^{s,w}_t$ total time for installing a technology by workforce category w working for supplier s during time-period t
- $OT^{s,w}_t$ overtime for installing a technology by workforce category w working for supplier s during time-period t
- $NC^{s,w}_t$ cumulative number of installations of a technology by workforce category w working for supplier s at the end of time-period t
- $IT^{s,w}_t$ installation time for a technology by workforce category w working for supplier s during time-period t
- $TT^{s,w}_t$ travel time between technology installations by workforce category w working for supplier s during time-period t

model runs are shown. The final section discusses these results in light of the new formulation and process of uncertainty analysis.

2. Model description

This paper describes the assessment of strategic workforce planning for a large-scale technology installation scheme. Incumbent technologies are located on customers' premises and are to be removed before the installation of new technologies. The objective function of the planning model is the minimisation of total costs arising from installation of new technologies. Costs are discounted to their present worth at the start of the installation scheme. The costs in the objective function include workforce costs, costs of maintaining and servicing the technologies, and the customers's costs associated with a technology.

Workforce costs are determined by the number required in workforce at any given time. The workforce is represented by aggregate variables and may be divided into categories as a function of experience. Changes to workforce categories may incur a cost in the form of hiring administration fees, training costs, and/or redundancy payments.

Minimisation of discounted workforce costs alone would defer all likely costs until the last time-period of the installation scheme. Yet reduced workforce costs must be traded against the benefits of installing the technologies closer to the start of the scheme. These benefits include reduced maintenance costs and reduced customer costs associated with the technology. The maintenance costs are to be borne by the employer of the workforce, e.g. the supplier. As the objective function contains costs for both the employer and the customer, the single objective includes both a social and a private cost to be minimised. The assumptions and formulation on which this objective function is based are now presented.