1 Industrial instances

We have used real industrial data for most of the parameters and sets from GKN Aerospace. However, processing times p^{ℓ}_{jk} of operation $j \in \mathcal{J}_\ell$ in machines $k \in \mathcal{N}^{\ell}_j$ (qualification required), and the qualification cost parameters β^{ℓ}_{jk}, $j \in \mathcal{J}_\ell$, $k \in \mathcal{N}^{\ell}_j$, were not available. In order to generate instances that represent possible realizations of the actual data we introduce the following distributions, which are based on knowledge of the managers.

Skewness of processing times. The *skew normal distribution* is a generalized normal distribution allowing for non-zero skewness; Weisstein (2021). We generate processing times p^{ℓ}_{jk}, $k \in \mathcal{N}^{\ell}_j$, $j \in \mathcal{J}_\ell$, for newly qualified machines from three differently skewed normal distributions with mean μ and skewness/shape parameter α: positive skew ($\alpha > 0$) denoted as `skew+`, negative skew ($\alpha < 0$) denoted as `skew-`, and zero skew denoted as ($\alpha = 0$) denoted as `skew0`. A location parameter/mean μ is based on the expected processing time of a given task (j, ℓ) on an already qualified machine $k \in \mathcal{K}^{\ell}_j \setminus \mathcal{N}^{\ell}_j$ and which is similar to that of the machine being qualified. For all these distributions, we set $\sigma := 0.1\mu$; according to the internal statistical process control data (and managerial experience) processing times of newly qualified allocations have a standard deviation of 10% of the expected value.

Range of values for the qualification cost: The exact cost for qualifying a machine for a task (j, ℓ) is not known a priori, and for prediction the engineering team has to spend time on simulations. Hence, the input received is the so-called *cost levels*, assigned to each qualification. For testing our model and proposed modifications, we use two sets of cost levels: $\mathcal{H} = \{1, \ldots, \beta_{\max}\}$, with $\beta_{\max} = 20$. The qualification costs are selected from different discrete distributions over the discrete domain $\mathcal{H}$.

Nominal qualification cost. Letting π_h be the frequency of cost level $h \in \mathcal{H}$, its relative frequency is $\hat{\pi}_h := (\sum_{i \in \mathcal{H}} \pi_i)^{-1} \pi_h$; we also define $\hat{\pi}_0 = 0$. To determine a cost β^{ℓ}_{jk}, a sample α is drawn from the interval $[0, 1]$. Then,

$$\beta^{\ell}_{jk} := \begin{cases} h \in \mathcal{H} : \sum_{i=0}^{h-1} \hat{\pi}_i \leq \alpha < \sum_{i=0}^{h} \hat{\pi}_i, & \alpha \in [0, 1), \\ |\mathcal{H}|, & \alpha = 1. \end{cases}$$

The frequency distributions are defined as follows. For each $h \in \mathcal{H}$, $\pi_h = 1$ (`Uniform`), $\pi_h = h$ (`Right`), $\pi_h = |\mathcal{H}| - (h-1)$ (`Left`), $\pi_h = \min\{h;\ |\mathcal{H}| - (h-1)\}$ (`Symmetric`), and $\pi_h = \min\{h;\ |\mathcal{H}| - (h-1);\ \max\{h - \lceil \frac{|\mathcal{H}|-1}{2} \rceil;\ \lfloor \frac{|\mathcal{H}|+1}{2} \rfloor - (h-1)\}\}$ (`Bimodal`).

References

Weisstein, E.W. 2021. Skew normal distribution.