École polytechnique de Louvain

Optimization of production planning with resource allocation

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The Village n°1 problem

Village n°1 is a belgian company employing persons with disabilities. They offer services to companies and private individuals such as industrial jobs. They are currently in the process of automating the way they schedule these jobs. The company has internal work for their employees but also receives demands from external clients. They need to assign workers for one or more time periods to those demands. They also need to assign other resources such as vehicles, machines, locations to these demands. Moreover, persons with disabilities have more constraints related to their working capabilities and availabilities. The workers need specific skills and may have some restrictions which prevent them to work for certain jobs (e.g. a worker can't lift more than five kilograms). They also have some incompatibilities with other workers or clients making them unable to work with or for those people.

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Models for the Village n^{o}1 problem

5.1 Mixed Integer Programming Model

5.1.1 Variables

$$w_{ijkl} = \begin{cases} 1 & \text{if worker } i \text{ is working at time } j \text{ for demand } k \text{ at position } l \\ 0 & \text{otherwise} \end{cases}$$

$$m_{ij} = \begin{cases} 1 & \text{if machine } i \text{ is used for demand } j \\ 0 & \text{otherwise} \end{cases}$$

$$z_{ij} = \begin{cases} 1 & \text{if zone } i \text{ is used for demand } j \\ 0 & \text{otherwise} \end{cases}$$

5.1.2 Complete Model

$$\begin{aligned}
\min \quad & \sum_{k\in D}\sum_{l\in d_k^P}\sum_{i\in W} min(\sum_{j\in T} w_{ijkl}, 1) && && (5.1)\\
\text{s.t} \quad & \sum_{i\in W} w_{ijkl} = 1, && \forall k \in D, j \in d_k^T, l \in d_k^P && (5.2)\\
& \sum_{k\in D}\sum_{l\in d_k^P} w_{ijkl} \leq 1, && \forall i \in W, j \in T && (5.3)\\
& t_j \notin d_k^T \implies \forall i, l \; w_{ijkl} = 0, && \forall j \in T, k \in D && (5.4)\\
& t_j \notin w_i^T \implies \forall k, l \; w_{ijkl} = 0, && \forall j \in T, i \in W && (5.5)\\
& \sum_{l\in d_k^P} w_{ajkl} + w_{bjkl} < 2, && \forall (a,b) \in I_{ww}, j \in T, k \in D && (5.6)\\
& d_k^c = c \implies \forall l \; w_{ijkl} = 0, && \forall (i,c) \in I_{wc}, j \in T, k \in D && (5.7)\\
& w_{ijkl} = 0, && \forall j \in T, k \in D, l \in d_k^P, && (5.8)\\
& && i \in W \setminus W_{d_k^{s_l}} && \\
& z_i \notin d_j^Z \implies z_{ij} = 0, && \forall i \in Z, j \in D && (5.9)\\
& |d_j^Z| > 0 \implies \sum_{i\in Z} z_{ij} = 1, && \forall j \in D && (5.10)\\
& \sum_{i\in Z} z_{ik} \leq 1, && \forall j \in D, k \in d_j^O && (5.11)\\
& m_i \notin d_j^M \implies m_{ij} = 0, && \forall i \in M, j \in D && (5.12)\\
& \sum_{i\in M_k} m_{ij} = |d_j^{M_k}|, && j \in D, k \in d_j^M && (5.13)\\
& \sum_{i\in M} m_{ik} \leq 1, && \forall j \in D, k \in d_j^O && (5.14)\\
& w_{ijkl} \in \{0,1\}, && \forall i \in W, j \in T, k \in D, l \in d_k^P && (5.15)\\
& m_{ij} \in \{0,1\}, && \forall i \in M, j \in D && (5.16)\\
& z_{ij} \in \{0,1\}, && \forall i \in Z, j \in D && (5.17)
\end{aligned}$$

The objective function is stated in (5.1), it minimizes the number of different workers for every position between periods of that demand. $min(\sum_{j\in T} w_{ijkl}, 1)$ is one if the worker i is working for that position at that time, 0 otherwise. Hence, the sum of that value for all worker will be equal to the number of worker for that shift.

Constraint (5.2) ensures that each position is filled by only one worker. Constraint (5.3) ensures that no worker works for multiple demands at the same time period. The constraints (5.4) and (5.5) ensures that no worker is working for a demand that is not occurring or when is himself not available. Constraint (5.6) ensures that no incompatible workers work together while (5.7) ensures that no incompatible pair of worker and client work together. Constraint (5.8) ensures that no worker work for a position in which they are not qualified to work at.

Constraint (5.9) ensures that no zone is assigned to a demand in which this zone is not a possible assignment. (5.10) ensures that only one zone is assigned to this demand if this demand is in need of a zone. Constraint (5.11) ensures that no zone is assigned to two overlapping demands in time.

Constraint (5.12) ensures that no machine is assigned to a demand not in need of that machine. Constraint (5.13) ensures that the required number for each machine is satisfied. And again, (5.14) ensures that no machine is assigned to two overlapping demands in time.

Finally (5.15), (5.16) and (5.17) ensure the variables only takes binary values.

5.2 Constraint Programming Model

The translation to the mathematical (MIP) model to the CP model is fairly straightforward. Binary variables are translated to integer variables, each value representing one resource (i.e. worker, zone or machines).

5.2.1 Variables

First, we need to express the set of workers for each demand at each time period in which that demand occurs. This is done by using a 3-dimensional array of variables. The first dimension being the indices of the time periods, the second dimension is the indices of the demands while the last dimension is the list of worker variables. This last dimension has the size of the number of required workers for that demand.

$$w[i][j][k] \in W \tag{5.18}$$

(5.18) is the worker working at time i for demand j at position k with $t_i \in T$, $d_i \in D$ and $t_i \in d_j^T$.

The same reasoning is used for zones and machines:

$$m[i][j] \in M \tag{5.19}$$

$$z[i] \in Z \tag{5.20}$$

(5.19) is the j^{th} machine used for demand i while (5.20) is the zone used for demand i

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