| Index | Revised Model 3 | Ulrich et al. |
|---|---|---|
| **Vehicles** | $0 \leq v \leq V-1$ | $1 \leq v \leq V$ |
| **Customers** | $0 \leq i, j \leq N$ | |
| **Jobs** | $0 \leq p, q \leq P, i, j$ | $1 \leq j \leq J$ |
| **Tour** | $0 \leq h \leq H-1$ | $1 \leq t \leq J$ |
| **Machines** | | $1 \leq m \leq M$ |

| Parameter | Revised Model 3 | Ulrich et al. |
|---|---|---|
| **Job Size** | $d_{ip}$ | $u_j$ |
| **Processing Time** | $\rho_p$ | $d_j$ |
| **Machine Setup/Ready Time** | $\sigma_{pq}$ | $r_m$ |
| **Vehicle Setup Time** | $s_0, s_i$ | $\hat{r}_v, s_j$ |
| **Vehicle Capacity** | $c_v$ | $c_v$ |
| **Travel Time** | $t_{ij}$ | $t_{ij}$ |
| **Very Large Number** | $M$ | $q$ |
| **Time Windows** | $a_i, b_i$ | $\underline{w_j}, \overline{w_j}$ |

| Variables | Revised Model 3 | Ulrich et al. |
|---|---|---|
| **Job Completion Time** | $f_p$ | $C_j$ |
| **All Jobs Completion Time** | $F$ | |
| **Trip Start Time** | $k_{vh}$ | $S_{vt}$ |
| **Arrival/Delivery Time at Node** | $\alpha_i$ | $D_j$ |
| **Delivery Tardiness** | $l_i$ | $T_j$ |
| **Job Processing Sequence** | $x_{pq}$ | $x_{ij}$ |
| **Job Machine Mapping** | | $y_{mj}$ |
| **Node, Vehicle and Trip Mapping** | $y_{ivh}$ | $g_{jvt}$ |
| **Node Node Vehicle Trip Map** | $z_{ijvh}$ | $z_{ijvt}$ |
| **Vehicle Usage** | $w_v$ | |

| Constraint | Revised Model 3 | Ulrich et al. |
|---|---|---|
| **Production Sequence** | $\sum_{p=0,p\neq q}^{P} x_{pq} = 1 \forall q = 0,1,2,3,4...P$ | $\sum_{j=1}^{J} y_{mj} \leq 1 \forall m = 1,2,3,...M$ |
| | $\sum_{q=0,p\neq q}^{P} x_{pq} = 1 \forall p = 0,1,2,3,4...P$ | $\sum_{i=1,i\neq j}^{J+1} x_{ji} \forall j = 1,2,3,...J$ |
| | $x_{pq} \in \{0,1\}$ | $y_{mj} \in \{0,1\}$ |
| | | $x_{ij} \in \{0,1\}$ |
| | | $\sum_{m=1}^{M} y_{mj} + \sum_{i=1,i\neq j}^{J} x_{ij} = 1 \forall j = 1,2,3,...J$ |
| **Job Completion Time** | | $C_j \geq y_{mj}(r_m + p_j)$<br>$\forall j = 1,2,3,...J; m = 1,2,3,...M$ |
| | | $C_j \geq C_i + p_j - q(1 - x_{ij})$<br>$\forall i, j = 1,2,3,...J; i \neq j$ |
| **Customer/Job Vehicle Tour Assignment** | $\sum_{v=0}^{V-1} \sum_{h=0}^{n-1} y_{ivh} = 1 \forall i = 1,2,3,...n$ | $\sum_{v=1}^{V} \sum_{t=1}^{J} g_{jvt} = 1 \forall j = 1,2,3,...J$ |
| | $y_{jvh} \in \{0,1\}$ | $g_{jvt} \in \{0,1\}$ |
| **Empty Tour** | $y_{0vh} \geq y_{ivh}$<br>$\forall i = 1,2,3,...n; v = 0,1,2,...V-1;$<br>$\forall h = 0,1,2,...n-1$ | $g_{0vt} \geq g_{jvt}$<br>$\forall j = 1,2,3,...J; v = 1,2,3,...V;$<br>$\forall t = 1,2,3,...J$ |
| | $y_{n+1vh} \geq y_{ivh}$<br>$\forall i = 1,2,3,...n; v = 0,1,2,...V-1;$<br>$\forall h = 0,1,2,...n-1$ | |
| **Active and Empty Tour** | $M \sum_{i=1}^{n} y_{ivh} \geq \sum_{j=1}^{n} y_{jvh+1}$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-2$ | $q \sum_{j=1}^{J} g_{jvt} \geq \sum_{j=1}^{J} g_{jvt+1}$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J-1$ |
| **Demand Quantity and Vehicle Capacity** | $\sum_{i=1}^{n} \sum_{p=1}^{P} d_{ip} y_{ivh} \leq c_v$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | $\sum_{j=1}^{J} u_j g_{jvt} \leq c_v$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J$ |
| **Vehicle Usage** | $y_{0vh} \geq w_v$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | |

| Constraint | Revised Model 3 | Ulrich et al. |
|---|---|---|
| **Vehicle Routing** | $z_{0ivh} + z_{0jvh} + y_{ivh} + y_{jvh} \leq 3$<br>$z_{in+1vh} + z_{jn+1vh} + y_{ivh} + y_{jvh} \leq 3$<br>$\forall i, j = 1,2,3,...n$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | |
| | $y_{jvh} = \sum_{i=0,i\neq j}^{n} z_{ijvh}$<br>$y_{jvh} = \sum_{i=1,i\neq j}^{n+1} z_{jivh}$<br>$\forall j = 1,2,3,...n$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | $g_{jvt} = \sum_{i=0,i\neq j}^{J} z_{ijvt}$<br>$g_{jvt} = \sum_{i=1,i\neq j}^{J} z_{jivt}$<br>$\forall j = 1,2,3,...J$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J$ |
| | $z_{ijvh} \in \{0,1\}$ | $z_{ijvt} \in \{0,1\}$ |
| **Vehicle Tour Start Time** | $k_{vh} \geq s_0 + F$<br>$F = \sum_{p=0}^{P} \rho_p \sum_{i=1}^{n} d_{ip} + \sum_{p=0,p\neq q}^{P} \sum_{q=0,p\neq 1}^{P} \sigma_{pq} x_{pq}$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | $S_{v1} \geq \hat{r}_v + s_0$<br>$S_{vt} \geq C_j + s_0 - q(1 - g_{jvt})$<br>$\forall j = 1,2,3,...J$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J$ |
| | $k_{vh+1} \geq \alpha_j + s_j + t_{ij} - M(1 - z_{ijvh})$<br>$\forall j = 1,2,3,...n$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-2$ | $S_{vt+1} \geq D_j + s_j + t_{j0} + s_0 - q(1 - g_{jvt})$<br>$\forall j = 1,2,3,...J$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J-1$ |
| | $k_{vh} \geq 0$<br>$F \geq 0$ | |
| **Arrival/Delivery Time** | $\alpha_i \geq k_{vh} + t_{0i} - M(1 - y_{ivh})$<br>$\forall i = 1,2,3,...n$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | $D_j \geq S_{vt} + t_{0j} - q(1 - g_{jvt})$<br>$\forall j = 1,2,3,...J$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J$ |
| | $\alpha_j \geq \alpha_i + s_i + t_{ij} - M(1 - z_{ijvh})$<br>$\forall i, j = 1,2,3,...n; i \neq j$<br>$\forall v = 0,1,2,...V-1$<br>$\forall h = 0,1,2,...n-1$ | $D_j \geq D_i + s_i + t_{ij} - q(1 - z_{ijvt})$<br>$\forall i, j = 1,2,3,...J; i \neq j$<br>$\forall v = 1,2,3,...V$<br>$\forall t = 1,2,3,...J$ |
| | $\alpha_i \geq a_i$<br>$\forall i = 1,2,3,...n$ | $D_j \geq w_j$<br>$\forall j = 1,2,3,...J$ |
| | $\alpha_i \geq 0$ | |
| **Tardiness** | $l_i \geq \alpha_i - b_i$<br>$l_i \geq 0$<br>$\forall i = 1,2,3,...n$ | $T_j \geq D_j - \overline{w_j}$<br>$T_j \geq 0$<br>$\forall j = 1,2,3,...J$ |

| Objective | Revised Model 3 | Ulrich et al. |
|---|---|---|
| **Minimise Tardiness** | $C^l \sum_{i=1}^{n} l_i$ | $\sum_{j=1}^{J} T_j$ |
| **Minimise Processing Time** | $C^\rho \sum_{i=1}^{n} \sum_{p=1}^{P} \rho_p d_{ip}$ | $\sum_{j=1}^{J} C_j$ |
| **Minimise Manufacturing Cost** | $\sum_{p=0, p\neq q}^{P} \sum_{q=1}^{P} C^\sigma_{pq} x_{pq}$ | |
| **Minimise Vehicle Cost** | $C^v \sum_{v=1}^{V} w_v$ | |
| **Transportation Cost** | $C^t \sum_{i=0, i\neq j}^{n} \sum_{j=1}^{n+1} \sum_{v=1}^{V} \sum_{h=1}^{n} t_{ij} z_{ijvh}$ | |