Appendix A: The details of the proposed transformation approach for the IS-MRIPSP

The proposed MIP model for the IS-MRIPSP:

Project makespan

$$Min\ \left[\underline{Z_1},\overline{Z_1}\right] = \sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_J},\overline{EFT_J}\right]}^{\left[\underline{LFT_J},\overline{LFT_J}\right]} \left[\underline{t},\overline{t}\right] \otimes x_{J1[\underline{t},\overline{t}]}$$

Resource utilization costs

$$Min\ \left[\underline{Z_2},\overline{Z_2}\right] = \sum_{r}^{R} \left[\underline{C_r},\overline{C_r}\right] \otimes \left[\underline{K_r},\overline{K_r}\right]$$

Subject to;

Constraints for mode and completion time allocation

$$\sum_{m=1}^{M_j} \sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_j},\overline{EFT_j}\right]}^{\left[\underline{LFT_j},\overline{LFT_j}\right]} x_{jm[\underline{t},\overline{t}]} = 1 \qquad \forall j \in J$$

Additional constraints in the relations between completion times and activity durations

$$\sum_{m=1}^{M_j} \sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_j},\overline{EFT_j}\right]}^{\left[\underline{LFT_j},\overline{LFT_j}\right]} \left[\underline{t},\overline{t}\right] \otimes x_{jm[\underline{t},\overline{t}]} \gtrsim \sum_{m=1}^{M_j} \sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_j},\overline{EFT_j}\right]}^{\left[\underline{LFT_j},\overline{LFT_j}\right]} \left[\underline{d_{jm}},\overline{d_{jm}}\right] \otimes x_{jm[\underline{t},\overline{t}]} \qquad \forall j \in J$$

Precedence constraints

$$\sum_{m=1}^{M_i} \sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_i},\overline{EFT_i}\right]}^{\left[\underline{LFT_i},\overline{LFT_i}\right]} \left[\underline{t},\overline{t}\right] \otimes x_{im[\underline{t},\overline{t}]} \lesssim \sum_{m=1}^{M_j} \sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_j},\overline{EFT_j}\right]}^{\left[\underline{LFT_j},\overline{LFT_j}\right]} \left(\left[\underline{t},\overline{t}\right] \ominus \left[\underline{d_{jm}},\overline{d_{jm}}\right]\right) \otimes x_{jm[\underline{t},\overline{t}]}$$

$$\forall j \in J, \forall i \in P_j$$

After applying the proposed interval programming & chance constrained optimization based transformation approach:

$$f_1 = Min\ \ m\left(\left[\underline{Z_1},\overline{Z_1}\right]\right) = \sum_{\underline{t}\in\ \underline{EFT_J}}^{\overline{LFT_J}} \sum_{\overline{t}\in\underline{EFT_J}}^{\overline{LFT_J}} \left(\underline{t}+\overline{t}\right)\big/_{2}\ .\ x_{J1\underline{t}\overline{t}}$$

$$f_2 = Min\ \ m\left(\left[\underline{Z_2},\overline{Z_2}\right]\right) = \sum_{r}^{R} \frac{\left(\underline{C_r}+\overline{C_r}\right).\left(\underline{K_r}+\overline{K_r}\right)}{2}$$

$$\sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} x_{jm\,\underline{t}\,\overline{t}} = 1 \qquad \forall j \in J$$

$$\sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} \underline{d_{jm}}\ .x_{jm\,\underline{t}\,\overline{t}} \le \sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} \left[\theta.\underline{t}+(1-\theta).\overline{t}\right].x_{jm\,\underline{t}\,\overline{t}} \qquad \forall j \in J$$

$$\sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} \overline{d_{jm}}\ .x_{jm\,\underline{t}\,\overline{t}} \le \sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} \left[\theta.\overline{t}+(1-\theta).\underline{t}\right].x_{jm\,\underline{t}\,\overline{t}} \qquad \forall j \in J$$

$$\sum_{m=1}^{M_i} \sum_{\underline{t}\in\ \underline{EFT_i}}^{\overline{LFT_i}} \sum_{\overline{t}\in\underline{EFT_i}}^{\overline{LFT_i}} \underline{t}\ .\ x_{im\,\underline{t}\,\overline{t}} \le \sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} \left[\alpha.\left(\underline{t}-\underline{d_{jm}}\right)+(1-\alpha).\left(\underline{t}-\overline{d_{jm}}\right)\right].x_{jm\,\underline{t}\,\overline{t}}$$

$$\sum_{m=1}^{M_i} \sum_{\underline{t}\in\ \underline{EFT_i}}^{\overline{LFT_i}} \sum_{\overline{t}\in\underline{EFT_i}}^{\overline{LFT_i}} \overline{t}\ .\ x_{im\,\underline{t}\,\overline{t}} \le \sum_{m=1}^{M_j} \sum_{\underline{t}\in\ \underline{EFT_j}}^{\overline{LFT_j}} \sum_{\overline{t}\in\underline{EFT_j}}^{\overline{LFT_j}} \left[\alpha.\left(\overline{t}-\overline{d_{jm}}\right)+(1-\alpha).\left(\overline{t}-\underline{d_{jm}}\right)\right].x_{jm\,\underline{t}\,\overline{t}}$$

$$\forall j \in J, \forall i \in P_j$$

After applying the compromise programming technique:

$$Minimize\ \ Z_1^+ + Z_1^- + Z_2^+ + Z_2^-$$

Subject to;

$$Z_1 + Z_1^+ - Z_1^- = 0$$

$$Z_2 + Z_2^+ - Z_2^- = 0$$

$$Z_1 = \frac{\sum_{\underline{t}\in\ \underline{EFT_J}}^{\overline{LFT_J}} \sum_{\overline{t}\in\underline{EFT_J}}^{\overline{LFT_J}} \left(\underline{t}+\overline{t}\right)\big/_{2}\ .\ x_{J1\underline{t}\overline{t}} - f_1^*}{f_1^{max} - f_1^*}$$

$$Z_2 = \frac{\sum_{r}^{R} \frac{\left(\underline{C_r}+\overline{C_r}\right).\left(\underline{K_r}+\overline{K_r}\right)}{2} - f_2^*}{f_2^{max} - f_2^*}$$

$$Z_1^+, Z_1^-, Z_2^+, Z_2^- \ge 0$$

The proposed MIP model for the IS-MRIPSP (Continued):

Constraints for renewable resource availabilities

$$\sum_{j}^{J}\sum_{m=1}^{M_j}\left[\underline{k_{jmr}},\overline{k_{jmr}}\right]\Big/\left[\underline{E_{jr}},\overline{E_{jr}}\right]\otimes\sum_{[\underline{\tau},\overline{\tau}]\in[\underline{t},\overline{t}]}^{\left[\underline{t}+\underline{d_{jm}}-1,\overline{t}+\overline{d_{jm}}-1\right]} x_{jm[\underline{\tau},\overline{\tau}]}\lesssim\left[\underline{K_r},\overline{K_r}\right]\otimes\left[\underline{R_r},\overline{R_r}\right]$$

$$\forall r\in R,\qquad \forall\left[\underline{t},\overline{t}\right]\mid \underline{t}=\overline{t}\in T$$

Chance constraints for non-renewable resource availabilities

$$Pr\left\{\sum_{j}^{J}\sum_{m=1}^{M_j}\left[\underline{y_{jmn}},\overline{y_{jmn}}\right]\otimes\sum_{[\underline{t},\overline{t}]\in\left[\underline{EFT_j},\overline{EFT_j}\right]}^{\left[\underline{LFT_j},\overline{LFT_j}\right]} x_{jm[\underline{t},\overline{t}]}\lesssim\left[\underline{N_n},\overline{N_n}\right]\right\}\geq\beta_n$$

$$\forall n\in N\quad and\quad \left[\underline{N_n},\overline{N_n}\right]\sim Normal\left(\left[\underline{\mu_n},\overline{\mu_n}\right],\left[\underline{\sigma_n^2},\overline{\sigma_n^2}\right]\right)$$

Definition of interval-valued decision variables

$$x_{jm[\underline{t},\overline{t}]}\in\{0,1\}\qquad\forall j\in J,\qquad\forall m\in M,\qquad\forall\left[\underline{t},\overline{t}\right]\mid\underline{t}\leq\overline{t}\in\left[\underline{EFT_j},\overline{LFT_j}\right]$$

$$\left[\underline{K_r},\overline{K_r}\right]\geq 0\qquad\forall r\in R$$

After applying the proposed interval programming & chance constrained optimization based transformation approach (Continued):

$$\sum_{j}^{J}\sum_{m=1}^{M_j}\frac{\underline{k_{jmr}}}{\overline{E_{jr}}}.\left(\sum_{\underline{\tau}=\underline{t}}^{\beta.\left(\underline{t}+\underline{d_{jm}}-1\right)+(1-\beta).\left(\underline{t}+\overline{d_{jm}}-1\right)}\ \sum_{\overline{\tau}\geq\underline{\tau}}^{T}x_{jm\,\underline{\tau}\,\overline{\tau}}\right)\leq\left[\Delta.\underline{K_r}+(1-\Delta).\overline{K_r}\right].\underline{R_r}$$

$$\sum_{j}^{J}\sum_{m=1}^{M_j}\frac{\overline{k_{jmr}}}{\underline{E_{jr}}}.\left(\sum_{\underline{\tau}=\underline{t}}^{\beta.\left(\underline{t}+\underline{d_{jm}}-1\right)+(1-\beta).\left(\underline{t}+\overline{d_{jm}}-1\right)}\ \sum_{\overline{\tau}\geq\underline{\tau}}^{T}x_{jm\,\underline{\tau}\,\overline{\tau}}\right)\leq\left[\Delta.\overline{K_r}+(1-\Delta).\underline{K_r}\right].\overline{R_r}$$

$$\forall r\in R,\qquad\forall\underline{t}=\overline{t}\in T$$

$$\underline{N_n}\sim N\left(\underline{\mu_n},\underline{\sigma_n^2}\right)\qquad\forall n\in N$$

$$\overline{N_n}\sim N\left(\overline{\mu_n},\overline{\sigma_n^2}\right)\qquad\forall n\in N$$

$$\sum_{j}^{J}\sum_{m=1}^{M_j}\underline{y_{jmn}}.\sum_{\underline{t}\in\underline{EFT_j}}^{\overline{LFT_j}}\ \sum_{\overline{t}\in\overline{EFT_j}}^{\overline{LFT_j}}x_{jm\,\underline{t}\,\overline{t}}\leq\zeta_n\qquad\forall n\in N$$

$$\sum_{j}^{J}\sum_{m=1}^{M_j}\overline{y_{jmn}}.\sum_{\underline{t}\in\underline{EFT_j}}^{\overline{LFT_j}}\ \sum_{\overline{t}\in\overline{EFT_j}}^{\overline{LFT_j}}x_{jm\,\underline{t}\,\overline{t}}\leq\psi_n\qquad\forall n\in N$$

$$F(\zeta_n)=F(\psi_n)=\beta_n\qquad\forall n\in N$$

$$\zeta_n=F^{-1}\left(\beta_n\mid\underline{\mu_n},\underline{\sigma_n}\right)=\underline{\mu_n}+\underline{\sigma_n}.\sqrt{2}.erf^{-1}(2.\beta_n-1)\qquad\forall n\in N$$

$$\psi_n=F^{-1}\left(\beta_n\mid\overline{\mu_n},\overline{\sigma_n}\right)=\overline{\mu_n}+\overline{\sigma_n}.\sqrt{2}.erf^{-1}(2.\beta_n-1)\qquad\forall n\in N$$

$$x_{jm\,\underline{t}\,\overline{t}}\in\{0,1\}\qquad\forall j\in J,\qquad\forall m\in M,\qquad\forall\,\underline{t}\leq\overline{t}\in\left[\underline{EFT_j},\overline{LFT_j}\right]$$

$$\underline{K_r},\overline{K_r}\geq 0\qquad and\qquad\underline{K_r}\leq\overline{K_r}\qquad\forall r\in R$$