Research article

An environmental decision support system for manufacturer-retailer within a closed-loop supply chain management using remanufacturing

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Appendix

$$TS_{C1} = \frac{L}{T} \Big[S_{CM} + P_{CM}(\alpha t_{m1} + \frac{\beta}{2} t_{m1}{}^2) + H_{CM} \frac{e^{-t_{m1}\theta_1}}{2\theta_1^3} [2(-\beta + \beta_1 + (\alpha - \alpha_1)\theta_1) + e^{t_{m1}\theta_1}(2(\beta - \beta_1) + 2(-\alpha + $$

$$\alpha_1 + t_{m1}(-\beta + \beta_1))\theta_1 + t_{m1}(2(\alpha - \alpha_1) + t_{m1}(\beta - \beta_1))\theta_1^2)] + \frac{1}{2\theta_1^3} H_{CM}[2\alpha_1\theta_1(-1 + e^{(-t_{m1}+t_{m2})\theta_1} + (t_{m1} - $$

$$t_{m2})\theta_1) + \beta_1(2 - 2e^{(-t_{m1}+t_{m2})\theta_1} + \theta_1(2(-1 + e^{(-t_{m1}+t_{m2})\theta_1})t_{m2} + (t_{m1} - t_{m2})(-2 + (t_{m1} + t_{m2})\theta_1)))] + $$

$$D_{CM} \frac{e^{-t_{m1}\theta_1}}{2\theta_1^2} [2(-\beta + \beta_1 + (\alpha - \alpha_1)\theta_1) + e^{t_{m1}\theta_1}(2(\beta - \beta_1) + 2(-\alpha + \alpha_1 + t_{m1}(-\beta + \beta_1))\theta_1 + t_{m1}(2(\alpha - $$

$$\alpha_1) + t_{m1}(\beta - \beta_1))\theta_1^2)] + \frac{1}{2\theta_1^2} D_{CM}[2\alpha_1\theta_1(-1 + e^{(-t_{m1}+t_{m2})\theta_1} + (t_{m1} - t_{m2})\theta_1) + \beta_1(2 - 2e^{(-t_{m1}+t_{m2})\theta_1} + $$

$$\theta_1(2(-1 + e^{(-t_{m1}+t_{m2})\theta_1})t_{m2} + (t_{m1} - t_{m2})(-2 + (t_{m1} + t_{m2})\theta_1)))]] + \frac{LZ_r}{T}[O_{cr} + \frac{P_{cr}}{\theta_2^2}[\{(x - \phi\varphi + yt_r)\theta_2 - $$

$$y\} + [\{f_0\,\theta_2(1 - e^{-\theta_2(u-t_{r2})})\} + \{(x - \phi\varphi + yu)\theta_2 - y\}]e^{-\theta_2(t_r-u)}] - \frac{H_r}{\theta_2^2}[\{(x - \phi\varphi + \frac{y}{2}(u - t_r))(u - $$

$$t_r)\theta_2 - y(u - t_r)\} - (D_0 - \phi\varphi)(e^{\theta_2 u} - e^{\theta_2 t_{r2}})(e^{-\theta_2 u} - e^{-\theta_2 t_r}) + \{(x - \phi\varphi + yu) - \frac{y}{\theta_2}\}(1 - $$

$$e^{-\theta_2(t_r-u)})] - \frac{(D_0 - \phi\varphi)}{\theta_2{}^2}\left[(e^{-\theta_2 t_{r2}} - e^{-\theta_2 u}) + (t_{r2} - u)\theta_2\right] - \frac{D_r}{\theta_2}\left[\left\{\left(x - \phi\varphi + \frac{y}{2}(u - t_r)\right)(u - t_r)\theta_2 - y(u - t_r)\right\} - \right.$$

$$\left. t_r)\right\} - (D_0 - \phi\varphi)(e^{\theta_2 u} - e^{\theta_2 t_{r2}})(e^{-\theta_2 u} - e^{-\theta_2 t_r}) + \left\{(x - \phi\varphi + yu) - \frac{y}{\theta_2}\right\}(1 - e^{-\theta_2(t_r-u)})\right] -$$

$$\frac{D_r(D_0 - \phi\varphi)}{\theta_2}\left[(e^{-\theta_2 t_{r2}} - e^{-\theta_2 u}) + (t_{r2} - u)\theta_2\right] - \frac{B_r e^{-\rho t_r}}{\rho^3}\left[\{(x - \phi\varphi + yt_r)\alpha - 2y\}e^{\alpha t_r} - ((x - \phi\varphi)\rho - \right.$$

$$\left. y)\rho t_r - ((x - \phi\varphi)\rho - 2y)\right] + L_S\left[(x - \phi\varphi)u + \frac{yu^2}{2} - \frac{(x-\phi\varphi)e^{-t_r^2\rho}(-1+e^{u\rho})}{\rho} - \frac{ye^{-t_r\rho}(1+e^{u\rho}(-1+u\rho))}{\rho^2} + \right.$$

$$\left. \frac{(-1+e^{(-t_r+u)\rho}+t_r\rho-u\rho)(D_0 - \phi\varphi)}{\rho}\right)\right] + \frac{1}{T}\left[S_{CR} + P_{CR}(at_R + \frac{bt_R^2}{2}) + H_{CR}\frac{e^{-t_R\theta_1}}{2\theta_1^3}[(2(-b + \beta_1 + (a - \alpha_1)\theta_1) + \right.$$

$$e^{t_R\theta_1}(2(b - \beta_1) + 2(-a + \alpha_1 + t_R(-b + \beta_1))\theta_1 + t_R(2(a - \alpha_1) + t_R(b - \beta_1))\theta_1^2))] + \frac{1}{2\theta_1^3} H_{CR}[2\alpha_1\theta_1(-1 + $$

$$e^{(-t_R+T)\theta_1} + (t_R - T)\theta_1) + \beta_1(2 - 2e^{(-t_R+T)\theta_1} + \theta_1(2(-1 + e^{(-t_R+T)\theta_1})T + (t_R - T)(-2 + (t_R + T)\theta_1)))] + $$

$$D_{CR}\frac{e^{-t_R\theta_1}}{2\theta_1^2}[(2(-b + \beta_1 + (a - \alpha_1)\theta_1) + e^{t_R\theta_1}(2(b - \beta_1) + 2(-a + \alpha_1 + t_R(-b + \beta_1))\theta_1 + t_R(2(a - \alpha_1) + $$

$$t_R(b - \beta_1))\theta_1^2))] + \frac{1}{2\theta_1^2} D_{CR}[2\alpha_1\theta_1(-1 + e^{(-t_R+T)\theta_1} + (t_R - T)\theta_1) + \beta_1(2 - 2e^{(-t_R+T)\theta_1} + \theta_1(2(-1 + $$

$$e^{(-t_R+T)\theta_1})T + (t_R - T)(-2 + (t_R + T)\theta_1)))] + C_{CR}\sigma\delta T(D_o - \phi\varphi)]\ ,$$

$$TS_{C2} = \frac{L}{T}\left[S_{CM} + P_{CM}(\alpha t_{m1} + \frac{\beta}{2}t_{m1}{}^2) + H_{CM}\frac{e^{-t_{m1}\theta_1}}{2\theta_1^3}[2(-\beta + \beta_1 + (\alpha - \alpha_1)\theta_1) + e^{t_{m1}\theta_1}(2(\beta - \beta_1) + 2(-\alpha + \right.$$

$$\alpha_1 + t_{m1}(-\beta + \beta_1))\theta_1 + t_{m1}(2(\alpha - \alpha_1) + t_{m1}(\beta - \beta_1))\theta_1^2)] + \frac{1}{2\theta_1^3} H_{CM}[2\alpha_1\theta_1(-1 + e^{(-t_{m1}+t_{m2})\theta_1} + (t_{m1} - $$

$$t_{m2})\theta_1) + \beta_1(2 - 2e^{(-t_{m1}+t_{m2})\theta_1} + \theta_1(2(-1 + e^{(-t_{m1}+t_{m2})\theta_1})t_{m2} + (t_{m1} - t_{m2})(-2 + (t_{m1} + t_{m2})\theta_1)))] + $$

$$D_{CM}\frac{e^{-t_{m1}\theta_1}}{2\theta_1^2}[2(-\beta + \beta_1 + (\alpha - \alpha_1)\theta_1) + e^{t_{m1}\theta_1}(2(\beta - \beta_1) + 2(-\alpha + \alpha_1 + t_{m1}(-\beta + \beta_1))\theta_1 + t_{m1}(2(\alpha - $$

$$\alpha_1) + t_{m1}(\beta - \beta_1))\theta_1^2)] + \frac{1}{2\theta_1^2} D_{CM}[2\alpha_1\theta_1(-1 + e^{(-t_{m1}+t_{m2})\theta_1} + (t_{m1} - t_{m2})\theta_1) + \beta_1(2 - 2e^{(-t_{m1}+t_{m2})\theta_1} + $$

$$\theta_1(2(-1 + e^{(-t_{m1}+t_{m2})\theta_1})t_{m2} + (t_{m1} - t_{m2})(-2 + (t_{m1} + t_{m2})\theta_1)))]] + \frac{LZ_r}{T}[O_{cr} - \frac{P_{cr}(D_0 - \phi\varphi)}{\theta_2}[1 - $$

$$e^{\theta_2(t_{r2}-t_r)}] + H_r(D_0 - \phi\varphi)(\frac{-1+e^{\theta_2(t_{r2}-t_s)}-t_{r2}\theta_2+\theta_2 t_s}{\theta_2^2}) + \frac{D_r(D_0 - \phi\varphi)(-1+e^{\theta_2(t_{r2}-t_r)}-t_{r2}\theta_2+t_r\theta_2)}{\theta_2} + $$

$$B_r(-\frac{e^{-t_r\rho}\left((x - \phi\varphi)\alpha(1-e^{u\rho}+u\rho)-y(2+u\rho+e^{u\rho}(-2+u\rho))\right)}{\rho^3} - \frac{e^{-t_r\rho}D_0\left(-e^{\rho t_r}+e^{v\rho}(1-v\rho+\rho t_r)\right)}{\rho^2} + $$

$$\frac{e^{-t_r\rho}(y-(x - \phi\varphi)\rho+e^{u\rho}(-y+(x - \phi\varphi+yu)\rho))(-u+t_r)}{\rho^2}) + L_S\left[(x - \phi\varphi)u + \frac{yu^2}{2} - \frac{(x-\phi\varphi)e^{-t_r^2\rho}(-1+e^{u\rho})}{\rho} - \right.$$

$$\left. \frac{ye^{-t_r\rho}(1+e^{u\rho}(-1+u\rho))}{\rho^2} + \frac{(-1+e^{(-t_r+u)\rho}+t_r\rho-u\rho)(D_0 - \phi\varphi)}{\rho}\right)\right] + \frac{1}{T}[S_{CR} + P_{CR}(at_R + \frac{bt_R^2}{2}) + H_{CR}\frac{e^{-t_R\theta_1}}{2\theta_1^3}[(2(-b + \beta_1 + $$

$$(a - \alpha_1)\theta_1) + e^{t_R\theta_1}(2(b - \beta_1) + 2(-a + \alpha_1 + t_R(-b + \beta_1))\theta_1 + t_R(2(a - \alpha_1) + t_R(b - \beta_1))\theta_1^2))] + $$

$$\frac{1}{2\theta_1^3} H_{CR}[2\alpha_1\theta_1(-1 + e^{(-t_R+T)\theta_1} + (t_R - T)\theta_1) + \beta_1(2 - 2e^{(-t_R+T)\theta_1} + \theta_1(2(-1 + e^{(-t_R+T)\theta_1})T + (t_R - $$

$$T)(-2 + (t_R + T)\theta_1)))] + D_{CR}\frac{e^{-t_R\theta_1}}{2\theta_1^2}[(2(-b + \beta_1 + (a - \alpha_1)\theta_1) + e^{t_R\theta_1}(2(b - \beta_1) + 2(-a + \alpha_1 + t_R(-b + $$

$$\beta_1))\theta_1 + t_R(2(a - \alpha_1) + t_R(b - \beta_1))\theta_1^2))] + \frac{1}{2\theta_1^2} D_{CR}[2\alpha_1\theta_1(-1 + e^{(-t_R+T)\theta_1} + (t_R - T)\theta_1) + \beta_1(2 - $$

$$2e^{(-t_{\mathrm{R}}+\mathrm{T})\theta_1} + \theta_1(2(-1 + e^{(-t_{\mathrm{R}}+\mathrm{T})\theta_1})\mathrm{T} + (t_{\mathrm{R}} - \mathrm{T})(-2 + (t_{\mathrm{R}} + \mathrm{T})\theta_1)))] + C_{CR}\sigma\delta T(D_o - \phi\varphi)].$$