Chapter 8
WIP Limiting Control Strategies

8.1.

$$\mathbf{r} = (1, 0.8095, 0.5714)$$

8.3. (a)

For a CONWIP level of seven jobs:

Measure	WS 1	WS 2	WS 3
$CT_k(7)$	0.305 hr	2.050 hr	1.687 hr
$\lambda_k(7)$	1.807/hr	1.807/hr	1.627/hr
$WIP_k(7)$	0.552	3.704	2.744
$u_k(7)$	0.361	0.904	0.813

with $CT_s = 4.782$ hr, $WIP_s = 7$, and $th_s = 1.464$/hr.

(b)

For a CONWIP level of ten jobs:

Measure	WS 1	WS 2	WS 3
$CT_k(10)$	0.317 hr	2.985 hr	2.221 hr
$\lambda_k(10)$	1.886/hr	1.886/hr	1.697/hr
$WIP_k(10)$	0.598	5.631	3.771
$u_k(10)$	0.377	0.943	0.849

with $CT_s = 6.546$ hr, $WIP_s = 10$, and $th_s = 1.528$/hr.

8.5. For all cases, the CONWIP level is ten jobs:

(a)

Measure	WS 1	WS 2	WS 3	WS 4	WS 5
$CT_k(10)$	0.664 hr	0.664 hr	1.958 hr	1.958 hr	7.428 hr
$\lambda_k(10)$	0.498/hr	0.498/hr	0.498/hr	0.498/hr	0.995/hr
$WIP_k(10)$	0.330	0.330	0.974	0.974	7.391
$u_k(10)$	0.249	0.249	0.498	0.498	0.995

with $CT_s = 20.100$ hr, $WIP_s = 10$, and $th_s = 0.498$/hr.

(b)

Measure	WS 1	WS 2	WS 3	WS 4	WS 5
$CT_k(10)$	0.364 hr	1.333 hr	2.398 hr	0.571 hr	17.669 hr
$\lambda_k(10)$	0.250/hr	0.250/hr	0.250/hr	0.250/hr	0.500/hr
$WIP_k(10)$	0.091	0.333	0.599	0.143	8.834
$u_k(10)$	0.083	0.250	0.375	0.125	1.000

with $CT_s = 40.005$ hr, $WIP_s = 10$, and $th_s = 0.250$/hr.

(c)

Measure	WS 1	WS 2	WS 3	WS 4	WS 5
$CT_k(10)$	0.381 hr	1.599 hr	1.846 hr	0.533 hr	17.922 hr
$\lambda_k(10)$	0.375/hr	0.375/hr	0.125/hr	0.125/hr	0.500/hr
$WIP_k(10)$	0.143	0.600	0.231	0.067	8.960
$u_k(10)$	0.125	0.375	0.187	0.062	1.000

with $CT_s = 40.003$ hr, $WIP_s = 10$, and $th_s = 0.250$/hr.

8.7. (a)

$$\mathbf{r} = (1, 0.4762, 0.5714)$$

(b)

Notice that the cycle times are not the correct values, but the point of the problem is to insure that the measures can be obtained without having to do the interation; thus, the values below make the assumption that the values given in the problem are correct. This yields

Measure	WS 1	WS 2	WS 3
CT_k	8.357 hr	5.001 hr	24.951 hr
λ_k	0.320/hr	0.152/hr	0.183/hr
WIP_k	2.675	0.762	4.563

with $CT_s = 58.324$ hr, $WIP_s = 8$, and $th_s = 0.137$/hr.

(c)

The following results are from the Marginal Distribtuion Analysis Algorithm of Property 8.4 with a CONWIP level of 8.

$CT_1 = 14.634$ hr, $CT_2 = 3.249$ hr, $CT_3 = 7.051$ hr, and $th_s = 0.170$/hr.

8.9.

This is a redo of Problem 8.5 (a) with an additional machine at the second and fifth workstations.

Measure	WS 1	WS 2	WS 3	WS 4	WS 5
$CT_k(10)$	0.765 hr	0.515 hr	2.881 hr	2.881 hr	3.300 hr
$\lambda_k(10)$	0.733/hr	0.733/hr	0.733/hr	0.733/hr	1.466/hr
$WIP_k(10)$	0.561	0.378	2.112	2.112	4.838

with $CT_s = 13.644$ hr, $WIP_s = 10$, and $th_s = 0.733$/hr.

8.11.
This is a redo of Problem 8.4 for non-exponential times.

Measure	WS 1	WS 2	WS 3
$CT_k(5)$	21.466 min	64.417 min	230.640 min
$\lambda_k(5)$	0.024/min	0.020/min	0.014/min
$WIP_k(5)$	0.523	1.269	3.208
$u_k(5)$	0.365	0.591	0.835

with $CT_s = 7.988$ hr, $WIP_s = 5$, and $th_s = 0.626$/hr.

8.13. This is a redo of Problem 8.5 with an additional product.

(a)

Product 1			
Measure	WS 1	WS 2	WS 3
$CT_k^1(5)$	13.8827 hr	1.0055 hr	1.3876 hr
$\lambda_{1,k}(5)$	0.3228/hr	0.2613/hr	0.1845/hr
$WIP_k^1(5)$	4.4813	0.2628	0.2559

Product 2			
Measure	WS 1	WS 2	WS 3
$CT_k^2(8)$	13.9489 hr	1.2485 hr	0.7291 hr
$\lambda_{2,k}(8)$	0.5295/hr	0.2846/hr	0.3541/hr
$WIP_k^2(8)$	7.3865	0.3554	0.2582

Product 3			
Measure	WS 1	WS 2	WS 3
$CT_k^3(7)$	13.9035 hr	0.9127 hr	0.9237 hr
$\lambda_{3,k}(7)$	0.4643/hr	0.3665/hr	0.2281/hr
$WIP_k^3(7)$	6.4548	0.3345	0.2107

(b)
$CT_s = 33.7446$ hr, $WIP_s = 20$, and $th_s = 0.5927$/hr.

8.15. (a)

$$\mathbf{r}^1 = (1, 0.737, 0.702)$$
$$\mathbf{r}^2 = (1, 0.5, 1.111)$$

(b)

$$
\begin{aligned}
CT_1^1 &= E[T_s(1,1)] + E[T_s(1,1)] * 7 * 1 * CT_1^1 / (1 * CT_1^1 + 0.737 * CT_2^1 + 0.702 * CT_3^1) \\
&\quad + E[T_s(2,1)] * 5 * 1 * CT_1^2 / (1 * CT_1^2 + 0.5 * CT_2^2 + 1.111 * CT_3^2) \\
CT_2^1 &= E[T_s(1,2)] + E[T_s(1,2)] * 7 * 0.737 * CT_2^1 / (1 * CT_1^1 + 0.737 * CT_2^1 + 0.702 * CT_3^1) \\
&\quad + E[T_s(2,2)] * 5 * 0.5 * CT_2^2 / (1 * CT_1^2 + 0.5 * CT_2^2 + 1.111 * CT_3^2) \\
CT_3^1 &= E[T_s(1,3)] + E[T_s(1,3)] * 7 * 0.702 * CT_3^1 / (1 * CT_1^1 + 0.737 * CT_2^1 + 0.702 * CT_3^1) \\
&\quad + E[T_s(2,3)] * 5 * 1.111 * CT_3^2 / (1 * CT_1^2 + 0.5 * CT_2^2 + 1.111 * CT_3^2) \\
CT_1^2 &= E[T_s(2,1)] + E[T_s(2,1)] * 4 * 1 * CT_1^2 / (1 * CT_1^2 + 0.5 * CT_2^2 + 1.111 * CT_3^2) \\
&\quad + E[T_s(1,1)] * 8 * 1 * CT_1^1 / (1 * CT_1^1 + 0.737 * CT_2^1 + 0.702 * CT_3^1) \\
CT_2^2 &= E[T_s(2,2)] + E[T_s(2,2)] * 4 * 0.5 * CT_2^2 / (1 * CT_1^2 + 0.5 * CT_2^2 + 1.111 * CT_3^2) \\
&\quad + E[T_s(1,2)] * 8 * 0.737 * CT_2^1 / (1 * CT_1^1 + 0.737 * CT_2^1 + 0.702 * CT_3^1) \\
CT_3^2 &= E[T_s(2,3)] + E[T_s(2,3)] * 4 * 1.111 * CT_3^2 / (1 * CT_1^2 + 0.5 * CT_2^2 + 1.111 * CT_3^2) \\
&\quad + E[T_s(1,3)] * 8 * 0.702 * CT_3^1 / (1 * CT_1^1 + 0.737 * CT_2^1 + 0.702 * CT_3^1)
\end{aligned}
$$

(c) Notice that the cycle times are not the correct values, but the point of the problem is to insure that the measures can be obtained without having to do the interation; thus, the values below make the assumption that the values given in the problem are correct. This yields

Product 1			
Measure	WS 1	WS 2	WS 3
$CT_k^1(8)$	8.5430 hr	16.8550 hr	8.0860 hr
$\lambda_{1,k}(8)$	0.3003/hr	0.2213/hr	0.2108/hr
$WIP_k^1(8)$	2.5658	3.7300	1.7042

Product 2			
Measure	WS 1	WS 2	WS 3
$CT_k^2(5)$	8.2750 hr	16.4390 hr	9.6810 hr
$\lambda_{2,k}(5)$	0.1835/hr	0.0917/hr	0.2039/hr
$WIP_k^2(5)$	1.5183	1.5081	1.9736

(d)

$u_1 = 0.876$, $u_2 = 0.847$, and $u_3 = 0.924$

(e)

$CT_s = 40.4344$ hr, $WIP_s = 13$, and $th_s = 0.3215$/hr.

8.16.

Note that the r values are wrong in the table for Product 2.

8.17.

Product 1			
Measure	WS 1	WS 2	WS 3
$CT_k^1(5)$	9.4913 hr	0.9059 hr	1.3069 hr
$\lambda_{1,k}(5)$	0.4557/hr	0.3689/hr	0.2604/hr
$WIP_k^1(5)$	4.3254	0.3342	0.3403

Product 2			
Measure	WS 1	WS 2	WS 3
$CT_k^2(8)$	9.6084 hr	1.1484 hr	0.6511 hr
$\lambda_{2,k}(8)$	0.7504/hr	0.4033/hr	0.5018/hr
$WIP_k^2(8)$	7.2101	0.4632	0.3268

$CT_s = 21.7840$ hr, $WIP_s = 13$, and $th_s = 0.5968$/hr.