## Solution

| PPI_TL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |               | Α          | В          | Agg. A&B   |            |                          |  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|---------------|------------|------------|------------|------------|--------------------------|--|
| Kwt         25         25.0         25.0         ton         Physical weight capacity           Kcu         2750         2750.0         2750.0         ft^3         Effective cube capacity           unit cube         6         15         ft^3         Effective cube capacity           unit weight         67         80         lb           unit value         3015         1000         \$           s         11.1667         5.3333         9.4449         lb/ft^3         Density           d         688         688         688         mi         Distance           r         2.6991         2.6991         \$/mi         TL rev per loaded tr-mi           MC_TL         60.73         60.73         60.73         Min charge TL           MC_LTL         95.40         95.40         Min charge LTL           qmax         15.3542         7.3333         12.9868         ton         Max payload           f         150         30         180         ton/yr         Annual demand           n         9.76933514         4.09090909         13.8602442         per yr           (1)         w         26.3686436         \$/mi         Monetary weight                                                                                                                             |     | PPI_TL        | 138.6      | 138.6      | 138.6      | Jul 18 (P) | Prod Price Index for TL  |  |
| Kcu                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     | PPI_LTL       | 182.9      | 182.9      | 182.9      | Jul 18 (P) | Prod Price Index for LTL |  |
| unit cube         6         15         ft^3           unit weight         67         80         lb           unit value         3015         1000         \$           s         11.1667         5.3333         9.4449         lb/ft^3         Density           d         688         688         688         mi         Distance           r         2.6991         2.6991         \$/mi         TL rev per loaded tr-mi           MC_TL         60.73         60.73         \$/mi         Min charge TL           MC_LTL         95.40         \$/mi         Min charge LTL           qmax         15.3542         7.3333         12.9868         ton         Max payload           f         150         30         180         ton/yr         Annual demand           n         9.76933514         4.09090909         13.8602442         per yr           (1)         w         26.3686436         \$/mi         Monetary weight           TC_FTL         18141.63         7596.81         25738.43         \$           a         1         1         Inventory fraction           v         90000         25000         79166.6667         \$/ton         Value                                                                                                                                  |     | Kwt           | 25         | 25.0       | 25.0       | ton        | Physical weight capacity |  |
| unit weight         67         80         lb           unit value         3015         1000         \$           s         11.1667         5.3333         9.4449 lb/ft^3         Density           d         688         688         688 mi         Distance           r         2.6991         2.6991         \$/mi         TL rev per loaded tr-mi           MC_TL         60.73         60.73         \$ Min charge TL           MC_LTL         95.40         \$ Min charge LTL           qmax         15.3542         7.3333         12.9868 ton         Max payload           f         150         30         180 ton/yr         Annual demand           n         9.76933514         4.09090999         13.8602442 per yr           (1)         w         26.3686436         \$/mi         Monetary weight           TC_FTL         18141.63         7596.81         25738.43         \$           a         1         1         Inventory fraction           v         90000         25000         79166.6667         \$/ton         Value per ton           h         0.3         0.3         0.3         1/yr         Inventory carrying rate           IC_FTL <td< td=""><td></td><td>Kcu</td><td>2750</td><td>2750.0</td><td>2750.0</td><td>ft^3</td><td>Effective cube capacity</td></td<> |     | Kcu           | 2750       | 2750.0     | 2750.0     | ft^3       | Effective cube capacity  |  |
| unit value         3015         1000         \$           s         11.1667         5.3333         9.4449         lb/ft^3         Density           d         688         688         688         mi         Distance           r         2.6991         2.6991         \$/mi         TL rev per loaded tr-mi           MC_TL         60.73         60.73         \$ Min charge TL           MC_LTL         95.40         \$ Min charge LTL           qmax         15.3542         7.3333         12.9868         ton         Max payload           f         150         30         180         ton/yr         Annual demand           n         9.76933514         4.09090909         13.8602442         per yr           (1)         w         26.3686436         \$/mi         Monetary weight           TC_FTL         18141.63         7596.81         25738.43         \$           a         1         1         Inventory fraction           v         90000 f         25000         79166.6667         \$/ton         Value per ton           h         0.3         0.3         0.3         1/yr         Inventory carrying rate           IC_FTL         414562.5                                                                                                                            |     | unit cube     | 6          | 15         |            | ft^3       |                          |  |
| s       11.1667       5.3333       9.4449       lb/ft^3       Density         d       688       688       688       mi       Distance         r       2.6991       2.6991       \$/mi       TL rev per loaded tr-mi         MC_TL       60.73       60.73       \$ Min charge TL         MC_LTL       95.40       \$ Min charge LTL         qmax       15.3542       7.3333       12.9868       ton       Max payload         f       150       30       180       ton/yr       Annual demand         n       9.76933514       4.09090909       13.8602442       per yr         (1)       w       26.3686436       \$/mi       Monetary weight         TC_FTL       18141.63       7596.81       25738.43       \$         a       1       1       Inventory fraction         v       90000       25000       79166.6667       \$/ton       Value per ton         h       0.3       0.3       0.3       1/yr       Inventory carrying rate         IC_FTL       414562.5       55000       308436.123       \$                                                                                                                                                                                                                                                                                          |     | unit weight   | 67         | 80         |            |            |                          |  |
| d 688 688 688 mi Distance r 2.6991 2.6991 2.6991 \$/mi TL rev per loaded tr-mi MC_TL 60.73 60.73 60.73 \$ Min charge TL MC_LTL 95.40 95.40 \$ Min charge LTL qmax 15.3542 7.3333 12.9868 ton Max payload f 150 30 180 ton/yr Annual demand n 9.76933514 4.09090909 13.8602442 per yr (1) w 26.3686436 \$/mi Monetary weight TC_FTL 18141.63 7596.81 25738.43 \$  a 1 1 1 1 Inventory fraction v 90000 725000 79166.6667 \$/ton Value per ton h 0.3 0.3 0.3 1/yr Inventory carrying rate IC_FTL 414562.5 55000 308436.123 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     | unit value    |            |            |            |            |                          |  |
| r 2.6991 2.6991 2.6991 \$/mi TL rev per loaded tr-mi  MC_TL 60.73 60.73 60.73 \$ Min charge TL  MC_LTL 95.40 95.40 \$ Min charge LTL  qmax 15.3542 7.3333 12.9868 ton Max payload  f 150 30 180 ton/yr Annual demand  n 9.76933514 4.09090909 13.8602442 per yr  (1) w 26.3686436 \$/mi Monetary weight  TC_FTL 18141.63 7596.81 25738.43 \$  a 1 1 1 Inventory fraction  v 90000 725000 79166.6667 \$/ton Value per ton  h 0.3 0.3 0.3 1/yr Inventory carrying rate                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |               | 11.1667    |            | 9.4449     | lb/ft^3    |                          |  |
| MC_TL         60.73         60.73         60.73         \$ Min charge TL           MC_LTL         95.40         95.40         \$ Min charge LTL           qmax         15.3542         7.3333         12.9868 ton         Max payload           f         150         30         180 ton/yr         Annual demand           n         9.76933514         4.09090909         13.8602442 per yr           (1)         w         26.3686436         \$/mi         Monetary weight           TC_FTL         18141.63         7596.81         25738.43         \$           a         1         1         Inventory fraction           v         90000         25000         79166.6667         \$/ton         Value per ton           h         0.3         0.3         0.3         1/yr         Inventory carrying rate           IC_FTL         414562.5         55000         308436.123         \$                                                                                                                                                                                                                                                                                                                                                                                                      |     | d             |            |            |            |            |                          |  |
| MC_LTL         95.40         95.40         \$ Min charge LTL           qmax         15.3542         7.3333         12.9868 ton         Max payload           f         150         30         180 ton/yr         Annual demand           n         9.76933514         4.09090909         13.8602442 per yr           (1)         w         26.3686436         \$/mi         Monetary weight           TC_FTL         18141.63         7596.81         25738.43         \$           a         1         1         Inventory fraction           v         90000         25000         79166.6667         \$/ton         Value per ton           h         0.3         0.3         0.3         1/yr         Inventory carrying rate           IC_FTL         414562.5         55000         308436.123         \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     | -             |            |            |            |            | •                        |  |
| qmax         15.3542         7.3333         12.9868 ton         Max payload           f         150         30         180 ton/yr         Annual demand           n         9.76933514         4.09090909         13.8602442 per yr           (1)         w         26.3686436         \$/mi         Monetary weight           TC_FTL         18141.63         7596.81         25738.43         \$           a         1         1         Inventory fraction           v         90000         25000         79166.6667         \$/ton         Value per ton           h         0.3         0.3         0.3         1/yr         Inventory carrying rate           IC_FTL         414562.5         55000         308436.123         \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |               |            |            | 60.73      | \$         |                          |  |
| f 150 30 180 ton/yr Annual demand n 9.76933514 4.09090909 13.8602442 per yr (1) w 26.3686436 \$/mi Monetary weight  TC_FTL 18141.63 7596.81 25738.43 \$  a 1 1 1 1 Inventory fraction v 90000 25000 79166.6667 \$/ton Value per ton h 0.3 0.3 0.3 1/yr Inventory carrying rate IC_FTL 414562.5 55000 308436.123 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |     | MC_LTL        |            |            |            |            |                          |  |
| n       9.76933514       4.09090909       13.8602442       per yr         (1)       w       26.3686436       \$/mi       Monetary weight         TC_FTL       18141.63       7596.81       25738.43       \$         a       1       1       Inventory fraction         v       90000       25000       79166.6667       \$/ton       Value per ton         h       0.3       0.3       0.3       1/yr       Inventory carrying rate         IC_FTL       414562.5       55000       308436.123       \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | qmax          | 15.3542    | 7.3333     | 12.9868    | ton        |                          |  |
| (1) w 26.3686436                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     | f             |            |            |            | ,          | Annual demand            |  |
| TC_FTL 18141.63 7596.81 25738.43 \$  a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     | n             | 9.76933514 | 4.09090909 | 13.8602442 | per yr     |                          |  |
| a 1 1 1 1 Inventory fraction  v 90000 25000 79166.6667 \$/ton Value per ton  h 0.3 0.3 0.3 1/yr Inventory carrying rate  IC_FTL 414562.5 55000 308436.123 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | (1) |               |            |            |            |            | Monetary weight          |  |
| v     90000     25000     79166.6667     \$/ton     Value per ton       h     0.3     0.3     0.3     1/yr     Inventory carrying rate       IC_FTL     414562.5     55000     308436.123     \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     | TC_FTL        | 18141.63   | 7596.81    | 25738.43   | \$         |                          |  |
| h 0.3 0.3 1/yr Inventory carrying rate IC_FTL 414562.5 55000 308436.123 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |     | а             |            | -          |            |            |                          |  |
| IC_FTL 414562.5 55000 308436.123 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |               |            |            |            |            |                          |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     |               |            |            |            |            | Inventory carrying rate  |  |
| TLC_FTL 432704.127 62596.8062 334174.556 \$ TLC Full Truckload                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |               |            |            |            | •          |                          |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     | TLC_FTL       |            |            |            |            | TLC Full Truckload       |  |
| q*TL 3.2120 2.7254 3.7515 ton Optimal TL size                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |     |               |            | 2.7254     | 3.7515     | ton        | Optimal TL size          |  |
| TC_TL 86722.7662 20440.752 89099.1723 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | TC_TL         | 86722.7662 | 20440.752  | 89099.1723 | \$         |                          |  |
| IC_TL 86722.7662 20440.752 89099.1723 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | IC_TL         | 86722.7662 | 20440.752  | 89099.1723 | \$         |                          |  |
| TLC*_TL 173445.532 40881.504 178198.345 \$ TLC Optimal TL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |     | TLC*_TL       | 173445.532 | 40881.504  | 178198.345 | \$         | TLC Optimal TL           |  |
| rLTL 1.33881879 2.32441095 \$/ton-mi                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     | rLTL          | 1.33881879 | 2.32441095 |            | \$/ton-mi  |                          |  |
| TC_LTL 138166.1 47975.842 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |     | TC_LTL        | 138166.1   | 47975.842  |            |            |                          |  |
| IC_LTL 22490.23 7775.97 \$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |     | IC_LTL        | 22490.23   | 7775.97    |            | \$         |                          |  |
| TLC*_LTL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | TLC*_LTL      | 160656.33  | 55751.81   |            | \$         | TLC Optimal LTL          |  |
| qLTLmax 3.63 1.73 ton                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     | qLTLmax       | 3.63       | 1.73       |            | ton        |                          |  |
| q*LTL 0.83297144 1.03679618 ton Optimal LTL size                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     | q*LTL         | 0.83297144 | 1.03679618 |            | ton        | Optimal LTL size         |  |
| Min TLC 160656.33 40881.50 178198.34                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     | Min TLC       | 160656.33  | 40881.50   | 178198.34  |            |                          |  |
| (2) TL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | (2) |               |            | TL         |            |            |                          |  |
| Min TLC A+B 201537.83                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     | Min TLC A+B   |            | 201537.83  |            |            |                          |  |
| (3) TLC A+B - A&B 23339.49                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | (3) | TLC A+B - A&B |            |            | 23339.49   |            |                          |  |

| С   | D             | E                                 | F                                 | G                                | Н         | I                            |
|-----|---------------|-----------------------------------|-----------------------------------|----------------------------------|-----------|------------------------------|
|     |               | Α                                 | В                                 | Agg. A&B                         |           |                              |
|     | PPI TL        | 138.6                             | =E2                               | =F2                              | Jul 18 (F | Prod Price Index for TL      |
|     | PPI LTL       | 182.9                             | =E3                               | =F3                              | Jul 18 (F | Prod Price Index for LTL     |
|     | Kwt           | 25                                | =E4                               | =F4                              | ton       | Physical weight capacity     |
|     | Kcu           | 2750                              | =E5                               | =F5                              | ft^3      | Effective cube capacity      |
|     | unit cube     | 6                                 | 15                                |                                  | ft^3      |                              |
|     | unit weight   | 67                                | 80                                |                                  | lb        |                              |
|     | unit value    | =E7*E32/2000                      | 1000                              |                                  | \$        |                              |
|     |               | =E7/E6                            | =F7/F6                            | =\$G27/(E27/E9+F27/F9)           | lb/ft^3   | Density                      |
|     |               | 688                               | =E10                              | =F10                             | mi        | Distance                     |
|     |               | =2*(E2/102.7)                     | =E11                              | =F11                             | \$/mi     | TL rev per loaded tr-mi      |
|     |               | =(E11/2)*45                       | =(F11/2)*45                       | =(G11/2)*45                      | \$        | Min charge TL                |
|     | MC_LTL        | =(E3/104.2)*(45+E10^(28/19)/1625  | =(F3/104.2)*(45+F10^(28/19)/162   |                                  | \$        | Min charge LTL               |
|     |               | =MIN(E4,E9*E5/2000)               | =MIN(F4,F9*F5/2000)               | =MIN(G4,G9*G5/2000)              | ton       | Max payload                  |
|     | f             | 150                               | 30                                | =E27+F27                         | ton/yr    | Annual demand                |
|     | n             | =E27/E26                          | =F27/F26                          | =G27/G26                         | per yr    |                              |
| (1) | W             | =E28*E11                          |                                   |                                  | \$/mi     | Monetary weight              |
|     | TC_FTL        | =E28*E11*E10                      | =F28*F11*F10                      | =G28*G11*G10                     | \$        |                              |
|     |               | 1                                 | =E31                              | =F31                             |           | Inventory fraction           |
|     | V             | 90000                             | =2000*F8/F7                       | =(E27/\$G27)*E32+(F27/\$G27)*F32 | \$/ton    | Value per ton                |
|     | h             | 0.3                               | =E33                              | =F33                             | 1/yr      | Inventory carrying rate      |
|     |               | =E31*E32*E33*E26                  | =F31*F32*F33*F26                  | =G31*G32*G33*G26                 | \$        |                              |
|     | TLC_FTL       | =E30 + E34                        | =F30 + F34                        | =G30 + G34                       | \$        | TLC Full Truckload           |
|     | t_max         | =1/12                             |                                   |                                  | yr/TL     | 1-month interval constraint  |
|     |               | =1/E36                            |                                   |                                  | TL/yr     |                              |
|     |               | =MAX(E28,E37)*E11*E10             |                                   |                                  | \$        |                              |
|     | IC_1mo        | =E31*E32*E33*E27/MAX(E28,E37      |                                   |                                  | \$        |                              |
|     | TLC_1mo       | =E38+E39                          |                                   |                                  | \$        | TLC 1-mo interval constraint |
|     | q*TL          | =MIN(SQRT((E27*MAX(E11*E10,E      | =MIN(SQRT((F27*MAX(F11*F10,F      | =MIN(SQRT((G27*MAX(G11*G10,G2    | ton       | Optimal TL size              |
|     | TC TL         | =(E27/E41)*MAX(E11*E10,E13)       | =(F27/F41)*MAX(F11*F10,F13)       | =(G27/G41)*MAX(G11*G10,G13)      | \$        | i i                          |
|     | IC TL         | = E31*E33*E32*E41                 | = F31*F33*F32*F41                 | = G31*G33*G32*G41                | \$        |                              |
|     | TLC* TL       | =E42 + E43                        | =F42 + F43                        | =G42 + G43                       | \$        | TLC Optimal TL               |
|     | rLTL          | =E3*(((E9^2)/8+14)/((E50^(1/7)*E1 | =F3*(((F9^2)/8+14)/((F50^(1/7)*F1 | i                                | \$/ton-mi | ·                            |
|     |               |                                   | =F27*MAX(F10*F45,F24/F50)         |                                  | \$        |                              |
|     | IC LTL        | =E31*E32*E33*E50                  | =F31*F32*F33*F50                  |                                  | \$        |                              |
|     |               | =E46+E47                          | =F46+F47                          |                                  | \$        | TLC Optimal LTL              |
|     |               | =MIN(5,650*E9/2000)               | =MIN(5,650*F9/2000)               |                                  | ton       |                              |
|     |               | 0.832971444189039                 | 1.03679618177092                  |                                  | ton       | Optimal LTL size             |
|     |               | =MIN(E35,E44,E48)                 | =MIN(F35,F44,F48)                 | =MIN(G35,G44,G48)                |           |                              |
| (2) | 120           | (200,277,270)                     | TL                                | (550,644,640)                    |           |                              |
| (~) | Min TLC A+B   |                                   | =E51+F51                          |                                  |           |                              |
| (3) | TLC A+B - A&B |                                   | 2011101                           | =F53-G51                         |           |                              |
| (5) | ILC ATD - AGD |                                   |                                   | -1 33-03 1                       |           |                              |