**EXERCISES**

9.11. Sequencing Jobs A fundamental model in scheduling contains a set of jobs that are waiting to be processed by a machine or processor. The machine is capable of handling only one job at a time, so the jobs must be processed in sequence. The problem is to find the best sequence for a given objective function.

For example, the processor might be an integrated machining center that performs a number of metal-cutting operations on components for complex assemblies. Ten different components have reached the center and are awaiting processing. These jobs and their processing times (expressed in hours) are described in the following table. In addition, each job has a corresponding due date that has been calculated by the production control system. As a result of the sequence chosen, each job will either be on time or late. If it is late, the amount of time by which it misses its due date is called its tardiness. The objective is to minimize the total tardiness in the schedule.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Processing time | 6 | 1 | 2 | 5 | 9 | 8 | 12 | 3 | 9 | 7 |
| Due date | 17 | 5 | 25 | 15 | 20 | 8 | 44 | 24 | 50 | 20 |

Build a model for this problem for solution with the evolutionary solver. Initialize the run with the jobs in numbered sequence. What is the minimum total tardiness and the sequence that achieves it?

**9.12. Sequencing Tasks** Eight insurance policies are in the queue waiting to be evaluated by the underwriting department. Each policy has a known processing time (in hours), a due date (derived from customer expectations) and a penalty factor (which is the Marketing Department’s importance weighting for the customer.)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Job*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** |
| ***Process time*** | 13 | 9 | 8 | 12 | 7 | 10 | 14 | 11 |
| ***Due date*** | 55 | 13 | 27 | 51 | 43 | 24 | 32 | 62 |
| ***Penalty factor*** | 5 | 7 | 3 | 4 | 4 | 8 | 6 | 6 |

In this situation, the objective is to minimize the penalty-weighted tardiness. In other words, if a policy evaluation is completed by its due date, then no penalty is incurred. If the evaluation completes after its due date, the penalty is the penalty factor multiplied by the tardiness.

1. Suppose the measure of scheduling effectiveness is the sum of the penalties for the late policies—that is, the total weighted tardiness. Build a model for this problem for solution with the evolutionary solver. Initialize the run with the jobs in numbered order. What is the best (smallest) possible value of the sum?
2. Suppose instead that the measure of scheduling effectiveness is the worst of the penalties for the late policies—that is, the maximum weighted tardiness. What is the best (smallest) possible value of the maximum?

9.13. Touring the Agents Professor Moonlight runs a fund of funds in order to supplement his academic salary. Every winter, he pays a visit to each of the fund managers with whom he works. These visits are all made in one trip, during which he visits investment agents in nine cities. Prof. Moonlight doesn’t mind flying, but he dislikes long flights. For this trip, he wants to find a route through the various cities starting and ending in San Antonio, and he wants the longest leg of the trip (measured in miles) to be as short as possible. The pairwise distances in miles are shown below.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | San Antonio | Phoenix | Los Angeles | Seattle | Detroit | Atlanta | New York | Boston | Philadelphia |
| San Antonio | 0 | 602 | 1376 | 1780 | 1262 | 935 | 1848 | 2000 | 1668 |
| Phoenix | 602 | 0 | 851 | 1193 | 1321 | 1290 | 2065 | 2201 | 1891 |
| Los Angeles | 1376 | 851 | 0 | 971 | 2088 | 2140 | 2870 | 2995 | 2702 |
| Seattle | 1780 | 1193 | 971 | 0 | 1834 | 2178 | 2620 | 2707 | 2486 |
| Detroit | 1262 | 1321 | 2088 | 1834 | 0 | 655 | 801 | 912 | 654 |
| Atlanta | 935 | 1290 | 2140 | 2178 | 655 | 0 | 940 | 1096 | 765 |
| New York | 1848 | 2065 | 2870 | 2620 | 801 | 940 | 0 | 156 | 180 |
| Boston | 2000 | 2201 | 2995 | 2707 | 912 | 1096 | 156 | 0 | 333 |
| Philadelphia | 1668 | 1891 | 2702 | 2486 | 654 | 765 | 180 | 333 | 0 |

Build a model for this problem for solution with the evolutionary solver. Initialize the run with your best guess as to the optimal sequence. What is the minimum value of the trip’s longest leg?

9.14. Optimizing Capacity Pelham Power Company (PPC) uses a system of boilers and turbines to produce power. PPC owns five boilers. If a given boiler is operated, it can produce steam within an output range given in the following table. Quantities are shown in tons. The cost per ton of producing steam is also shown in the table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Boiler | 1 | 2 | 3 | 4 | 5 |
| Min. | 300 | 325 | 350 | 355 | 375 tons of steam |
| Max. | 800 | 820 | 840 | 920 | 960 tons of steam |
| Cost | 2.20 | 2.35 | 2.50 | 2.65 | 2.80 dollars per ton of steam |

Steam from the boilers is used by the turbines to produce power. PPC owns four turbines. If a given turbine is operated, it can produce power from steam at the rate given in the following table. The amount of steam each turbine can accommodate is also shown in the table, along with the maximum and minimum of its input range (in tons of steam). The cost of producing power is also shown in the table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Turbine | 1 | 2 | 3 | 4 |
| Rate | 4.00 | 4.50 | 5.00 | 5.50 kwh per ton of steam |
| Min. | 420 | 450 | 480 | 510 tons of steam |
| Max. | 825 | 875 | 925 | 975 tons of steam |
| Cost | 2.15 | 2.50 | 2.75 | 2.95 dollars per ton of steam |

Build a model for this problem suited to the evolutionary solver. Initialize the model with all boilers and all turbines in the configuration. What is the minimum cost of deploying boilers and turbines to produce 10,000 kwh of power at PPC?

9.15. Smoothing Production A supplier of raw material has made plans to provide monthlydeliveries to a customer. The customer’s requirements are shown in the following table.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Units | 100 | 200 | 300 | 400 | 100 | 100 | 500 | 300 |

The raw material can be processed and prepared for delivery in any volume because part-time labor can be used, and the labor pool is quite large. However, changes in month-to-month production volumes can be costly. When production levels increase, costs must be incurred in acquiring and training new workers. When production levels decrease, costs are incurred due to layoff policies.

Based on historical data, the cost estimate for increasing production from one month to the next is $15 per unit increase in capacity. In the other direction, reducing production from one month to the next incurs a cost of $10 per unit reduction in capacity. The other relevant cost is the cost of inventory: each unit held in stock incurs a cost of $20 per month held.

Entering month 1, the starting inventory is 80 units, and the production level has been steady at 100 units. To make sure the plans can be extended into the future, inventory is required to be at least 50 units at the end of the eighth month, and the planned production level for month 9 is 200.

Build a model for this problem suited to the evolutionary solver. Initialize the model with your intuitive guess as to a good policy. What is a minimum-cost production plan for the supplier?

9.16. Dancing Partners Leah invited 15 friends to her place for a dance party. She assigned each guest a number from 2 to 16, reserving the number 1 for herself, and instructed everyone to wear their number visibly on their clothing. At one point in the evening when everyone was dancing, Leah noticed the sum of each couple's numbers was a perfect square. What number was Leah’s partner wearing?