

## Case Study II

### Multiperiod Multi-objective Workforce Planning Problem

*Due date: January 19, 2024 (23:59)*

Mercedes-Dantes Toys (MDT) is a company manufacturing toys such as wooden ships and plastic swords. The production techniques in the company are decided to be changed to adopt the latest trends in toy manufacturing at the end of 2023. New equipment will be bought for this purpose and this will also affect the mix of workers needed. In the toy market, workers are classified as type A, B, and C according to their qualifications. For the new equipment, type A and B workers will be needed much more than type C workers. Apart from that, Edmond, the director of the Data Analytics Department, states that the demand for toys is expected to decrease in the following years as more families prefer tablets and smartphones to entertain their children. Hence, the co may need to shrink its workforce over all worker types. In Table 1, the active (non-idle) workforce requirements for each type of worker are given for the next three years: 2024, 2025, and 2026. The company must meet the workforce requirements given in Table 1, exactly. The number of workers at hand at the beginning of 2024 are 1,150, 1,700, and 2,400 for types A, B, and C, respectively.

*Table 1: Active workforce requirements for each type of worker*

	Type A	Type B	Type C
2024	1,250	1,600	1,200
2025	1,800	2,250	750
2026	2,500	3,000	0

The Human Resources Department of the company should determine its set of actions considering the following aspects:

1. Hiring
2. Promoting by education
3. Degrading by performance review
3. Idleness
4. Outsourcing
5. Part-time working

As in most businesses, workers of the company may want to resign and work in a different company. The resignation percentages of the workers in a year are estimated to be 5%, 5%, and 10% for type A, B, and C workers, respectively. Assume that all of the current workforce has already been working in the company for many years.

At the beginning of each year, the company decides on the number of workers to hire from each type of worker, but there is an upper bound on new hirings in each year. The company can hire at most 600, 900, and 500 workers of types A, B, and C, respectively. **The costs of hiring a new worker for the company are \$650 /worker, \$550 /worker, and \$450 /worker for type A, B, and C workers.** Note that the current employment contract prohibits the resignation of the newly-hired workers in the first year of their employment.

In addition, the company may educate the workers in the current workforce in order to change their classification. At most 300 type C workers can be educated in a year, and promoted to type

B workers with a cost of **\$400/worker**. Similarly, type B workers can also be educated and promoted to type A; however, the ratio of educated type B workers to type A workers cannot be more than 20% of type B workers of the previous year. The cost of promoting type B workers to type A workers after education is **\$300/worker**. The company may also degrade a worker's classification after the worker's performance review results in the previous year. In such a case, 50% of the degraded workers are expected to resign from their jobs. Note that this resignation percentage should be considered separately from the resignation percentages stated in the third paragraph.

If there are more workers than needed in a year, some of the workers in the workforce may remain idle. The costs of idleness of a worker for a year are \$500/worker, \$500/worker, and \$200/worker for type A, B, and C workers, respectively.

In case the company requires more workers than the available workforce (i.e., on-hand plus new hirings) in a year, it may prefer to outsource workers from a job market. In a year, no more than 175 workers can be outsourced in total over all worker types. The cost of outsourcing is **\$1,200/worker, \$1,100/worker, and \$1,000/worker** for types A, B, and C workers per year. Besides, the company may hire part-time workers if there are fewer workers than required in a year. If a part-time worker is hired, the worker works half time of a regular worker. At most 80 workers can work part-time in a year, and the costs of part-time workers to the company are **\$550/worker, \$400/worker, and \$350/worker** for type A, B, and C workers for a year. Note that the workers that are outsourced or hired as part-time workers are considered seasonal workers. That is, they are not included in the regular workforce at the end of any year.

Assume that the foregoing decisions are made at the beginning of each year, and classification change processes (e.g., promoting and degrading) are instantaneous (i.e., the workers can work without any time loss due to these processes). The management of the MDT aims to minimize the number of idle workers as well as the total cost while determining the workforce plan covering the next three years. For this purpose, your team is hired as consultants by the company. At the end of the consultancy, you are expected to complete the following tasks:

- a) Solve the problem using the **weighted-sum method**. Try different weights to present the manager a number of solutions. Present at least four different solutions in your report. Hint: *Scaling is important! One way of scaling is to divide each objective function by its worst-case value in the nondominated set. To find the worst-case value of one objective in the nondominated set, optimize the other objective.*
- b) Solve the problem using **e-constraint method** and generate a number of efficient solutions. Present at least five different efficient solutions in your report. Also, by using the **extension of e-constraint method** demonstrated in Recitation 12 Question 2-b, show the set of all nondominated solutions in the objective space (i.e., on the plot where x-axis corresponds to the first objective (number of idle workers) and y-axis corresponds to the second objective (total cost)).  
*Hint: In the e-constraint method, formulate the first objective as a constraint and the second objective as the objective function and apply the iterations as explained in Recitation 12 Question 2-b.*
- c) Suppose MDT has targets about the number of idle workers and total cost.
  - **Total** cost over three years can be at most **\$3,200,000**.
  - **Total** number of idle workers **over three years** can be at most **2,200**.

Solve the problem using the goal programming method and generate a number of solutions using both **weighted** and **preemptive goal programming**. In weighted goal programming,

try different weights to present the manager a number of efficient solutions. Present at least five solutions in your report for the weighted goal programming method and exactly two solutions for the preemptive goal programming method.

Hint: *Scaling is important! You must scale the deviations from the goals as given in the lecture notes.*

- d) Compare the solutions found in parts (a), (b), and (c), and interpret the results.

In your case study report, you should provide your LP models that are formulated to answer the questions in parts (a), (b), and (c). As the company does not have any other optimization package, you should solve these models using Pyomo only.