# IEMS 313 Project: Phase I

7/16/2016

## 1 Notes

- All project files MUST be submitted electronically via Canvas. Your report, including appendices, must be submitted in a single PDF file. Please combine all other files (C++, Python, Matlab, Excel, AMPL etc.) into a single zip (or similar) file. Do not put your report in the zip file.
- This project must be done in groups of three or four people. You should not discuss your work with any person apart from those in your project group, the instructor, and the TA. However, you may do whatever independent research you feel necessary to understand and approach the problem. This includes nonprotected online resources.
- The purpose of this course project is to explore ways to solve a difficult optimization problem. We will spend much of our class time this quarter learning how to build and solve mathematical programs like linear and integer programs. However, sometimes math programs are not the best choice for optimization. Some problems can be solved to optimality using other techniques. For other problems, we can use heuristic techniques to get a quick solution that, although not guaranteed to be optimal, may be a good solution.

## 2 Problem Statement

In this project you will optimize the layout of a facility to achieve economic efficiency. Imagine you are starting a company authorized to produce a stuffed Willie the Wildcat for Northwestern University. You are given a set of $n$ machines for production. In this phase of the problem you can assume that each machine has the same size and shape, which is a square with edge length 10 meter.

The factory you have rented for production is a rectangle of which the length is $a \times 10$ meters and the width is $b \times 10$ meters (both $a$ and $b$ are integers). It is guaranteed that the factory has enough space to contain all machines, i.e. $ab \geq n$. In the production process, materials flow through the machines, which involves workers handling and transporting materials. The properties and characteristics of materials being moved between two machines can vary, requiring differing levels of tools and personnel. It is also possible that there may not be any material flow between two machines. Therefore, the unit material flow costs are different between different pairs of machines. Moreover, the costs to set up a machine in different blocks are also different. Suppose you are given the amount of flow and the unit cost of flow per ten meters between every pair of machines. As the manager, you need to make decisions to locate each of $n$ machines in the factory to minimize the total transportation cost.

To make the planning process easier, you have divided the factory into square blocks, each of which is a square with edge length 10m (Figure 1 shows a $20m \times 30m$ factory), so that each block can contain exactly one machine. You must decide in which block you should put each of the machines. You cannot put two machines on one block but you may leave some of the blocks empty. The distance between two blocks is the rectilinear distance between their top left corners.

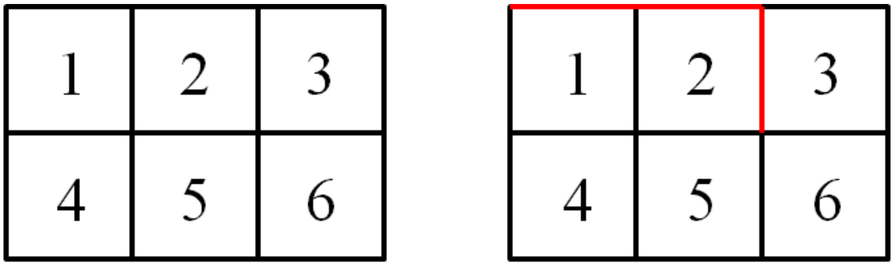


Figure 1: An illustration of 20m×30m factory and the distance between block 1 and block 6

For example, we have four machines to allocate in the above $20m \times 30m$ factory. Using units of $10m$, the distance between block 1 and block 2 is 1, the distance between block 1 and block 5 is 2, and the distance between block 1 and block 6 is 3, which is shown on the right graph in Figure 1. In Figure 2, the first value given in parentheses is the amount of material flow needed between two machines, and the second element is the unit cost per $10m$. Cost is in thousand of dollars. The cost of flow between a pair of machines is the product of the amount of flow, the unit cost per $10m$ and the rectilinear distance of it.

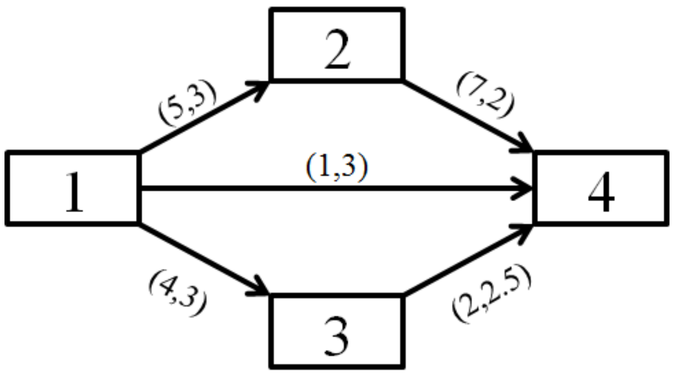


Figure 2: The flow diagram of four machines

The set up cost of each machine on each block is displayed in the following table. The unit of those costs is thousand of dollars.

| Machine\Block | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 10 | 20 | 15 | 10 | 5 | 15 |
| 2 | 27 | 14 | 8 | 6 | 19 | 13 |
| 3 | 10 | 12 | 15 | 9 | 11 | 14 |
| 4 | 13 | 25 | 30 | 2 | 5 | 7 |

Figure 3: The set up cost of each machine on each block

For this problem, if you implement the layout on the left in Figure 4, the total cost is 111 (setup cost $= 10 + 20 + 8 + 5 = 43$, transportation cost $= 5 \times 3 \times 1 + 4 \times 3 \times 1 + 1 \times 3 \times 1 + 7 \times 2 \times 2 + 2 \times 2.5 \times 2 = 68$). If you implement the layout on the right, the total cost is 122 (setup cost $= 20 + 8 + 5 + 14 = 47$, transportation cost $= 5 \times 3 \times 1 + 4 \times 3 \times 2 + 1 \times 3 \times 1 + 7 \times 2 \times 2 + 2 \times 2.5 \times 1 = 75$), given in thousands of dollars. Therefore, the left one is considered to be a better layout.

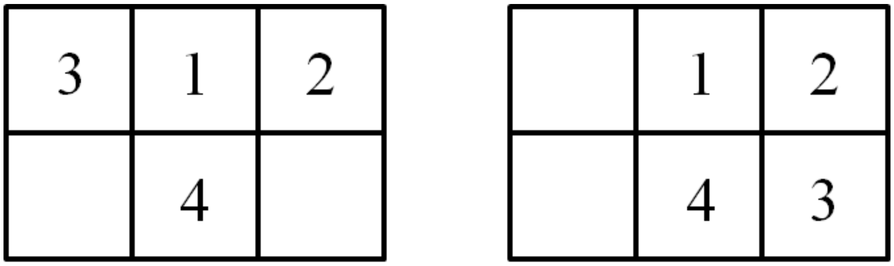


Figure 4: Two possible facility layouts

However, neither of these layouts achieves the lowest cost. The layout in Figure 5 will yield a cost of 85 and it is optimal. You could list all possible layouts to compare their costs, but it is extremely inefficient, especially when you have a larger factory (for this small example, there are 360 possible layouts!) Your task is to come up with a method to obtain a layout of which the total transportation is low.

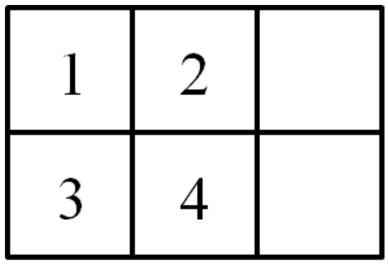


Figure 5: The optimal layout

## 3 Tasks

You tasks in this phase include the following components:

- Design a method(algorithm) that will provide a feasible layout with a low total cost.
- Program your method in the language of your choice (MATLAB, Python, C, C++, etc).
- Use your method to generate a feasible layout for each of the testing problems. Compute the total transportation cost obtained by your layout for each of them.

Your method should be simple to implement, and should not use any kind of mathematical programming(i.e, linear, integer or nonlinear programming formulations) in any way. Your method should be general–data-driven, but not tailored or limited to a specific type of data. That is, given any data with a certain input format, your method will be able to give a reasonable facility layout plan. You are encouraged to try many different ideas, but the methods you present in this project must be well motivated. For example, you should not simply randomly assign the machines to blocks.

## 4 Deliverables

1. Submit a report (in PDF) that is no more than 4 pages.
   (a) Describe your method for providing a feasible layout with a low total cost.
   (b) Justify why you think your method is good. If you can prove that your method provides an optimal solution, include your proof. If you think your method will not always provide an optimal solution, explain why.
   (c) Provie a summary of results for all testing problems, including machine locations and total costs.

2. Submit your code, including all the supplementary files to run your code.
3. Submit an appendix to your report (in the same file with the report) that contains the following materials:
   (a) Illustrate your method with the provided dataset in IllustrationData.pdf on Canvas. Report the solution your method provides and the total cost associated to the solution. Make sure your illustrations are clear but concise. Include a graphical/pictorial representation of your solution.
   (b) Give step-by-step instructions on how to run your code on a dataset. The dataset will have the same format as the sample dataset provided on Canvas. This is not an explanation of your method, but rather provides instructions to executed the implemented/coded algorithm you used on a general dataset. Make these instructions specific enough that someone can execute your code, and obtain the output, "from scratch."
   (c) You may submit another appendix which details additional information that you wish to provide to help your instructor and TA assess the quality of your investigation. For example, you may have considered, and then rejected other methods to obtain a feasible facility layout. You could explain one or more of these methods, report associated results, and explain why you ultimately rejected the approach.