Case study - Beam cutting

A construction company named *Shed-a-Light* builds commercial storage sheds. Each shed built is custom designed according to the customer’s needs, taking into consideration the customer’s product requirements, the landscape, the machinery (forklifts) requirements, depth and height of shelves, air circulation, etc.

*Shed-a-Light* developed a unique construction method that allows them to construct a complete shed within two days. However, for their method to work, they require that all machinery and materials be ready ahead of time. The basic materials required for constructing sheds are metal beams cut into rods of different lengths. The lengths are calculated meticulously and in extremely fine resolution so that the construction can proceed smoothly.

For each shed, an order of rods is placed with a supplier called *Light-Beam*.  
*Light-Beam* imports metal beams which come in a custom length of exactly 12005mm. They cut the beams into rods according to the specifications given by *Shed-a-Light*. Obviously, cutting specific lengths out of a custom 12005mm beam results in a fair amount of waste. Although there is a loss of 5mm for each cut made, we do not consider that as waste. The waste consists of the unused leftovers.

Accordingly, the utilization is calculated as the total length of parts cut from a beam as well as the total loss due to cutting. For example, if the supplier cuts a beam into three rods of lengths 7574.12mm, 2013.1mm, and 1147.17mm, the utilization would be and the waste would be .

*Shed-a-Light* is billed for all the beams their order requires, regardless of the waste. Emily, the Purchasing Manager of *Shed-a-Light,* was concerned with the wasted material. Her calculations showed that the waste can consist of more than 20% of the net length of rods ordered. He complained to Larry, the Production Manager at *Light-Beam*, about the amount of waste *Shed-a-Light* is billed for. Larry explained to Emily that finding the optimal segmentation of the beams is extremely hard. Finally, they came to an agreement that instead of Larry segmenting the beams himself, he would cut the beams according to any segmentation Emily would supply him with.

Emily quickly turned to Sara, a new and extremely promising LGO Intern who recently joined *Shed-a-Light*, and asked her to find the optimal segmentation for their recent order. As a first step, she asked Sara to focus only on one kind of beam profile, namely the S-150X4. The cost of such a beam is 1380$ per beam. The order of cuts is given in Beam\_cutting\_input.xlsx. The order consists of 398 rods.

1. Help Sara find the best possible segmentation of beams so as to minimize the total number of beams used. Your output should be given in the format provided in Beam\_cutting\_input.xlsx. Each gray cell represents the assignment of a specific rod. For example, if we decide to use beam number 1 for rod number 15 (of length 11953), we put 11953 in cell C19 of Worksheet A.

After studying the problem and the needs thoroughly, Sara found out that welding could increase the utilization significantly. After consulting with Larry, she learned that each weld of two pieces into a single rod costs 156$.

1. Help Sara improve the segmentation by including the welding option. For Example, if rod 15 is made up of two parts welded together, one of length 7854.5mm cut from beam number 1 and the second of length 4098.5mm cut from beam number 5, we put 7854.5 in cell C19 and 4098.5 in cell F19 of Worksheet B.

Instructions:

1. Apart from your solutions in the Excel sheet, please provide for each problem the Mixed Integer Linear Program you used.
   1. What were your decision variables?
   2. What was your objective function?
   3. What were your constraints?
2. To improve your running time, you may consider giving the solver a feasible, heuristic solution. If you decide to do so (highly recommended), please explain the idea behind the algorithm you used.
3. The running time to get an optimal solution could be extremely long and you should give the solver some stopping criteria such as time limit and precision.
4. We do not expect you to reach an optimal solution; try to get as good a solution as possible.
5. You would be scored according to your result (the better the solution, the better the score) as well as your originality, feasibility (an infeasible solution will be heaviliy penalized), and implementation.

Good Luck