IE 375 Comments on Homework #2

General Comment

To receive full points, I strongly recommend that you write the formulae before making the calculations since it is very likely that you make errors while dealing with the numbers. Unless you write the formulae at the beginning, incorrect numbers will indicate that you use an incorrect formula, thereby reducing your points from the homework.

Homework 2 statistics (out of 2, with bonus 3): Average: 1.14 (among submitted students) and 0.92 (all students). Standard Deviation: 0.63 (among submitted students) and 0.72 (all students)

Grade	**3**	**2**	**1**	**0**	**Not Submitted**
# of students	2	6	30	4	10

Question 1

The question is a reasonable application of forecasting and manpower planning in a service producing environment. To obtain the data supplied on the number of nurses needed per patient, depending on the patient type requires a lot of analysis, the ones you have learned in IE271. You used to apply your IE271 knowledge to manufacturing systems – here it is service systems. Of course, here the predictions are less accurate, as the number of patient types, probably, should be more.

The approach you are asked follow in parts a and b does not have an optimization associated with it. Rather, it determines a rule (like at most 10% increase is allowed) like fixed work-force you have seen in class.

This question includes two parts. In the first part, you have to multiply patient forecasts with number of nurses required per patient for each department. With this information, you can find the required number of nurses for each month.

In the second part, the hospital has a policy, which forces the hospital not to increase number of nurses more than 10% in any month. You are expected to suggest a new schedule by using this %10 limit in a possible increase. The plan you suggest must be logical – you do not want to have more nurses than the requirement, but if you are to obey %10 increase-limit while meeting demand, it is inevitable to work with more nurses than you actually need. You should realize that you have to decide on the number by looking at the month that has the largest requirement (in this case March), and go back in time considering the limiting 10% increase. There is no policy for decreasing the number of nurses so more nurses than requirement should be fired. You are expected to perform calculations and show your work.

Part c) requires you to model the situation using LP.

Comments regarding your performance:

- In *part a*, few did not change the number of nurses required per patient for critical care from 0.6 to 0.55. Those received at most 1 point from the question even if the remaining analyses were completely true.
- In *part a*, most did not justify why they rounded or not rounded the number of nurses required. Please remember that you may or may not round the numbers as long as you justify the decision. However, you are likely to lose points unless you justify.

- In *part a*, many of you rounded the number of nurses to the nearest integer due to the phrase "most closely match" in the given text. This type of mistake is unfortunately very common in general: Making a conclusion based on a phrase or sentence, although this conclusion conflicts with the rest of the text. Please see that in the main text, it is also stated "… the hospital has determined that the following ratios of nurses to patients are **required**". Rounding down the number of nurses makes the hospital incapable of meeting the requirements, leading to a failure of the hospital's main purpose.
- Few noticed this conflict and wrote a sentence similar to "Although rounding down prevents the hospital from meeting the requirements, I choose to round down since *part a* asked us to most closely match demand". The ones who addressed the issue could receive full points from *part a*.
- In *part b*, some used trial-error for the number of nurses to be hired in January. Those did not lose any points; however, I suggest coming up with simple methods to save time.
- Part c:
    - Some did not attempt to solve this part.
    - Serious mistakes include: (i) writing "if, elseif" conditions with words. Please note that you need to convert such sentences to equations, inequalities, etc. which are suitable for a Linear Programming model; (ii) writing non-linear models. Serious mistakes led to unacceptable answers for *part c*.
    - Additional major mistakes include: (i) not considering the one-month training period or not reflecting this feature in the objective function, (ii) issues in the worker balance constraint.
    - Minor mistakes include: (i) issues with time index, (ii) typos in the objective function or constraints (iii) defining redundant decision variables.
    - Few of you had serious mistakes. However, almost all of you had minor or major mistakes while formulating the problem as a Linear Program. I strongly recommend improving your modeling skills.
    - Few of you wrote lengthy models with no consistency. In such cases, please visit TA's office hours (or send an e-mail to get an appointment) so that we can discuss more about your model.
    - Some incorporated the buffer into the model whereas some defined a new parameter (number of nurses required as buffer). Both approaches are acceptable.

The ones who could formulate the problem in *part c* as a Linear Program with minor mistakes and could solve *parts a and b* without mistake received 2 points. The ones who have major mistakes in *part c* and no mistakes in *parts a and b* received 1.5 points. The ones who did not attempt to solve *part c* or had serious mistakes, and made no mistakes in *parts a and b* received 1 point. The ones who did not change the number of nurses required per patient for critical care as indicated in the problem, and did not attempt *part c* received zero points.

Grade	**2**	**1.5**	**1**	**0.5**	**0**
# of students	7	7	15	3	20

Question 2

The question is prepared to test your understanding and ability to model different situations arising in production planning as a mathematical program. What will make you different (as an IE) from all other disciplines is your ability to model and interpret such models. In that respect, your performance in this question should have been much better than the other questions in the homework.

While it has been argued by many that modeling involves art more than science (and thus cannot be learned), we believe that many problems in specific areas, particularly production planning problems have common features and one can get pretty good at modeling by solving problems and carefully reviewing existing models.

Make sure that you read the text, make a note of definitions and group those to remind you that they are related. The abbreviations used could have been simpler to ease your understanding. Nevertheless, you need to carefully read!

Following should help for the specific question and production planning models in general.

- Use separate variables (and separate constraints) whenever necessary for different products and locations. In this example, we need separate inventory balance constraints for yarn and fabric.
- An inventory balance equation should include everything that goes in and out of the inventory type. You need to incorporate the transfers in or out of an inventory type in your inventory balance equations. For our question, you should remember to include the use of fabric production for the yarn inventory – the demand for yarn is actually the production of the fabric.
- Inventory balance equations are sufficient to make sure that the demands are satisfied (or backordered and carried over to the next period).
- You need to associate all workforce levels (or any other resource capacities) with production quantities.
- Do not forget to write down the initial values of the inventory and workforce levels. The variables should also be designated non-negative when necessary.

<u>Comments regarding your performance:</u>

- Some assumed that the decision variables should be integer. Please see the relevant part of the text: "…Formulate the problem as a <u>linear programming</u> problem, assuming continuity of the decision variables". Therefore, assuming integer variables is considered as a major mistake. Please note that adding unnecessary constraints just to be safe may lead to reduction in points.
- Other major mistakes include omitting a decision variable/parameter or defining a wrong constraint for: (i) the inventory balance constraint; (ii) the relation between yarn production and fabric production; (iii) the relation between production and number of workers available.
- Minor mistakes are: (i) writing e^{yf} instead of $1/e^{yf}$ as well as a^f instead of $1/a^f$; (ii) redundant constraints or variables (if they do not conflict with the remaining parts of the model); (iii) not defining the initial inventory amount at time zero.
- Similar to Question 1 *part c*, few wrote lengthy models with no consistency. In such cases, please visit TA's office hours (or send an e-mail to get an appointment) so that we can discuss more about your model.
- Some modeled the monthly physical (technological) capacity of the plants by writing a constraint on production amount, whereas some wrote a constraint on the inventory level. Both approaches are acceptable.

The ones who could formulate the problem as a Linear Program without major mistakes received 2 points. The ones having at most 1 major mistake received 1.5 points. The ones making 2-3 major mistakes received 1 point. The ones having more than 3 major mistakes received 0.5 or 0 points.

Grade	**2**	**1.5**	**1**	**0.5**	**0**
# of students	11	3	17	8	13

Question 3

In this question, you are given a mathematical model and its primal and dual solutions, and you need to make an inference on the effect of changing the demand parameters. In real life, most of the time, demand parameters are not known for sure (may be represented by probability distribution – forecasts!); we usually cannot know the exact demand values. For simplicity, we assume that they are deterministic in our model, but we have to be careful about the possible additional cost of this assumption. We need to be able to analyze what would happen to our objective function if demand is higher or lower than expected.

To answer this question, you need to use the information you've learned in IE202 on duality. For a minimization problem, a dual variable corresponding to a constraint is how much the objective value would change if you increase the right-hand-side of this constraint by one unit. So, in our problem, if the dual variable is negative that means the objective function value would decrease if you increase the RHS of the corresponding constraint which reflects the forecasted demand. In the first two parts of the question, you were supposed to simply use this definition of dual variables. In the last part, calculating the primal objective function value was straightforward since the primal solution is given. In order to calculate the dual objective value, you need to cross product the dual variables with the right-hand-side values. Consequently, you would see that the primal and the dual objective function values are equal to each other (by strong duality).

<u>Comments regarding your performance:</u>

- Many of you did not attempt to solve this question.
- In *part a*, few gave conflicting arguments about shadow price. For instance, they stated that if shadow price is negative, then 1 unit increase in RHS leads to decrease in objective function. However, later on, they decided to increase the RHS values of the constraints having a positive shadow price while aiming to decrease objective function. Please review the definition of shadow price.
- In *part a*, few decided to change the RHS values of the constraints other than the demand constraints (c4,c5,c6). Please read the question carefully.
- In *part a*, many decided to revise only one of the demand forecasts. Since the question asks for all possible changes in the demand forecasts, those implicitly stated that they do not consider changing other demand forecasts. Please read the question carefully.
- In *part a*, some did not explain whether a positive/negative shadow price indicates a decrease/increase in the objective function. Instead, they just made the assumption that if shadow price is positive, then increasing RHS leads to an increase in the objective function.
- In *part a,* many tried to give an explanation for the signs of the shadow price, yet could not provide a complete argument. Still, thank you for the effort.

- In *part b*, almost all of the ones attempting question 3 could give a true answer in this part. Thanks!
- In *part c*, some did not to mention the upper and lower bounds that may change the shadow price.

The ones who made an assumption on the sign of the shadow price as well as did not mention the upper and lower bounds (aka allowable limits) could receive at most 0.5 points. The ones who mentioned the upper and lower bounds but made an assumption on the sign could receive 1 point. The ones who mentioned the upper and lower bounds, and tried to explain the sign yet failed to do so could receive 1.5 points. The ones who could explain the sign as well as the upper and lower bounds could receive 2 points.

Grade	**2**	**1.5**	**1**	**0.5**	**0**
# of students	4	4	6	11	27