The Judges' Commentary

The IMMC Judges congratulate the students who participated in IMMC 2017. The problem this year asked your expert group to create an algorithm that suggests the best places to hold a meeting given the number of participants, their home cities, approximate dates of the meeting, and other information that the meeting management company may request from its clients. We considered the problem to be very challenging since there are many factors that contribute to the productivity of the attendees at the meeting. Further, once a definition of productivity is established, there are several objectives that are possible. For example, should you maximize the average productivity of the group? Or, should you maximize the minimum productivity of any member of the group? We saw a wide range of creativity in answering these questions.

Characteristics of the Better Papers

What general characteristics distinguished the better papers? Paper 2017057 from the North Carolina School of Science and Mathematics, USA was designated as Outstanding. This paper presents a comprehensive and appropriate mathematical model, clearly communicates the team's modeling process, and articulately explains their results, as well their model's strengths and weaknesses. These characteristics, in general, distinguish better papers. We have two further recommendations for participating teams.

First, the better papers demonstrated excellent writing. The papers had a structure that was easy to follow and the papers complied with the rules of the contest which require a maximum of 21 pages (including a Summary page), all in font no smaller than 12 point type. The summaries of the better papers were excellent – they provided an overview of the process followed and a summary of the results obtained while exciting the reader of the summary to read the entire paper. A good summary also addresses the strengths and weaknesses of the model that was developed. All models have limitations and it is important to recognize and state those limitations. Examples of good summaries can be found in papers 2017007 (a clear explanation of the process followed by the team), 2017020 (with a nice description why some aspects were not taken into account) and 2017054 (very 'to the point').

Second, the better papers developed and presented their models in a very logical manner. They moved from the rather vague scenario that required maximizing productivity to identifying a problem they could model mathematically. They explained their assumptions very clearly and discussed how well their assumptions were met by the situation they had identified. They then tested their model against the data sets provided, and finally generalized their model to handle any data set. Some papers then performed tests to determine how sensitive their solutions were to changes in the data set thereby identifying the relative importance of each of their variables. Paper 2017045 shows a very consistent, clear and pleasantly readable approach of the problem, even though it may to be a rather simple one. This paper shows that even without using complicated formulae it is possible to describe a good model. Furthermore, in both paper 2017019 and paper 2017026, a nice use has been made of various types of pictures to explain their method and thinking, thus avoiding heaps of text and formulae thereby making the reading much more easy and pleasant.

Maximizing Group Productivity

Teams developed a wide range of definitions of productivity. First, they identified variables, such as "jet lag" caused by traveling in an east-west direction (typically approximated by the number of times zones crossed), the distance travelled by each attendee, the total travel time (including layovers, etc.) of each member, the ability of the destination city to host the meeting, changes in sunset time for each attendee, climate conditions especially temperature and altitude, and other factors.

Next, there was great variation on forming an objective function.

Defining a productivity function

A single variable: Some teams picked a single factor such as jet lag to optimize.

Multiple variables: Some teams picked several factors and weighted the relative importance of each factor to form the productivity function.

Addressing selected factors sequentially: Several teams picked the variables they wished to consider and addressed them sequentially. For example, Team 2017045 outlined a process of first determining a time zone in which to meet. Then, within that time zone, where was the general area that minimized the average travel distance and travel time. Then, what was an acceptable climate zone. Finally, considering the above, what were the cities which were considered appropriate to host the meeting? Only cities with international airports were considered to reduce the number of airline connections. By considering the most important variables first and allowing an acceptable range of satisfaction, they developed a process for converging to a solution they liked.

Beginning with a list of cities: Another distinct approach was to research a list of ideal cities to host meetings. Students found different organizations which ranked the desirability of the best host cities based upon different criteria. They then began eliminating cities based upon one or more of the variables listed, such as jet lag, distance traveled, time of travel, etc.

Choosing a metric to optimize
After defining productivity using a principal variable or a subset of variables, another important decision needed to be addressed. For example, suppose jet lag were the only variable considered. Should we minimize the average amount of jet lag? For example, if Shanghai were chosen, the average time zones crossed would be minimized. But one of the 6 members (Monterey, USA)

would have to cross 9 time zones. And the member from Melbourne, Australia would have a great distance to travel and a long travel time. What is the effect on the 6-person group productivity of one or more members with low productivity as defined by your team? Would a better solution be to minimize the maximum number of time zones crossed by a member of the group, or minimize the maximum distance traveled, or minimize the maximum time of travel of any member of the group?

Some Common Shortcomings

(1) Not considering travel time in realistic settings. Many teams used distance between cities as an approximation, which is not a good assumption. As a result, those teams computed absurd answers such as the middle of Siberia and North Korea. In reality, considering actual travel time makes the problem much easier. The meeting will preferably be held in cities with international connections or towns that are easily accessible from such cities.

(2) Many students use temperature difference as a penalty. But in reality, even people from very cold areas in winter would not mind being in a place like San Diego in winter, even though the temperature difference is huge.

(3) Some teams over emphasized the difference between East-West vs West-East travel. Actually, East-West long distance travel is typically faster because of the jet stream. Hong Kong to Seattle is 11 hours while Seattle to Hong Kong is 13.

Advice to teams participating in Future IMMC Challenges

Our advice is to allow plenty of time to construct a report. In fact, consider working on the report as soon as you begin work as it will be easier to follow your logic. Remember, you are communicating with judges from many countries of the world. Also, the judges are not necessarily familiar with the curricula of your school district. So, build a structure which allows you to present the development of your model in a logical and easily understood fashion. And the judges are not looking for the papers that use the most sophisticated mathematics. This is a mathematical **modeling** challenge so do not force the mathematics upon the given scenario. Rather, begin with the simplest mathematics that solves the problem you identified. Later, if you feel it is appropriate, you can refine your model to increase the accuracy, or change your assumptions to find a more appropriate solution.

Pictures, especially graphs, tables and schedules, can explain quite efficiently your ideas and by using them you can sometimes avoid a lot of text. Also the use of relevant pictures and graphs makes a report clearer and more pleasant to read. But please realize sometimes tables might better be in an appendix.

The use of formulae is of course quite essential in a mathematical modeling assignment. But the use of unexplained formulae will not make the report more convincing. So always make sure the reader believes the formulae used are at least understood by the writers themselves. Also realize the readers of your report are, though experienced mathematicians, not experts in all parts of the great world of math!

Appendices, especially references, are very useful. But **do not** expect the judges to read your appendices. We may refer to an appendix to check a reference or a step in your computer code, but otherwise may not examine or read an appendix. So, do not place anything important to the development of your model in an appendix.

Present the analysis and conclusions of your model in a manner that can be easily understood by a wide audience. Consider who would be using your model and explain your model to that audience as well as to the judges. Use graphs, charts, networks, and other appropriate visualizations where possible to aid the understanding by a wider audience. And remember: a maximum of 21 pages including the summary pages in a font size no smaller than 12 point type.

In summary we were quite impressed with the quality of each entry and urge each team member to continue to improve your modeling capabilities and participate in the IMMC and eventually undergraduate modeling challenges, and hone your ability to use the mathematical modeling reasoning process in your daily, and eventually professional life.