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OR/MS in Disaster Management

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Dear Readers,



I'd like to begin this letter by stating that this will be the last time I will be a part of ORMS Tomorrow in the Lead Editor's capacity. Leading and supervising this team has been an honor and I wish the new Lead-Editors the best in continuing the great work we've been doing. Our theme for this issue focusses on Hurricanes and the role ORMS plays in helping humanity deal with these natural disasters. This past year has seen a record number of Hurricanes landing in the United States and all of us, as Operations Research practitioners, have a duty in helping our planet tackle them. In this issue, we provide you with articles about forecasting techniques, the history of disaster management, the use of simulation to predict and assess hurricanes, and highlight student chapters that play important roles in this arena. I'm excited for you to read this issue. Besides new leadership, our magazine has also hired many new volunteers, all of whom are as excited as I am in providing you with the best perspective of news from the realm of Operations Research. I hope you enjoy the content and look forward to hearing any thoughts you may have regarding OR/MS Tomorrow via email at `orms_tomorrow@mail.informs.org`.

Siddhartha Nambiar
Lead Editor

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Operations Research in Disaster Management

OPERATIONS research in disaster management deals with methods and techniques in predicting and preventing disasters, such as hurricane, earthquake, floods, etc., and post-disaster management problems, such as relief measure, food supply, etc. The field has grown into a significant domain because of the direct impact that it has on people and their health. Disaster management is a sequence of operations that can be broadly classified based on the phases of a disaster, including mitigation, preparedness, response, and recovery. The Mitigation is the application of measures to prevent the onset or reduce the impact of the disaster. The Preparedness phase activities prepare the community to respond to disaster events. The Response phase is the utilization of resources and guidelines to preserve life, property of the community. Finally, the Recovery phase includes both long term and short term actions taken after the disaster occurs to stabilize the situation and restore normalcy. OR tools aid these operations from the standpoint of optimizing them and making the best possible use of available information and decision making. Tsunami in 2004 highlighted the gap in the disaster relief research and models in contrast to the other fields as it caused challenges in major relief measures and led to the realization of significance of humanitarian logistics. The OR/MS community faced the challenge of modeling, as the characteristics of disasters make response complicated and the inherent stochastic nature of the problem makes it hard, yet an important problem of practical significance. The seeming randomness of the impacts and problems and uniqueness of the incidents require dynamic, real-time effective solution, thus making OR/MS tools suitable. International Federation of Red Cross and Red Crescent Societies (IFRC) recorded 7184 disasters between 2000 and 2009. The world trade center attack (2011), Tsunami (2004) and hurricane Katrina (2005) and the Haiti earthquake (2010) put together have an estimated economic damage cost of 986,691 million dollars with 1,105,352 causalities. The daunting statistics show the need to develop strategies to reduce the impacts of disasters on humankind. Disasters can be natural or man-made, but both of them have severe consequences which are not well understood beyond the immediate effects on the people. For example, a hurricane can cause an entire city or state come to a standstill and with the globalization of economy and open markets, the impact transcends into regions which are not affected directly by the hurricane. The indirect consequences can be financial and hindrance to economic growth. A major incident in the economic powerhouse of the world can bring down the entire worlds' economy or can cause a shift in the economic growth pattern. There is an increasing recognition of the need for study of OR/MS issues in disaster management. The area that lacks OR/MS research is recovery planning in addressing key questions such as, what are the operational problems of damage assessment and cleanup? what are the key characteristics of food collection, allocation, and distribution? The announcement of EURO Management Science Strategic Innovation Prize (MSSIP 2006) and INFORMS 2010 conference hosting 16 tracks accounting for a total of 61 presentations in relevance to disaster management are promising steps towards answering the questions. Disaster management research can be traced back as early as World War II in the context of emergency responses and services. Although not until 1970, many seminal works on quick response to emergencies were cast as mathematical problems. The fire station location problem, unit commitment problem, and queuing and simulation models for ambulance services are some of the problems studied in the 1970s. Mathematical programming was the most common OR approach to the difficulties of disaster management followed by probability and statistics and then by simulation. Mathematical models dealt with problems like facility location, relief scheduling, stochastic assignment problem, distribution and transportation of relief supplies, such as food, medicine, etc. Statistics and probability played an essential role in mitigation and preparedness phase with forecasts of disaster events from historical data and also in data cleaning for further use in mathematical models while simulation was used to validate and replicate the disaster events and study their dynamics in order to provide a better understanding of the problem. While the emergency-related OR research date back to 1970, early 80's research was focused more on urban policy and emergency planning, such as fire station location, emergency medical service location planning, etc. In the 1990s, disaster-related research took off. The Union Carbide tragedy in Bhopal, India or the 1986 Chernobyl nuclear accident were the early disasters studied in extensive details. Within disaster management, works on applications of OR tools, such as network analysis and simulation to the process evaluation were relatively rare until the 1980s. From 1990 to early 2000, crowd evacuation in large public gatherings, ship evacuation, and emergency flight evacuation modeling were studied as fluid flow models or based on simulation models. Post tsunami (2004) OR methods in disaster management increased with its application in safety, relief logistics, volunteer scheduling,

food distribution, and indirect effects of disasters, such as hurricane disrupts power, causing shutdowns and outages, communication breakdowns, structural damage to building and road networks. The above problems directed the research on the reliability of the underlying systems, such as power and communication networks. The social and political nature of disaster management make the field suitable for data envelopment analysis, fuzzy systems, and systems dynamics. The key question is how to determine the decision rules on what method to use to address a specific class of disaster problems? Are the urban emergency planning models applicable to disaster relief planning or not? Problems in disaster relief management have multiple contradicting objectives and the social impacts of the relief are difficult to model because it is not straightforward to associate a number with actions that have a direct impact on human life. The interdisciplinary nature of the problem requires coordination between multiple organizations which necessitates effective data acquisition and communication systems. The RODOS (http://www.rodos.fzk.de/) project in Europe is a good example of such efforts. In summary, the role of OR/MS community has been instrumental in understanding the problem and nature of the disaster management. The nature of the problem needs attention from researchers in different fields, such as computers in OR, risk management, data analysis, and Machine learning for solving the posed challenges. Better management of disaster operations will improve readiness, increase responsiveness, and quick recovery.

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Pre-Disaster Management: A Quick View

NATURAL disasters can have a geophysical origin (such as earthquakes, volcanic eruptions, and landslides) or a climatic origin (such as hurricanes, cyclones, drought, and floods). Independent of their origin, however, today they tend to lead to increasingly higher human and material losses due to a multitude of factors, such as unplanned urbanization and increase in population and poverty (Hong, Lejeune, & Noyan, 2015). Because of this, natural disasters have consistently been major concerns for policy makers at national and local levels, especially in disaster-prone regions. Moreover, the recent occurrence of severe natural disasters has called attention not only upon their devastating effects but also upon their increasing frequency and has highlighted once more the need to enhance the effectiveness of our response to them. While we can never be fully prepared, adequate preparedness can significantly improve disaster response activities.

Disaster management can be defined as "the body of policy and administrative decisions, the operational activities, the actors and technologies that pertain to the various stages of a disaster at all levels" (Lettieri, Masella, & Radaelli, 2009, p. 117). Disaster management can be divided into two main sequential phases, namely, pre-disaster management and post-disaster management. Pre-disaster activities include prevention, mitigation, preparedness, and planning and are focused on avoiding or reducing the severity of any human and/or material losses caused by a disaster both in the short and long term. Post-disaster activities include response, recovery, reconstruction, and the commencement of a new cycle of assessment, while also incorporating the lessons learned. Although conceptually distinct, in practice, all these activities are intertwined.

Let us return to pre-disaster management activities. On the one hand, prevention and mitigation refer to political, legal, and infrastructural measures that can be taken up before a disaster; on the other hand, they refer to educating the general public about the potential effects of a disaster. Preparedness and planning are meant to improve emergency response and generally involve the assistance of fire brigades, hospitals, police, and any other authority or civic body that can assist the public in case of a disaster; also, the mobilization of resources in such locations so that they can be deployed easily to the affected areas in case of a disaster.

In the available literature on disaster management, attention has been generally given to post-disaster management, but as it can be easily inferred, work done in advance of a disaster is just as important (Salmeron & Apte, 2010). Balcık and Beamon (2008), for example, stated that "the facility location and stock pre-positioning decisions in the relief chain are critical components of disaster preparedness and hence, require long-term planning to achieve a high-performance disaster response" (p. 106). As a matter of fact, an important development in disaster management approaches over the past decade has been the recognition of their cyclical nature, which in turn, supported the need for efforts to be made prior to the occurrence of a disaster.

It is considered that the most important part of the pre-disaster phase is the early prediction of disaster so that pre-emptive action (such as the evacuation of people) can be taken to reduce

human, material, and economic casualties (Mandal, Saha, & Banerjee, 2005). This is nonetheless, a quite sensitive topic, as it must be considered that a false alarm can also trigger devastating effects, creating unnecessary panic and wastage of resources. Studies dedicated to this area are rather scarce.

Among the research works dedicated to pre-disaster management, most of the studies are actually conducted for estimating disaster waste. This is because disasters often create large volumes of debris and waste. In this sense, for example, Chen, Tsai, Hsu, and Shen (2007) created an estimation model for flood damage and Xiao, Xie, and Zhang (2012) for earthquakes damage. More recently, Brown and Milke (2016) surveyed feasibility, the choice of methods, and the effectiveness of post-disaster recycling using information gained from previous major natural disasters around the world. These works have been supported by Tabata, Wakabayashi, Tsai, and Saeki (2017), who stated that "no one can predict when natural disasters will occur, and no one can prevent occurrence of natural disasters. Therefore, we should plan the pre-disaster waste management based on the precautionary principle. Methods and inventory data that we created should not only be basic tools but also significant for national government and local municipalities" (p. 396). For explanatory purposes, the precautionary principle referred to here, advances that "where there is reason to regard a substance or a process as environmentally damaging, preventative action or regulation should be undertaken despite the absence of scientific certainty" (Attfield, 2015, p. 156).

It is without much doubt that many gaps remain in the understanding of disaster management, in general. Probably one of the most peculiar ones has to do with the very definition of 'disaster management': a quick view at the literature on the topic reveals that there is no unique definition of the concept. Nevertheless, conceptual debates should not stand in the way of making efforts to tackle the challenges brought about by natural disasters. Today, we need more studies that can support relevant stakeholders in making both strategic and tactical decisions, while also considering the interaction of short-term and long-term planning approaches.

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Operations Research in a Storm: An Interview with Dr. Clint Dawson

Can you briefly point out the series of events undertaken to simulate the results when a storm approaches and how this information is passed on for evacuation measures?

Every six hours the National Hurricane Center releases a forecast based on nine different weather models. They use the results of these models to come up with what is called the "consensus forecast." This consensus forecast is released at 4am, 10am, 4pm and 10pm. So every six hours you are getting an updated forecast of the hurricane track, intensity, wind speed and size.



We take that information, process it, and run a storm surge model based on this forecast. So, first this data gets translated into a mathematical model of wind and wind field. This is just a very simple vortex-shaped wind field because we don't have a complete description of the hurricane and the event. Post this translation of data, we run our storm surge model out several days depending on the length of the forecast. This information is post-processed, and the results are posted on the Coastal Emergency Risks Assessment website, cera.cct.lsu.edu. Anybody in the world can look at the results on this website.

For Harvey, in fact for all hurricanes this year, the simulations

were done here at the Texas Advanced Computing Center (TACC) in The University of Texas at Austin. So during Harvey, which was the first major storm this year, I helped get the forecast system for Texas in place. This is a big collaboration between many universities, and making sure that we have a forecast system for Texas was our responsibility. So when Harvey happened — which by the way happened very quickly! On Wednesday morning it was barely a tropical storm, by Thursday it was a full blown hurricane and by Friday it made landfall — we did not have a lot of time to get our act together, but we did and got things running. We started picking up the forecasts and producing results.

I was also producing results on my local machine for the Texas State Operations Center which is run through the Division of Emergency Management, a part of the Texas state government. They are responsible for working with all the government, county and city officials, and whoever is involved in deciding where and when to evacuate. They also have to figure out where to stage the resources and supplies, like trucks, first responders, etc., so that they can go in immediately after. They also have to work with the Department of Transportation to figure out which roads to use. So our storm surge model helps in these decisions. Because we model the flooding, we can tell which roads might be covered or clear, or which bridges may need to be raised because they are too close to the sea level. In other words, which evacuation routes to use and which routes to use for the first responders. This is the very first level of information that they are interested in.

After the storm is over, we work with people to go in and collect the data we use to physically model the storm as it really happened. This helps us analyze how well our model performed in terms of having the right physics in the concerned areas, identifying things we may have missed, etc.

Which other universities are collaborating in this project?

The collaboration is divided into the Gulf Coast and East Coast. The Gulf Coast comprises of Texas and Louisiana State University (LSU). LSU does storms that are going to impact Louisiana, Mississippi and Alabama. We don't work so much with Florida since they have their own system. We also work with the University of North Carolina. They do most of the East Coast.

How long does it take to run the simulation?

About an hour.

Okay, that's quite fast. So that should allow you to cover multiple scenarios since that's not very long?

Yes, we try to.

You mentioned that you get the weather forecast data from consensus weather report released every six hours by the National Hurricane Center. Is there any other kind of data that you need and utilize for this analysis?

Yes, we need to have a model ready with all the data for Texas, for example the bathymetry data and land cover data. This data already has to exist because you can't obtain and incorporate it on the fly. This data has to be ready to go pre-storm.

How well do the simulation results confirm to reality?

Our simulations did well because people went in right after the storm to collect all the data. Our simulation results were found to be pretty close, and they were a lot better than what was released by the federal government.

And how do you define pretty close?

Pretty close is subjective, but I would say we were within about half a meter to a meter of the surge in most cases. For example, we would predict say five meters of surge whereas the federal government predicted ten meters.

So given that there is an error interval of being within half a meter to a meter of the surge, what are the risks associated with the error, even if it's just by half a meter?

A meter can certainly make a difference. If we are down to the level of a particular house or street that is going to get flooded, then whether you are off by a meter is very important. But at least in the early stages of the hurricane, they want to get an idea of the range. The codes are never going to be exact in any situation because we don't have the exact wind data to start with. For example, one thing that happened in Rockport and Port Aransas area, from what I understand, was that a beach was eroded, and that caused a lot more surge to come in than anticipated. And it came in earlier than anticipated as well. And this was unanticipated because our code does not account for beach erosion, the reason being that it's just hard to know exactly where and how much erosion is going to happen. Erosion is sort of a binary thing, either the beach stays in place and does its job, or you could have a complete failure. For example, an entire section of the beach could get washed away, and that would create a new channel for all this water to get in and cause even more erosion. So you can have this sort of catastrophic failure. This happens a lot in hurricanes, and it's hard to predict exactly where and when it will happen.

I know you already mentioned not having exact wind data. What are the other bottlenecks you face?

Yes that's one bottleneck we

face, and we could probably do better if we used, say, a very highly accurate weather model, if it existed. The existing models are getting better at predicting and modeling hurricanes, but they are still not perfect.

We are sort of limited by what we think the coast looks like at a particular time. For example, this is 2017, and we actually built our model of the coast probably six or seven years ago. There has been a lot of development and changes since then, but we just don't have the money and resources to go back and redo everything every year. It's just too costly. So we just have to go off of older data, and sometimes very old data.

How much does it cost to redo data collection?

A lot, millions!

So, your current work is current state of the art and cutting edge. What are the future directions for your research?

Well, one of the things is that we don't model rainfall. Rainfall is an important component of a hurricane. There are other codes that do that, but they are not integrated with ours. We also don't model sediment erosion, as I mentioned earlier, so at present we are not doing a good job of modeling how the coast changes due to a storm. We are not modeling any sort of 3D effects. We are just doing 2D.

And what do you mean by 3D and 2D effects?

For example, to model any sort of sediment, you would need to do scouring. You would need to have a vertical component of velocity. If you have scouring, then you have velocity coming in, you get entrainment of sediment, and then it gets deposited again. We can't account for that right now because it's very computationally expensive. Running a 3D model is about ten times more expensive than running a 2D model.

That's interesting. Thanks for sharing all this information about your work with me. Is there anything about your work that I missed and you want to highlight?

Well another thing that we are concerned about is climate change and sea level rise. As we go into the future, we don't know, for example, how different the coast is going to look in ten, twenty, thirty or forty years. Even conservative projections look pretty drastic. But sea level rise varies in different places, so you don't know how much it's going to be even in, say, Texas versus Louisiana versus other places.



We also don't know exactly how future hurricanes are going to look and whether they are going to be stronger. This year was kind of eye opening in that respect in that we had so many strong hurricanes, and they maintained their strength for a long time, which does not usually happen. That was probably due to global warming since the ocean was very warm over very large distances.

Okay, and how did global warming cause the hurricane to maintain its strength for a longer period of time?

Because the hurricane gets it energy out of the ocean. So if the water is warm, it gets more energy and can sustain itself for longer. If you look at Harvey, it just blew up from a tropical storm to suddenly this Category 4 and then this huge rain bomb! And from what I understand, because I just got back from AGU (American Geophysical Union), the thing about Harvey that was unusual was that even after making landfall, it kept its rotation. So it sat over the coast, and it never broke apart. That's why you had these rain bands that were coming over and over and over again, and that's why the Houston area got so much rain. So Harvey was kind of unusual in that it just sat there and spun and never broke apart. But I understand that we don't get anything like what they get in India or like the Pacific storms. For example, in Taiwan they get tens of meters of rain. Sometimes it could be ten and twenty meters of rainfall. That's astonishing! And we got fifty inches, which is about a meter and a half.

Wow, yes! I guess the impact of the storm also varies from region to region depending on the infrastructure.

Yes, exactly.

Simulating StORMS and Hurricanes

EARLY in October of 2017, Hurricane Nate made landfall near the mouth of the Mississippi river, making it the fourth hurricane to make landfall in the United States. The last time the U.S saw as many hurricanes in a single year happened way back in 2005. While the landfall of Harvey and Irma were already historic events, making it the first time that two Atlantic hurricanes struck the U.S in the same year. Puerto Rico taking a direct hit from Maria meant that the U.S has now endured landfall from three category 3 hurricanes [1]. The devastating effects of these natural disasters further the need to bring together practitioners from different research areas to help tackle the problem. Operations Researchers, in the recent past, have become more involved in this effort. In

October 2017, National Science Foundation awarded $5.3 million in 59 grants to study hurricanes, among them a significant number were aimed towards the prediction and management of the storms.

So, where does simulation-modeling come in? The mathematical simulation of hurricanes is the most accepted approach for estimating wind speeds for the design of structures and assessment of hurricane risk [2]. The approach is used for developing coastal flood estimates, setting flood insurance rates and minimum floor elevations for buildings along the hurricane coastline of the United States, and the approach is routinely used in the banking and insurance industries for setting insurance rates. As such, any structure that is to be built in hurricane prone areas is tested with a combination of wind tunnel data and hurricane hazard models. When we pull up weather.com to keep track of any storms in our vicinity, it is important to understand that almost all the data that we see is a result of some sort of extrapolation based on other factors. For instance, a powerful hurricane would make it difficult to set up a weather station at the center tracking wind speeds and surge levels. Scientists use data obtained from a set of other locations and simulate the overall effect and strength of a hurricane.

Larry Russell described one of the first uses of simulation in 1968 in his Ph.D. thesis titled "Probability distribution for Texas gulf coast hurricane effects of engineering interest". The basic approach used in this work (and many subsequent studies) is similar in with respect to the fact that it is particularly suitable for sites where insufficient data does not permit getting the effects of a hurricane directly [3]. "First, site-specific statistics of key hurricane parameters including central pressure deficit, radius to maximum winds, heading, translation speed, and the coast crossing position or distance of closest approach are obtained. Assuming that the statistical distributions of these key parameters are known, a Monte Carlo simulation is used to generate a mathematical representation of a hurricane along a straight line path satisfying the sample data." [4]. The essential idea, like any simulation model, is to use existing data and information about what the general trends of the data look like to extrapolate and simulate further.

A common visual that we are exposed to during hurricane season are spaghetti plots. These are the outputs of different simulation runs on employing different parametric values. The model can then be stepped forward in time and the results are compared and used to gauge the amount of uncertainty in the forecast. If there is good agreement and the contours follow a recognizable pattern through the sequence, then the confidence in the forecast can be high. Conversely, if the pattern is chaotic i.e. resembling a plate of spaghetti then confidence will be low. The use of spaghetti models is commonly employed when describing the outputs of hurricane track models.

The most common types of simulation models today are related to disaster management from the point of view of humanitarian logistics. In the event of a disaster, there is hardly any time to try out different evacuation scenarios. This is where simulation models come in. Testing out different policies and scenarios in a mathematical abstraction of reality allows the government to be prepared when reality strikes, so to speak. If one knows with a high probability there will be major flooding in a certain area, the residents may be instructed to leave their homes. This plan is better than trying to rescue them with helicopters or boats once the actual disaster strikes. If long-range forecasts for severe storms are available, then people in the path of the storm can be given reliable advice about how to protect themselves. In fact, a majority of the grants given out by NSF in October are pertaining to this facet of simulation modeling.

NASA recently published an animation depicting this year's rough hurricane season. They did this by tracking what is carried on the wind. Tiny aerosol particles, such as smoke, dust, and sea salt are transported across the globe, making visible weather patterns and other normally invisible physical processes. The mathematical models use information from NASA satellites, and sea salt evaporated from the ocean to compute and observe more details of physical processes. Observing how these aerosols interact with the storm systems allows scientists to study the formation of storms [5].

The behavior of the atmosphere and weather is governed by physical laws, which can be expressed in the form of mathematical equations. These represent metrics like temperature, wind speed, humidity, etc. The ultimate goal of using simulations is to solve these equations and to have a forecast for the weather. The best forecasts are made by combining the forecasts from two or three different ones into a "consensus" forecast. The Hurricane Forecast Improvement Program's (HFIP) at the National Hurricane Center has a goal of having a 50 percent improvement within tropical cyclone track forecasting and intensity guidance by 2020. In addition, another goal of researchers working in this field is to be able to reduce the length of the forecast period, thus being able to make predictions in a matter of hours as opposed to days.

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Weather Forecasting Techniques

FROM the roaring waters of Hurricane Harvey to the raging wildfires in California, it is now evident more than ever that we need accurate and reliable weather forecasting techniques to help prepare for and mitigate the impacts of climate-induced phenomena, such as hurricanes and subsequent flooding, heat waves, and strong winds that could spread a limited house fire into an entire forest. So, what makes a good forecasting technique and what are the caveats of the techniques in practice today? These are the questions that this article aims to answer to better reflect how today's analytics community stands in dealing with weather forecasting challenges.

It is no secret that weather forecasting has been around for ages, rooting back to early civilizations when ancient people tried to predict weather for agriculture and marine transportation, among other purposes. In modern days, however, weather forecasting has evolved from an artistry into a scientific and professional discipline. With the increasing penetration of different forms of media, weather forecasting has become a service that can be commercialized and dispersed. As the nature and purpose of weather forecasting has changed throughout time, techniques for weather prediction have also progressed.

One of the simplest methods of weather forecasting is to use the historical averages of temperature and precipitation in a particular location. Known as the Climatology Method, this approach has many shortcomings, however, and is reliable only if there is little variance in the variables of interest. A more complicated approach is to match the present-day weather condition to a similar weather scenario in the past. A forecast is then generated to align with the area's previously observed weather progressions. This approach is known as the Analog Method because a similar condition (an analog) in the past serves as the basis for the forecast. This method by itself is not very effective because it is often not possible to find an exact analog for the present-day weather conditions. However, the Analog Method does provide interesting insights that could support the development of more sophisticated prediction models [1].

Numerical weather prediction (NWP) is another class of methods that uses computation, algorithms and equations to provide weather forecasts. With increased data availability and increasingly powerful artificial intelligence (AI) methods, weather forecasting is constantly improving in terms of reliability and accuracy.

Machine learning techniques have long been used to provide forecasts of meteorological indicators, such as precipitation and elevation [2]. One particular method for predicting daily rainfall divides the region of interest into several sub-areas and then models each sub-area using a Radial Basis Function Network (RBFN) based on precipitation data from 100 nearby locations. The RBFN generates a mapping that involves an interpolating function that passes through every data point. In the presence of noise, the interpolating function becomes smoother and is averaged over the noise to provide the best generalization.

Another canonical example of applications for weather forecasting techniques comes from the load forecasting problem. This problem deals with the prediction of power consumption (or "load" in electrical engineering jargon) and is central to power market operations and the reliability of the power grid. This is a particularly interesting application of weather forecasting that brings together several engineering, economic and natural science disciplines. The most common tools in this class of techniques include autoregressive integrated moving average (ARIMA) and partial autocorrelation functions (PACF) [3].

Flood forecasting is another major application of numerical-based methods for prediction of climate-based phenomena. A commonly adopted approach to flood forecasting is the ensemble prediction system (EPS) in which a collection of NWPs is utilized rather than a single deterministic outcome. These NWPs are usually coupled with hydrological models and river discharge predictions implemented though a decision support system. The backbone of this method is a Monte Carlo framework of NPWs that generates multiple weather condition scenarios. This method takes into account the uncertainties involved in the climate patterns and outputs several weather predictions for a given time and target location [4].

Despite major efforts in applying cutting-edge knowledge to the weather forecasting problem, there are still challenges that need to be overcome to provide more reliable and accurate predictions. Specifically, for AI-based models, several issues threaten the credibility of the methods. For one, the structure and design of the machine learning algorithm sometimes does not match the scale and scope of the task. For instance, if daily prediction of tem-

perature is the objective, the recorded climate data available for training and validation of the AI model may not span more than a few decades, a small data set compared to what AI can handle. Additionally, an overly sophisticated AI design for this limited data set increases the chances of overfitting and inaccurate predictions. Another major issue is the lack of a systematic testing for the AI-based techniques as there seems to be no benchmark measure to contrast the output of different prediction models. Yet another challenge is that temporal interdependence in the data hinders immediate application of AI-based tools. In this case, it is often difficult to fully understand and model uncertainties and error patterns, further complicating the development and validation of forecasting tools.

As more theoretical frameworks and computational capabilities become available, weather forecasting methods continue to improve and grow in scale. Further data accumulation also enables improved testing and validation of models. But good enough is never enough. If there is one thing we have learned from the recent hurricanes and wildfires, it is that you cannot be too careful when it comes to weather forecasting.

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Student Chapter Spotlight: University of Pittsburgh

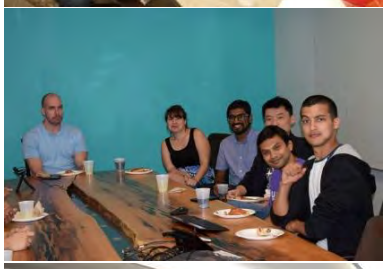
The University of Pittsburgh INFORMS Student Chapter primarily serves graduate students in the Industrial Engineering Department to encourage students to expand their networks and enhance their academic skills. In the past couple of years, we have made an effort to begin offering more academic and social events to our student members and have recently advertised our events more broadly to students in the business and engineering schools. We have a Facebook page and maintain our Chapter's page on the INFORMS website to update our members on upcoming events, as well as summarize recent events.















We have held a social event each month during 2017 to help students create a network and have fun while working hard at school. Each year, we have a social event at the beginning of the semester to welcome new students to the department. This year, we held a tailgate breakfast and rooted on our Pitt Panthers at Heinz Stadium. In October, we teamed up with the CMU INFORMS Chapter to see which chapter could knock down more pins at the bowling alley. In November, we let students put their strategy skills to use in a board game night where there was heavy competition in a game of spades and lots of collaboration to find cures for diseases in a game of Pandemic. In December, we look to finish up the semester by celebrating the end of the semester with root beer floats!

In addition, we have offered several academic events during 2017. The semester started with a student panel where more senior Ph.D. students offered advice to our first year Ph.D. and Masters students about succeeding in graduate school. In October, we held practice presentations before

the INFORMS Annual Meeting in Houston to let students practice their presentations and answer questions in front of a large group. This event also provided junior students with the opportunity to learn about on-going research in our department and what they can look forward to at their first conference. For our first INFORMS Speaker Series event, our chapter hosted Dr. Tasha Inniss, Director of Education and Industry Outreach at INFORMS. During Dr. Inniss's visit, we held a luncheon for our students to interact with her in a one-on-one setting to learn more about her experiences and the challenges she has faced throughout her career. She discussed her academic career as a professor, her time at the National Science Foundation, and details of her new position at INFORMS. Later that day, Dr. Inniss gave the seminar talk for all IE graduate students and discussed how she has used her applied mathematics background in all facets of her career. She also shared some tips that she has learned throughout her professional career.

In addition to these events, we have started hosting software tutorials to help our students understand different software packages that are used in research, but not covered in class. This semester, we hosted a tutorial on CPLEX and another tutorial on GUROBI. We invited students who have great experience in using the software to create a tutorial guide, walk students through a problem, and detail the basics of the software. Next semester, we plan to host an R Tutorial, as well as an Advanced CPLEX Tutorial.

Next semester, we are also looking forward to continuing our INFORMS Speaker series, practice presentations, and tutorials. We will hold our annual Mock Qualifiers to prepare our first-year students for their qualifying exams to officially become Ph.D. students within the department. Finally, we plan to take our students skating, host a March Madness tournament bracket, and hold a championship watch party, and celebrate the end of the semester with a picnic!

Student Chapter Spotlight: University of Texas at Dallas

The INFORMS student chapter at the University of Texas at Dallas (UT Dallas) was established in 2011 under the Supply Chain Management program. The INFORMS chapter has grown over the years and we are now a strong team including 25 officers as a part of the core team, about 290 lifetime members and over 900 members on OrgSync, the university portal for all student organizations.

Our main focus is to provide the students at UT Dallas with all the resources to make them industry ready. We organize guest speaker events, workshops, industry visits, professional development sessions, and business case competitions to help students build a strong overall personality by keeping them connected to the latest industry trends and with the best industry professionals.

This year we organized two Texas-level business case competitions. We wanted to give our students the exposure of interacting and competing against the top business schools in Texas. The Data Analytics Competition was held in April 2017 and was sponsored by UT Dallas, PepsiCo, and Tableau with representation by professionals from PepsiCo, Tableau, JC Penny, AT&T, and Goldman Sachs. A total of 142 teams registered from 7 Universities and all the students worked upon a real time business problem provided by PepsiCo. The prizes offered to the top three teams were $1500, $1200 and $900, respectively.

The second Texas Level business competition was focused on Operations Research. The competition was held in November 2017 and we partnered with a logistics start up, Ericson+Bergen, to develop a real world transportation and logistics business problem. We had a participation of 80 teams from 7 Texas Universities and industry representation from Ernst & Young, PepsiCo, American Airlines, Atos, Corian, and Ericson+Bergen on our Finale in the capacity of judges and networking professionals. The prize money for the competition for the top three places was $1000, $700 and $500, respectively.

In addition to our business competitions, we organized various guest speaker events and workshops throughout the year. The students really benefited from the Tableau workshop wherein professionals from Tableau themselves came in to teach the basics of data visualization with Tableau to the students.






Other events included speakers from Fortune 500 companies including J P Morgan, UT Southwestern Medical, IBM, BSNF railways, Ericsson, Goldman Sachs, PepsiCo, PWC, JC Penny and DHL.

Hurricane preparedness

The University of Texas at Dallas is a storm ready campus. The Environmental Health and Safety department (EH&S) helps ensure a safe and healthy living, working and learning experience. Staff members monitor and maintain environmental and laboratory safety, offer training and work collaboratively with schools and departments across campus to mitigate hazards.

UT Dallas also built an emergency information system known as E-Plan, in collaboration with the United States Environmental Protection Agency (EPA), and is a valuable resource to emergency responders assessing the extent of damage to chemical industry plants and other facilities in Gulf Coast states in the wake of Hurricane Katrina. It is now a proven system that provides first responders and other emergency preparedness personnel with on-site hazardous chemical information for facilities around the U.S. E-Plan is a web-based system that is very secure, easy to use, extremely responsive, and highly available. The E-Plan home page is located at https://erplan.net.

Milestones in 2017 and moving forward

In this year we have been constantly recognized for our efforts and hard work. In addition to winning the 2016 OWLIE award for the best student organization and being nominated as a finalist for the Golden Comet award at the UT Dallas, we recently received the INFORMS Student Chapter Annual Award with Summa Cum Laude honor in recognition of outstanding participation and performance, presented at the 2017 INFORMS Annual Meeting at Houston.

Our vision is to continue to strive to enrich the academic experience of students at UT Dallas with the latest industrial trends and expertise. We also work towards building and maintaining quality long-term professional relationships with all our partnering companies in order to provide the students with boundless networking opportunities.

We would like to take this opportunity to state that we would be organizing a Texas – Level Data Analytics Competition again in spring 2018 and we look forward to the support from the academic as well as industrial community to help us take the competition to new heights. Any support in the form of sponsorship, networking opportunities or even providing a real world business problem on which the students can work, would be greatly appreciated. If you are interested, you may reach out to us at informs@utdallas.edu, and we would be happy to discuss the proposals in detail.

We stay connected with all the students through OrgSync, our facebook page and our website. We also publish a semi-annual newsletter highlighting our achievements and giving the students a sneak-peak into the next semester.

Student Chapter Highlights

University of Alabama

ESTABLISHED in 2007, the INFORMS Student Chapter at the University of Alabama has a mission to promote interest in the fields of operations management, data analytics, and information systems. Our chapter provides a unique opportunity for students to work together, share ideas, network, and learn more about industry and academia. Our chapter also organizes training workshops in various programming languages and software. This year, our focus is to broaden our understanding of industry-desired skills because we want our undergraduate and graduate students to feel confident and ready for real-world challenges. To accomplish this goal, we plan to focus on one technical skill area each semester. For example, in the Fall 2017 semester, we used R to communicate data analysis techniques, and through a three-part series, offered our members courses in an Introduction to R, Data Analysis in R, and Machine Learning in R. In addition to these academic offerings, we provide our members the opportunity to network and socialize with their peers and invited speakers. We were lucky to host Dr. Anna Nagurney in November for a presentation about her research, work experience, and the challenges she has had in her professional life. For the upcoming spring semester of 2018, we are organizing more workshops and events in collaboration with other student organizations from the statistics and mathematics departments. We believe expanding our relationships with other societies is essential to our goal of representing the amazing world of operations management to the students at the University of Alabama.



University of Buffalo

THE University at Buffalo INFORMS Student Chapter (UB-INFORMS) put together a range of events in the Fall 2017 semester. Incoming graduate students were welcomed into the program with a reception. The UB-INFORMS group organized the "Game of thORnes," an Operations Research quiz game desi-

gned around the popular TV series to introduce the travelling salesman problem, the knapsack problem, and the Monty Hall problem, among others, and winners received INFORMS merchandise. In a joint event with the Institute of Industrial and Systems Engineers (IISE) undergraduate club, a panel of Masters and Ph.D. graduate students with diverse backgrounds was assembled to answer questions for current industrial engineering undergraduates interested in graduate school. The UB-INFORMS Pro-Bono Analytics team is on the verge of completing the first phase of its project with Meals on Wheels for Western New York. The chapter has also hosted workshops by student members on various software (including SQL), research talks, and monthly social events with food for the student body. UB-INFORMS has recently become more active in social media, and a new YouTube channel has been set up to provide videos of workshops and other events.



Carnegie Mellon University

The INFORMS Student Chapter at Carnegie Mellon University (CMU) held the first YinzOR Student Conference on August 26–27, 2017. The name of the conference combines *OR*, the acronym for Operations Research, with *Yinzer*, a native or inhabitant of the city of Pittsburgh. The goal of the conference was to convene Ph.D. students from a variety of programs related to OR, such as computer science, math, operations management, and operations research at Carnegie Mellon as well as industrial engineering at the University of Pittsburgh. The conference program mixed talks from those departments with keynotes by successful young researchers from academia and industry, who presented their work on disjunctive programming for clustering, online data-driven algorithms for healthcare, and artificial intelligence-beating professional poker players. Besides bridging the gap among students in different departments, the conference also served to welcome the new cohort of Ph.D. students.

Funding and resources for YinzOR were provided by the CMU Activities Fee and the Tepper School of Business.



Iowa State University

The The INFORMS Student Chapter at Iowa State University organized one event this semester. Some of our alumni from the industrial engineering department are working at the Wells Fargo Des Moines office. They visited our department to talk about the applications of operations research and analytics in the banking and finance sector. They also addressed their daily business operations. Through this event, our students (mostly graduate students) learned that there exist many opportunities for industrial engineering professionals. Our graduates tend to apply for industry positions in the non-finance sector, and we hope that our event increased the awareness of opportunities related to banking and finance.

University of Montreal

Since its inauguration in May 2016, the CORS/INFORMS Montreal Operations Student Chapter has worked tirelessly towards creating a tight-knit operations research student community. Our values are based on three pillars: knowledge sharing, work/life balance, and diversity.

With respect to knowledge sharing, we created series of joint student research seminars, software tutorials, distinguished speaker presentations, speed-networking sessions, and academic writing workshops to aid students in developing and polishing the technical and soft skills they need to succeed. We also compiled an online repository of resources (www.mtl-students.com/archive) for students to learn on their own time and at their own pace.

In our effort to foster a culture of work/life balance, we organize leisure activities, such as monthly coffee breaks, bi-monthly celebrations, barbecues, and afterschool outings. One of these special activities was a visit from the creator of Ph.D. comics, Jorge Cham.

Finally and most importantly, we seek to promote the work and encourage the participation of under-represented groups in OR/MS. This is accomplished through our social media initiatives, such as Twitter Tuesday and French Friday, the selection of our invited guest speakers, and the composition of our team. We strive to exemplify the Montreal and Canadian philosophy of drawing strength from our diversity.



Texas A&M University

The home of the INFORMS Student Chapter at Texas A&M (INFORMS at TAMU) is the Department of Industrial and Systems Engineering, but membership includes students from computer science, electrical engineering, and mathematics. The

chapter kicked off the fall semester with a "welcome back" party and a faculty-student bowling social. The chapter also debuted a series of Women in OR/MS (WORMS) interviews in its September newsletter. The first WORMS interview was with Dr. Michelle Alvarado of the University of Florida, and the series will continue in January 2018 with Dr. Burcu Keskin of the University of Alabama. Both of these women are former presidents of INFORMS at TAMU, which Dr. Keskin founded in 2004. Throughout Summer and Fall 2017, the chapter's Academic Team developed a series of data analy-sis workshops using the JMP Software from SAS. Additionally, the Annual Meeting and Academic Teams hosted student presentation practice sessions preceding the 2017 INFORMS Annual Meeting in Houston. Texas A&M sent twenty-four student volunteers to serve at the Annual Meeting. Finally, the chapter's Industry Team has hosted several companies to discuss career options for students in OR/MS and related fields.

Connect with INFORMS at TAMU online to learn more about upcoming initiatives.

Website: http://www.informstamu.com

Twitter: @INFORMS TAMU

University of Virginia

THE University of Virginia (UVA) INFORMS Student Chapter is dedicated to fostering community among its members as well as supporting professio-nal development. To this end, the chapter looks for every opportunity to connect students who otherwise might never have met and to strengthen existing relationships. Forging these relationships is vital to a student's success professionally and academically. In 2017 the chapter facilitated many opportunities, including orientation events for new graduate students in the spring and fall, group hikes in the Shenandoah/Blue Ridge Mountain region, trips to local breweries, and a Thanksgiving potluck dinner, among others. The dinner was an opportunity for students who may or may not have been able to go home for Thanksgiving to enjoy quality time together and a delicious meal. The UVA student chapter is honored to serve the student body here at the University of Virginia in Charlottesville.







