



informatics HEALTHCARE 2017  
**ROTTERDAM**



DE DOELEN INTERNATIONAL  
CONGRESS CENTRE


ROTTERDAM, NETHERLANDS  
JULY 26-28

informatics.



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**W**elkom to INFORMS Healthcare 2017 in downtown Rotterdam, Netherlands! Thank you for joining the INFORMS healthcare community on its first conference endeavor outside of North America. It is because of your participation, and the participation of your colleagues, that the biennial INFORMS Healthcare conferences have grown into leading meetings, where cutting edge practices and science are exchanged. We are grateful to and honored by the many participants from across the globe who have come to share their presentations, posters, papers, and practices, and look forward to an exciting conference!

You have come to Rotterdam, Netherlands, at a time when health and healthcare are main priorities in national and international policy agendas. Fortunately, many present policies build on recent achievements. Many of today's newborns in developed countries are expected to live to the age of 100. Life expectancy in Africa has increased by almost 10 years since 2000. Further progress, however, cannot be taken for granted. The challenges of age and lifestyle-related conditions place increasing burdens on many of our societies and economies. Moreover, some countries face infectious disease outbreaks and humanitarian challenges.

Expectations of the potential that scientific advances in information technology and optimization methods hold to confront these challenges and continue progress are high. Robots, smart homes, smart wearables, smart pills, intelligence, algorithms, etc., should bring further improvement of health across the globe. Technologies that produce and use new data, Big Data, to improve health service operations through analytics will be presenting their work at the 2017 Healthcare Conference. The year 2017 is a moment in time with special opportunities for the INFORMS community to live up to expectations, solve challenges, and improve health. Our INFORMS Healthcare 2017 conference is a platform for this purpose—a platform to exchange ideas, present, learn, be inspired, and inspire.

We believe Rotterdam is an appropriate conference location, as it is rapidly earning itself a reputation for being a modern urban hotspot. A melting pot of 180 nationalities built around one of the world's leading harbors. A city that was ranked as a top 10 city to visit in 2016 by Lonely Planet, with great art, architecture, and nightlife. An entrepreneurial city with a vibrant health service industry; home to the largest academic medical center in the Netherlands—Erasmus Medical Center. A driving force behind the highly esteemed Dutch Health System, ranked 1st in Europe since 2008 by the European Consumer Health Index.

We appreciate the importance the Municipality of Rotterdam and Erasmus University Rotterdam attach to hosting the conference, and all their support. The staff of Rotterdam Partners has been particularly supportive. Likewise, the INFORMS staff has also done a wonderful job to make the conference happen.

A special thanks goes out to our plenary guests Erik Gerritsen, Secretary General of the Dutch Ministry of Health, Welfare and Sport; Eric de Roodenbeke, President of the International Hospital Federation; and Gisele Roesems, Deputy Head, Unit ICT for Health & Wellbeing, DG Connect, European Commission, and to our plenary speakers Dimitris Bertsimas, MIT, and INFORMS president Brian Denton, University of Michigan.

Moreover, we thank the HAS Sponsored Paper Competition chairs Sarang Deo and Greg Zaric; Poster Session chair Erwin Hans; Sponsored Session chairs Mehmet Ayvaci and Qingxia Kong; our local program chair Sandra Sulz; General Cluster chair Sanjay Mehrotra; and our Invited Session chairs Omid Nohadani, Mohsen Bayati, Julie Swann, Tarun Mohan Lal, Nan Kong, Vishal Ahuja, Hari Balasubramanian, Chaitra Gopalappa, Oguzhan Alagoz, Anil Aswani, and Diwakar Gupta. Without all of you, the conference program would never have become such a prominent display of the best the INFORMS Healthcare community has to offer.

We wish all participants a memorable conference and stay!

Edwin Romeijn | Program Chair

Joris van de Klundert | Conference Chair

## GENERAL CHAIR

- **Joris van de Klundert**  
Institute of Health Policy & Management Erasmus,  
University Rotterdam  
vandeklundert@bmg.eur.nl

## PROGRAM CHAIRS

- **Edwin Romeijn**  
H. Milton Stewart School of Industrial & Systems  
Engineering, Georgia Institute of Technology  
edwin.romeijn@isye.gatech.edu
- **Sandra Sulz**  
Institute of Health Policy & Management,  
Erasmus University Rotterdam  
sulz@bmg.eur.nl

## HAS STUDENT PAPER COMPETITION CHAIRS

- **Sarang Deo**  
Indian School of Business  
sarang\_deo@isb.edu
- **Greg Zaric**  
Ivey Business School, University of Western Ontario  
gzaric@ivey.uwo.ca

## ADVISORY COMMITTEE

- **Jan Hazelzet**  
Erasmus MC, Erasmus University Rotterdam  
j.a.hazelzet@erasmusmc.nl
- **Vikram Tiwari**  
School of Medicine, Vanderbilt University  
vikram.tiwari@vanderbilt.edu
- **Christos Vasilakis**  
School of Management, University of Bath  
c.vasilakis@bath.ac.uk

## POSTER SESSION CHAIR

- **Erwin Hans**  
Faculty of Behavioural, Management & Social Sciences,  
University of Twente  
e.w.hans@utwente.nl

## LOCAL COMMITTEE

- **Kristiaan Glorie**  
Department of Mathematics, Vrije Universiteit Amsterdam  
km.glorie@vu.nl
- **Harwin de Vries**  
Erasmus School of Economics, Erasmus U. Rotterdam  
hdevries@ese.eur.nl

## SPONSORED SESSION CHAIRS

- **Qingxia Kong**  
Rotterdam School of Management, Erasmus U. Rotterdam  
q.kong@rsm.nl

- **INFORMS Healthcare Applications Society:**  
**Mehmet U.S. Ayvaci**  
The University of Texas at Dallas  
mehmet.ayvaci@utdallas.edu

## INVITED SESSION CHAIRS

- **Disease and Treatment Modeling:**  
**Omid Nohadani**  
Department of Industrial Engineering & Management  
Sciences, Northwestern University  
nohadani@northwestern.edu
- **Healthcare Data Analytics &  
Machine Learning: Mohsen Bayati**  
Graduate School of Business, Stanford University  
bayati@stanford.edu
- **Health and Humanitarian Systems:**  
**Julie Swann**  
H. Milton Stewart School of Industrial & Systems  
Engineering, Georgia Institute of Technology  
julie.swann@isye.gatech.edu
- **Health Information Technology  
& Management: Tarun Mohan Lal**  
Mayo Clinic Rochester  
MohanLal.Tarun@mayo.edu
- **Health Operations Management: Nan Kong**  
Weldon School of Biomedical Engineering,  
Purdue University  
nkong@purdue.edu
- **Vishal Ahuja**  
Cox School of Business, Southern Methodist University  
vahuja@smu.edu
- **Disparities in Health/Low & Middle  
Income Settings/Global Health:**  
**Hari Balasubramanian**  
Department of Mechanical & Industrial Engineering,  
University of Massachusetts Amherst  
hbalasubraman@ecs.umass.edu
- **Chaitra Gopalappa**  
Department of Mechanical & Industrial Engineering,  
University of Massachusetts Amherst  
chaitrag@umass.edu
- **Medical Decision Making: Oguzhan Alagoz**  
Department of Industrial & Systems Engineering,  
University of Wisconsin-Madison  
alagoz@enr.wisc.edu
- **Personalized Medicine: Anil Aswani**  
Department of Industrial Engineering & Operations  
Research, University of California Berkeley  
aaswani@ieor.berkeley.edu
- **Public Health & Policy Making:**  
**Diwakar Gupta**  
Department of Industrial & Systems Engineering,  
University of Minnesota  
guptad@umn.edu

**TUESDAY, JULY 25**

**9am–6pm**      **Registration**  
De Doelen, Ground Floor

**12:15pm**      **Pre-Conference  
Field Trip (optional)**  
Erasmus Medical Center  
Pick-up at De Doelen Main Entrance  
at 12:15pm

**WEDNESDAY, JULY 26**

**7:30am–5pm**      **Registration**  
Ground Floor, De Doelen

**8:30–10am**      **Technical Session (WA)**  
Various Locations

**10–10:30am**      **Coffee Break**  
Jurriaanse & Van der Mandele Zaal  
Foyer, First Floor

**10:30–11:30am**      **Welcome & Plenary:  
Dr. Dimitris Bertsimas**  
Willem Burger Zaal

**11:30am–12:30pm** **Lunch Break** (on your own)

**1–2:30pm**      **Technical Session (WB)**  
Various Locations

**2:30–3:30pm**      **Poster Sessions with Break**  
Van der Mandele Zaal Foyer, First Floor

**3:30–5pm**      **Technical Session (WC)**  
Various Locations

**6–8pm**      **Reception-Raderstoomboot  
De Majesteit**  
Pick-up at De Doelen Main Entrance  
at 5:45pm

**THURSDAY, JULY 27**

**7:30am–5pm**      **Registration**  
Ground Floor, De Doelen

**8:30–10am**      **Technical Session (TA)**  
Various Locations

**10–10:30am**      **Coffee Break**  
Van der Mandele Zaal Foyer, First Floor

**10:30am–12noon**      **Technical Session (TB)**  
Various Locations

**12noon–1:30pm**      **Lunch Speaker:  
Dr. Eric de Roodenbeke &  
Dr. Erik Gerritsen**  
Willem Burger Zaal

**1:30–3pm**      **Technical Session (TC)**  
Various Locations

**3–3:30pm**      **Coffee Break**  
Van der Mandele Zaal Foyer, First Floor

**3:30–4:30pm**      **Plenary: Dr. Brian Denton**  
Willem Burger Zaal

**FRIDAY, JULY 28**

**7:30am–12noon**      **Registration**  
De Doelen, Ground Floor

**8–9:30am**      **Technical Session (FA)**  
Various Locations

**9:30–10am**      **Coffee Break**  
Van der Mandele Zaal Foyer, First Floor

**10–11:30am**      **Technical Session (FB)**  
Various Locations

**11:35am–1:05pm**      **Technical Session (FC)**  
Various Locations

**SATURDAY, JULY 29**

**8:30am**      **Post-Conference  
Field Trip (optional)**  
Social Tour Amsterdam  
Pick-up at De Doelen Main Entrance  
at 8:30am

**MASTER TRACK SCHEDULE**

Inside Back Cover includes a convenient summary showing the tracks, times, and locations.

## TUESDAY, JULY 25

- **Pre-Conference Field Trip (optional)**  
Participants had the option of registering for fabulous pre and post-conference field trips. If you pre-registered for a field trip you will receive a ticket in your registration pack. Buses will depart the De Doelen International Congress Centre, at the main entrance, Kruisplein 40. Buses will return to the De Doelen International Congress Centre following the field trips. Tickets will NOT be available to purchase on-site.
- **Breaks & Poster Sessions:**  
Van der Mandele Zaal & Jurriaanse Foyer

## WEDNESDAY, JULY 26

- **Coffee Break**  
10–10:30am  
Van der Mandele Zaal & Jurriaanse Foyer
- **Plenary: Dimitris Bertsimas**  
10:30–11:30am  
Willem Burger Zaal  
*Personalized Medicine: A Vision for Research and Education*
- **Poster Sessions & Refreshments**  
2:30–3:30pm  
Van der Mandele Zaal & Jurriaanse Foyer
- **Welcome Reception**  
6–8pm  
Raderstoomboot De Majesteit  
Buses will depart the De Doelen International Congress Centre, at the main entrance, Kruisplein 40. Buses will return to the De Doelen International Congress Centre following the reception.
- **Boat Schedule**  
Trip through one of Europe's largest harbours. During the trip there will be luxurious hot and cold snacks, including the infamous Dutch bitterballen.
  - **6pm** Welcome with a glass of Cava (Spanish champagne)
  - **6:30pm** Departure
  - **7:45pm** Return
  - **8pm** End

## THURSDAY, JULY 27

- **Coffee Break**  
10–10:30am  
Van der Mandele Zaal & Jurriaanse Foyer
- **Lunch Speakers:**  
**Erik Gerritsen & Eric de Roodenbeke**  
12noon–1:30pm  
Willem Burger Zaal  
*The INFORMS Contribution for the Health Systems & Hospitals of the Future*
- **Coffee Break**  
3–3:30pm  
Van der Mandele Zaal & Jurriaanse Foyer
- **Plenary: Brian Denton**  
3:30–4:30pm  
Willem Burger Zaal  
*Operations Research in Medicine: Past, Present and Future*

## FRIDAY, JULY 28

- **Coffee Break**  
9:30–10am  
Van der Mandele Zaal & Jurriaanse Foyer

## SATURDAY, JULY 29

- **Post-Conference Field Trip (optional)**  
Participants had the option of registering for fabulous pre and post-conference field trips. If you pre-registered for a field trip you will receive a ticket in your registration pack. Buses will depart the De Doelen International Congress Centre, at the main entrance, Kruisplein 40. Buses will return to the De Doelen International Congress Centre following the field trips. Tickets will NOT be available to purchase on-site.

## DINNER & NIGHTLIFE

The center of Rotterdam is organized around two main streets—'Blaak' and 'Coolsingel'—and is now known as the 'Cool district.' While these main streets themselves are not particularly interesting, there are many pleasant spots for lunch, drinks, dinner, and nightlife. Most can easily be reached from the venue on foot (less than a 15-minute walk). Alternatively, there is good public transport. For these short distances, taxis are also quite affordable. Here is a list of areas you may want to discover after conference hours:

- China Town. Very close to the venue: Westersingel, Kruiskade, Mauritsweg.
- 'Witte de With' De Witte de Withstraat (10-minute walk) is one of the busiest streets for nightlife in Rotterdam. It has terraces, variety of restaurants, also in side streets, popular with locals.
- Hofplein – Luchtsingel. The area at the end of the Coolsingel around the Hofplein is quickly developing. It hosts the Rotterdam Biergarten, where you can enjoy German beer and accompanying simple dinners (bratwurst, hamburger) in an urban-style Biergarten. The luchtsingel ('air canal') walkway starts here and brings you to the former railway station area 'Station Hofplein' or 'De Hofbogen.' A variety of shops, bars, and restaurants with up to two Michelin stars.
- A must visit in Rotterdam is 'De Markthal' (market hall), close to Blaak, at the east end of the central shopping area. It has many shops with great food to buy or try, small cafes, bars, and restaurants. Dinner and nightlife continue along the streets 'Binnenrotte' and 'Meent,' parts of which can be crowded, as they are popular with locals.
- From Markthal, you can take the pedestrian bridge crossing Blaak, called 'Overblaak', which is home to the famous cubic houses (one of which can be visited). Descending on the other side, you enter another popular nightlife area, Oude Haven (Old Harbor), one of the few areas in Rotterdam with a historic feel. Another popular set of restaurants and some really good terraces can be found here.
- The forefront of city development lies south of the river Maas, in Rotterdam Zuid. Walk the Coolsingel to the south, toward the Erasmus Bridge and Rotterdam South skyline. At the end of the bridge turn right and you are in 'Kop van Zuid.' It hosts some good bars and restaurants, some with excellent river views. The west end is host to the former Holland America Line building, now in operation as a large Art Deco-style fish restaurant. The windy terrace offers great river views. From here, you can return to the city center with a spectacular water taxi ride.
- Two minutes farther south, across a pedestrian bridge, is the area off the Fenix Food Factory and Deliplein. The Food Factory offers a wonderful selection of local beer, cheese, charcuterie, bread, as well as international food, in a sustainable environment. It closes around 7pm most days. For dinner, exit toward Deliplein where there is an array of affordable restaurants from which to choose.
- The restaurant in the Euromast is 100 meters above the city and offers views from up to 180 meters above the city. Panoramic views even show The Hague. Stay late enough to enjoy the sunset, and subsequently watch the sky turn dark and city lights turn on.

## SIGHTSEEING

- Rotterdam hosts the small historic area called Delftshaven, birthplace of the flying Dutchman, Piet Hein.
- Rotterdam hosts several museums, in particular, Boymans & Van Beuningen Kunsthal, and Netherlands Photo Museum (all within 10 minutes walking distance from the conference venue).
- A boat bus departs twice per hour in the direction of Kinderdijk, a famous UNESCO world heritage site for windmills.
- Delft is less than 15 minutes by train. In Delft you find Delft blue porcelain and a beautiful historic city center.
- The city of Gouda is home to the cheese of the same name. It is 20 minutes by train. Gouda has a historic city center and a cheese market.
- The Hague is also less than 20 minutes by train. Closely adjacent to each other in the city center you will find the historic Dutch parliament buildings, Museum Mauritshuis (paintings by Vermeer), and the Escher Museum. The Hague is also home to the International Court of Justice.
- The Netherlands offers wide sandy beaches. From Rotterdam Central Station you can take a train to the beaches of Hoek van Holland (30 minutes), or via The Hague to Scheveningen.
- Amsterdam is less than an hour by train (take the intercity direct train, which is slightly more expensive). A one-day walking tour of the center of Amsterdam is well worth the visit, especially if you hop on a canal boat tour once you get tired of walking. Amsterdam also hosts truly great museums, such as the Rijksmuseum and the Van Gogh Museum, and the Anne Frankhuis. If you want to visit any of the tourist hot spots, book tickets online and well in advance! Amsterdam is full of tourists.



## ROTTERDAM WILL BE FULL OF LIFE IN JULY 2017

Unlike many other nearby Dutch cities, Rotterdam is not known for its authentic golden century canals. Nor tulips or cheese. Apart from being the birthplace of Erasmus in the 15th century, Rotterdam didn't gain importance until the 19th century when the harbor started developing. The city center was largely destroyed in WWII, after which a new modern city was developed, and is in fact still developing. The latest advancements are gaining Rotterdam an international reputation, especially because of the architecture. In addition, it has a very active cultural agenda that you will inevitably and cheerfully be exposed to during the conference days. While we hope you will focus on the conference, you may want to check for things to do: <https://en.rotterdam.info/agenda/>. Here we present information on two events that you will find difficult to ignore, no matter how strongly you focus on the conference.

### – **Rotterdam Unlimited**

The most inevitable of events taking place concurrently with INFORMS Healthcare 2017 will be the Rotterdam Unlimited Festival. During the last week of July, Rotterdam will be full of food, music, and other forms of entertainment. Starting Friday afternoon, July 28, the city center will turn into a pedestrian zone, with a food market (Mercado) on the central street Coolingsel. The nights of July 28 and 29 will offer many stages with (free) live music, and attract cheerful crowds. On Saturday, July 29, Rotterdam will celebrate its own 'Mardi Gras': a Caribbean-style summer carnival.

### – **UEFA 2017 Women's European Soccer Championship**

The historic soccer stadium Spangen (1916) will be home to many of the matches of the Women's European Soccer championships. There will be a third-round match on July 26 (8:45pm) and a quarterfinal on Saturday, July 29 (8:45pm).





## **BADGES REQUIRED** (for Technical Sessions)

IINFORMS Healthcare 2017 badges must be worn to all sessions and events, and will be checked prior to entering the room. All attendees, including speakers and session chairs, must register and pay the registration fee, and pick up their badges from the registration desk. Lost badges can be replaced at the registration desk.

## **PRESENTERS: AV, COURTESY TO SPEAKERS**

Projectors and laptops will be available in every technical session room. If you have a Mac, don't forget your own adapter. Technical assistance will be available for any AV problems. You may need an adapter to connect your computer to the local voltage in Netherlands (23v).

During technical sessions, silence cell phones and mobile devices. Note that the use of camera and recording devices is prohibited unless you have received prior permission from the speaker.

## **PRESENTATION GUIDELINES**

Session locations are listed in the Technical Sessions section and in the Master Track Schedule. Please be on time for your session and check-in with the session chair.

- Presentations are expected to be in English.
- Limit the presentation to key issues with a brief summary.
- Time your presentation to fit within your designated time span, leaving time for audience questions.
- You may bring copies of your paper or other handouts to distribute to the audience.

## **SESSION CHAIR GUIDELINES**

The role of the Chair is to coordinate the smooth running of the session. The Chair:

- Begins & ends each session on time. Each session lasts 90 minutes, with the time per session determined by the number of papers in the session. Equal time should be given to each paper.
- Introduces each presentation (the title of the paper and the name of the author).
- Completes the session attendance and leaves the form in the session room when departing.

## **QUESTIONS?** (about the Program, Presentations, Changes or Cancellations)

Come by the INFORMS Registration Desk located at the ground floor, De Doelen, if you have any questions.

**WEDNESDAY, JULY 26 (2:30–3:30pm)**

Van der Mandele Zaal & Jurriaanse Foyer, 1st Floor

Be sure to attend these important and lively sessions. Poster Session presentations allow authors to present projects that may be at early stages of development. This is an opportunity for colleagues working in similar areas to critique, make suggestions, and provide encouragement. Light refreshments will be served.

Abstracts for these presentations are on pages 26–28.

1. **Factors Influencing Choice of Health System Access Level in China** Yun Liu, Erasmus University Rotterdam, Qingxia Kong, Shasha Yuan, Joris van de Klundert
2. **Evaluation of On-line Bin Packing Algorithm for Surgical Case Assignment** Boon Yew Ang, Analyst, Singapore Health Services, Shao Wei (Sean) Lam, Wee Kiang (Andrew) Tan, Li Ying Karina Ng, Meh Meh Goh, Chen Ee Lee, Eng Hock (Marcus) Ong, Kevin Lim, Hiang Khoon Tan
3. **Proactive & Dynamic Inventory Policies for Mitigation & Prevention of Drug Shortages** Jacqueline Griffin, Northeastern University, Rana Azghandi
4. **The Effect of Wearable Devices & Gamification on Adopting Healthier Lifestyle** Abdullah Al Nuaim, University of Colorado Denver, Mohammed Khojah
5. **Simulating Hand-Washing Behaviour & Influenza Transmission from Health Initiative Studies Amongst University Students** Omid Mohammadi, Concordia University, Ketra Schmitt
6. **Research on Medical Information Sharing of Medical Consortium in China Based on Evolutionary Game Theory** Qiang Zhang, Shanghai Jiao Tong University
7. **A Hybrid Genetic Algorithm with 2D Encoding for Solving the Rehabilitation Patient Scheduling Problem** Nhat-To Huynh, National Tsing Hua University
8. **Optimal Treatment Strategies for Glycemic Control for Patients with Type 2 Diabetes** Fanwen Meng, National Healthcare Group, Yan Sun, Melvin Khee Shing Leow
9. **Operating Room Rescheduling after a Large Disruption to the Post-Anesthesia Care Unit Beds** Danial Khorasanian, Isfahan University of Technology, Franklin Dexter, Ghasem Moslehi
10. **The Main Opportunities & Challenges of Private Medicine in Low and Middle Income Countries of Eastern Europe** Tetyana Sandulovych, Commercial Head, Medical Plaza, Multidisciplinary Clinic
11. **Nurses' Work with Interruptions: An Objective Model for Testing Interventions** Robert A. Myers, Wright State University, Pratik J. Parikh
12. **Piecing Multiple Sclerosis Together Through Mobile Technology** Fletcher Lee Hartsell, Duke University
13. **Redesign of Patient Flow & Resource Allocation in a High-Volume Emergency Department** Sakine Batun, Department of Industrial Engineering, Middle East Technical University, Alpin İlayda Özmen, Deniz Tanrıkut, Gökçem Yiğit, Medya Tekeş, Nur Keskin, Melih Celik
14. **The Impact of Competency Frameworks to Improve Leadership Performance in Healthcare Organisations. The Case of the Kingdom of Saudi Arabia** Namshan Algarni, Cranfield University, Dr. Patrick McLaughlin, Dr. Ahmed Al-Ashaab
15. **Predicting Stroke Onset by Machine Learning Using Medical Data, Blood Flow Simulation Data & Blood Vessel Shape Data** Masaaki Suzuki, Tokyo University of Science, Yu-Chen Chen, Soichiro Fujimura, Takashi Suzuki, Hiroyuki Takao, Toshihiro Ishibashi, Yuichi Murayama, Hayato Ohwada
16. **Assessing Connectedness among U.S. Healthcare Facilities to Guide Regional Prevention of Multidrug Resistant Organisms** Rachel Slayton, U.S. Centers for Disease Control and Prevention, Prabasaj Paul, James Baggs, John Jernigan
17. **Impact of Feature Selection on the Performance of Single Classifiers in Predicting Depression in the Elderly: Emphasis on Accuracy & Area Under the ROC Curve** Eunsung Lee, CSRI (Creativity Science Research Institute)
18. **Sepsis Watch: Intensive Care Unit Lab Predictions** Andrea McCarter, Georgia Institute of Technology, Soorya Eswaran, Srujana Buddi, Kevin Johnson, Kevin Gu, Kshitish Deo, Shamim Nemati, Matthew Stanley, Vibhore Kumar
19. **The Most Efficient Critical Vaccination Coverage and its Equivalence with Maximizing the Herd Effect** Lotty Evertje Duijzer, Erasmus University Rotterdam, Willem L. van Jaarsveld, Jacco Wallinga, Rommert Dekker

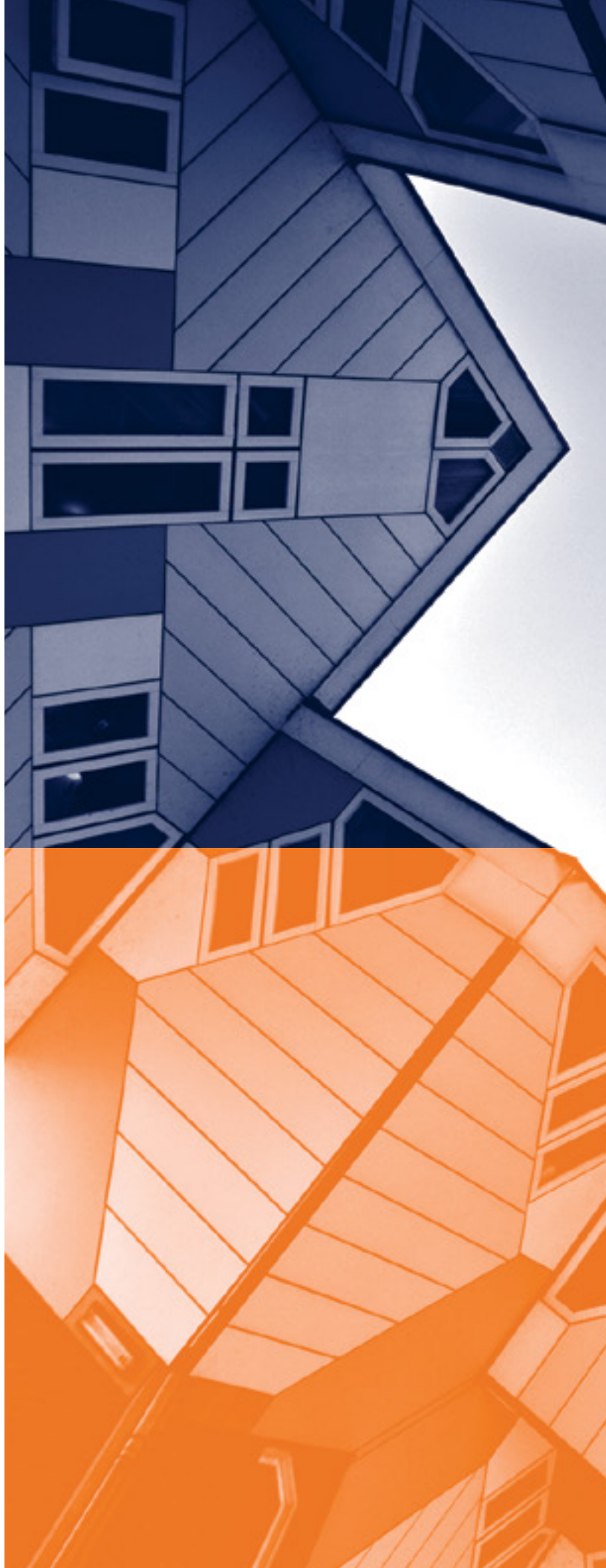
- 20. Best Combination of Base-Meta Learner in the Stacking Classifier to Optimize its Performance in Predicting Depression in the Elderly** Kun Chang Lee, Sungkyunkwan University
- 21. Reducing the Dimensionality of Patient Pathway Analysis: An Algorithmic Approach** Katherine Bobroske, University of Cambridge, Michael Freeman, Feryal Erhun, Lawrence Huan
- 22. Exploring the Impact of Security and Privacy on Mobile Health Applications Ranking** Yazan Alnsour, University of Illinois Springfield
- 23. A Fuzzy Hybrid MCDM Approach for Health Technology Assessment** Hakan Tozan, Istanbul Medipol University

## MOBILE APP

The INFORMS Meeting App is available for iOS and Android devices. Detailed information, including the schedule of sessions, session abstracts, meeting locations, maps, exhibit hall details, and much more can be found on the app. This dynamic app can be downloaded directly to your device by visiting the iTunes or Google Play Stores and searching for "INFORMS Meetings." When you view the meeting program in the app, you can either browse through the parallel sessions and special events or search for a specific speaker or keywords. As you locate the events, sessions, and presentations you are interested in, click on the star button, which bookmarks it to the My Schedule itinerary. Use My Schedule for a quick reference tool.

One of the great features of the conference app is that it will allow attendees—upon logging in—to search for other attendees, and send messages and requests through INFORMS Connect.

Note: Previous versions of this App should be removed before downloading the 2017 Healthcare App.



WEDNESDAY, JULY 26 (10:30–11:30am)



**Dimitris Bertsimas**  
Operations Research Center,  
Massachusetts Institute  
of Technology

Dimitris Bertsimas is the *Boeing Leaders for Global Operations Professor of Management*, a Professor of Operations Research, the Codirector of the Operations Research Center, and the Director of the Master of Business Analytics at MIT.

A faculty member since 1988, his research interests include optimization, stochastic systems, machine learning, and their application. In recent years, he has worked in robust optimization, statistics, healthcare, transportation, and finance. Bertsimas was a cofounder of Dynamic Ideas, LLC, which developed portfolio management tools for asset management. In 2002, the assets of Dynamic Ideas were sold to American Express. He is also the founder of Dynamic Ideas Press, a publisher of scientific books, the cofounder of Benefits Science, a company that designs healthcare plans for companies, of Dynamic Ideas Financial, a company that provides financial advice to customers, of Alpha Dynamics, an asset management company, P2 Analytics, an analytics consulting company, and of MyA health, a personalized healthcare advice company.

Bertsimas has coauthored more than 200 scientific papers and renowned books. He holds a BS in electrical engineering and computer science from the National Technical University of Athens, Greece, as well as an MS in operations research and a PhD in applied mathematics and operations research from MIT.

**Personalized Medicine: A Vision for Research and Education** Medicine as taught in medical schools and as practiced today is not personalized. We present a research program to develop an algorithmic theory of personalized medicine applied to the major human diseases. Using electronic medical records and genomic data and in collaboration with major medical centers and medical doctors, we present our ongoing efforts to develop algorithms that propose personalized treatments for individual patients that suffer from these diseases. The new personalized medicine methods are based on new cutting-edge machine learning algorithms that use modern optimization methods and improve upon classical approaches. We further discuss the implications of our work on the education of the next generation of doctors.

THURSDAY, JULY 27 (12noon–1:30pm)



**Dr. Erik Gerritsen**  
Secretary General at the Ministry of  
Health, Welfare and Sport

Erik Gerritsen was appointed Secretary General at the Ministry of Health, Welfare and Sport in June 2015. During his many years of government service, he has gained experience in a wide range of fields. As Secretary General he is not only in charge of the general governance of the Ministry, but is also responsible for the Macroeconomic Issues and Labour Market Department and the Financial and Economic Affairs Department of the Ministry.

Dr. Gerritsen began his career at the Ministry of Finance. In 1996 he was appointed Director, Financial and Economic Affairs of the Ministry of Foreign Affairs, where he became deputy Secretary General in 1999. In 2000 he made the transition to the Municipality of Amsterdam. As City Clerk of Amsterdam he was the primary advisor to the College of Mayor and Alderpersons. He was ultimately responsible for services in the city and for representing the City of Amsterdam in various regional, national and European matters. From 2007 until 2009 he was “ambassador for knowledge” of the Municipality. In 2009 he became Chairman of the Amsterdam Regional Youth Protection Agency.

Erik Gerritsen was born in The Hague in 1962 and studied political science at the Erasmus University in Rotterdam and public administration and information management at the Amsterdam University.



**Dr. Eric de Roodenbeke**  
CEO, International  
Hospital Federation

Eric de Roodenbeke received his PhD in 1956. He is a French national with an extensive international experience in health systems and policies and a strong background in hospital management. Since June 2008 he holds the position of CEO of the International Hospital Federation. Prior to this he worked at the World Health Organization and the World Bank leading various health intervention, educational, management, and capacity building programmes mostly in Africa. He was Director of several French hospitals for 10 years. He also worked at the French Ministry of Foreign Affairs for 10 years both at headquarters and in field

projects in Africa. Eric de Roodenbeke holds a PhD in health economics, a Hospital Administration post graduate diploma, and a University diploma in public health. He has taught in various masters programs and senior continuous education courses and published several books as well as various articles in professional journals.

**The INFORMS Contribution for the Health Systems and Hospitals of the Future** Over the past years, the Dutch Health System has received considerable international praise. At the same time, however, there are concerns about the sustainability and the adaptations that are needed to meet future societal needs. In most scenarios, information technology and analytics play an important enabling role to provide solutions for the challenges ahead.

Much of the discussions on making adaptations to health systems, whether in the Netherlands or abroad, focus around the pivotal role of hospitals. In addition to other advances, information technology will change their relationships with patients, with primary care, and is already bringing some of the services from the real physical world to the Internet. There is a role to play for operations research and analytics to design these transitions and develop their cost-effectiveness.

Two highly distinguished guests will share their views on these developments. Erik Gerritsen will position the Dutch health system and unveil the plans to meet future challenges. Eric de Roodenbeke will discuss the present and future roles of hospitals, and share his views on the role of information technology and analytics.

After presenting their views, the plenary speakers will involve the audience through a series of propositions regarding the contribution the INFORMS community can make to promote effective solutions for the identified challenges.

#### THURSDAY, JULY 27 (3:30–4:30pm)



Brian Denton  
Department of Industrial &  
Operations Engineering,  
University of Michigan

Brian Denton has a joint appointment with Urology and Industrial & Operations Engineering (IOE)

departments. He joined the IOE faculty in 2012. His primary research interests are in optimization under uncertainty with applications to medical

decision making related to the detection, treatment, and prevention of chronic diseases. He is a member of the Institute for Healthcare Policy and Innovation at University of Michigan and he holds a fellowship appointment at the Cecil Sheps Health Services Research Center at University of North Carolina at Chapel Hill. Brian is the current president of the INFORMS for 2017.

Previously, he has been a Senior Associate Consultant at Mayo Clinic, and a Senior Engineer at IBM. In 2009 he received the National Science Foundation Career Award. He also won the INFORMS Service Section Prize (2010), the INFORMS Daniel H. Wagner Prize (2005), the Institute of Industrial Engineers Outstanding Publication Award (2005), and the Canadian Operations Research Society Best Paper Award (2000). He has coauthored more than 50 journal articles and conference proceedings, and has 25 patents granted by the U.S. Patent and Trademark Office.

**Operations Research in Medicine: Past, Present and Future** Operations Research (O.R.) methods such as decision analysis, simulation, stochastic models, and optimization, have a long and rich history of use for research and practice in medicine over the last several decades. Applications include cancer screening, diabetes treatment, glaucoma monitoring, organ transplants, radiation therapy, and many others. In this talk I will discuss some of the ways O.R. has had an impact on medicine in the past, drawing on several specific examples in the area of chronic diseases. Next, I will discuss some contemporary applications and discuss the research challenges and the opportunities these problems present to drive the development of new O.R. methods. Finally, I will conclude by summarizing some of the exciting new directions where O.R. can play a much needed role in the future including personalized medicine, biomarkers for early detection of diseases, and the development of artificial and regenerated organs.

## THANKS TO OUR 2017 HEALTHCARE CONFERENCE SPONSORS


**The H. Milton Stewart School of Industrial and Systems Engineering (ISyE) at the Georgia Institute of Technology**

is the largest program in industrial and systems engineering, and has been named the top ranked program by *U.S. News & World Report* for more than two decades. The ISyE undergraduate program offers a track-based curriculum that allows students to either obtain a broad industrial engineering education or specialize in operations research, supply chain engineering, quality and statistics, or economic and financial systems. ISyE's graduate program offerings include master's degrees in analytics, operations research, statistics, health systems, supply chain engineering, and industrial engineering; and PhD degrees in operations research, industrial engineering, and machine learning. ISyE faculty conduct research in methodological areas such as optimization, statistics, analytics, machine learning, stochastic systems, simulation, and system informatics and control; and application-driven areas such as supply chain engineering and logistics, health systems, advanced manufacturing, energy, and sustainable systems engineering.



**Erasmus University Medical Center Rotterdam** is committed to a healthy population and excellence in healthcare through research and education. It is in the top 10 of best medical institutes in Europe (QS Ranking 2016) and excels in various research fields, studying fundamental and clinical domains as well as public health and prevention. Bibliometric indicators place Erasmus MC in the top 20 of clinical medicine worldwide. In addition to scientific research, patient care and education are core tasks of Erasmus MC. It is the top referral centre for a region of about five million inhabitants. Erasmus MC is the largest medical school in the Netherlands, with around 3,100 medical students and around 250 PhD graduates yearly.



**The Institute of Health Policy & Management (iBMG) of Erasmus University Rotterdam (EUR)** is leading in the Netherlands with its educational and research activities targeted at policy and management issues in healthcare. The institute offers a bachelor programme, five master programmes, and post-academic educational programmes and courses. At iBMG, research and educational activities are closely intertwined. Knowledge and experiences of various scientific disciplines such as economics, law, social-medical sciences, organisational science, and public administration are brought together and applied to the healthcare sector. This multidisciplinary approach to education and research is unique.



**Erasmus Research Institute of Management (ERIM)** is a research school of Erasmus University Rotterdam (EUR). ERIM was founded in 1998 by two schools of EUR: Rotterdam School of Management, Erasmus University (RSM) and Erasmus School of Economics (ESE). Consistently ranked in the top three of management research centres in Europe, ERIM is a community of over 350 management scientists who publish in leading academic journals. For aspiring researchers, ERIM offers an advanced doctoral programme in business and management. ERIM is accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW).



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**Rotterdam Partners** has the objective of strengthening the economy of Rotterdam and the region. We work for businesses, visitors, and residents who are already based in the city or those who plan to visit or establish themselves in Rotterdam in the future. Rotterdam Partners has a number of core tasks. First of all, Rotterdam Partners is the link that connects, strengthens, and enhances local and regional networks. In addition, we facilitate the organisation of activities, respond to queries from those considering relocating to Rotterdam, and work toward addressing economic issues. We also undertake initiatives to promote innovation in the Rotterdam economy. Finally, we bring together supply and demand in fields like tourism, business events, and conferences.



**University of Cologne**  
Faculty of Management and Social Sciences  
Health Economics: Health Care Management and Social Policy

**University of Cologne** The Faculty of Management, Economics and Social Sciences of the University of Cologne has a strong tradition in both fundamental and applied research. In research, we strive to fulfill our mission "Innovation for Society" by rigor and relevance. We strive for rigorous basic research published in top ranked scientific journals that is relevant for business practice, economics, and the development of society. Our interdisciplinary approach of Business Administration, Health Care Management, and Social Policy aim to address the interfaces between Management, Economics, and Medicine.

## INFORMS ANNUAL & INTERNATIONAL MEETINGS

2017

- **INFORMS Annual Meeting**  
October 22–25  
George R. Brown Convention Center & Hilton Americas Houston  
Houston, TX  
Chair: Bill Klimack, Chevron  
<http://meetings.informs.org/houston2017/>
- **Winter Simulation Conference (WSC) 2017**  
December 3–6  
Red Rock Casino Resort & Spa  
Las Vegas, NV  
Chair: Ernest H. Page, MITRE  
<http://www.wintersim.org>

2018

- **INFORMS Conference on Business Analytics & Operations Research**  
April 15–17  
Marriott Waterfront Hotel  
Baltimore, MD  
Chair: Jack Kloeber, Kromite, LLC  
<http://meetings.informs.org/analytics2018/>
- **INFORMS International Meeting**  
June 17–20  
Taipei International Convention Center  
Taipei, Taiwan  
Chair: Grace Lin, Asia University  
<http://meetings.informs.org/2018international/>
- **INFORMS Annual Meeting**  
November 4–7  
Phoenix Convention Center  
Phoenix, AZ  
Chair: Young-Jun Son, University of Arizona

## INFORMS COMMUNITY/ CHAPTER MEETINGS

2018

- **INFORMS Optimization Society Conference**  
March 23–25  
University of Colorado  
Denver, CO  
Chair: Stephen Billups, University of Colorado Denver  
<http://orwe.mines.edu/conference/>
- **INFORMS Marketing Science Conference**  
June 14–16  
Temple University  
Philadelphia, PA  
Chair: Xueming Luo, Temple University
- **INFORMS MSOM International Conference**  
June 30–July 2  
National University of Singapore  
Singapore

Go to <https://www.informs.org/Meetings-Conferences/Conference-Calendar> for a searchable INFORMS Conference Calendar

## How to Navigate the Technical Sessions

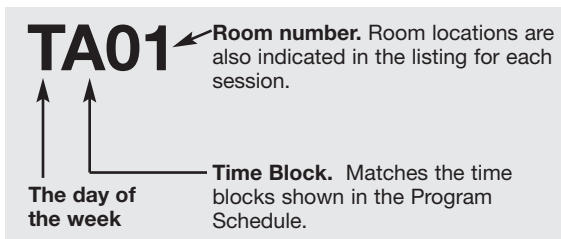
There are four primary resources to help you understand and navigate the Technical Sessions:

- This Technical Session listing, which provides the most detailed information. The listing is presented chronologically by day/time, showing each session and the papers/abstracts/authors within each session.
- The Author and Session indices provide cross-reference assistance (pages 61-67).
- The floor plan is on the back cover and shows you where technical session tracks are located.
- The Master Track Schedule is on the inside back cover.

## Quickest Way to Find Your Own Session

Use the Author Index (pages 62-65) the session code for your presentation will be shown along with the room location. You can also refer to the full session listing for the room location of your session.

## The Session Codes



## Time Blocks

### Wednesday

- A — 8:30am - 10:00am
- Plenary — 10:30am - 11:30pm
- B — 1:00am - 2:30pm
- Poster — 2:30pm -3:30pm
- C — 3:30pm - 5:00pm

### Thursday

- A — 8:30am - 10:00am
- B — 10:30am - 12:00pm
- Plenary — 12:00pm - 1:30pm
- C — 1:30pm - 3:00pm
- Plenary — 3:30pm - 4:30pm

### Friday

- A — 8:00am - 9:30am
- B — 10:00pm - 11:30pm
- C — 11:35pm - 1:05pm

## Wednesday, 8:30am - 10:00am

### ■ WA01

Van Cappellen Zaal, Ground Level

### Empirical and Experimental Research in Healthcare Operations

Sponsored: Health Applications  
Sponsored Session

Chair: Evrim D. Gunes, Koc University, Koc University, Istanbul, 34450, Turkey, egunes@ku.edu.tr

#### 1 - Knowledge-Work in Healthcare: Confronting the Tradeoff between Task Speed and Care Quality

Craig Froehle, University of Cincinnati, 2925 Campus Green Drive, Cincinnati, OH, 45221-0130, United States, craig.froehle@uc.edu, Lauren F. Laker

Healthcare has increased its reliance on electronic records and other information systems. As a result, providers are frequently being subjected to information overload (IO). To combat IO, we propose using “emphasis framing” tactics. We test the efficacy of emphasis framing using an in-depth behavioral experiment involving emergency physicians developing a preliminary plan of care for a new patient. We find that emphasis framing significantly increases quality of care, but at a cost.

#### 2 - Financial Health and Hospital Operations

Christopher J. Chen, London Business School, Regent's Park, London, NW14SA, United Kingdom, cchen@london.edu, Nicos Savva

We analyze how changes in hospital spending on patient care affects readmissions and mortality rates, and lays the foundation for studying the impact of funding cuts on operational decisions such as staffing levels and mix. Combining datasets from the Centers for Medicare & Medicaid Services (CMS) on hospital quality and financial performance, and using instrumental variable estimation to address endogeneity in hospital spending, we find that a 1% increase in spending per patient reduces aggregate readmissions by 0.053%. Our findings indicate potential negative impacts from cuts on patient outcome and sets up further tests on the resource pecking order.

#### 3 - An Empirical Analysis of Diagnostic Test Ordering Behavior of Physicians at Outpatient Units Under the Influence of Workload

Busra Ergun Sahin, Koc University, Istanbul, Turkey, busrasahin16@ku.edu.tr, Evrim Didem Gunes, Ayse Kocabiyyoglu

We investigate the influence of workload on the use of diagnostic tests by physicians in outpatient units. The objective in this paper is to show using actual operational data from hospitals, that healthcare delivery workers demonstrate adaptive behavior in response to the amount of workload. We hypothesize that physicians order more diagnostic tests when they have less time to spend with the patient, and we test this hypothesis using data from different clinics in a large training and research hospital.

### ■ WA02

Arcadis Zaal, First Floor

### ALIO Sponsored Session

Invited: Health Operations Management  
Invited Session

Chair: Rodrigo A. Carrasco, PhD, Universidad Adolfo Ibanez, Universidad Adolfo Ibanez, Santiago, Chile, rax@uai.cl

#### 1 - Multi-Objective Admission Planning Problem: A Two-Stage Stochastic Approach

Ana Celeste Batista, Pontifical Catholic University of Chile, Avda Vicuna Mackenna 4860, Santiago, Chile, abatista@uc.cl, Jorge R. Vera, David Pozo

Effective admission planning can improve inpatient throughput and waiting times. The decisions are generally focused on the resource efficiency avoiding patient service criteria. We present a multi-objective admission planning problem to deal simultaneously with patient and hospital perspectives. We develop a stochastic model taking into account demand and bed capacity uncertainties. The model estimate the effect of admission policies with data from a Chilean hospital.

## 2 - Cost Effectiveness Analysis of Hep C Treatments: Beyond Markov

Susana Mondschein, Universidad Adolfo Ibanez,  
2640 Diagonal las Torres, Penalolen, Santiago, 7550000, Chile,  
susana.mondschein@uai.cl, Natalia Yankovic

In recent years, highly effective treatments for hepatitis C virus became available. However, a careful cost effectiveness evaluation is needed, due to the economic constraints most health care systems face. We propose a dynamic programming model with age dependent transitions. The solution is of a threshold type, i.e. new drugs are cost effective for patients at a given level of fibrosis if younger than a pre-specified limit, otherwise a conservative approach of closely monitor the evolution of the patient should be followed.

## 3 - Operating Room Scheduling with Variable Procedure Times

Rodrigo A. Carrasco, UAI Systems Director, Universidad  
Adolfo Ibanez, Santiago, Chile, rax@uai.cl, Javiera Barrera,  
Susana Mondschein, Macarena Azar

The operating room scheduling problem has been tackled from many different perspectives. In this work, we propose a time-indexed scheduling formulation using chance constraints related to the surgery duration probability distribution for each surgeon, to improve the scheduling of an operating theater. Through simulations and the use of real instances, we report the performances for different metrics, showing the importance of using historical data and adding the

## ■ WA04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning I

Contributed Session

Chair: Behrouz Bakhtiari, Ryerson University, 508 - 666 Spadina Avenue, Toronto, ON, M5S 2H8, Canada, bbakhtiari@ryerson.ca

## 1 - Effective Treatments with Chronic Disease Management: Leveraging Patient Trajectories with Hidden Markov Models

Stefan Feuerriegel, Dr, University of Freiburg,  
Platz der Alten Synagoge, Freiburg, 79098, Germany,  
stefan.feuerriegel@is.uni-freiburg.de, Michael Hörner

Recent innovations in IT-enabled health tracking allow for the close monitoring of patients. The seemingly inexhaustible volume of collected data can eventually facilitate new insights into medical conditions, especially for patients suffering from chronic diseases. While the data itself is readily available, further effort is necessary to develop statistical approaches that can derive latent medical conditions from this information and make corresponding recommendations for more effective treatment plans customized to individuals. For this purpose, we propose the use of hidden Markov models as means to identify the "true" medical condition of patients.

## 2 - A Day in the Life of Magnetic Resonance Imaging: Assessing the Variety and Appropriateness of Exams Being Performed in Canada

Sonya Vanderby, University of Saskatchewan, 57 Campus Drive,  
Saskatoon, SK, S7N 5A9, Canada, sonia.vanderby@usask.ca,  
Andreea Badea, Juan Nicolás Peña Sánchez, Neil Kalra,  
Paul Babyn

We studied the volumes, types and appropriateness of Magnetic Resonance Imaging (MRI) exams performed across Canada. Exam data for one common day were obtained from 13 academic hospitals. Exam appropriateness was evaluated via published exam appropriateness tools. Among the sample of 1087 exams, brain exams were the most common anatomically; cancer was the most common cause. 87.0% to 87.4% of the exams were appropriate based on the 2 main evaluation tools but results differed by anatomic region.

## 3 - Inpatient and Post Discharge Care Package Design with Data Driven Machine Learning Algorithm

Jingjing Guan, Postdoctoral Fellow, City University of  
Hong Kong, 5-216 Lau Ming Wai Academic Building, Hong Kong,  
jguan4@cityu.edu.hk, Eman Leung, Frank Y. Chen

Repeated hospitalization is a fact of life in aging population. A patient's well-being after being discharged from a hospital is a function of whether the patient has received sufficient inpatient care and if the levels and duration of post-discharge care are adequate enough for delaying future hospitalization. We first use machine learning methodology to train a model using 20 years of data extracted from an inpatient hospital to identify the function for patient segments (partitioned based on demographics, cumulative length of stay and diagnoses of chronic diseases). The accuracy of the algorithm will be tested against the inpatient and post-discharge care allocation of an out-of-sample cohort.

## 4 - Using Bayesian Networks to Predict Diabetes

Behrouz Bakhtiari, Assistant Professor, Ryerson University,  
508 - 666 Spadina Avenue, Toronto, ON, M5S 2H8, Canada,  
bbakhtiari@ryerson.ca, Aziz Guergachi, Karim Keshavjee

In this study, we develop a Bayesian Networks (BN) model for Diabetes prediction. For predictors, variables from EMR data are selected based on their relevance and correlations. The structure of the BN is determined using score-based structure learning algorithms. Based on the model developed, inferences on the probabilities associated with the Diabetes disease are provided. The data used for this analysis has been acquired from the Canadian Primary Care Sentinel Surveillance Network database.

## ■ WA05

Schadee Zaal, Third Floor

### Stochastic Models for Hospital Operations Management

Invited: Health Operations Management

Invited Session

Chair: Na Geng, Shanghai Jiao Tong University, Shanghai Jiao Tong University, Shanghai, 200240, China, gengna@sjtu.edu.cn

## 1 - Admission Quota for Elective Patients under Uncertain Emergency Demands

Jiajun Dai, Shanghai Jiao Tong University, Shanghai, China,  
imbetterbetter@sjtu.edu.cn, Na Geng, Xiaolan Xie

To determine the admission quota for elective inpatients by considering the uncertain emergency arrival, this paper proposes a Markov Decision Process model with the objective to maximize the revenue from accepting the elective inpatients minus the overcapacity penalty. Structural properties of the optimal policy are established and heuristic policies are proposed to solve the real size problems. Numerical experiments are performed to compare the performance of different policies and identify the influence of different parameters.

## 2 - Big Data Based Optimization of Healthcare Resources Allocation for Asthma Considering Air Pollution

Li Luo, Sichuan University, Chengdu, China, luolicc@scu.edu.cn

Asthma is a common, chronic, not easy to cure, and environment-sensitive disease. The study researches on the impact of air pollution and treatment schemes on the healthcare resource demand of asthma, based on environmental monitoring data and healthcare insurance data of Chengdu, in China, then optimizes the healthcare resource allocation, by dynamically scheduling healthcare resource to break the shackles from healthcare institutes, is of great practical significance.

## 3 - Optimal Issuing and Ordering Policies for Inventory Management of Blood Platelet

Na Geng, Shanghai Jiao Tong University, Shanghai, China,  
gengna@sjtu.edu.cn

Blood platelet is a typical perishable product. The fresher the blood platelet is, the more utility the patient gets. The classical first-in, first-out is not always the optimal issuing policy. To deal with the issuing and ordering policies, this paper proposes a Markov Decision Process model with the objective of maximizing patients' utility minus weighted waiting, inventory, and salvage cost. Structural properties of the optimal control policies are established.

## ■ WA06

Van Beuningen Zaal, Third Floor

### Optimization Modeling for Medical Decision Making

Invited: Medical Decision Making

Invited Session

Chair: M. Gabriela Sava, Clemson University, 145 Sistine Hall,  
Clemson, SC, 29634, United States, msava@clemson.edu

## 1 - On Using Sensitivity and Stability Analysis to Optimize Patient-centered Medical Decision Making

M. Gabriela Sava, PhD, Clemson University, Clemson, SC,  
United States, msava@clemson.edu, Luis G. Vargas,  
Jerrold H. May, James G. Dolan

Custom tailoring a sensitivity and stability analysis for an individual patient faced with choosing a colorectal cancer screening option might be appropriate if there are particular considerations involved with that patient. For routine cases, patients classified as having an average risk for colorectal cancer, it may be sufficient to partition the space of patients based on their preferences, and to produce a generic analysis that would be a good approximation across each partition of the space.

**2 - Multi-objective Optimization in Radiotherapy**

Rens van Haveren, Erasmus MC - Cancer Institute, Rotterdam, Netherlands, r.vanhaveren@erasmusmc.nl, Ben J. Heijmen, Gerda M. Verduijn, Marleen Keijzer, Włodzimierz Ogryczak, Sebastiaan Breedveld

Radiotherapy is used to treat over 50% of all cancer patients. Due to each patient's unique anatomy, a personalized treatment plan is required. This plan specifies how the dose (resulting from the irradiation) is distributed inside the patient's body. The main goal is to sufficiently irradiate the tumor, while the other goals are to keep the doses to the surrounding healthy organs as low as possible. Hence, treatment planning is a multi-objective optimization problem and usually involves 10-30 correlated objectives. This talk discusses automated methods that aim to balance these objectives optimally for each patient resulting in a favorable balance between probability of cure and quality of life.

**3 - Optimal Treatment Plans for Volumetric Modulated ARC Therapy (VMAT) using Branch-and-Price**

Pinar Dursun, Bogaziçi University, Bogaziçi Üniversitesi 34342 Bebek, Istanbul, 34342, Turkey, pinar.dursun@boun.edu.tr, Z. Caner Ta Kin, I. Kuban Altinel

Radiation can be delivered continuously during VMAT, because the gantry of the linear accelerator (linac) may rotate on one or more arcs. Linac is also equipped with a multileaf collimator (MLC) that shapes the radiation. These properties make VMAT powerful in obtaining high conformal plans in terms of dose distribution with short treatment times. However, the apertures that composed by the MLC are interdependent, which makes planning hard. We propose a mixed integer linear programming model and a branch-and-price algorithm for optimal treatment planning.

**WA08**

Ruys Zaal, Fourth Floor

**Data-driven Models in Health Care Operations**

Invited: Health Operations Management

Invited Session

Chair: Ana Cecilia Zenteno, Massachusetts General Hospital, Boston, MA, 02114, United States, Azentenolangle@Partners.org

**1 - Evaluating Usefulness of Information Quality in Predicting Daily Surgical Volume**

Vikram Tiwari, Vanderbilt University Medical Center, 1211 21st Ave South, Medical Arts Building 422H, Nashville, TN, 37212, United States, vikram.tiwari@vanderbilt.edu, Joonyup Eun, Warren S. Sandberg

We develop a data-driven methodology for predicting day-of-surgery case volume at both the individual surgeon level and the surgical service level. We quantify the incremental value of accounting for errors in the data, as well as using better parameterized data. Results highlight the tradeoff between 'more data that has errors' versus 'lesser but cleaner data'.

**2 - Data-driven Appointment-scheduling under Uncertainty: The Case of an Infusion Unit in a Cancer Center**

Nikolaos Trichakis, MIT, 100 Main Street, E62-576, Cambridge, MA, 02143, United States, ntrichakis@mit.edu, Avishai Mandelbaum, Petar Momcilovic

We consider appointment scheduling under a time-varying number of servers, in a data-rich setting with uncertain service times and punctuality. Our data-driven approach, based on infinite-server queues, yields tractable solutions for hundreds of jobs and servers. We successfully test our approach against near-optimal algorithms, which were developed for merely single-servers. This entails a robust optimization algorithm with novel uncertainty sets. To test for practical performance, we leverage a unique dataset from a cancer center, that combines real-time locations, EHRs and appointments log. Focusing on the Infusion Unit (90 appointments, 25 infusion chairs), we reduce cost by 30%.

**3 - Models Based on Longitudinal Healthcare Data**

Hari Balasubramanian, University of Massachusetts-Amherst, 160 Governors Drive, Amherst, MA, 01003, United States, hbalasubraman@ecs.umass.edu

We discuss methods for analyzing data concerning healthcare encounters at the individual level. These encounters can be of various types - outpatient, emergency room, inpatient, pharmaceutical etc. Each encounter happens on a certain day (or a certain hour) and when such data is collected over a period of time, it creates an evolving point process unique to each individual. The point process provides information about the intensity and diversity of encounters - how frequent and how fragmented the care is across multiple settings. We provide examples where such data could be used and discuss the stochastic methods that are best suited for generating insights.

**4 - Online Scheduling Algorithms for Infusion Outpatients**

Kimia Ghobadi, MIT, 100 Main Street, E62-459, Cambridge, MA, 02142, United States, kimiag@mit.edu, Michael Hu, Inga Lennes, Retsef Levi, John Stone, Ana Cecilia Zenteno

We developed online intra- and inter-day algorithms to schedule infusion appointments for outpatients. Each appointment is scheduled without prior knowledge of future appointments with the goal of minimizing the number of required resources. We analyze the algorithms' performance and our results show up to 45% decrease compared with historical resource utilization.

**WA09**

Van Rijckevorsel Zaal, Fourth Floor

**Scheduling and Planning I**

Contributed Session

Chair: Deepak Agrawal, Pennsylvania State University, 801 Southgate Drive, A4, State College, PA, 16801, United States, agrawal.deepankur@gmail.com

**1 - Effects of Rescheduling on Patient No-show Behavior in Outpatient Clinics**

Zhichao Zheng, Singapore Management University, 50 Stamford Road, Lee Kong Chian School of Business, Singapore, 178899, Singapore, danielzheng@smu.edu.sg

We study the effects of waiting time and rescheduling on no-show behavior in an outpatient appointment system for both new and follow-up patients. Using comprehensive clinical data, we demonstrate that waiting time has little effect on no-show behavior of follow-up patients. Instead, their no-show probability decreases significantly if their appointments were rescheduled at their own requests but increases significantly if they were rescheduled by the clinic. New patients, in contrast, are only concerned about waiting time and are insensitive to who initiates the rescheduling. Our results provide useful implications for managing no-shows.

**2 - Reducing Clinic Variability Through Same-day Scheduling, Intervention for No-shows and Seasonal Adjustments**

Kum-Khiong Yang, Professor, Singapore Management University, Lee Kong Chian School of Business, 50 Stamford Road, Singapore, 178899, Singapore, kkyang@smu.edu.sg, Tugba Cayirli

This study investigates demand and capacity strategies for reducing clinic variability. These include (i) same-day scheduling to control for random walk-ins, (ii) no-show intervention, where the clinic calls advance-booked patients a day before and releases canceled slots to same-day demand, and (iii) adjustments to daily number of appointments to match seasonal variations in demand. These strategies implemented over the IBFI and Dome rules result in improvements in clinic performance measured in terms of patient wait times, physician idle time and overtime.

**3 - Prescription-based Market Analysis for Oral Antidiabetic Drugs in Taiwan from 2004 to 2013**

Hui-Min Wang, Physician, PuLi Branch, Veteran General Hospital Taichung, Nantou, Taiwan, wanghm1964@gmail.com, Mei-Ting Tsai

Pharmaceutical companies compete in research and development for new type 2 diabetes drugs. In this diversified market, factors driving the market shares remain unclear. This study aims to investigate the market situation in Taiwan via a prescription-based analysis. The prescription data are collected from Taiwan Health Insurance Database for a period of ten years. Incorporating with the drug events, the prescribing habits of physicians, the effects of price changes and new drug launches on the market penetration of the seven categories of oral anti-diabetic drugs are discussed.

**4 - Multi-clinic Scheduling of Multi-priority Patients with Preference, Cancellation and No Show**

Deepak Agrawal, Pennsylvania State University, 310 Leonhard Building, University Park, PA, 16802, United States, dua143@psu.edu, Guodong Pang, Soundar Kumara

Reasons of No-shows and how to avoid it, has been focus of the research since more than a decade. No-show adds up to the increases healthcare waste. Motivated by this we aim to develop advanced scheduling models which can reduce No-shows by scheduling appointments at patients' preferred day and time with their preferred physicians and at preferred clinic location. Researchers have acknowledged that each patient may have different priority. Our model considers patient segments with different priorities to design an efficient yet profitable scheduling system, while maximizing patient access. We develop an performance improvement heuristic to solve the intractable dynamic programming problem.

## ■ WA10

Plate Zaal, Fourth Floor

### Supply Chains I

Contributed Session

Chair: Maryam Dehghani, RMIT University, La Trobe Street, Melbourne, Australia, maryam.dehghani@rmit.edu.au

#### 1 - On the Management of Blood Inventory when Transfers Exist

Marilyn T. Lucas, University of Vermont, 202 Kalkin Hall  
55 Colchester Avenue, Burlington, VT, 05405-0157, United States,  
mlucas@bsad.uvm.edu, David Novak, S. Karti Puranam

This project analyzes inventory and supply issues related to blood storage and usage by the blood bank of a large regional hospital when uncontrolled transfers of “about to expire” blood from smaller hospitals throughout the region routinely occur. We develop an optimization model, derive simple decision rules, and complement our findings with a generalized simulation analysis, relying on actual demand and transfer data from the hospital, and perform extensive sensitivity analyses on various parameters of the model.

#### 2 - Double Cross-match and a Hybrid Issuance Policy to Improve Blood Bank Inventory Management

Ali Haji Agha Bozorgi, Post-Doctoral Fellow, Sharif University of Technology, Tehran, Iran, Islamic Republic of,  
bozorgi.ie@gmail.com

We develop a new inventory management model as a decision making tool to help making tactical and operational level decisions for a Hospital Blood Bank inventory management, including issuance policy, and collection and ordering policy, to reduce blood wastage and shortage. We propose a multi period, multi-product inventory problem that performs double cross match of blood units, with a new issuance policy. Using the cross match ratio, we determine core demand of each patient, as well as reserve demand. We then define an assignment problem to determine patients who can share reserve demand. At the end of each period, we update the inventory status (as we deal with aging products, in a multi period model).

#### 3 - An Age Based Lateral Transshipment Policy for Perishable Items

Maryam Dehghani, RMIT University, La Trobe Street, Melbourne, Australia, maryam.dehghani@rmit.edu.au, babak abbasi

Lateral transshipment is an efficient policy designed to improve the performance of a supply chain. Despite the importance of transshipment for perishable items, few studies consider the issue of perishability. In this paper, we propose a new transshipment policy for perishable items based on the age of the oldest item in the system. We develop a heuristic solution using partial differential equations. We compare the performance of our transshipment policy to the transshipment policy that is currently practiced in Australian hospitals. The results show that by setting the optimal threshold, hospitals could transfuse fresher units of blood in two days while reducing their total inventory cost by 5%.

## ■ WA11

Van der Vorm Zaal, Fourth Floor

### Medical Decision Making I

Contributed Session

Chair: Ainize Cidoncha, IS Global, Cholmeley Park, London, N6 5 EU, United Kingdom, ainizecm@gmail.com

#### 1 - Optimal Resource Allocation for Network Protection Against Epidemic Processes

Victor Manuel Preciado, Raj and Neera Singh Assistant Professors,  
University of Pennsylvania, 3330 Walnut Street, Philadelphia, PA,  
19103, United States, preciado@seas.upenn.edu

We study the problem of containing epidemics outbreaks taking place in an arbitrary network by distributing protection resources throughout the nodes of the network. We consider two types of protection resources: (i) Preventive resources able to defend nodes against the spread and (ii) corrective resources able to neutralize the spread after a node has been infected. We assume that both types of resources have an associated cost and study the problem of finding the cost-optimal distribution of resources throughout the nodes of the network. We show that for a wide class of cost functions, this problem can be solved in polynomial time using Geometric Programming (GP).

#### 2 - A Novel Approach for Polypharmacy Assessment using Multi-criteria Decision Analysis and Multi-expert Opinions

Anissa Frini, Professor, Université du Québec à Rimouski, 1595,  
Boulevard Alphonse Desjardins, Lévis, QC, G6V 0A6, Canada,  
Anissa\_Frini@uqar.ca, Caroline Sirois, Marie-Laure Laroche

Although older individuals are exposed to polypharmacy, there is no clear definition of what are appropriate and inappropriate polypharmacy. This article proposes an original approach for classifying polypharmacy using multi-criteria sorting methods ELECTRE Tri and ELECTRE Tri-C and results from a DELPHI approach. Data from multi-expert drug assessment is aggregated and a multi-criteria evaluation vector representing the collective opinion of the clinicians is obtained. Then, the MCDA sorting methods are applied to evaluate and assign polypharmacy to one of the three categories: inappropriate, more or less appropriate or appropriate.

#### 3 - Combinatorial Survival Patterns

Munevver Mine Subasi, Associate Professor, Florida Institute of Technology, 150 West University Blvd, Melbourne, FL, 32901, United States, msubasi@fit.edu, Ersoy Subasi, Travaughn Bain, Melissa Stradley Moreno, Megan M. Moreno

We propose an algorithm that integrates a multiclass classification method with traditional survival analysis. The method identifies survival patterns as optimal solutions of a mixed linear integer program and uses Kaplan Meier survival estimators to predict the survival time of patients. In contrast to many statistical methods, the proposed technique is guided by the collective strength of the subsets of features referred to as combinatorial biomarkers. We apply our method to African-American Study of Chronic Kidney Disease and Hypertension to identify survival patterns based on the patients' clinical features and SNPs that can accurately separate the early event and late event patients.

#### 4 - A Multi-criteria Approach to Strategy Development for Expanding the Care for Chagas Disease

Ainize Cidoncha, IS Global, London, N6 5 EU, United Kingdom,  
ainizecm@gmail.com, Gurram Gopal

This project developed a Multi-Criteria Decision Analysis methodology (MCDA) and software for determining strategies for scaling up the medical care for diseases, using Chagas Disease in Bolivia as a case study. A modified version of the WHO building blocks model was used as a framework for the study. Analytical Hierarchy Process, MCDA and Data Envelopment Analysis were incorporated into a decision-making tool which enabled managers to evaluate options and construct efficient, implementable strategies based on data from stakeholders. The methodology can be used for any disease.

## ■ WA12

Mees Zaal, Fourth Floor

### Radiation Therapy Planning

Invited: Disease and Treatment Modeling

Invited Session

Chair: Omid Nohadani, Northwestern University, Evanston, IL, 60208-3119, United States, nohadani@northwestern.edu

#### 1 - Knowledge Driven Robust Framework for Radiation Therapy Protocol Optimization

Omid Nohadani, Northwestern University, 2145 Sheridan Road, Technological Institute M233, Evanston, IL, 60208-3119, United States, nohadani@northwestern.edu, Nastaran Shojaei, Seyed Iravani

Clinical decisions typically follow established protocols. These are either derived from first principles, past experimentations, or experts' knowledge. Whenever their implementation turns infeasible, decision makers relax a subset to attain practicable solutions, using personal experience. We provide a framework for robustly optimizing protocols by systematically extracting knowledge from past decisions and current protocols, while inherently accounting for uncertainties. To demonstrate the approach, we study the case of radiation therapy using a large set of past head-and-neck treatments.

**2 - Robustness in Hypoxia-guided Radiation Therapy**

Arkajyoti Roy, Bowling Green State University, 349 Business Administration Building, Applied Statistics and Operations Research, Bowling Green, OH, 43403, United States, aroy@bgsu.edu, Omid Nohadani

Reduced radiosensitivity from low oxygen concentration in tumor cells has an adverse effect on radiation therapy treatments. Reoxygenation leads to uncertain temporal variations in cell oxygenation, ranging from short-term fluctuations due to perfusion to gradual changes from angiogenesis. In this work, we model the reoxygenation trajectory to reside in a time-dependent uncertainty set that is updated by mid-treatment observations. A robust optimization model incorporating the uncertainty set is solved for a discrete set of clinically realistic scenarios. A prostate case is used to evaluate the robust method in comparison to current clinical practice.

**3 - Supporting the Design of Radiotherapy Treatment Planning using Data Envelopment Analysis**

Emma Stubington, Lancaster University, Lancaster, United Kingdom, e.stubington@lancaster.ac.uk, Matthias Ehrgott, Omid Nohadani

Complications arise in treatment planning from conflicting objectives; an ideal plan would maximise radiation to the tumour and minimise radiation to healthy cells. If a plan does not meet clinical criteria it must be re-optimised using trial and error. We use Data Envelopment Analysis to assess the quality of individual plans and suggest improvements by comparing them against existing plans. Robust Optimisation and simulation are used to account for the effects of uncertainty during treatment.

**■ WA13**

Van Weelde Zaal, Fourth Floor

**Machine Learning for Optimizing Healthcare Delivery**

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Suchi Saria, Johns Hopkins University, Baltimore, MD, 21218, United States, ssaria@cs.jhu.edu

**1 - Real Time Risk Models for Patient Deterioration and Triage**

Rebecca Steorts, Duke University, Durham, NC, United States, beka@stat.duke.edu

We propose a class of loss functions and predictive risk models for patient deterioration. Our models are composed of the the probability to event (disease), the probability of treatment, and the cost incurred by a particular medical center. Based on these loss functions and risk models, we make recommendations using electric health record data regarding decisions that can be made by clinicians, administrators, and hospitals.

**2 - Learning Individualized Treatment Effects from Observational Data: An Application to Cardiology**

Mihaela van der Schaar, UCLA, Los Angeles, CA, United States, mihaela@ee.ucla.edu

This paper presents a new methodology for identifying individualized treatment effects from observational data. This is a challenging problem since the data is biased. We show that our new methods are significantly outperforming state-of-the-art solutions on individualized treatment effects. These techniques can transform the way in which medicine is practiced, by learning personalized treatment policies. We highlight the performance of our method in the context of heart failure, where we study the efficacy of Left Ventricular Assist Devices (LVADs) for specific individuals.

**3 - Learning Treatment Response Models from Multivariate Longitudinal Data**

Adarsh Subbaswamy, Johns Hopkins University, 3400 North Charles Street, 160 Malone Hall, Baltimore, MD, 21218-2608, United States, asubbaswamy@jhu.edu, Hossein Soleimani, Suchi Saria

Methods for assessing patient risk or predicting time until a critical event depend on irregularly measured, unaligned time-series data from multiple clinical markers. These methods also need to account for treatment effects, which mask the underlying health status of patients. In this talk I will present an unsupervised model for decomposing observed trajectories of multiple markers into baseline progression and treatment response components. First, I will show the structure learned on clinical data for kidney injury patients treated with dialysis. Then I will compare the model's ability to predict trajectories in the presence of treatment effects with relevant baselines.

**Wednesday, 10:30am - 11:30am****■ Plenary**

Willem Burger Zaal

Dimitris Bertsimas Plenary

**Plenary Session****1 - Personalized Medicine: A Vision for Research and Education**

Dimitris Bertsimas, Massachusetts Institute of Technology, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, dbertsim@mit.edu

Medicine as taught in medical schools and as practiced today is not personalized. We present a research program to develop an algorithmic theory of personalized medicine applied to the major human diseases. Using electronic medical records and genomic data and in collaboration with major medical centers and medical doctors, we present our ongoing efforts to develop algorithms that propose personalized treatments for individual patients that suffer from these diseases. The new personalized medicine methods are based on new cutting edge Machine Learning algorithms that use modern optimization methods and improve upon classical approaches. We further discuss the implications of our work on the education of the next generation of doctors.

**Wednesday, 1:00pm - 2:30pm****■ WB01**

Van Cappellen Zaal, Ground Level

**Empirical Healthcare Operations**

Sponsored: Health Applications

Sponsored Session

Chair: Hessem Bavafa, Wisconsin School of Business, Madison, WI, 53706, United States, hbavafa@bus.wisc.edu

**1 - Rating GP Performance using ED Data**

Sandra Suelz, Erasmus University-Rotterdam, Rotterdam, Netherlands, sulz@bmg.eur.nl, Nicos Savva

Measuring access and clinical quality of GP care is difficult either due to data unavailability, low frequency of data collection, or inconsistent data collection across GPs. ED-level data, however, exists and is comparable across hospitals. We use UK-based data to analyze whether ED-level data can be used to assess GP performance thereby distinguishing between accessibility for acute conditions and management of long-term care conditions.

**2 - Causes and Consequences of Patient Bed Assignment Decisions in Hospitals**

Jillian Berry Jaeker, Boston University, 595 Commonwealth Avenue, Room 657A, Boston, MA, 02215, United States, jjaecker@bu.edu, Sandra Sülz, Jonas Schreyögg

This project aims to analyze the role of the admitted department in hospitals on the quality and cost of care. Using a national dataset of inpatient visits, we explore the conditions that lead to secondary inpatient unit placement and the resulting care pathways.

**3 - Drivers of Productivity in Radiology**

Maria R. Ibanez, Harvard Business School, 500 Soldiers Field Road, Wyss House, Boston, MA, 02163, United States, mibanez@hbs.edu

Using detailed data on millions of radiological studies interpreted by physicians, we study the drivers of speed and quality of the interpretation, and identify implications for scheduling and allocation of work across workers.

**4 - Patient Portals in Primary Care**

Hessem Bavafa, Wisconsin School of Business, 4284C Grainger Hall, 975 University Avenue, Madison, WI, 53706, United States, hbavafa@bus.wisc.edu

Interest in innovative healthcare delivery models has increased due to measures such as the Affordable Care Act, which is designed to expand insurance coverage and contain healthcare costs. One innovation that has been forwarded as a low-cost alternative to physician office visits is "e-visits," or secure messaging between patients and physicians. We evaluate the effect of e-visit adoption on patient health and physician productivity using a panel dataset from a primary care provider in the US.

## ■ WB02

Arcadis Zaal, First Floor

### Healthcare Service Management

Invited: Health Operations Management

Invited Session

Chair: Haiyan Wang, Southeast University, Nanjing, 210096, China, hywang@seu.edu.cn

Co-Chair: Weili Xue, Southeast University, Nanjing, 210096, China, weili@seu.edu.cn

#### 1 - Optimal Operation Strategy of Intelligent Health Information Service Considering Dynamic Consuming Behavior

Haiyan Wang, Southeast University, School of Economics & Management, Sipailou 2, Nanjing, 210096, China, hywang@seu.edu.cn

Intelligent health information (referred to as IHIS) has been proved to be an effective method for health management. However few current researches consider the dynamic pricing and operation mechanism; to fill this gap, this research proposes a dynamic IHIS pricing model. Results show: (1) The best strategy is to give a 'free-charge period' before charging a fee for customized service. (2) The platform change rate of potential customers has significant influence on the public service effort.

#### 2 - Analysis of Health Information Exchange as a Multi-sided Market

Weili Xue, Southeast University, Hankou Road 22, Nanjing, China, weili@seu.edu.cn

In this talk, we are to establish a single stage equilibrium model for the healthcare information exchange from the perspective that the platform performs as a multi-sided market. We analyze how the participants behavior, the network effect influence the sustainability of the platform and the structure of the market.

#### 3 - Service Systems Decision of Health Data Bank for Different Users

Yixin Liang, Southeast University, Nanjing, China, 542793435@qq.com, Lindu Zhao

This paper relies on health data bank, to explore the optimal provision decision of medical services based on health care big data. The study designed decision-making mechanisms including the health management programs for healthy people, the treatment programs for the patients, and the health care services for rehabilitation to improve the value of health care data.

## ■ WB03

Zeelenberg Zaal, Second Floor

### Resource Allocation and Incentive Design in Healthcare Settings

Invited: Public Health and Policy Making

Invited Session

Chair: Diwakar Gupta, University of Minnesota, Minneapolis, MN, guptad@umn.edu

#### 1 - One- Or Two-channel Subsidies? Donor Funding for Drug Availability

Iva Petrova Rashkova, Washington University in St Louis, Washington University in St Louis, St Louis, MO, 63130, United States, irashkova@wustl.edu

We study the decision of a donor subsidizing health programs in a country by allocating a fixed budget between the commercial and non-commercial distribution channels to maximize consumption. While the non-commercial channel is affordable, it exhibits a random quantity yield. On the contrary, the commercial channel supplies a predictable quantity at a higher price. We characterize the optimal budget allocation decision and show that the variability of the random quantity yield in the non-commercial channel generates inter-channel cannibalization and reduces total consumption. The two channels complement each other when the random yield of the non-commercial one is either very high or very low.

#### 2 - New Models to Predict Transplant Survival

Pinar Keskinocak, Georgia Institute of Technology, School of Indust/System Eng, 765 Ferst Drive, Atlanta, GA, 30332, United States, pinar@isye.gatech.edu, Ethan Mark, David Goldsman, Joel Sokol

We present new models for predicting organ transplant survival curves. Our model for the general population achieves better 5-year out of sample prediction, as measured by the concordance index, than similar models published recently in literature. We also present findings on important variables affecting survival outcomes, and on the performance of the model by different patient groups. Lastly, we present a survival model for patients receiving transplants from "increased risk" donors.

#### 3 - Hospital-physician Gainsharing Contracts

Diwakar Gupta, University of Minnesota, 130B Mechanical Engineering, 111 Church Street SE, Minneapolis, MN, 55455, United States, guptad@umn.edu, Mili Mehrotra, Xiaoxu Tang

Episode Payment Models allow participants to realize gains from cost reduction and to share them with collaborators. We develop gainsharing contracts that do not implicate the Social Security Act, mitigate agency costs, and impact of different levels of risk aversion.

## ■ WB04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning II

Contributed Session

Chair: Pervaiz Akhtar, University of Hull, Cottingham Road, Hull, HU6 7RX, United Kingdom, Pervaiz.Akhtar@hull.ac.uk

#### 1 - Regional Integrated Elderly Care System – A Systems Analysis Approach

Olli Halminen, Aalto University, Maarintie 8, Espoo, 02150, Finland, olli.halminen@aalto.fi, Mika Linna

We employ a predictive model to analyze patient transitions and social and health care costs within a regional elderly care system. Using individual level national registry data of 320 659 patients linked with cost accounting data we create a model to predict costs and outcomes and investigate their relationship to various provider models. We demonstrate and discuss the relevance of such models and data when used by regional healthcare managers.

#### 2 - Accurate and Timely Real-time Prediction of Sepsis using an End-to-end Multitask Gaussian Process RNN Classifier

Joseph Futoma, Duke University, Durham, NC, United States, jfutoma14@gmail.com, Sanjay Hariharan, Katherine Heller

We present an end-to-end classifier that uses streaming physiological data to predict the onset of sepsis. Our framework models the multivariate trajectories of physiological time series using multitask Gaussian processes, seamlessly accounting for the high uncertainty, frequent missingness, and irregular sampling rates associated with real clinical data. The Gaussian process is directly connected to a deep recurrent neural network classifier that predicts whether a patient encounter will become septic. In a large cohort of inpatient encounters at our university health system we find that it outperforms several baselines at predicting sepsis, including the NEWS score in use at our hospital.

#### 3 - Models to Predict Hospital Occupancy for Early Intervention and Long-term Resource Planning

Tze Chao Chiam, Christiana Care Health System, Newark, DE, 19103-1363, United States, tze.c.chiam@christianacare.org, Pan Wu, Stephen Hoover, Mitchell Fawcett, Michelle Wheeler, Kelsey Jarrod, Varadarajan Subbiah

Quantifying and responding to hospital congestion is a crucial and well-researched area. However, many hospital's tactical plans to reduce congestion only trigger after the hospital is already congested. The implementation of predictive models in this space allows interventions to be enacted before capacity situations occur. We take several approaches to model development for hospital congestion, considering inpatient occupancy rates and emergency department boarding. Model results have many uses including strategic planning, such as staff scheduling, and contingency response, such as expediting patient transfers or discharges. Model evaluation designs will also be discussed.

#### 4 - Humanitarian Healthcare Services: Resilient Data and Information Processing Systems

Pervaiz Akhtar, Senior Lecturer (Associate Professor), University of Hull, Cottingham Road, Hull, HU6 7RX, United Kingdom, Pervaiz.Akhtar@hull.ac.uk, Victoria-Sophie Osburg

This study prioritizes three resilient data and information processing (RDIP) systems (manual, semi-automated, and fully-automated) by utilizing the literature review and analytic network process approach. Results indicate that fully-automated systems are more effective to build RDIP systems for humanitarian healthcare services. This attributes to key determinants, contemporary dimensions and enablers such as the Internet of Things, Big Data collection and analytics, drone applications, data mining skills, among others). Also, semi-automated systems play a key role for certain enablers. The implications arising from the finding are further discussed for healthcare practitioners.

## ■ WB05

Schadee Zaal, Third Floor

### Optimization Approaches for Healthcare Decision-Making under Uncertainty

Invited: Health Operations Management

Invited Session

Chair: Alba Rojas-Cordova, Virginia Tech, Blacksburg, VA, 24060, United States, albarc@vt.edu

#### 1 - Robust Post-donation Blood Screening under Prevalence Rate Uncertainty

Hadi El-Amine, George Mason University, 4310 Cotswolds Hill Ln, Fairfax, VA, 22030, United States, helamine@gmu.edu, Douglas Bish, Ebru Bish

Blood product safety, in terms of being free of transfusion-transmittable infections, is crucial. Under prevalence rate uncertainty, various objective functions, including minimization of the maximum regret, were considered in order to determine a “robust” post-donation blood screening strategy that minimizes the risk of releasing an infected unit of blood into the blood supply. Efficient and exact algorithms are provided.

#### 2 - Optimal Inventory Control for Drug Supply

Nan Kong, Purdue University, 206 South Marting Jischke Drive, Biomedical Engineering, West Lafayette, IN, 47906-2032, United States, nkong@purdue.edu, Wei-An Chen

As clinical trials face increasing challenges such as high cost, development delays, competition among trial sites, a drug supply analytics tool is needed. We propose an innovative inventory optimization model that incorporates features of clinical supplies. Compared to the classic model, our model involves free-stopping mechanism and inverse-discount factor. We use the model to tradeoff the overall operational cost and early trial termination loss under patient subject enrollment uncertainty.

#### 3 - Optimal Processing of Human Donor Milk

Lisa M. Maillart, University of Pittsburgh, 1030 Benedum Hall, Pittsburgh, PA, 15261, United States, maillart@pitt.edu

Donated breast milk — collected, processed and dispensed via non-profit milk banks in the U.S. — is the standard of care for premature and unhealthy infants whose mothers cannot provide adequate supply. We formulate mixed-integer programs to optimize the daily decisions involved in the pooling of milk from different donors to meet macronutrient requirements across different product types, and the batching of pooled milk for efficient pasteurization. Our numerical results demonstrate significant improvements compared to historical decisions at our partner milk bank.

#### 4 - Optimal Resource Allocation for Sequential Adaptive Clinical Trials

Alba Rojas-Cordova, Virginia Tech, 1253 Progress Street NW Apt. 4800J, Blacksburg, VA, 24060, United States, albarc@vt.edu, Ebru Korular Bish

Adaptive clinical trials for new drugs promise significant benefit to both the pharmaceutical industry and the patients, but complicate resource allocation. We study the sequential resource allocation decision in the context of Phase 3 group sequential adaptive trials, which allow for early trial termination, and quantify the impact of interim analyses on the new drug’s misclassification risk and time-to-market, as well as the firm’s profit. To this end, we build a stochastic dynamic programming model that incorporates Bayesian updates on the drug’s efficacy. We study structural properties of an optimal resource allocation strategy and perform a numerical analysis based on realistic data.

## ■ WB06

Van Beuningen Zaal, Third Floor

### Optimization of Medical Decision Making for Chronic Diseases

Invited: Medical Decision Making

Invited Session

Chair: Selin Merdan, University of Michigan, Ann Arbor, MI, 48105, United States, smerdan@umich.edu

#### 1 - Optimizing Medical Treatment Decisions for the Prevention of Heart Attack and Stroke

Lauren N. Steimle, University of Michigan, 3261 Bolgos Circle, Ann Arbor, MI, 48105, United States, steimle@umich.edu, Weiyu Li, Jeremy Sussman, Rodney Hayward, Brian T. Denton

Treatment of blood pressure and cholesterol is crucial in the prevention of major cardiovascular events. We present a stochastic model developed from longitudinal patient data from electronic health records to model the progression of these risk factors over time. We discuss approaches for addressing missing data and other sources of bias that confound model development. Finally, we describe a method for optimizing treatment decisions, and present results using data from a large U.S. population.

#### 2 - Impact of False Positives on the Cost-effectiveness of Lung Cancer Screening

Iakovos Toumazis, Stanford University, Department of Radiology, James H. Clark Center, Room S255, Stanford, CA, 94305-5446, United States, iakovos.toumazis@stanford.edu, Emily Tsai, Ayca Erdogan, Summer Han, Ann Leung, Sylvia Plevritis

We assess the benefits and cost of various screening strategies for lung cancer (LC) using a data driven microsimulation model. We simulate individuals’ LC progression in the presence and absence of screening strategies, which vary in terms of starting and stopping age, screening frequency, and smoking criteria. We identify the efficiency frontier and show that the cost-effectiveness of LC screening is significantly affected by the management of false-positive results. We examine the effect of the number of subsequent exams and disutility associated with false-positives, and conduct univariate sensitivity analyses to test the robustness of our findings to changes in key input model parameters.

#### 3 - Robust Optimization Framework to Account for Prediction Errors for Cancer Diagnosis

Selin Merdan, University of Michigan, 1640 McIntyre Street, Ann Arbor, MI, 48105, United States, smerdan@umich.edu, Brian T Denton

Multiple diagnostic tests are often available for diagnosing diseases such as cancer; however, how best to use these tests to render a diagnosis is challenging because there is often a tradeoff between the benefits of diagnosis and the harms and costs associated with the diagnostic tests themselves. We present a robust optimization model for determining the optimal assignment of composite diagnostic tests based on individual patient risk factors to achieve an optimal balance between the benefits and harms of diagnostic tests. We further provide a specific example in the context of radiologic imaging to detect metastatic prostate cancer.

## ■ WB07

Willem Burger Zaal

### HAS Student Paper Competition

Sponsored: Health Applications

Sponsored Session

Chair: Sarang Deo, School of Business, ISB Campus, Gachibowli, Hyderabad, 500032, India, sarang\_deo@isb.edu

Co-Chair: Greg Zaric, Ivey Business School, Ivey Business School, 1255 Western Road, London, ON, N6G 0N1, Canada, gzaric@ivey.uwo.ca

#### 1 - Managing Appointment-based Services in the Presence of Walk-ins

Shan Wang, Shanghai Jiao Tong University, Xuhui District, 1954 Huashan Road, Shanghai, 200030, China, wangshan\_731@sjtu.edu.cn

#### 2 - Robust Defibrillator Deployment under Cardiac Arrest Location Uncertainty via Row-and-Column Generation

Auyon Siddiq, UC Berkeley, Berkeley, CA, United States, auyon.siddiq@berkeley.edu

### 3 - The Effect of Online Reviews on Physician Demand: A Structural Model of Patient Choice

Yuqian Xu, New York University, 44 West 4th Street, New York, NY, 10012, United States, lillian.xyq@gmail.com

### 4 - Routing and Scheduling with Synchronization and Stochastic Durations: Applications in Home-Healthcare and Operating Rooms Scheduling Problems

Seyed Hossein Hashemi Doulabi, Polytechnique, Montreal, QC, 02215, Canada, hashemi.doulabi@polymtl.ca

### 5 - A Causal Tree Approach for Personalized Health Care Outcome Analysis

Guihua Wang, University of Michigan, 1209 McIntyre Drive, Ann Arbor, MI, 48105, United States, guihuaw@umich.edu

## ■ WB08

Ruys Zaal, Fourth Floor

### Operations Research and informations Systems for Healthcare Efficiency

Invited: Health Operations Management

Invited Session

Chair: Beste Kucukyazici, McGill University, Montreal, QC, H3A 1G5, Canada, beste.kucukyazici@mcgill.ca

Co-Chair: Kartik Krishna Ganju, Temple University, Philadelphia, PA, 19122, United States, tuc67632@temple.edu

#### 1 - Redesigning the Emergency Department to Improve Flow and Reduce Waiting Times

Dmitry Krass, University of Toronto, Rotman School of Management, 105 St George Street, Toronto, ON, M5S 3E6, Canada, krass@rotman.utoronto.ca, Opher Baron, Tianshu Lu

The head of emergency department (ED) at Southlake Hospital in Newmarket, ON, Dr. Marko Duic has developed a rather radical new design for the ED that affects almost every aspect of how ED is configured and functions. In the last few years the ED at Southlake has been ranked #1 with respect to TPIA (Time to Physician Initial Assessment) in Ontario. In this talk we document the key aspects of new design and present empirical evidence of its efficiency. In particular we show that the efficiency gains were not a result of either exogenous factors or increased resource usage, but were indeed due to the new design of the ED.

#### 2 - Just What the Doctor Ordered? Physician Mobility after the Adoption of Electronic Health Records

Kartik Krishna Ganju, McGill University, Montréal, QC, H3A 2M1, Canada, kartik.ganju@mcgill.ca

In this paper, we investigate how the implementation of electronic health record systems (EHRs) affects physician mobility and the decision to continue practicing at their current hospital. Despite recent claims, results do not suggest that such technology adoption is associated with accelerated retirement on the part of physicians.

#### 3 - On Reducing Consultation Wait Times in ED

Beste Kucukyazici, McGill University, 1001 Sherbrooke West, Montreal, QC, H3A 1G5, Canada, beste.kucukyazici@mcgill.ca, Cheng Zhu, Rick Mah

This study focuses on reducing emergency department overcrowding by shortening waiting times for a consultation by a specialist. In this context, we develop a stochastic dynamic modeling to study the prioritization of patients by ED physicians to facilitate the consultation request as well as a queuing model to optimize the response time of specialists to these requests. This study provides important managerial insights for hospitals of different sizes as well as specialty portfolios.

## ■ WB09

Van Rijkevorsel Zaal, Fourth Floor

### Scheduling and Planning II

Contributed Session

Anders Nordby Gullhav, Norwegian University of Science & Technology, Department of Industrial EC & Tech Man, Trondheim, 7491, Norway, anders.gullhav@iot.ntnu.no

#### 1 - A Simulation Based Neighborhood Search Algorithm to Schedule Patients at a Multi-facility Healthcare Diagnostic Center

Varun Jain, Indian Institute of Technology Madras, Department of Management Studies, IIT Madras, Chennai, 600036, India, varunjain.vj.5@gmail.com, Usha Mohan

Random arrival of multi category patients with different priority levels at a multi facility diagnostic center is modelled. Sequential decision making under uncertainty is captured using Markov Decision Process (MDP) with the objective of maximizing net revenue and used Dynamic Programming (DP) to solve it. To address dimensionality and scalability issues of MDP, Decentralized MDP (D\_MDP) formulation is proposed. Simulation Based Neighborhood Search Algorithm (SBNSA) was employed to improve DP solution for D\_MDP. These solutions were compared with three other rule-based heuristics using simulation.

#### 2 - Outpatient Scheduling Considering Unpunctuality

Jiafu Tang, Professor, Dongbei University of Finance and Economics, Jianshan Str. 217, Shahekou District, Dalian, 116025, China, jftang@mail.neu.edu.cn

We extend the outpatient appointment scheduling to consider patient's arrival unpunctuality and try to answer the questions: does the optimal appointment interval under unpunctuality still display the shape of dome, what do the system performances behave, and which types of unpunctuality behaviors is the most impact. A stochastic programming model is developed to help hospital manager determine a set of appointment intervals for outpatient admitting unpunctuality, towards minimizing the weighted patient waiting times, doctor's idle time and overtime. Series of numerical experiments are designed to test how schedule adjusts to accommodate the uncertainty of unpunctuality.

#### 3 - Appointment Scheduling at the MRI Labs of a Norwegian Hospital

Anders N. Gullhav, Norwegian University of Science and Technology, Department of Industrial Ec & Tech Man, Trondheim, 7491, Norway, anders.gullhav@ntnu.no, Marielle Christiansen, Anders R. Eilertsen, Bjorn Nygreen, Hanna M. Selvaag

The increasing demand for health care services combined with the targets for high utilization and low waiting time, the appointment scheduling at hospitals is unmanageable without decision support. We study the appointment scheduling at the MRI (magnetic resonance imaging) labs of a major Norwegian hospital, serving both inpatients and outpatients, with different priorities. The arrival of requests for scans is stochastic, and the length of a scan varies. We simulate the appointment process to test different scheduling approaches on real data.

## ■ WB10

Plate Zaal, Fourth Floor

### Supply Chains II

Contributed Session

Chair: Jacqueline Griffin, Northeastern University, 360 Huntington Ave., 334 Snell Engineering Center, Boston, MA, 2115, United States, ja.griffin@neu.edu

#### 1 - A Simulated Annealing Heuristic with Restart Strategy for the Blood Pickup Routing Problem

Vincent F. Yu, Professor, National Taiwan University of Science and Technology, 43, Section 4, Keelung Road, Taipei, 10607, Taiwan, vincent@mail.ntust.edu.tw, Nur Mayke Eka Normasari, Titi Iswari, Hsiu-I Ting

This research studies the blood pickup routing problem (BPRP). The goal of BPRP is minimizing the collection routes of blood bags between a central blood bank and a set of donation sites while observing the time window constraints of donation sites and the spoilage time constraint of blood. We formulate the problem as a mixed integer linear program and develop a simulated annealing heuristic with restart strategy to solve the problem. Computational results indicate that the proposed solution approach performs well on solving BPRP.

#### 2 - Effect of Regional Block Blood Centers on Japanese Blood Services

Mari Ito, Tokyo University of Science, 2641 Yamazaki, Noda-shi, Chiba, 278-8510, Japan, mariito@rs.tus.ac.jp, Ryuta Takashima, Kazuhiro Kobayashi

We assess regional block blood centers, which were established by Japanese Red Cross in 2012, by using an inventory control model of blood products. We propose a mathematical programming model which minimizes the number of blood products collected and transferred while maintaining a safe minimum blood supply. We evaluate an effect of regional block blood centers on the number of collected, transferred and discarded blood products.

#### 3 - Proactive Blood Assignment Models for Shortage Prevention

Jacqueline Griffin, Assistant Professor, Northeastern University, 360 Huntington Ave., 334 Snell Engineering Center, Boston, MA, 02115, United States, ja.griffin@northeastern.edu, Nooshin Valibeig

Blood transfusion is a critical and life saving medical treatment, which relies on access to compatible blood types to that of the patient. In isolated environments, such as in the aftermath of a disaster, demand for blood units is often unpredictable and the timing for replenishment of the blood bank is unreliable. Correspondingly, the risk and the cost of blood shortages is high. We develop multiple proactive blood allocation policies using stochastic optimization models and methods. Via simulation, we demonstrate the benefits of implementing a proactive approach to blood unit assignments which accounts for cross-matching criteria in order to prevent blood shortages.

## ■ WB11

Van der Vorm Zaal, Fourth Floor

### Medical Decision Making II

Contributed Session

Chair: Anna Muzalyova, University of Augsburg, Neusasser Strasse 47, Augsburg, 86156, Germany, anna.muzalyova@unikat.uni-augsburg.de

#### 1 - Optimal Antihypertensive Therapy Plan for Patients with Diabetes

Saeideh Mirghorbani, Ph.D Student, University of Alabama, 1214, 12th st, apt 17, Tuscaloosa, Tuscaloosa, AL, 35401, United States, smirghorbani@crimson.ua.edu, Sharif Melouk, John Mittenthal

The importance of cardiovascular risks in diabetic patients has been emphasized because of their high cardiovascular mortality rate. Antihypertensive medications are a class of medicines used to lower blood pressure and mitigate the risk of heart problems. In this research, we address the optimal antihypertensive therapy plans considering patient adherence as well as the influence of the medication side-effects. We develop a finite horizon, discounted Markov decision process in which patients transition through health states. The objective is to maximize the expected quality-adjusted life years.

#### 2 - The Development of Patient-centered Healthcare Delivery System: An Indian Case Study

Prdip Kumar Ray, Professor, Indian Institute of Technology Kharagpur, Kharagpur, Kharagpur, 721302, India, pkray2010@gmail.com, Abhik Patra

The rapid change of the dynamics of the health care delivery system and patient satisfaction and expectation, as well as unpredictable and diversified complex healthcare environment, has exerted the pressure on the healthcare providers to reevaluate the managerial decision based on the consequences of patient-centered care. A Quality Function Deployment-led model is developed through the cooperation between patients, healthcare providers and healthcare personnel for the patient-centered health care delivery system by countering the patient's expectation. The managerial model is deployed in an acute-care hospital in India for efficacy.

#### 3 - Personalized Online Portal Services and Patient Readmission

Soheil Sibdari, University of Massachusetts, 1933 Commonwealth Avenue, Unit 408, Brighton, MA, 02135, United States, ssibdari@umassd.edu

In this research we study the impact of online portals on patient knowledge and satisfaction with health services. Using available data we provide a personalized method to offer targeted and automated services for individual patient. In a case framework, we also measure the impact of such technology on patient knowledge and address to what extent personalized information and health tips might lower patient readmission.

#### 4 - Health Behavior of Hay Fever Sufferers

Anna Muzalyova, Scientific assistant, University of Augsburg, Neusaesser Straße 47, Augsburg, 86156, Germany, anna.muzalyova@unikat.uni-augsburg.de

Allergic rhinitis (AR) is the most frequent allergic disorder in pollen sensitized people and a major disease in European population. We investigated the health behavior of AR sufferers so as to evaluate the level of their well-being by undertaking an explorative cross-sectional survey. AR exhibited a significant impact on daily activities and caused substantial loss of productivity. Still, there was a high rate of undiagnosed and unexplained allergies and improperly treated AR sufferers.

## ■ WB12

Mees Zaal, Fourth Floor

### Disease and Treatment Modeling I

Contributed Session

Chair: Walter Alejandro Silva Sotillo, University of Southern Florida, 10212 Altavista Ave., Tampa, FL, 33647, United States, silvasotillo@mail.usf.edu

#### 1 - Measuring Resilience after a Pandemic Influenza Outbreak

Walter Alejandro Silva Sotillo, Doctoral Candidate, University of South Florida, 4202 E. Fowler Ave, Tampa, FL, 33620, United States, silvasotillo@mail.usf.edu, Daniel Romero Rodriguez

Periodic emergence of avian influenza has heightened concerns for a possible pandemic outbreak. From a public health preparedness standpoint, it is essential to assess the possible impact of an Influenza pandemic and to assess resilience levels: the ability to minimize the number of infected people and a quick recovery after a pandemic outbreak. We estimated the resilience levels that a population could face in case of an emerging influenza outbreak. We analyzed three scenarios of transmissibility and the use of non-pharmaceutical interventions. This research is the first exploration to design policies that will enhance resilience capabilities in cities that could be disrupted by a pandemic.

#### 2 - Reassessing the Threat of Pandemic in Light of the 2016 Olympics

Douglas Alan Samuelson, President / Chief Scientist, InfoLogix, Inc., 8711 Chippendale Court, Annandale, VA, 22003-3807, United States, samuelsondoug@yahoo.com

Consider what could happen if a highly lethal, highly infectious organism were introduced at a world-sized event such as the Olympics. Political and social consequences would greatly magnify the already horrific effect. We discuss a June 2016 wargame and related analyses that assessed this scenario. Although no such event occurred, what did happen was that Zika virus spread to 47 states of the US within two months. Much better preparedness is needed. We offer some recommendations.

**3 - Optimizing Distribution of Pandemic Influenza Antiviral Drugs**

Bismark Singh, University of Texas at Austin, Austin, TX, 78703, United States, bismark.singh@utexas.edu

We provide a method for optimizing pharmacy-based distribution of antivirals during an influenza pandemic in terms of overall access, and apply it to Texas, USA. We found that during the 2009 influenza pandemic, Texas achieved an estimated statewide access of 88% (proportion of population willing to travel to the nearest dispensing point) but only 34.5% in small ZIP codes. Optimized distribution networks increased expected access to 91% overall and 60% in hard-to-reach regions, and 2 or 3 major pharmacy chains achieved near maximal coverage in well-populated areas. This model was developed as a collaboration with public health officials and is available as a Web-based decision support tool.

**4 - Estimating Disease Burden of a Potential H7N9 Pandemic Influenza Outbreak in the United States**

Walter A Silva, PhD Candidate, University of South Florida, 4202 E. Fowler Ave, Tampa, FL, 33620, United States, silvasotillo@mail.usf.edu, Tapas K. Das

Since spring 2013, periodic emergence of avian influenza A(H7N9) virus in China has heightened concerns for a possible pandemic outbreak. Till January 2017, A(H7N9) has resulted in 918 laboratory-confirmed cases of human infections causing 359 deaths. The aim of this research is to present disease burden estimates from a potential A(H7N9) pandemic outbreak throughout the United States. The method uses a machine learning technique, an agent based simulation model and non-pharmaceutical interventions. We used U.S. demographic and epidemiological available reports. The results show that an A(H7N9) pandemic is likely to impact the lower age group at twice the rate as that of the other age groups.

**WB13**

Van Weelde Zaal, Fourth Floor

**Data-Driven Algorithms for Healthcare Problems**

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Hamsa Sridhar Bastani, Stanford University, Stanford, CA, 94305, United States, hsrldhar@stanford.edu

**1 - Data-driven Approaches to Improve the Kidney Allocation System**

Nikolaos Trichakis, MIT, 100 Main Street, E62-576, Cambridge, MA, 02143, United States, ntrichakis@mit.edu, Chaithanya Bandi, Phebe T. Vayanos

We present a data-driven optimization approach to estimate wait times for individual patients in the U.S. Kidney Allocation System, based on the very limited system information that they possess in practice. To deal with this information incompleteness, we develop a novel robust optimization analytical framework for wait time estimation in multiclass, multiserver queuing systems. We calibrate our model with highly detailed historical data and illustrate how it can be used to inform medical decision making and improve patient welfare.

**2 - Optimal Timing of Diabetes Treatment with Multiple Drugs**

Shasha Han, NUS Business School, Biz 2 Building B1, 1 Business Link, PhD Office, Singapore, shashahan@u.nus.edu, Joel Goh

Diabetes is a leading chronic condition worldwide that predisposes patients to cardiovascular conditions. Effective management of cholesterol and blood pressure levels using drugs can reduce the incidence of these negative cardiovascular outcomes. Existing guidelines for drug therapy are very broad. In this study, we develop targeted guidelines for diabetic patients based on observable demographic characteristics using a Markov Decision Process model. The model is calibrated from data drawn from a national registry of diabetic patients in a metropolitan South East Asian nation.

**3 - Bayesian Bandits for Sequential Clinical Trials of Multiple Technologies**

Ozge Yapar, The Wharton School of University of Pennsylvania, 3730 Walnut Street, 500 Jon M. Huntsman Hall, Philadelphia, PA, 19104, United States, yapar@wharton.upenn.edu, Stephen E. Chick, Noah Gans

We focus on the design of multiarm multistage (MAMS) clinical trials. We build on two trends, on the one hand allowing for more than two arms in a trial and on the other using information accumulated during a trial to modify its experimental design as the trial progresses. We frame the problem as a stoppable bandit problem with multiple correlated arms, and we allow for arbitrarily many stages of sampling by using a diffusion approximation that allows for adaptive stopping rules. We develop new allocation and stopping rules that can be used in fully sequential sampling algorithms.

**4 - Avoiding the Exploration-exploitation Tradeoff in Online Decision-making**

Hamsa Sridhar Bastani, Stanford University, 10 Comstock Circle, Apt 304, Stanford, CA, 94305, United States, hsrldhar@stanford.edu, Mohsen Bayati, Khashayar Khosravi

The contextual bandit literature focuses on an exploration-exploitation tradeoff because exploration-free greedy policies may yield poor performance in general. However, greedy policies are desirable when experimentation is costly or unethical (e.g., clinical settings). We posit a sufficient set of additional assumptions under which a greedy policy is asymptotically optimal. Next, we present Greedy-First, a new algorithm that uses observed data to determine whether to follow a greedy policy or to explore. This algorithm is asymptotically optimal without our additional assumptions, and significantly reduces experimentation in simulations.

**Wednesday, 2:30pm - 3:30pm****WP01**

Poster Session

Van der Mandele Zaal & Jurriaanse Foyer

**1 - Factors Influencing Choice of Health System Access Level in China**

Yun Liu, PhD Student, Erasmus University Rotterdam, Bayle Building-Campus Woudestein Burgemeester Oudlaan 50, Rotterdam, 3062PA, Netherlands, liu@bmg.eur.nl, Qingxia Kong, Shasha Yuan, Joris Van De Klundert

The imbalances in health system access and utilization among higher and lower level facilities in China reduce effectiveness and efficiency. We present a systematic review of the factors affecting patient choice of health system access. The results identified patient factors, provider factors, context factors and composite factors. Among the most frequently mentioned factors (drug variety, perceived quality, transportation convenience and equipment), less drug variety, obsolete equipment and perceived poor quality appear to push patients from lower level to higher level facilities. Further research is required to advance the evidence on effect sizes and the interactions between factors.

**2 - Evaluation of On-line Bin Packing Algorithm for Surgical Case Assignment**

Boon Yew Ang, Analyst, Singapore Health Services, Singapore, 169856, Singapore, ang.boon.yew@singhealth.com.sg, Shao Wei Sean Lam, Wee Kiang Andrew Tan, Li Ying Karina Ng, Meh Meh Goh, Chen Ee Lee, Eng Hock Marcus Ong, Kevin Lim, Hiang Khoon Tan

Operating theatre (OT) surgical case assignment (SCA) is an essential process which involves assigning hospital surgeries to available OT slots. On-line bin packing (OBP) algorithms are commonly used for such scheduling decisions. A discrete-event simulation model for a large public hospital in Singapore was developed and used to compare various OBP algorithms for the OTSCA.

**3 - Proactive and Dynamic Inventory Policies for Mitigation and Prevention of Drug Shortages**

Jacqueline Griffin, Northeastern University, 360 Huntington Ave., 334 Snell Engineering Center, Boston, MA, 02115, United States, ja.griffin@northeastern.edu, Rana Azghandi

Over the past decade, there has been an epidemic of drug shortages plaguing the U.S. While efforts have been made to address robustness of pharmaceutical supply chains, the shortages persist. Two common drivers of drug shortages are (1) the disruptions in manufacturing and (2) the responses by decision makers throughout the supply chain to these disruptions. To understand and characterize the relationship between these drivers we develop a systems dynamics model. We find that the best inventory policies, for various decision makers, evolve with the type of disruption. Further we develop a stochastic modeling approach to identify optimal inventory policies pertaining to system characteristics.

**4 - The Effect of Wearable Devices and Gamification on Adopting Healthier Lifestyle**

Abdullah Al Nuaim, University of Colorado Denver, 1475 Lawrence St, Denver, CO, 80202, United States, abdullah.alnuaim@ucdenver.edu, Mohammed Khojah

Fitness trackers have been promoted as a mean for adults and children to adopt an active and healthy lifestyle. However, such a claim has not been empirically tested. Our study aims to fill this gap by using a randomized control trial (RCT). Participants will be randomly assigned to control group or one of two treatment groups with different level of treatments. The results should inform healthcare professionals, educators, policy makers as well as consumers about the effect of such approach.

### 5 - Simulating Hand-washing Behaviour and Influenza Transmission from Health Initiative Studies Amongst University Students

Omid Mohammadi, Concordia University, 1515 Saint-Catherine West., EV S3.330, Montreal, QC, H3G 2W1, Canada, omid3713@gmail.com, Ketra Schmitt

We investigate the effects of participating in health awareness initiatives amongst university students and simulate their resulting behaviour in an agent-based model. Only students in the treatment group are educated by a healthcare expert on the appropriate actions and necessity of hand-washing. From both the treatment and control group, data is collected in the form of questionnaires and used for simulating the interactions of students and their hand-washing behaviour in a school setting.

### 6 - Optimal Resource Allocation for Network Protection Against Epidemic Processes

Victor Manuel Preciado, Raj and Neera Singh Assistant Professor, University of Pennsylvania, 3330 Walnut Street, Philadelphia, PA, 19103, United States, preciado@seas.upenn.edu

We study the problem of containing epidemics outbreaks taking place in an arbitrary network by distributing protection resources throughout the nodes of the network. We consider two types of protection resources: (i) Preventive resources able to defend nodes against the spread and (ii) corrective resources able to neutralize the spread after a node has been infected. We assume that both types of resources have an associated cost and study the problem of finding the cost-optimal distribution of resources throughout the nodes of the network. We show that for a wide class of cost functions, this problem can be solved in polynomial time using Geometric Programming (GP).

### 7 - Research on Medical Information Sharing of Medical Consortium in China Based on Evolutionary Game Theory

Qiang Zhang, Shanghai Jiao Tong University, Shanghai, China, zq6670418@sjtu.edu.cn

Based on evolutionary game theory, an evolutionary game model between hospitals and governments is established and the equilibrium state under different conditions are studied. The results show that reducing the risk cost of information sharing, standardizing and improving the quality of information sharing in the hospital, making attractive reward and proper punishment policy are the key factors to promote the medical information sharing. The results can provide a reference for governments to establish reward and punishment mechanism to stimulate information sharing.

### 8 - A Hybrid Genetic Algorithm with 2-D Encoding for Solving the Rehabilitation Patient Scheduling Problem

Nhat-Huynh, National Tsing Hua University, Hsinchu, Taiwan, hnto@dut.udn.vn

To enhance the patients' satisfaction and operation efficiency, this study proposed a hybrid genetic algorithm that combines genetic algorithm and simulated annealing to solve the rehabilitation patient scheduling effectively and efficiently. A special 2-dimension encoding method was designed to represent the sequence of patients and their operations. In addition, a heuristic timetabling algorithm was developed for decoding a sequence into the best solution. To validate the proposed approach, several experiments were conducted based on the real data in rehabilitation hospitals in Taiwan.

### 9 - Optimal Treatment Strategies for Glycemic Control for Patients with Type 2 Diabetes

Fanwen Meng, National Healthcare Group, 3 Fusionopolis Link, #03-08, Nexus@One-North, Singapore, 138543, Singapore, fanwen\_meng@nhg.com.sg, Yan Sun, Melvin Khee Shing Leow

In Singapore, diabetes is one of most common chronic diseases with a prevalence rate of 13% and one of the top 6 causes of death in 2015. A central focus in management of type 2 diabetes is glycemic control. In this study, we aim to determine optimal treatment policy of medication initiation for glycemic control using a Markov decision process model. We compare the derived treatment strategy with current protocol in Singapore. Preliminary numerical analysis demonstrates the improvement on expected QALYs compared with the current practice. The proposed model would facilitate clinical decision making process and help clinicians to make informed treatment decisions for patients with type 2 diabetes.

### 10 - Operating Room Re-scheduling After a Large Disruption to the Post-anesthesia Care Unit Beds

Danial Khorasanian, Isfahan University of Technology, Isfahan, 8415683111, Iran, Islamic Republic of, d.khorasanian@in.iut.ac.ir, Franklin Dexter, Ghasem Moslehi

In 2014, a sudden pipe burst resulted in loss of post-anesthesia care unit (PACU) beds in a large hospital in Boston. Some alternative beds were used for patient recovery, but capacity was less than baseline, causing many cancellations. Analogously, operating room (OR) rescheduling after an unexpected decrease in PACU beds, physical and/or nursing is considered in this paper. It is assumed that patients can be recovered in ORs or PACU, and objective is to minimize cancellations. The model can solve all instances with 4 ORs and any number of PACU beds. For instances with up to 10 ORs and any number of PACU beds, efficient solution is obtained heuristically by a hybrid method.

### 11 - The Main Opportunities & Challenges of Private Medicine in Low And Middle Income Countries of Eastern Europe

Tetyana Sandulovych, Commercial Head, Medical Plaza, Multidisciplinary Clinic, 141A O. Polya Ave, Dnipro, 49055, Ukraine, zorievna7@gmail.com

In Eastern Europe, Ukraine and Belarus, there are more than 51 million people. Health care systems in these countries are in transition from an outdated model of Healthcare (inherited from the Soviet Union) to a modern, efficient models of Healthcare system. Private medical centers have the little share of the market (about 10 per cent of Health care) , but reflect the need for patients to high-quality medical services.

### 12 - Nurses' Work with Interruptions: An Objective Model for Testing Interventions

Robert A. Myers, Wright State University, 3640 Colonel Glenn Highway, 207 Russ Engineering Center, Dayton, OH, 45435, United States, robert.a.myers@wright.edu, Pratik J. Parikh

We present a model of nurses' work, comprehending both detrimental and beneficial interruptions, and generating insights into the onset of interruptions and the evaluation of interventions. Our data driven model was informed by observation of nurses in a trauma center, including 259 interruptions during 580 nursing activities. The resulting stochastic non-stationary model, with source and activity-dependent interruptions, is instantiated as a simulation and demonstrated using interventions emulating 'do not disturb' strategies and a more focused 'triaging' of phone calls.

### 13 - Piecing Multiple Sclerosis Together through Mobile Technology

Fletcher Lee Hartsell, Clinical Assistant Professor, Duke University, 200 Trent Dr, Durham, NC, 27710, United States, lee.hartsell@duke.edu

Multiple sclerosis (MS) is an immune-mediated neurodegenerative disorder whose course is the culmination of a complex and prolonged interplay between genetics, environmental factors, and human behavior. MS Mosaic is a longitudinal study that takes advantage of recent innovations in smartphones, wearable sensors, cloud computing, and machine learning to collect, store, and analyze nearly continuous data from an engaged community of participant collaborators, thereby accelerating discovery and facilitating responsive and personalized health care.

### 14 - Redesign of Patient Flow and Resource Allocation in a High-volume Emergency Department

Sakine Batun, Middle East Technical University, Department of Industrial Engineering, Middle East Technical University, Ankara, 06800, Turkey, sakine@metu.edu.tr, Alpin Layda Özmen, Deniz Tanrikut, Gökçem Yi it, Medya Teke , Nur Keskin, Melih Celik

We consider the operations of a high-volume emergency department where the waiting times are above the acceptable levels for a significant proportion of the patients. We describe the system by using a detailed simulation model and utilize this model evaluate the impact of various improvement opportunities such as using different policies about the patient flow (e.g., about triage method, patient prioritization, patient streaming) and resource allocation (e.g., about allocation of staff to shifts and patient groups).

### 15 - The Impact of Competency Frameworks to Improve Leadership Performance in Healthcare Organisations. The Case of the Kingdom of Saudi Arabia

Namshan Algarni, PhD Researcher, Cranfield University, 315 South Row, Milton Kyens, MK9 2FH, United Kingdom, n.a.algarni@cranfield.ac.uk, Dr. Patrick McLaughlin, Dr. Ahmed Al-Ashaab

This study proposes a theoretical framework to address how leadership competency strengthens the relationship between leaders and followers in order to improve leadership performance in the healthcare organizations. This study is expected to contribute to the existing literature on leadership and social identity by providing empirical data regarding the significance of leadership competency to improve leadership performance in this sector. The suggested interventions should enabled healthcare organizations to achieve the ideal positions of these developed themes.

### 16 - Predicting Stroke Onset by Machine Learning using Medical Data, Blood Flow Simulation Data and Blood Vessel Shape Data

Masaaki Suzuki, Tokyo University of Science, Chiba, Japan, m-suzuki@rs.tus.ac.jp, Yu-Chen Chen, Soichiro Fujimura, Takashi Suzuki, Hiroyuki Takao, Toshihiro Ishibashi, Yuichi Murayama, Hayato Ohwada

Stroke is the fourth leading cause of death and the number one cause of bedridden in Japan. A stroke occurs suddenly and it is extremely difficult to predict it. The purpose of this research is to predict stroke by machine learning using medical data and engineering data, and to enable reasonable and optimal treatment according to the onset risk. In this study, we construct highly accurate classifier for stroke prediction using clinical data, computational fluid dynamics simulation data of cerebral blood flow, three-dimensional blood vessel shape data, and also extract dominant factors of onset.

**17 - Assessing Connectedness among U.S. Healthcare Facilities to Guide Regional Prevention of Multidrug Resistant Organisms**  
Rachel Slayton, U.S. Centers for Disease Control and Prevention, Atlanta, GA, United States, via3@cdc.gov, Prabasaj Paul, James Baggs, John Jernigan

We used patient-level administrative data to quantify healthcare facility connectedness through patient transfers in Oregon and Washington states. We developed a negative binomial generalized linear model to examine the association between the annual facility-level incidence of Clostridium difficile infections (CDI) and connectedness, adjusting for hospital-level factors. Connectedness was independently associated with CDI incidence; hospitals that were most highly connected had significantly higher rates. Highly connected hospitals might provide a target group for coordinated public health interventions to reduce spread of multidrug resistant organisms regionally.

**18 - Impact of Feature Selection on the Performance of Single Classifiers in Predicting Depression in the Elderly: Emphasis on Accuracy and Area under the ROC Curve**  
Eunsung Lee, Principal Researcher, CSRI (Creativity Science Research Institute), Seoul, Korea, Republic of, starystar725@gmail.com

By using 1,619 data sample regarding depression in the Korean elderly (2008 ~2013), this study analyzed the changes in performance of five single classifiers after feature selection (FS). The Best-First FS method with backward search selected four out of nine features such as the number of household members, marriage status, activities limit, and stress. Compared with the result prior to FS, the usage of those four features after FS produced statistically significant increase in the accuracy from 0.844 to 0.856 and in the AUC from 0.711 to 0.719. Single classifiers used for the experiment include logistic regression, decision tree, support vector machine, neural network, and naive Bayesian network.

**19 - Sepsis Watch: Intensive Care Unit Lab Predictions**  
Andrea McCarter, Graduate Student, Georgia Institute of Technology, Atlanta, GA, 30332, United States, amccarte@gmail.com, Soorya Eswaran, Srujana Buddi, Kevin Johnson, Kevin Gu, Kshitish Deo, Shamim Nemati, Matthew Stanley, Vibhore Kumar

The Sepsis Watch application predicts the values of six labs which are advance indicators of sepsis. Using an extract of the MIMIC III critical care database from the MIT Lab for Computational Physiology, a Gaussian process prediction model was developed for white blood counts, hemoglobin, bilirubin, platelets, creatinine, and lactate. The application, after a physician and patient are selected, launches the display of six screens with both the actual and predicted lab values. When a lab prediction is in the critical range, a mobile message is sent to the physician.

**20 - The Most Efficient Critical Vaccination Coverage and its Equivalence with Maximizing the Herd Effect**  
Lotty Evertje Duijzer, Erasmus University-Rotterdam, P.O. Box 1738, Rotterdam, 3000 DR, Netherlands, duijzer@ese.eur.nl, Willem L Jaarsveld, van, Jacco Wallinga, Rommert Dekker

We study vaccination in an age-structured population. We prove that minimizing the stockpile size that is required to prevent an increase in infections, is equivalent with maximizing the herd effect. To find the optimal allocation over the age groups, we prove that a greedy algorithm is optimal for separable mixing. For the general case, we propose an efficient solution method using Perron-Frobenius Theory. We show that the optimal allocation can considerably reduce the required vaccine stockpile.

**21- Best Combination of Base-meta Learner in the Stacking Classifier to Optimize its Performance in Predicting Depression in the Elderly**  
Kun Chang Lee, Professor, Sungkyunkwan University, Myung Ryun 3-53, Chong No-Ku, Seoul, 03063, Korea, Republic of, kunchanglee@gmail.com, Kun Chang Lee, Professor, SAIST (Samsung Advanced Institute for Health Sciences & Technology), Myung Ryun 3-53, Chong No-Ku, Seoul, 03063, Korea, Republic of, kunchanglee@gmail.com

In the healthcare studies, stacking has been used extensively as one of ensemble classifiers. It is basically composed of base-meta learner. Therefore, how to combine the base-meta learners really matters to the stacking performance. However, there is no study investigating the best combination of base-meta learners in the stacking to predict depression in the elderly. By using KNHANES data samples and five single classifiers (LR, DT, NN, SVM, NBN), we applied a number of base-meta learner combinations to compute changes in accuracy and AUC. The stacking worked best when LR-DT is used as a base-meta combination, with accuracy 0.852 and AUC 0.798. The combination NN-SVM was the poorest with AUC 0.50.

**22 - Reducing the Dimensionality of Patient Pathway Analysis: An Algorithmic Approach**  
Katherine Bobroske, University of Cambridge, Trumpington St, Cambridge, CB2 1AG, United Kingdom, kab80@cam.ac.uk, Michael Freeman, Feryal Erhun, Lawrence Huan

There exist numerous combinations of patient pathways for any single disease, making it difficult for physicians to understand and recommend the most appropriate treatment plan. We propose an application of the Needleman-Wunsch algorithm to evaluate similarities (both in content and structure) between two patient pathways. Then we propose an unsupervised algorithm to cluster similar pathways. Researchers can leverage this approach to better understand pathway characteristics and consequences.

**23 - Exploring the Impact of Security and Privacy on Mobile Health Applications Ranking**  
Yazan Alnsour, University of Illinois Springfield, Springfield, IL, 62703, United States, yalns2@uis.edu

The wide spread of mobile technology motivated healthcare providers to embrace mobile health technology. Although enabling users to utilize mobile devices to communicate with providers and access services offers numerous benefits, many risks regarding security and privacy arise. This research investigates how security and privacy measures impact the ranking of mHealth apps in the digital market. A dataset of 3,000 health apps was collected to conduct an empirical analysis. We find that high measures of security and privacy positively impact the ranking of the health app.

**24 - A Fuzzy Hybrid MCDM Approach for Health Technology Assessment**  
Hakan Tozan, Assoc. Prof., Istanbul Medipol University, Beykoz, Istanbul, 34810, Turkey, e.hakan.t@gmail.com, Mumtaz Karatas

In this study, we have developed a hybrid fuzzy multi-criteria decision making (MCDM) support tool which combines four MCDM methods: viz. AHP, VIKOR, TOPSIS, and Goal Programming, for health technology Assessment. Three health technology alternatives with respect to 22 criteria have been assessed as an application.

**Wednesday, 3:30pm - 5:00pm**

**■ WC02**

Arcadis Zaal, First Floor

**EMS Related Topics**

Invited: Health Operations Management

Invited Session

Chair: Derya Demirtas, University of Twente, P.O. Box 217, Enschede, 7500 AE, Netherlands, d.demirtas@utwente.nl

**1 - Models for Proactive Relocations of Ambulances**  
Robert van der Mei, CWI & VU University Amsterdam, Science Park 123, Amsterdam, 1098XG, Netherlands, mei@cwi.nl

In serious life threatening situations where every second counts, the time presence of an ambulance at the emergency scene can make the difference between survival and death. Dynamic Ambulance Management (DAM) provides a powerful means to reduce ambulance response times. In this talk, I will discuss several relocation algorithms for DAM, and research challenges that we are facing.

**2 - Comparison of Static Ambulance Location Models**  
Theresia van Essen, Delft University of Technology, Mekelweg 4, Delft, 2628 CD, Netherlands, j.t.vanessen@tudelft.nl, Pieter van den Berg

We compare several ambulance location models on coverage and response time criteria. The computational results show that the Maximum Expected Covering Location Problem (MEXCLP) and Average Response Time Model (ARTM) perform the best over all considered criteria. Based on these results, we propose four alternative models that combine the good coverage provided by MEXCLP and the quick response times provided by ARTM. All considered models provide good solutions, however, the Multiple Response Times Target Model (MRTTM) outperforms the other models based on computation time.

### 3 - Incorporating Coverage for Emergency Calls in Scheduling Patient Transportations

Pieter van den Berg, RSM, Burgemeester Oudlaan 50, Rotterdam, 3062 PA, Netherlands, vandenbergrsm@rsm.nl, Theresia van Essen

Many ambulance providers operate both advanced life support (ALS) and basic life support (BLS) ambulances. Typically, emergency calls can only be executed by ALS vehicles, whereas non-urgent patient transportations can either be served by an ALS or a BLS ambulance. BLS vehicle capacity does normally not suffice for all transportation requests. The remaining transportations are performed by ALS ambulances, which reduces coverage for emergency calls. We present a model to determine routes for BLS vehicles, so as to maximize the remaining coverage by ALS ambulances.

### 4 - Do High Risk Neighbourhoods Stay High Risk?: Spatiotemporal Trend Analysis of Out-of-Hospital Cardiac Arrests

Derya Demirtas, University of Twente, Dept. Industrial Engineering & BIS, P.O. Box 217, Enschede, 7500AE, Netherlands, d.demirtas@utwente.nl, Timothy Chan

Cardiac arrest intervention and prevention programs should target geographical areas with high risk of out-of-hospital cardiac arrest (OHCA). Although these long-term, location-based interventions implicitly assume that the geographical distribution of OHCA risk remains stable over time, there is a paucity of evidence to support this assumption. This study measures the spatiotemporal stability of OHCA at the neighbourhood level in a large Canadian urban setting.

## WC03

Zeelenberg Zaal, Second Floor

### Operations Research for Chronic Care

Sponsored: Public Health and Policy Making

Sponsored Session

Chair: Vedat Verter, McGill University, Montreal, QC, H3A 1G5, Canada, vedat.verter@mcgill.ca

#### 1 - Incentive Design for Coordination in Care of Chronic Patients

Sasa Zorc, INSEAD, 1 Ayer Rajah Avenue, PhD Office, Singapore, 138676, Singapore, sasa.zorc@insead.edu, Stephen E Chick, Sameer Hasija

We develop a model of outcomes-based contracting in care of chronic patients, using data from United Kingdom's NHS. The government contracts with healthcare providers in effort to maximise population health minus the cost. We consider the decision of whether to contract with individual healthcare providers or groups of such providers, as well as which contract type to use. Individual contracts fail to provide the desired incentives if providers under such contracts cooperate (collusion), however so do group contracts if group members fail to coordinate (free-riding). We demonstrate that individual outcomes-adjusted capitation contracts are the most resistant to these adverse effects.

#### 2 - A Model for Managing Chronic Care with Patient Activation Measures

Evrin D Gunes, Koc University, Rumeli Feneri Yolu, Sariyer, Istanbul, 34450, Turkey, egunes@ku.edu.tr, Lerzan E. Ormeci, Odysseas Kanavetas, Christos Vasilakis

We develop a MDP framework to manage care for patients with multiple chronic conditions via a complex care hub. Complex care provision influences the evolution of PAM, an indicator for healthy behavior, which affects the evolution of health state of patients. We explore optimal policies to minimise healthcare costs.

#### 3 - Incentive Programs for Reducing Readmissions when Patient Care is Co-produced

Dimitrios Andritsos, HEC Paris, Departement MOSI, 1 Rue De La Liberation, Jouy-en-Josas, 78351, France, andritsos@hec.fr, Christopher S Tang

To compare the effectiveness of three different hospital reimbursement schemes (i.e., Fee-for-Service, Pay-for-Performance and Bundled Payment) in reducing readmissions, we develop a "health co-production" model in which the patient's readmission is "jointly controlled" by the efforts exerted by both the hospital and the patient.

### 4 - Designing a Rural Network of Dialysis Facilities

Vedat Verter, McGill University, Faculty of Mgmt, 1001 Sherbrooke Street West, Montreal, QC, H3A 1G5, Canada, vedat.verter@mcgill.ca, Michael Klein, Brian Moses

We study the Dialysis Facility Network Design Problem, where long travel times impact patient welfare. Regardless of the travel burden, some patients will always opt to go to an in-centre or satellite facility, while others will always opt for home dialysis. For many, the choice will vary depending on the location of available facilities. The model determines the best network of dialysis facilities with consideration for budget and capacity management constraints as well as patient preferences for facility or home dialysis. Through a case study, we find that with the same budget, the optimal solution results in considerable reductions in maximum and mean patient travel times with less variability.

## WC04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning III

Contributed Session

Chair: Dursun Delen, Oklahoma State University, 700 North Greenwood Avenue, Tulsa, OK, 74106, United States, dursun.delen@okstate.edu

#### 1 - Hierarchical Infinite Factor Models for Improving the Prediction of Surgical Complications Across Hospitals

Katherin Heller, Duke University, Durham, NC, United States, kheller@gmail.com, Elizabeth Lorenzi

In order to better predict surgical complications at a particular hospital, we develop a hierarchical latent factor transfer learning model, which leverages data on surgical complications across all hospitals nationally. Our goal is to build a risk-assessment model for surgery patients in our own hospital, using institutional and national surgical outcomes data. The national surgical outcomes data is collected through NSQIP (National Surgery Quality Improvement Program), a database housing almost 4 million patients from over 700 hospitals. We find that our methodology can model surgical complications well, improving overall predictions at our hospital.

#### 2 - Cluster-based Identification of Heterogeneity in Meta-analysis

Andreas Brieden, Full Professor, UniBW Munich, Werner-Heisenberg-Weg 39, Neubiberg, 85579, Germany, andreas.brieden@unibw.de

In classical meta-analysis fixed or random effect models are frequently applied to estimate the effect of a new medical treatment for the patients. Although these models allow for some heterogeneity in the results of the different studies which have to be integrated it might happen that the degree of heterogeneity is too large to accept the results of the meta-analysis. A typical reason for such an effect could be a significant difference in the study cohorts with respect to relevant clinical parameters. In this talk a twostep approach to handle this heterogeneity is presented. In a first step homogeneous cohorts are computed by means of quadratic optimization, followed by cluster based meta-analyses.

#### 3 - Multicriteria Decision Analysis for Production Capacity and Demand of Patients: A Case Study in a Hospital in Brazil

Thiago Magalhaes Amaral, UNIVASE, Petrolina, Brazil, prof.thiago.magalhaes@gmail.com, Júlia Góes Matos, Ana Cristina Gonçalves Castro Silva

Demand forecasting and multicriteria decision used to support strategic planning of hospital, where it is assumed that demand of may have seasonality trends and more possible alternatives to solve the overcrowding problem. The best alternatives to adjust the hospital's production capacity to the demand of patients can be chosen using and comparing different demand forecasting models associated with the multicriteria decision method PROMETHEE II. Study show that the linear regression and Holt-Winters multiplicative seasonality method for a period of twelve months have adapted better. Improved flow of information showed the most suitable alternative for solving the problem of the hospital.

#### 4 - Development of a State-of-the-art CDSS for Diabetic Retinopathy

Dursun Delen, Research Director, Professor & Research Director, 700 N. Greenwood Ave., OSU Tulsa, NH341, Tulsa, OK, 74106, United States, dursun.delen@okstate.edu, Saeed Piri

We present the results and the lessons-learned of developing a CDSS for early detection/diagnosis of diabetic retinopathy. Although preventable with early diagnosis, retinopathy is the most common cause of vision loss among diabetic patients. In this study, we analyzed EHR data from more than 1.4M diabetic patients to develop several types of predictive models, each focusing on discerning characteristics of the data/features included and/or different data preprocessing methods employed. Along with the presentation of the comparative analyses (i.e., the prediction accuracy of different models), ranked-importance of variables and practical implications of the CDSS are also discussed.

## WC05

Schadee Zaal, Third Floor

### Managing Health Care Costs and Quality under Uncertainty

Invited: Health Operations Management

Invited Session

Chair: Hummy Song, The Wharton School, University of Pennsylvania, Philadelphia, PA, 19104, United States, hummy@wharton.upenn.edu

#### 1 - Yardstick Competition for Service Systems and Hospital Reimbursement

Nicos Savva, London Business School, Regent's Park, London, NW1 4SA, United Kingdom, nsavva@london.edu, Tolga Tezcan, Ozlem Yildiz

Yardstick competition is a regulatory scheme for local monopolists (e.g., hospitals), where the monopolist's reimbursement is linked to her performance relative to other equivalent monopolists. This regulatory scheme provides cost-reduction incentives and has been used for hospital reimbursement throughout the developed world. This paper uses a game-theoretic queueing model to investigate how yardstick competition performs in service systems (e.g., hospital emergency departments), where, in addition to incentivizing cost reduction, the regulator's goal is to provide incentives to reduce customers' waiting times.

#### 2 - Gatekeeping under Time Pressure: An Empirical Study of Hospital Admission Decisions in the Emergency Department

Michael Freeman, Judge Business School, University of Cambridge, Trumpington Street, Cambridge, CB2 1AG, United Kingdom, mef35@cam.ac.uk, Susan Robinson, Stefan Scholtes

We study admission decisions made by physicians in a congested ED using a data set comprising more than 600,000 visits over a 7-year period. We find that when the ED becomes busier, physicians make increasingly more observational admissions but also fewer discharge errors. This leads to a bullwhip-type effect: demand surges in the ED leads to relatively greater demand pressures in the hospital. We then identify an intervention that can significantly reduce the negative demand-propagation effect.

#### 3 - Allocating Inpatient Beds to Off-service Patients: Tradeoffs and Consequences

Hummy Song, The Wharton School, University of Pennsylvania, 560 Jon M. Huntsman Hall, 3730 Walnut Street, Philadelphia, PA, 19104, United States, hummy@wharton.upenn.edu, Anita L. Tucker, Ryan Graue, Sarah Moravick, Julius Yang

Given a highly variable patient census at the service line level yet a fixed allocation of inpatient beds to service lines, a significant portion of admitted patients become "off-service" patients. These patients are physically located in a bed that belongs to a different service line while still being cared for by a physician of the service line. We examine the tradeoffs and consequences of assigning incoming patients to an off-service bed as opposed to an on-service bed.

## WC06

Van Beuningen Zaal, Third Floor

### Panel Session: Developing Natural History Models for Medical Decision Making

Invited: Medical Decision Making

Invited Session

Moderator: Oguzhan Alagoz, University of Wisconsin-Madison, Madison, WI, 53706, United States, alagoz@engr.wisc.edu

#### 1- Panel on Developing Natural History Models for Medical Decision Making

Oguzhan Alagoz, University of Wisconsin-Madison, 3242 Mechanical Engineering Building, 1513 University Avenue, Madison, WI, 53706, United States, alagoz@engr.wisc.edu

Natural history of a disease, which represents the onset and progression of a disease without an intervention, provides critical inputs for operations research models for medical decision making. We will share our experiences in developing natural history models for various diseases including end-stage liver diseases and breast cancer. We will also focus on challenges and opportunities associated with developing natural history models.

#### 2 - Panelist – Natural History Modeling For End-stage Liver Disease And Breast Cancer

Oguzhan Alagoz, University of Wisconsin-Madison, 3242 Mechanical Engineering Building, 1513 University Avenue, Madison, WI, 53706, United States, alagoz@engr.wisc.edu

#### 3 - Panelist – Using Longitudinal Data to Build Natural History Models

Brian T Denton, University of Michigan, 2893 IOE Building, Dept of Industrial and Operations Engineering, Ann Arbor, MI, 48109-2117, United States, btdenton@umich.edu

#### 4 - Panelist

Ayca Erdogan, San Jose State University, Davidson College of Engineering, Industrial and Systems Engineering, San Jose, CA, 95192, United States, ayca.erdogan@sjsu.edu

#### 5 - Panelist

Julie Simmons Ivy, North Carolina State University, 111 Lampe Drive, P.O. Box 7906, Raleigh, NC, 27695-7906, United States, jsivy@ncsu.edu

## WC08

Ruys Zaal, Fourth Floor

### Mathematical Models of Sepsis and Hospital-Acquired Infections

Invited: Health Operations Management

Invited Session

Chair: Sean Barnes, Univ of Maryland-College Park, College Park, MD, 20742, United States, sbarnes@rhsmith.umd.edu

#### 1 - Personalizing Interventions in Multimorbid Patients with Sepsis

Julie Simmons Ivy, North Carolina State University, 111 Lampe Drive, P.O. Box 7906, Raleigh, NC, 27695-7906, United States, jsivy@ncsu.edu, Nisha Nataraj, Muge Capan, James R Wilson, Ryan Arnold, Jeanne Marie Huddleston

The lack of a gold-standard diagnostic test makes sepsis, the leading cause of in-hospital mortality, difficult to diagnose and necessitates timely intervention. The presence of comorbidities further complicates diagnosis and treatment. This study uses inpatient electronic health records over multiple visits from a large hospital system to develop a simulation-based framework to personalize sepsis intervention strategies based on comorbidity profiles identified via hierarchical cluster analysis.

#### 2 - Agent-based Mediation Modeling of a Controlled Trial to Reduce the Transmission of Multidrug-resistant Organisms

Sean Barnes, Univ of Maryland-College Park, 4352 Van Munching Hall, University of Maryland, College Park, MD, 20742, United States, sbarnes@rhsmith.umd.edu, Daniel Morgan, Lisa Pineles, Anthony Harris

In 2011-2012, the University of Maryland School of Medicine led a 20-site randomized controlled trial to assess the benefits of universal gloves and gowns to reduce the transmission of multidrug-resistant organisms in acute-care hospitals. This intervention resulted in a statistically significant decrease in the acquisition rate for methicillin-resistant *Staphylococcus aureus*, but the direct effect, relative to secondary effects such as the hand hygiene compliance of healthcare workers and visit rates to patients, was unclear. We develop an agent-based model and, after calibration it across all study sites, use it to estimate the reduction in transmission directly due to this intervention.

#### 3 - MRSA Transmission Dynamics in an Endemic NICU Setting with a Targeted Decolonization Program

Rebecca Pierce, Johns Hopkins Bloomberg School of Public Health, 235 Carroll St. NW, Apt. 417, Baltimore, MD, United States, rpierc13@jhu.edu, Aaron M. Milstone, Justin Lessler

MRSA is a leading cause of infection in the NICU. We assessed the impact of decolonization on unit-based MRSA transmission. Retrospective NICU data (2007-2014) were collected. We used MCMC methods to fit a probabilistic transmission model to this data. To account for weekly screening, we imputed MRSA colonization times. 4412 neonates were admitted and screened for MRSA. We observed 84 incident MRSA-positives. The per-day probability of MRSA transmission from decolonized neonates was 95% less than that from MRSA-colonized, non-decolonized neonates (0.00045% vs 0.0086%, ratio=0.05, 95% credible interval ratio: 0.02-0.09). Decolonization appears to reduce risk of MRSA transmission in the NICU.

## ■ WC09

Van Rijckevorsel Zaal, Fourth Floor

### Scheduling and Planning III

Contributed Session

Chair: Samuel van Brummelen, University of Twente, Drienerloaan 5, Enschede, 7522 NB, Netherlands, s.p.j.vanbrummelen@utwente.nl

#### 1 - Outpatient Appointment Scheduling: What is the Problem?

Alex Kuiper, Assistant professor, University of Amsterdam, Plantage Muidergracht 12, Amsterdam, 1018 TV, Netherlands, a.kuiper@uva.nl, Jeroen de Mast

We find that the problem of appointment scheduling has meager substantiation, neither from the perspective of theory in operations management, nor from field studies analyzing the actual objectives and challenges of appointment scheduling in real healthcare operations. Therefore, by means of a multiple case study research, we address two research questions: What is the structure of the problem of appointment scheduling in outpatient clinics? What are current practices and underlying assumptions and conceptualizations in the field? The study is limited to static scheduling in outpatient clinics.

#### 2 - Multi-period Appointment Sequencing and Scheduling

Sakine Batun, Middle East Technical University, Department of Industrial Engineering, Middle East Technical University, Ankara, 06800, Turkey, sakine@metu.edu.tr, Utku Tarik Bilgic

Single-period appointment scheduling for a given sequence of outpatient procedures is a well-studied problem. We consider the problem of determining the sequence of and the appointment times for a given set of surgeries to be operated over a multi-period planning horizon in the presence of patient no-shows and uncertainty in surgery durations. We formulate and solve the problem as a two-stage stochastic program to estimate the value of capturing uncertainty, simultaneous optimization of sequencing and scheduling decisions, and considering a multi-period planning horizon.

#### 3 - Dynamic Appointment Based on Behaviors of Heterogeneous Outpatients

Wensi Zhang, Beijing Institute of Technology, No. 5 Zhongguancun South Street, Haidian, Beijing, 100081, China, wensi0211@hotmail.com

Considering heterogeneous patients with different service durations, the dynamic appointment problem is modeled as Markov decision process in discrete time to maximize expected profit of the system by drawing upon ideas from capacity allocation. Overbooking policy is deployed to eliminate the impact of patient cancellation and no-show behaviors. Optimal dynamic appointment policy is obtained by backward induction dynamically allocate available capacity to incoming demand. For the purpose of decreasing dimensions of system state space, a heuristic method is introduced to solve the problem and the effectiveness of heuristic method has been illustrated by simulation.

#### 4 - Combining Appointments and Walk-in at Dutch Blood Collection Sites.

Samuel P. van Brummelen, Sanquin Research, Amsterdam, Netherlands, s.p.j.vanbrummelen@utwente.nl, Marieke Dijkink, Katja van den Hurk, Wim L. de Kort, Nico M. Van Dijk

The Dutch organization responsible for blood collection and distribution, Sanquin, wants to implement an appointment system for whole blood donors, and aims for 80% of the whole blood donations to use this new system instead of the current walk-in system. We present an approach to schedule the appointments in this new system using a queuing model, taking the already existing appointments for plasma donors and the arrival pattern of the remaining walk-in donors into account.

## ■ WC10

Plate Zaal, Fourth Floor

### Supply Chains III

Contributed Session

Chair: Rommert Dekker, Erasmus University-Rotterdam, Burg. Oudlaan 50, P. O. Box 1738, Rotterdam, 3000 DR, Netherlands, rdekker@ese.eur.nl

#### 1 - An Examination of Optimal Strategies to Reduce Smoking Prevalence and Related Intervention Costs: An Optimal Control Problem

Ruoyan Sun, University of Michigan, Ann Arbor, MI, United States, sunry@umich.edu, David Mendez

We construct a time-variant optimal control model to figure out the best combination of initiation & cessation programs over time that minimizes the weighted sum of smoking prevalence & program costs. We obtain the optimal solution to the model analytically & further analyze the ratio of optimal initiation

& cessation programs. We use results from two empirical interventions in the UK and the National Survey on Drug Use and Health in the US to set parameter values. The optimal cost ratio starts around 0.14 & increases to 1.74 in 30 years. Smoking prevalence is estimated to be 2.97% with optimal interventions versus the original 8.54% in 30 years. Two extensions of this model are also discussed.

#### 2 - Public Pharmaceuticals Supply Chain Reform in Morocco

Abdelaziz Berrado, University Mohammed V in Rabat, BP 765, Avenue Ibn Sina, Agdal, Rabat, 10080, Morocco, berrado@emi.ac.ma, Abdelaziz Berrado, Ecole Mohammadia D'Ingenieurs, Rabat, Morocco, berrado@emi.ac.ma

The Moroccan Ministry of Health seeks the redesign of its public pharmaceutical products supply chain. In this policy framework, we are considering a research direction about the redesign of the distribution network of this SC taking into account the specificity of the health sector in this emerging country. Prior work led to the choice of a distribution network design at a macro level taking into account the preferences of the decision makers at the and patients' priorities. Now, it is a matter of making decisions concerning facilities' locations, capacity and roles and to shed light on the appropriate transportation strategy and multi-echelons inventory policies for this SC.

#### 3 - Literature Review the Vaccine Supply Chain

Rommert Dekker, Erasmus University-Rotterdam, Burg. Oudlaan 50, P.O Box 1738, Rotterdam, 3000 DR, Netherlands, rdekker@ese.eur.nl, Lotty Evertje Duijzer, Willem Jaarsveld, van

In this literature review we classify the literature on vaccine logistics using a supply chain perspective. We distinguish between the following four components: composition, production, allocation and distribution. We find that the vaccine supply chain is characterized by high uncertainty in both supply and demand; asymmetry between supplier, public health organization and end customer; complex political decisions concerning allocation and the crucial importance of deciding and acting in time.

## ■ WC11

Van der Vorm Zaal, Fourth Floor

### Medical Decision Making III

Contributed Session

Chair: Alejandro Marciano, Karolinska Institutet, K54, Stockholm, 14186, Sweden, alejandro.marciano@ki.se

#### 1 - Estimating the Risk of Reidentification in Healthcare Data

Anand N. Vidyashankar, George Mason University, 4000 University Drive MS4A7, Fairfax, VA, 22030, United States, avidyash@gmu.edu

Estimating the risk of re-identification from de-identified healthcare data is critical due to regulatory and contractual restrictions. In this talk, we describe new composite metrics, robust statistical models and methods for estimating this risk and study their properties. We establish that while our proposed methods facilitate a principled approach for sharing information between healthcare entities, compared to naive approaches, they also minimize the operational cost for a variety of practically encountered cost functions. We also evaluate our methods under model misspecification. We illustrate the impact of the findings on the existing policy using publicly available datasets.

#### 2 - Richness of Home Health Data for Value Based Care and Outcomes

Jakka Sairamesh, CEO and President, CapsicoHealth, Inc, 2225 E Bayshore Rd STE 200, Palo Alto, CA, 94303, United States, jramesh\_88@yahoo.com, Robert Rosati

Home health care (Medicare based) is based on a 60-day episode model which enables a rich data driven (OASIS) foundation for patient quality improvement, appropriate matching of patient needs to services. We will present a rich data platform that brings together clinical, cost and financial data for providers to reduce cost of care, improve quality and prepare for future value based payment programs. We present risk models for ED visit risk and hospitalization showed nearly a 0.82 C-statistic value and a 0.69 PPV value (precision). The models for high utilization showed a C-statistic value of 0.78 for predicting a high PMPM (\$2000 per month per member).

### 3 - Developing an Artificial Intelligence Hybrid Model Based on Neural Networks in Decision Support Systems in the Field of Medical Data

Roya Soltani, Islamic Azad University Science and Research Branch, Tehran, Iran, Islamic Republic of, royasoltani@iust.ac.ir, Arvin Azizian, Reza Tavakkoli Moghaddam

Considering the importance of predicting cardiac-pulmonary test results on Chemical injuries' expensive data and the high cost of these tests for chemical injuries, the high time consumption nature of these tests in the stage of performing and results announcement, as well as knowing that at different stages (e.g. user error in recording the results), there is also the possibility of data loss, the missing data and then isolating them have been addressed in the present study and K-means method has been used to fill the missing values.

### 4 - The Socioeconomic Implications of Treatment – The Role of Multiregistry-based Population Studies in Musculoskeletal Conditions

Alejandro Marcano, MD, Karolinska Institutet, Karolinska Institutet, K54, Stockholm, 14186, Sweden, alejandro.marcano@ki.se, Richard Nordenvall, Pär Karlsson, Martin Gerdin, Johanna Adami, Mårten Palme, Ville Mattila, Shahram Bahmanyar, Li Felländer-Tsai

The effects of medical treatment can extend to the economy and society. A deeper understanding of how treatment choices affect non-clinical outcomes is necessary, especially in orthopedics where restoring optimal physical function is critical. We linked data from national registries and studied how treatment choice affects income, adjusting for sex, age, comorbidities, type of work, region and education. This population-based model shows how some covariates such as sex, age, level of education and type of work can modify the effect of treatment. The study of covariates supports the decision-making process, guiding the physician about which patients could benefit from surgical procedures.

## ■ WC12

Mees Zaal, Fourth Floor

### Disease and Treatment Modeling II

Contributed Session

Chair: Jussi Keppo, National University of Singapore, Mochtar Riady Building, BIZ 1 8-69, 15 Kent Ridge Drive, Singapore, 119245, Singapore, keppo@nus.edu.sg

#### 1 - Forecasting Outpatient Visits for Influenza-like Illness in Taiwan

Mei-Ting Tsai, Associate Professor, National Chung Hsing University, 145 Xingda Road, Department of Business Administration, Taichung, 40227, Taiwan, mtsai@dragon.nchu.edu.tw, Jui-Ying Tsai

Studies on Influenza-like Illness (ILI) have been getting lots of attention. During flu seasons, the number of outpatient for ILI is very volatile, which complicates preparation of medical supply. Scholars have tried to forecast ILI from different sources and angles. In addition to the temporal correlation, this study investigates the geographic correlation of ILI patients among cities in Taiwan. Data collected from Centers for Disease Control since 2009 are adopted to construct an empirical example. The proposed models are expected to provide more accurate forecasting results.

#### 2 - Assessing Intervention Strategies for Influenza using a Closed Form Formula for R0

Zeynep Gökçe Yildiz, PhD Student, Bogazici University, Istanbul, Turkey, zeynep.yildiz@boun.edu.tr

The behaviour of agent based disease spread models with overlapping mixing groups is mainly assessed by simulation. We develop a formula that can calculate the exact value of R0 in stochastic SIR models with overlapping mixing groups. It can be used for parameter calibration and the assessment of different intervention strategies especially household quarantine, use of antiviral drugs and vaccination are considered.

#### 3 - Simulating the Rate of Transmission for Influenza Within an Aircraft Cabin During a Commercial Flight

Mojtaba Zargoush, Concordia University, 1515 Saint-Catherine St W, EV 13-109, Montreal, QC, H3G 2W1, Canada, mj.zargoush@gmail.com, Ketra Schmitt, Ali Akgunduz

Inflight transmission of communicable disease is often cited as a risk of air travel. However, few studies have investigated the disease dynamics of transmission inflight, particularly during the peak season of a disease. We simulate the rate of transmission of influenza within an aircraft using numerous preventive factors. We implement an agent-based model to evaluate different strategies such as using face masks, regular sanitizing, installing UV lights, and redesigning floor plans such as using curtains between seating, to find solutions to decrease influenza transmission.

#### 4 - Understanding the Swine Flu Epidemic with an Equilibrium Vigilance Model

Jussi Keppo, National University of Singapore, Mochtar Riady Building, BIZ 1 8-69, 15 Kent Ridge Drive, Singapore, 119245, Singapore, keppo@nus.edu.sg, Elena Quercioli, Lones Smith

Contagious diseases are passed on when contagious and susceptible individuals meet. This paper introduces and explores a new matching game, characterized by individuals meeting pairwise, possibly unwittingly passing along a disease in a contagion-like fashion. We assume that individuals can expend costly effort to avoid acquiring it. In this population game, efforts are strategic substitutes: The harder other individuals try, the more lax one can be. We solve for the unique Nash equilibrium when individuals are heterogeneous. We then estimate this structural model and show that it improves on the explanation of the data without endogenous behavior.

## ■ WC13

Van Weelde Zaal, Fourth Floor

### Public Health Preparedness: Answering (Largely Unanswerable) Questions with Operations Research

Invited: Public Health and Policy Making

Invited Session

Chair: Margaret L. Brandeau, Stanford University, Stanford, CA, 94305-4026, United States, brandeau@stanford.edu

#### 1 - Public Health Preparedness: Answering (Largely Unanswerable) Questions with Operations Research

Margaret L Brandeau, Stanford University, Management Science and Engineering, 475 Via Ortega, Stanford, CA, 94305-4026, United States, brandeau@stanford.edu

Public health security - achieved by effectively preventing, detecting, and responding to events that affect public health such as bioterrorism, disasters, and naturally occurring disease outbreaks - is a key aspect of national security. However, effective public health preparedness depends on answering largely unanswerable questions. For example: What is the chance of a bioterror attack in the United States in the next five years? What is the chance of an anthrax attack? What might be the location and magnitude of such an attack? This talk describes how OR-based analyses can provide insight into complex public health preparedness planning problems - and thus support good decisions.

## Thursday, 8:30am - 10:00am

## ■ TA01

Van Cappellen Zaal, Ground Level

### Scheduling and Planning IV

Contributed Session

Chair: Ilze Ziedins, The University of Auckland, Department of Statistics, Private Bag 92019, Auckland, 1, New Zealand, i.ziedins@auckland.ac.nz

#### 1 - Enhancing Optimization-based Tools to Support Long-term Care Planning: Combining Stochastic Models with Scenario Reduction Approaches

Teresa Cardoso-Grilo, Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal, teresa.sofia.grilo@iscte.pt, Centre for Management Studies, Instituto Superior Técnico, Lisbon, Portugal, teresa.sofia.grilo@iscte.pt, Mónica Oliveira, Ana Barbosa-Póvoa

Improving long-term care (LTC) delivery is in the political agenda of European countries with a National Health Service structure. An adequate planning of such networks implies accounting for multiple policy objectives, such as equity, health and wellbeing benefits, and costs, as well as anticipating the impact of key uncertainties. This study proposes a stochastic multi-objective mathematical programming model to support the planning of LTC networks (in terms of services' location and capacity planning), which is informed by alternative scenario reduction techniques. A Portuguese case study is explored showing the scope for exploring novel approaches for scenario reduction.

## 2 - An Effective Adding Capacity Policy in Outpatient Capacity Allocation

Bowen Jiang, Northeastern University, Dalian, China, ddxx100@sina.cn, Jiafu Tang, Chongjun Yan

Adding capacity policy allows using additional capacity if all regular capacity is reserved for both routine patients and same-day patients. Uncertainties of patient demand and no-show are considered when formulating doctor overload, which causes weighted cost by additional capacity. Numbers of additional capacity (NA) and regular capacity allocated to routine patient (Nr) are two decision variables towards the maximum expected profit. We prove that the expected profit is a unimodal function of the additional capacity when its number exceeds a threshold. Numerical experiments show that Nr is more stable to the change of no-show probability under the adding capacity policy.

## 3 - Threshold Policy for Operational Difficulties in Reverse Referral Partnerships

De Teng, Shanghai Jiao Tong University, Shanghai, China, tengde143@163.com, Na Li, Nan Kong

Reverse referral, implemented to alleviate the imbalanced utilization of medical resource in Chinese hierarchical healthcare system, is facing some operational difficulties caused by profit-driven features of hospitals. To deal with these difficulties, we propose a self-optimized threshold control policy, which is applied in three scenarios in a Two-level Cooperative Hospitals System of reverse referral partnerships. Optimization based on queuing performance measures and iterative simulation are used to derive the optimal control policies.

## 4 - Strategic Bidding in a Discrete Accumulating Priority Queue

Ilze Ziedins, The University of Auckland, Department of Statistics, Private Bag 92019, Auckland, New Zealand, i.ziedins@auckland.ac.nz, Raneetha Abeywickrama, Moshe Haviv

We consider a single server M/G/1 queue in which customers accumulate priority linearly while waiting. The rate at which a customer accumulates priority depends on the priority class they have entered. Upon arrival, each customer pays to enter one of the finite number of priority classes, without knowing the state of the queue. Accumulating priority queues have been proposed for healthcare settings, since they permit a patient's priority to increase with time spent in the queue. We obtain the Nash equilibrium for this system.

## TA02

Arcadis Zaal, First Floor

### Emergency Medical Services I

Contributed Session

Chair: Henrik Andersson, Norwegian University of Science & Technology, Gloschaugen, Alfred Getz vei 3, Trondheim, 7491, Norway, henrik.andersson@iot.ntnu.no

#### 1 - The New Bi-objective Mathematical Model for Locating Emergency Medical Service

Ehsan Rashidzadeh, PhD Student of Industrial Engineering, Islamic Azad University, Science and Research Branch, Daneshgah Blvd, Simon Bulivar Blvd, Tehran, Iran, Islamic Republic of, ehsan\_rashidzadeh67@yahoo.com, Hedyeh Tahmouresi, Reza Fattahi

Emergency Medical Service is the first step to survive people who need medical services. The location of EMS plays substantial role to decrease the response time and saving people's live. Establishing cost of EMS and increasing number of served patients, are two conflict objectives. In this work, we use location problem to present a bi-objective mathematical programming model and solving it in order to maximize expected survival probability of patients and minimize establishing costs of EMS stations.

#### 2 - Using the "Floating Patients" Method to Balance Crowding between the Hospital Emergency Department and Other Departments

Guy Wachtel, Bar-Ilan University, Ramat Gan, Israel, Guy.Wachtel@biu.ac.il, Amir Elalouf

We propose a model and scheduling algorithmic approach to reduce crowding in emergency departments (EDs) and ameliorate patients service. The method is a Floating Patients (FP) one: ED triage send some patients to hospitalization departments instead of performing full tests in the ED, thus balancing crowding between departments. An efficient Fully Polynomial Time Approximation Scheme (FPTAS) gives fair results. We present first notes from its application in a real ED.

## 3 - Strategic Ambulance Location for Heterogeneous Regions

Henrik Andersson, Norwegian University of Science and Technology, Gloschaugen, Alfred Getz vei 3, Trondheim, 7491, Norway, henrik.andersson@iot.ntnu.no

To achieve high quality Emergency Medical Services, planning is of vital importance. An important strategic/tactical problem is to locate ambulance stations and allocate ambulances to these stations. We present a new model for this problem suitable for regions with heterogeneous demand and multiple performance measures. The model locates/allocates stations/ambulances, calculates the service/arrival rates for each station and the probabilities that a call is served by a given station. The model is tested on a combined urban and rural area in Norway with multiple performance measures. Compared with the current solution, the model gives better performance on each performance measures used.

## TA03

Zeelenberg Zaal, Second Floor

### Data-driven Policies for Differentiated Care

Invited: Public Health and Policy Making

Invited Session

Chair: Diana Maria Negoescu, University of Minnesota, Minneapolis, MN, 55455, United States, negoescu@umn.edu

#### 1 - Family-customized Nutritious and Low-cost Dietary Planning Support

Anil Aswani, UC Berkeley, 8 10th St, Apt. 1704, San Francisco, CA, 94103, United States, aaswani@berkeley.edu, Melanie Manguin, Pedro Ivo Bastos Hespanhol, Matt Olfat

Poor nutrition leads to increases in chronic and acute diseases. New approaches to encourage families to eat healthier diets could improve population health and reduce health care spending. This talk describes a novel optimization model for dietary planning that includes temporal constraints to model the time required to prepare foods. We construct an approximation algorithm to efficiently solve this optimization model, and then we describe a data-driven learning approach that tunes the optimization model parameters to customize the dietary plans. We conclude with a brief summary of a mobile application we have developed implementing these approaches into a mobile tool for dietary planning.

#### 2 - Reducing Readmissions through Inpatient Outpatient Joint Control

Xiang Liu, University of Michigan, 322 Village Green Boulevard, Apt 204, Ann Arbor, MI, 48105, United States, liuxiang@umich.edu, Mariel Lavieri, Jonathan Helm, Ted Skolarus

Hospital readmissions affect hundreds of thousands of patients, placing a tremendous burden on the healthcare system. We develop a two-stage stochastic dynamic programming framework that spans the inpatient stay and the post-discharge outpatient monitoring to reduce readmissions. By reducing readmission risk in the 1st stage, and monitoring the patient's condition in the 2nd stage, our model goal is to jointly guide discharge and post-discharge decisions. This could lead to reduced readmissions.

#### 3 - Modeling And Optimization of HIV Viral Load Monitoring Policies in Resource-limited Settings

Diana Maria Negoescu, University of Minnesota, 111 Church Street SE, Minneapolis, MN, 55455, United States, negoescu@umn.edu, Zhenhuan Zhang, Heiner C. Bucher, Eran Bendavid

Viral load (VL) testing is the most critical monitoring tool for assessing the effectiveness of treatment in HIV patients. The optimal frequency of VL monitoring remains unknown, despite it being the costliest routine monitoring tool for HIV in Sub-Saharan Africa. We formulate a model parameterized using person-level longitudinal data to simulate adherence behavior and disease dynamics over time, and to develop monitoring schedules that adapt to patient characteristics. We then evaluate the total costs and quality-adjusted life years achieved by monitoring VL at fixed intervals (status quo), as well as at variable intervals based on an individualized risk assessment of virologic failure.

#### 4 - Designing Response-adaptive Methods for Multi-arm Clinical Trials using Decision Theory and the Gittins Index

Sofia S. Villar, MRC Biostatistics Unit University of Cambridge, School of Clinical Medicine, Cambridge, United Kingdom, sofia.villar@mrc-bsu.cam.ac.uk

Adaptive designs that use accrued data to improve clinical trials have attracted much attention both from methodologists and practitioners. The multi-armed bandit problem is a decision-theoretic framework from which patient allocation rules can be derived to formulate a Bayesian adaptive design. I will present recent results that illustrate why the implementation of this approach in practice could be desirable and in which circumstances. I will describe recent modifications to the original Gittins index solution method that aim at overcoming specific practical limitations to its use and I will discuss the remaining methodological challenges that need to be addressed.

## ■ TA04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning IV

Contributed Session

Chair: Wenchang Zhang, Robert H Smith School of Business, 12001 Old Columbia Pike, Apt 811, Silver Spring, MD, 20904, United States, wzhang@rhsmith.umd.edu

#### 1 - Clustering of Survival Data using Non-Coxian Phase Type Distributions

Hannah Johns, RMIT University, Melbourne VIC, Australia, htjohns@gmail.com, John Hearne, Leonid Churilov

Modelling of survival data such as length of stay and time-to-completion is a critical component in analyzing health care processes. Such modelling with Coxian phase type distributions allows for survival data to be clustered according to the journey taken through the process. Using stroke rehabilitation data, we present a generalization of this clustering method to other phase-type structures, reducing number of parameters fitted and providing clusters where Coxian phase type clustering fails.

#### 2 - A Data Warehouse of Health Services Administration Related Databases

Sue Feldman, University of Alabama at Birmingham, 1720 2nd Avenue South, SHPB 590K, Birmingham, AL, 35294, United States, sf8588@gmail.com, Bunyamin Ozaydin, Ferhat Zengul, Nurettin Oner

Health services researchers (HSR) spend unnecessary time performing aggregation of raw data from multiple data sources. Often, each researcher duplicates this effort for each project, facing the same challenges and pitfalls previously experienced. We describe the process by which to create a data warehouse that includes the most frequently used HSR databases. The design includes the capacity for subsequent updates of the existing databases and the addition of new databases. We discuss system structures and integrations of data dictionaries provided by the data sources, which allow creation of dimensions and measures for a business intelligence system, as well data analytics tools.

#### 3 - Accelerating the Adoption of Bundled Payment Reimbursement Systems – a Data Driven Approach Utilizing Claims Data

Wenchang Zhang, University of Maryland, College Park, MD, 20742, United States, wzhang@rhsmith.umd.edu, Margret Bjarnadottir, Ruben Proano, David Anderson, Renata Alexandra Konrad

The CMS launched the Bundled Payments for Care Improvement in 2013 aiming for large-scale adoptions. One of the challenges of implementing the bundled payment system is to identify procedural homogeneous groups within an episode of care, to which a flat reimbursement rate can be applied. In this study, we propose a clustering approach to automatically detect and visually represent homogeneous sub-groups of services for a given condition. We apply the approach to cohorts of total knee replacement and congestive heart failure separately. The automatically extracted service clusters with different cost patterns highlight provider's financial risk under bundled payments.

## ■ TA05

Schadee Zaal, Third Floor

### Health Care Modeling

Invited: Health Operations Management

Invited Session

Chair: Taylor Corcoran, University of California-Los Angeles, Los Angeles, CA, 90024, United States, taylor.corcoran.1@anderson.ucla.edu

#### 1 - Contracts for Healthcare Referral Services

Fernanda Bravo, Assistant Professor, UCLA Anderson School of Management, 110 Westwood Plaza, B4.11, Los Angeles, CA, 90024, United States, fernanda.bravo@anderson.ucla.edu, Elodie Adida

We focus on the B2B interaction and payment contracts between a healthcare service requester and a provider. The requester exerts preventive effort to maintain patients' health. When necessary, patients are referred to the provider, at the requester's expense. The provider may exert non-reimbursable effort to reduce the chance of poor patient outcomes, which incur further costs for the requester. We find that fee-for-service (FFS) induces neither system nor social optimum efforts. However, a penalty contract can generally align the decisions with either system or social optimum. Furthermore, we find that patients may benefit from having a coordinating contract replace FFS.

#### 2 - Approximation Methods for Markov Decision Processes with Application to Clinical Trial Design

Vishal Ahuja, Southern Methodist University, Cox School of Business, P.O. Box 750333, Dallas, TX, 75275, United States, vahuja@smu.edu, John R Birge

Multi-armed bandit problems, typically modeled as Markov decision processes (MDPs), exemplify the exploration vs. exploitation tradeoff. For many practical problems of interest, the state space is intractably large, rendering exact approaches to solving MDPs impractical. We propose a novel approximation approach that combines the strengths of multiple methods - grid-based state discretization, methods to improve approximation accuracy, and simulation, to obtain near-optimal policies for large scale MDPs with minimal added computational burden. Our numerical analysis shows our design to be almost as good as a fully optimal design and superior to existing heuristics.

#### 3 - Flexible FDA Approval Policies

Taylor Corcoran, UCLA Anderson School of Management, 110 Westwood Plaza, Los Angeles, CA, 90024, United States, taylor.corcoran.1@anderson.ucla.edu, Elisa Frances Long, Fernanda Bravo

Current U.S. FDA approval standards require pharmaceutical companies to demonstrate drug efficacy at a 0.05 significance level using clinical trial outcomes. This policy ignores heterogeneity in disease characteristics, such as the severity and prevalence, the level of research and development taking place, and the number of alternative drug treatments available for patients. We develop a queueing framework to analyze the drug approval process that incorporates such factors. We derive optimal approval policies and conduct a numerical study for three diseases (HIV, hypertension, and breast cancer).

#### 4 - Designed Sampling from Large Databases for Controlled Trials

Sanjay Mehrotra, Northwestern University, Dept of IE / M S C246 Tech Inst, 2145 Sheridan Road, Evanston, IL, 60208-3119, United States, mehrotra@iems.northwestern.edu, Daniel Apley, Liwen Ouyang

We will present a methodology for clinical trial design that uses multi-attribute information from a clinical database, with the goal of extracting more information from the trial than what might be possible using a traditional randomized control trial design. The methodology is tested using simulated data generated from a real-setting motivation. We find that the standard error is significantly lower for the same cohort size, or a much smaller cohort can be constructed for a given standard error on the covariates.

## ■ TA06

Van Beuningen Zaal, Third Floor

### Complications in Cost-effectiveness Analyses: Data Scarcity, Model Uncertainty, and Implementation Challenges

Invited: Disparities in Health, Low and Middle Income Settings, Global Health

Invited Session

Chair: Sze-Chuan Suen, University of Southern California, 3715 McClintock Ave., GER 240, Los Angeles, CA, 90089, United States, ssuen@usc.edu

#### 1 - Prioritizing Treatment in a Tuberculosis Transmission Network

Sze-chuan Suen, University of Southern California, 3715 McClintock Ave., GER 240, Los Angeles, CA, 90089, United States, ssuen@usc.edu

Tuberculosis (TB) continues to kill over a million people annually, despite effective medical treatments. TB trends vary widely by age, and understanding transmission patterns is critical for maximizing disease prevention efforts. We focus on identifying priority age-groups for treatment using a case study in India. We calibrate transmission networks to data on age-specific prevalence and TB natural history. Using these networks, we identify age-groups for which treatment reduces overall prevalence the most, increasing the effectiveness of limited control resources.

#### 2 - Disease Evolution: Modeling the Model

Julia L Higle, PhD, University of Southern California, Los Angeles, CA, United States, julie.higle@usc.edu

A mathematical or computational model of a disease requires the specification of model parameters, including observable parameters, for which modeled outputs are consistent with observed data. Uncertainty and noise within the available data can have a negative impact on confidence in recommendations and conclusions derived via the model. This can be especially problematic when only limited data are available. We present a model of the disease modeling process, and suggest methods for increasing the resilience of the model / recommendations.

**3 - Hepatitis B Control in China: Models to Support Policy Change**

Margaret L Brandeau, Stanford University, Management Science and Engineering, 475 Via Ortega, Stanford, CA, 94305-4026, United States, brandeau@stanford.edu

In low-and middle-income countries, mathematical models can be particularly useful for identifying cost-effective public health interventions and supporting policymakers in informed decision making. We describe our model-based analyses of potential hepatitis B vaccination policies in China. Our work helped encourage policymakers in China to enact legislation to provide free catch-up vaccination for hundreds of millions of children - an important step in eliminating health disparities, reducing discrimination, and ensuring that millions of people can now be protected from hepatitis B.

**4 - Optimal Control of an Infectious Disease with Drug Resistance**

Lauren Cipriano, Ivey Business School, 1255 Western Road, Room 2361, London, ON, N6G 0N1, Canada, lcipriano@ivey.uwo.ca, Naveed Chehraz, Eva Enns

We study the optimal treatment policy for an SIS-type infectious disease with drug resistance. We prove that the optimal policy is bang-bang with a single switching time and we find that the value function is not Lipschitz continuous. Using numerical analysis, we demonstrate that the optimal policy changes form when the disease transmission rate is a function of disease prevalence (e.g., as a result of social distancing). Our solution approach can be generalized to other control problems.

**TA07**

Willem Burger Zaal

**Analyzing & Optimizing the Patient Path to Care**

Sponsored: Health Applications

Sponsored Session

Chair: Bob Batt, University of Wisconsin-Madison, 975 University Ave., Madison, WI, 53706, United States, bob.batt@wisc.edu

**1 - Proactive Customer Service: Operations and Economics**

Tolga Tezcan, London Business School, Regent's Park, London, NW14SA, United Kingdom, ttezcan@london.edu, Kraig Delana, Nicos Savva

We examine proactive service of customers, which is particularly useful in settings where customers are more flexible than service capacity. Our research uses queueing theory (diffusion limit approximations) to quantify the performance improvement and economic theory (simultaneous move game) to identify under what conditions customers would willing to adopt the proactive service. We show that all customers benefit by proactive service even if only a fraction of customers are flexible. Despite the substantial reductions in delays, we find customers tend to under adopt proactive service compared to socially optimal due to a positive externality.

**2 - An Expected Coverage Model with a Cutoff Priority Queue**

Laura Albert, PhD, UW-Madison, Madison, WI, United States, laura@engr.wisc.edu, Soovin Yoon

In emergency medical service systems, the response to urgent emergency calls can be delayed when the system is congested. To address this, we propose a spatial Hypercube approximation model with a cutoff priority queue that estimates performance measures for a system where some servers are reserved exclusively for high priority calls when the system is congested. The spatial Hypercube approximation model evaluates public safety systems that employ a cutoff priority queue. A mixed integer linear programming model uses the Hypercube model to design a system in a cutoff priority queue paradigm.

**3 - Evaluating Hospital Readmission Decisions**

Gabriel Zayas-Caban, 1731 Broadview Lane, Apartment 402, Ann Arbor, MI, 48105, United States, gzayasca@umich.edu, Amy Cochran, Keith Kocher

The Hospital Readmissions Reduction Program penalizes hospitals with excess readmissions. Re-evaluating admissions decisions, providers have considered delays or increases in decisions. To understand the impact of these changes on patient outcomes, we analyzed over 150,000 encounters in the Emergency Department from the University of Michigan from 2012 through 2015. A Hidden Markov model is fit to the data to capture the interplay between confounding latent variables (e.g. patient severity) and admission decision process. This allowed us to gain insight into how decisions are made and how changes in decisions impact patient outcomes.

**4 - Distance, Quality, or Relationship? Interhospital Transfer of Heart Attack Patients**

Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill, Kenan-Flagler Business School, CB #3490, Mccoll Building, Chapel Hill, NC, 27599, United States, lauren\_lu@unc.edu, Susan F Lu

We empirically investigate the pattern of where heart attack patients are transferred between hospitals. Using 2011 Florida State Emergency Department and Inpatient Databases, we demonstrate the relative importance of three key factors in determining transfer destinations: (1) the distance between sending and receiving hospitals, (2) publicly-reported quality measures of receiving hospitals, and (3) the relationship between sending and receiving hospitals as indicated by whether they are affiliated with the same multihospital system.

**TA08**

Ruys Zaal, Fourth Floor

**Operating Room Scheduling I**

Invited: Health Operations Management

Invited Session

Chair: Willem van Jaarsveld, Technische Universiteit Eindhoven, Rotterdam, NL-3000DR, Netherlands, W.L.v.Jaarsveld@tue.nl

Co-Chair: Guanlian Xiao, Technische Universiteit Eindhoven, Eindhoven, 5653BA, Netherlands, xglian@gmail.com

**1 - A Reservation Policy for Medical Diagnostic Resource Allocation**

Weifen Zhuang, School of Management, Xiamen University, China, School of Management, Xiamen University, Xiamen, 361005, China, wfzhuang@xmu.edu.cn

Medical diagnostic facilities such as CT or MRI, the critical part of a comprehensive health care system, play an important role in the proper diagnosis and timely treatment of diseases. Hospital managers are under great pressure to manage such facilities efficiently and effectively. This problem is much critical in China, especially in the large tertiary hospitals. In this paper, we study the problem of resource allocation for medical diagnostic facilities, accessed by three types of patients. Both inpatients and outpatients have to make an appointment in advance and emergency patients walk in directly. We formulate the dynamic programming model of the resource allocation problem and study the structural properties, based on which we fully characterize the optimal reservation policy. An upper-bound to the DP value is obtained from a standard "hind-sight" optimal argument, and it is asymptotically optimal. A lower-bound to the DP is created through three independent newsvendor problems constrained by the capacity. The gap between the upper-bound and lower-bound is explicitly quantified and is of order square-root-of-T. Numerical studies show that the performance of bounds works very well. The practice and data of West China Hospital are used for analysis and implementation. We propose and compare three heuristic policies analytically. Numerical study illustrates that our heuristic policy outperforms the hospital's target policy significantly.

**2 - Overbooking or Pre-charge: A Comparison of the Strategies for Healthcare Appointment with No-show**

Guohua Wan, Shanghai Jiao Tong University, Shanghai, China, ghwan@sjtu.edu.cn, Yan Zhan

Patient no-shows of scheduled appointments is a serious problem for healthcare service providers. To mitigate this negative effect, the pre-charge strategy, which charges a deposit when a patient makes an appointment, is increasingly used by appointment systems. With the pre-charge strategy, the deposit may or may not be refunded. In practices, if the refunding policy is adopted, then the deposit may be partially or fully refunded if the cancellation is informed; if the no-refunding policy is adopted, then the deposit is not refunded thus no-show may occur without informed cancellation. We study the performance of both the pre-charge strategy and the widely used overbooking strategy and show that the pre-charge strategy with full refund significantly outperforms the overbooking strategy in terms of service providers' net profits. We also drive the condition under which the refund policy outperforms the no-refund counterpart, demonstrating the value of no-show information. Furthermore, we model dynamic appointment scheduling as a Markov decision problem, conduct comprehensive numerical experiments based on parameters driven from a hospital, and obtain a few managerial insights for dynamic appointment scheduling.

**3 - Optimizing Ending Time of Colorectal Cancer Screening for High-risk Patient**

Jing Li, Jiangnan University, Wuxi, China, lijing7978651@163.com, Pu Xujin

As the third leading death cause in US, colorectal cancer(CRC) has raised much attention. Age-dependent recommendations of screening are provided currently. We build a markov decision process to study the optimal final age of CRC screening for high-risk patients, taking patients' status into account. We derived a threshold policy for the screening age which depends on patients' health status. Numerical result show that our policy can improve the overall QALYs and provide robust policy to all patients.

#### 4 - Stochastic Programming Analysis and Solutions to Schedule Overcrowded Operating Rooms In China

Willem van Jaarsveld, Assistant Professor, Erasmus University-Rotterdam, P.O Box 1738, Room H11-10, Rotterdam, NL-3000DR, Netherlands, W.L.v.Jaarsveld@tue.nl

As a result of the growing demand for health services, China's large city hospitals have become markedly overstretched, resulting in delicate and complex operating room scheduling problems. While the operating rooms are struggling to meet demand, they face idle times because of (human) resources being pulled away for other urgent demands, and cancellations for economic and health reasons. In this research we analyze the resulting stochastic operating room scheduling problems, and the improvements attainable by scheduled cancellations to accommodate the large demand while avoiding the negative consequences of excessive overtime work. We present a three-stage recourse model which formalizes the scheduled cancellations and is anticipative to further uncertainty. We develop a solution method for this three-stage model which relies on the sample average approximation and the L-shaped method. The method exploits the structure of optimal solutions to speed up the optimization. Scheduled cancellations can significantly and substantially improve the operating room schedule when the costs of cancellations are close to the costs of overtime work. Moreover, the proposed methods illustrate how the adverse impact of cancellations (by patients) for economic and health reasons can be largely controlled. The (human) resource unavailability however is shown to cause a more than proportional loss of solution value for the surgery scheduling problems occurring in China's large city hospitals, even when applying the proposed solution techniques, and requires different management measures.

#### ■ TA09

Van Rijckevorsel Zaal, Fourth Floor

#### Scheduling and Planning V

Contributed Session

Chair: Alexander Tesch, Zuse Institute Berlin, Takustraße 7, Berlin, 14195, Germany, tesch@zib.de

##### 1 - Scheduling of Operating Theatres using Simulation-based Decision Process Modeling

Anders Reenberg Andersen, Technical University of Denmark, Anker Engélunds Vej 1, Kgs. Lyngby, 2800, Denmark, arean@dtu.dk, Bo Friis Nielsen, Thomas Jacob Riis Stidsen, Line Blander Reinhardt

Scheduling of patients for hospital operating theatres is a well-known problem in the literature, and yet it appears in many different variations. In this study, our objective is to minimize the long-term costs associated with a scheduling of patients to days and rooms within a rolling planning horizon. We model this problem by using a simulation-based Markov decision process. Numerical experiments indicate that this approach is more adaptive to increasing costs than a non-anticipative GRASP heuristic.

##### 2 - Markov Decision Process for Optimizing Bed Reservation Policy in Intensive Care Units

Xuanjing Li, Tsinghua University, Room 519, ShunDe, Beijing, China, lixj15@mails.tsinghua.edu.cn

In practice, ICUs administrators reserve some beds or early discharge current patient for those serious patients to avoid dangerous condition. A Markov Decision Process (MDP) model is established to strike balance between rejection of incoming patient and the early discharge in the near future. We propose a reservation policy by analyzing the properties of the optimal function including monotony, concavity and decreasing marginal reward.

##### 3 - LP-based Scheduling Policies for Stochastic Operation Room Scheduling

Alexander Tesch, Zuse Institute Berlin, Takustraße 7, Berlin, 14195, Germany, tesch@zib.de

Efficient operation room scheduling subject to unknown operational times is one of the core problems in healthcare optimization. Recently, LP-based scheduling policies have not only been shown to yield provable approximation guarantees, first computational studies give rise to applications to real-world problems. Our talk deals with the practical evaluation of LP-based scheduling policies from the background of minimizing the total overtime in the operation rooms. The performance of the presented algorithms is compared to different assignment heuristics according to deterministic lower bounds and simulations based on real data from a major hospital in Berlin.

#### 4 - Using Critical Path Method-material Requirements Planning for Scheduling Surgeries

Ali Ardalan, Professor, Old Dominion University, 4900 Hampton Blvd, Norfolk, VA, 23454, United States, aardalan@odu.edu

Surgery suites are expensive resources and their high utilization helps keeping hospital costs in control. We propose deploying a methodology that is developed by integrating critical path method and material requirements planning to ensure that all of the resources necessary for a surgery (the project) to be available when they are needed and the quantity that are needed. This method distinguishes between resources that are depleted as they are used, such as supplies, and those that will continue to be available after they provide the service, such as doctors and nurses.

#### ■ TA10

Plate Zaal, Fourth Floor

#### Supply Chains IV

Contributed Session

Chair: Hamideh Anjomshoa, IBM Research Australia, 2/175 Highfield Road, Camberwell, Victoria, 3124, Australia, hamideh.a@au.ibm.com

##### 1 - Hospital Medication Reorder Policy under Demand and Supply Uncertainties

Jiana-Fu Wang, Associate Professor, National Chung Hsing University, 250 Kuo Kuang Road, Marketing Department, Taichung, 40227, Taiwan, jfwang@dragon.nchu.edu.tw, Mei-Ting Tsai, Yi-Ching Liou

It had been decades that drug shortage affects daily practice in healthcare institutes inevitably. This study intends to find replenishment policies for a hospital taking uncertainties of demand and supply into account. We develop medicine classification matrix in terms of shortage severity. Medicine demand and supply are modeled stochastically. As a result, dedicated reorder policy is made for each medication category. The proposed framework and empirical examples are expected to support better replenishment decision while considering cost and healthcare quality.

##### 2 - Cost Sharing for Capacity Transfer in Cooperating Queueing Systems

Yinlian Zeng, The Chinese University of Hong Kong, The Chinese University of Hong Kong, Room A605, PGH 5, Shatin, N.T., Hong Kong, elainezeng007@gmail.com, Lianmin Zhang, Xiaoqiang Cai, Jun Li

Hospitals or clinics can often be modeled as queueing systems. In this paper, we consider the capacity transfer problem among cooperating queueing systems (hospitals/clinics). We first design efficient algorithms to solve the capacity transfer problem. Then, we propose cost allocation rules to allocate the total cost among the participants in the framework of cooperative game theory.

##### 3 - Optimal Utilisation Target for Surgery Resources in Hospitals

Hamideh Anjomshoa, IBM Research Australia, 2/175 Highfield Road, Camberwell, Victoria, 3124, Australia, hamideh.a@au.ibm.com

Optimal planning surgeries is critical and complex in a hospital. One of the challenges for decision makers is to set the expected resource utilisation for surgeries, in order to improve the efficiency and flow of patients in hospitals. Over-utilisation and under-utilisation are both not desired. In this talk, we present a Mixed Integer Programming Model with multi-objectives including and the numerical results. We also compare the effect of different decisions on the performance.

## ■ TA11

Van der Vorm Zaal, Fourth Floor

### Organ Transplant

Contributed Session

Chair: Sommer Gentry, US Naval Academy, Mathematics Department, 572-C Holloway Road, Annapolis, MD, 21402, United States, gentry@usna.edu

#### 1 - Transparent and Portable Markov Modeling for Medical Cost-effectiveness

Gordon B Hazen, Professor Emeritus, Northwestern University, Dept of Industrial Eng & Mgmt Sciences, Technological Institute, Evanston, IL, 60208-3119, United States, gbh305@northwestern.edu, Matthew Pilecki, James Carr, Michael Markl

Markov models are widespread in medical cost-effectiveness. Although model transparency is a recognized goal in publication guidelines, complete model specification is uncommon. StoTree is a new and freely available Excel addin for finite-state continuous-time Markov models that allows separate formulation and linking of model components. This facilitates transparency and allows the re-use of model components in multiple applications. We review properties of StoTree, and illustrate its use in constructing a complex model of heart monitoring following cardiac transplant.

#### 2 - COP: Inducing Organ Discards and Patient Deaths on Transplant Wait Lists

Mohammad Delasay, Tepper School of Business, Carnegie Mellon University, 6315 Forbes Avenue, #1105, Pittsburgh, PA, 15217, United States, delasays@cmu.edu, Sridhar Tayur

We investigate transplant waiting list management from the viewpoint of a transplant center in the presence of the conditions of participation (COP). According to the COP, centers with a lower-than-expected one-year post-transplant patient survivals are at the risk of losing their programs. Using flexible Lyapunov functions, we analyze a queuing model that captures important factors affecting the post-transplant survivals, including different organ qualities and patient health states, and health deterioration on the waiting list. Using patient and transplant-level data, we illustrate that setting the COP expectations without a careful consideration of transplant center-specific conditions could move the COP away from a net-benefit approach in favor of maximizing outcomes only by invoking the transplant centers to cherry-pick the transplant candidate and the offered organs. Our model can guide policy makers to evaluate the effects of the COP and set the appropriate post-transplant outcome expectations.

#### 3 - Comparing Different Forms of the Equity Objective in Redistricting of U.S. Liver Allocation

Sommer Gentry, Professor, US Naval Academy, Mathematics Department, 572-C Holloway Road, Annapolis, MD, 21402, United States, gentry@usna.edu, Olivia McQuade

In the U.S., deceased-donor liver allocation rules greatly disadvantage patients in some geographic areas, but distances are too long to transport every liver to the top patient. We have proposed optimized redistricting to reduce geographic disparity, by minimizing the sum of absolute differences from the number of livers per district in an idealized distribution. We test alternative objective functions including minimizing the maximum difference and minimizing the percent deviation from ideal, and discuss which conform to intuitive notions about fairness to patients.

## ■ TA12

Mees Zaal, Fourth Floor

### Disease and Treatment Modeling III

Contributed Session

Chair: Sean Manzi, University of Exeter, Room 2.32 South Cloisters, St Luke's Ca, Exeter, EX1 2LU, United Kingdom, s.s.manzi@exeter.ac.uk

#### 1 - Effects of Different Kinds of Intervention on Cognitive Function of the Elderly

Aihua Li, Central University of Finance and Economics, 39# South College Road, Haidian District, Beijing, 100081, China, neu\_aihua@126.com

Aging is a serious problem in the world, which carries out many issues related with the elderly health both in body and life, health aging is our inevitable social issue and we should pay appropriate attention to it. This paper analyzes effects of different kinds of intervention on cognitive function to the elderly, which whether fitness intervention, brain health intervention and social intervention could effectively mitigate cognitive decline in the elderly with Chinese Longitudinal Healthy Longevity Survey (CLHLS) queue data. Firstly, we horizontally studied the related samples in 2002 with propensity score matching, after which we carried out statistical test and preliminary found brain health intervention contributes greatly on elderly cognitive function with improving the average MMSE scores. Except horizontal research, we studied the related samples in 2002, 2005 and 2008 vertically, after analysis of binary logistic regression, and found that the three kinds of intervention have significantly statistics meaning on the elderly cognitive function. The research also shows that fitness intervention, brain health intervention and social intervention could help mitigate the decline trend of elderly cognitive function.

#### 2 - Estimating Progression Rate Change in Parkinson's Disease

Mahboubeh Madadi, Assistant Professor, Louisiana Tech University, College of Engineering and Science, P.O Box 10348, Ruston, LA, 71272, United States, madadi@latech.edu

Parkinson's disease is the second most common late life neurodegenerative disease after Alzheimer's disease. Recently, the focus of many researchers has been on the development of interventions to slow the Parkinson's disease progression. This stimulates the need for accurate characterization of the progression rate of Parkinson's disease. In this study, we apply deep learning (deep neural network) to estimate the changes in the rate of Parkinson's disease progression.

#### 3 - Optimal Screening Policies for Alzheimer's Disease

Zehra Onen, Dr., Istanbul Bilgi University, Istanbul, Turkey, zehra.onen@gmail.com, Serpil Sayin

Alzheimer's Disease (AD) is believed to be the most common type of dementia. Even though screening for AD has been discussed widely, there is no screening program integrated as a policy in any country. This work investigates the derivation of optimal screening policies for AD using Markov models. In this model, not only clinical states but also a preclinical state and a possible treatment for the latter are considered. We compute quality adjusted life year optimizing policies assuming different levels of treatment effectiveness and identify the cases that are most cost effective.

#### 4 - Decoding Dementia Triage and the Role of Modelling

Sean Manzi, Dr, University of Exeter, Room 2.32 South Cloisters, St Luke's Campus, Exeter, EX1 2LU, United Kingdom, s.s.manzi@exeter.ac.uk, Charlene Ronquillo, Laura Pickup, Laura Hill, David Llewellyn

A project was undertaken to model the impact of a new triage app on waiting times for dementia assessment. The impact of the modelling process on stakeholder expectations and decision-making was also studied using a qualitative approach. The model showed that waiting times would increase for 50 days after implementation of the new triage method before starting to decrease. The simulation findings and their influence on stakeholder expectations and planning will be presented.

## ■ TA13

Van Weelde Zaal, Fourth Floor

### Advanced Data Analytics for Healthcare

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Gah-Yi Ban, London Business School, London, NW1 4SA, United Kingdom, gban@london.edu

#### 1 - Machine Learning Approach to Nurse Staffing

Gah-Yi Ban, London Business School, Regent's Park, London, NW1 4SA, United Kingdom, gban@london.edu

We apply two types of machine learning algorithms for nurse staffing in a hospital emergency room, standard machine learning (ML) and kernel optimization (KO). We find that (i) the best KO and ML algorithms beat the best practice benchmark by 23% and 24% respectively in the out-of-sample cost with statistical significance at the 5% level, and (ii) the best KO algorithm is faster than the best ML algorithm by three orders of magnitude and the best practice benchmark by two orders of magnitude.

#### 2 - Inferring Queue Transition Dynamics by Boosting Hazard Regression

Donald Lee, Yale School of Management, 165 Whitney Ave, Box 208200, New Haven, CT, 06520, United States, donald.lee@yale.edu, Ningyuan Chen

The customer transition dynamics for a variety of queuing networks can be modelled as a failure process. In order to better understand these dynamics from a data-driven viewpoint, we propose a practical gradient boosting procedure for flexibly estimating the transition intensities. Our procedure comes with statistical oracle guarantees when flexible regression tree-based models are used. We apply it to shed new light on an existing empirical operations question regarding the impact of staff workload on service rates in an emergency department.

#### 3 - Personalizing Health Treatments using Bayesian Inverse Optimization

Anil Aswani, UC Berkeley, 8 10th St, Apt 1704, San Francisco, CA, 94103, United States, aaswani@berkeley.edu, Philip Kaminsky, Yonatan Mintz, Elena Flowers, Yoshimi Fukuoka

Treatments for managing chronic disease are sensitive to patient adherence, as well as to the treatment efficacy on each patient. Better quantification of such parameters can improve the efficiency of health care delivery (by more accurate allocation of costly treatment resources) and improve health outcomes (by prompting earlier escalation of care when needed). This talk describes a Bayesian approach to inverse optimization that can quantify such parameters. We provide mathematical programming formulations for and theoretical results about our approach, and conclude with simulations that show the effectiveness of our approach in personalizing a weight loss and physical activity treatment.

## Thursday, 10:30am - 12:00pm

## ■ TB01

Van Cappellen Zaal, Ground Level

### IT Enabled Patient Empowerment and Engagement

Sponsored: Health Applications

Sponsored Session

Chair: Jiban Khuntia, Business School, University of Colorado, Denver, CO, 80202, United States, jiban.khuntia@ucdenver.edu

Co-Chair: Yazan Alnsour, University of Illinois, Springfield, IL, 62703, United States, yalns2@uis.edu

#### 1 - How Virtual Care Enhances Healthcare Delivery in Rural Areas in the United States

Yazan Alnsour, University of Illinois at Springfield, One University Plaza, MS UHB 4021, Springfield, IL, 62703, United States, yalns2@uis.edu, Rassule Hadidi, Neetu Singh

The technology advancements in healthcare have transformed the way providers are able to deliver care to patients. HIT and medical apps are the key in this transformation. HIT also plays an essential role in increasing the efficiency of healthcare delivery. Virtual care using telehealth platforms have proven to improve patient care outcomes by providing better accessibility to medical services, health care professionals, and eliminating the need for unnecessary hospitalization. Virtual care follow ups have reduced the time between appointments for both patients and providers.

#### 2 - How do EMRs and Integration Lower Healthcare Cost in Developing Countries: Evidence from Health Failure Patients LOS

Mohammad Alsharo, Al Albayt University, P.O.BOX 130040, Mafraq, 25113, Jordan, mohammad.alsharo@aabu.edu.jo

Healthcare providers in developing countries are trying to catch up with the new health information technology (HIT) advancements and trends. In this paper, we examine the impact of using EMR system on healthcare cost in a developing country in the Middle East. We argue that EMR and integration capabilities help providers reduce hospital length of stay (LOS). Our findings show that EMR systems can reduce unnecessary hospital length of stay (LOS) which subsequently reduces cost and the risk of hospital-acquired conditions (HACs) while maintaining quality.

#### 3 - Exploring the Impact of Security on User Evaluation of Mobile Health Applications

Abdullah Albizri, Montclair State University, Montclair, NY, United States, albizria@montclair.edu

The wide spread of mobile technology motivated healthcare providers to embrace mobile health technology (mHealth). Although enabling users to utilize mobile devices to communicate with providers and access services offers numerous benefits, many risks regarding security and privacy arise. This research investigates how security and privacy measures impact the evaluation of mHealth apps. A datasets of 3,000 health apps were collected to conduct an empirical analysis. We find that high measures of security and privacy positively impact the ratings of the health app.

## ■ TB02

Arcadis Zaal, First Floor

### Emergency Medical Services II

Contributed Session

Chair: Gabriela Noemi Gongora Svartzman, Stevens Institute of Technology, 1 Castle Point On Hudson, Hoboken, NJ, 07030, United States, ggongora@stevens.edu

#### 1 - Modelling Emergency Departments using Discrete Event Simulation with a New Approach for Quantifying Busyness

Adele H Marshall, Queen's University Belfast, University Road, Belfast, BT71NN, United Kingdom, a.h.marshall@qub.ac.uk, Laura Boyle, Mark Mackay

The number of presentations to emergency departments (EDs) continues to increase, resulting in overcrowding and frequent breach of four-hour clinical guidelines. Discrete event simulation (DES) is an effective modelling technique for EDs, enabling the user to evaluate the impact of various experimental scenarios on ED performance. Application of DES modelling to a major ED in South Australia will be presented, in addition to a novel approach for quantifying the 'busyness' of EDs.

#### 2 - How do Patients' Perception and Self-interests Affect Emergency Department Crowding in Hospitals?

Ying Xu, Assistant Professor, Singapore University of Technology and Design, 8 Somapah Road, Engineering System & Design, Singapore, 487372, Singapore, xu\_ying@sutd.edu.sg, Shrutivandana Sharma, Manu Gupta

We investigate the crowding problem in hospitals' emergency departments (EDs) from the perspective of demand management. We propose a novel congestion game model that provides the first systematic methodology to simultaneously analyze the effects of ED resource allocation as well as patients' perception and self-interests when they can choose between ED and primary care. We perform extensive numerical experiments to study the impact of perception errors and patients' self-interests on ED demand and resulting crowding, and compare them with optimum centralized patient flows.

#### 3 - Simulating and Visualizing Emergency Departments for Improved Waiting Times and Patients' Decision Making Process

Gabriela Noemi Gongora Svartzman, PhD Student, Stevens Institute of Technology, 1 Castle Point On Hudson, Hoboken, NJ, 07030, United States, ggongora@stevens.edu, Jose Emmanuel Ramirez-Marquez

Long waiting times in the Emergency Departments (ED) across the U.S. has been identified as a major concern by the American College of Emergency Physicians. This issue causes patient dissatisfaction, patients leaving and physicians receiving negative referrals. This work identifies bottlenecks in the ED processes, tests scenarios and provides decision making suggestions to ED's policies through an Agent Based Simulation. The findings of the simulation were used to develop a visualization tool to aid both physicians and patients through the decision making process at the ED. Subsequently patients can have options about their stay and their treatment.

## ■ TB03

Zeelenberg Zaal, Second Floor

### Panel Session – Operations Management: Current Practice and its Implications for Policy

Invited: Public Health and Policy Making

Invited Session

Moderator: Edward Anderson, University of Texas-Austin, IROM Department, 2110 Speedway Avenue, B6500, Austin, TX 78712, Edward.Anderson@mcombs.utexas.edu

#### 1 - Panel Session – Operations Management: Current Practice and its Implications for Policy

Edward G. Anderson, University of Texas McCombs School of Business, Austin, TX, 78712, United States, edward.anderson@mcombs.utexas.edu

To a great extent, the greatest discussion on how to improve healthcare systems centers on policy issues, particularly in the United States. That said, there are tremendous sub-policy challenges in all nations with respect to Healthcare Operations and Systems Engineering. The experts on the panel will discuss the latest work that they and other colleagues are working on in Healthcare Operations Management/Systems Engineering. They will then discuss what future trends in this research should be undertaken. Finally, they will treat the implications of this research for policy.

#### Panelist

Craig Froehle, University of Cincinnati, 2925 Campus Green Drive, Cincinnati, OH, 45221-0130, United States, craig.froehle@uc.edu

#### Panelist

Robert Batt, Wisconsin School of Business, UW-Madison, 5279 Grainger Hall, 975 University Ave., Madison, WI, 53706, United States, bob.batt@wisc.edu

#### Panelist

Edward G Anderson, University of Texas-Austin, IROM Department, 2110 Speedway Avenue, Austin, TX, 78712, United States, ed@edanderson.org

## ■ TB04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning V

Contributed Session

Chair: Ivan Lugovoi, HEC Paris, 1 Square Theodore Judlin, Paris, 75015, France, ivan.lugovoi@hec.edu

#### 1 - Developing an Adaptive Order Recommender System: A Case of Pulmonary Outpatient Clinics

Yi-Shan Sung, Research Assistant, The Pennsylvania State University, University Park, PA, 16802, United States, yqs5097@psu.edu

Placing clinical orders for a patient is a time-consuming process which is easy to end up with wrong, missing and duplicate orders. This research aims at building an order recommender system to predict the potential clinical orders that a provider would give to a patient in an upcoming appointment. This system is developed by integrating machine learning with network-based inference method and validated using electronic health record data in pulmonary clinics. The implementation of the system will help in easing order documentation and enhancing order effectiveness.

#### 2 - Patient Condition Based Inventory Control of Medicines in Hospitals

Esha Saha, Research Scholar, Indian Institute of Technology Kharagpur, Department of Industrial and Systems Engineering, Indian Institute of Technology Kharagpur, Kharagpur, 721302, India, eshasaha83@gmail.com, Pradip Kumar Ray

Continuous monitoring of patients admitted in various hospital units may result in multi-dimensional information on patient condition over time which can be utilized in making diverse managerial decisions. In the present study, a Markov model for determining the optimal inventory policies for medicines based on the patient condition is developed under stochastic and non-stationary demand scenario. The patient condition states are described by the type of diagnosis, oral and intravenous medications administered and other factors like dose of medicines and its time of administration.

#### 3 - A Data-driven Approach for Drug Replenishment in Hospital Wards

Tommaso Levato, PhD Student, Universita degli Studi di Firenze, Dipartimento di Ingegneria dell'Informazione, Via di Santa Marta 3, Firenze, 50139, Italy, tommaso.levato@gmail.com, Leonardo Galli, Federica Picca Nicolino, Fabio Schoen, Luca Tigli, Filippo Visintin

We present an optimization approach designed to help a decision maker in periodic replenishment for drugs in a ward. The optimization model is coupled with machine learning to learn relevant information on drug consumption and suggests order quantities to avoid rush orders and excessive inventory. Decisions are based on historical data on drug consumptions and on information on the number, length of stay and other characteristics of the patients and have been validated through simulation.

#### 4 - Process Innovation in the Pharmaceutical Industry

Ivan Lugovoi, PhD Student, HEC Paris, 1 Rue de la Libération, Jouy-en-Josas, 78350, France, ivan.lugovoi@hec.edu

Using a unique dataset of process - patent expert evaluations combined with the quarterly sales of eighty generic pharmaceutical products over a ten-year period we find that process-patent activation is associated with a significant increase in a company's market share; an effect which persists over time. To explain this effect we evaluate process innovation across three dimensions: novelty, strength and depth. We find that two of these dimensions are mainly responsible for explaining the effect: the strength, which measures the difficulty of bypassing a firm's patents and the depth, which captures how broadly the firm's process-patent portfolio covers the stages of the manufacturing process.

## ■ TB05

Schadee Zaal, Third Floor

### Coordination and Optimization in Healthcare

Invited: Health Operations Management

Invited Session

Chair: Na Li, Shanghai Jiaotong University, SJTU, The School of Mechanical Engineering, Shanghai, 200240, China, na-li03@sjtu.edu.cn

Co-Chair: Xiaolei Xie, Tsinghua University, Tsinghua, Beijing, China, xxie@tsinghua.edu.cn

#### 1 - Markov Decision Process for Optimizing Bed Reservation Policy in ICUs

Xuanjing Li, Tsinghua University, Beijing, 100084, China, lixj15@mails.tsinghua.edu.cn, Xiaolei Xie, Dacheng Liu, Na Geng

In practice, ICUs administrators reserve some beds or early discharge current patients for those serious patients to avoid dangerous condition. A Markov Decision Process (MDP) model is established to strike balance between rejection of incoming patient and the early discharge in the near future. We propose a reservation policy by analyzing the properties of the optimal function including monotony, concavity and decreasing marginal reward.

#### 2 - Threshold Policy for Operational Management in Reverse Referral Partnerships

Na Li, Shanghai Jiaotong University, Shanghai, China, na-li03@sjtu.edu.cn, Nan Kong, De Teng

Reverse referral, implemented to alleviate the imbalanced utilization of medical resource in Chinese hierarchical healthcare system, is facing some operational difficulties caused by profit-driven features of hospitals. To deal with these difficulties, we propose a self-optimized threshold control policy, which is applied in three scenarios in a Two-level Cooperative Hospitals System of reverse referral partnerships. Optimization based on Markov performance measures are used to derive the optimal control policies.

#### 3 - Differentiated Design of Copayment for Multi-tiered Healthcare System in China

Yewen Deng, Shanghai Jiaotong University, Shanghai, China, ywdeng@sjtu.edu.cn, Na Li, Zhibin Jiang

We build a choice model to obtain more comprehensive information on preferences of patient's medical-care-seeking behavior and apply the BCMP theory to derive analytical results on performance measures of the queueing network model. Combining the empirical investigation with theoretical results, we build an optimization model to design the differentiated copayment to guide the government to manage China's multi-tiered healthcare system effectively.

## ■ TB06

Van Beuningen Zaal, Third Floor

### Maximizing Health under Constraints in Developing Countries

Invited: Disparities in Health, Low and Middle Income Settings, Global Health

Invited Session

Chair: Julie Simmons Ivy, North Carolina State University, Raleigh, NC, 27695-7906, United States, jsivy@ncsu.edu

#### 1 - Modeling Impact of Interventions on Mother to Child Transmission of HIV

Elizabeth McCarthy, Clinton Health Access Initiative, P.O. Box 51071 Ridgeway, Lusaka, Zambia, emccarthy@clintonhealthaccess.org, Jessica Joseph

Antiretroviral therapy during pregnancy and breastfeeding has proven so effective that virtual elimination of mother-to-child transmission (MTCT) of HIV has become an attainable goal. Yet health systems constraints in many resource-limited countries remain a barrier. We developed a computer-based state-transition model using Markov cohort simulation to estimate MTCT. The model, a tool for decision-makers, compares the impact on MTCT of different programmatic interventions to retain women and infants in care, and improve basic health services such as strengthening maternal and infant testing, improving adherence to visit schedules, and preventing stock-outs of essential commodities.

#### 2 - Technology use Findings Informing Resource-poor Environments and their Healthcare Needs

Fay Payton, Professor, North Carolina State University, COM, Box 7229, Raleigh, NC, 27695, United States, fay\_payton@ncsu.edu

In a prior study, we used a technology adoption model to assess the use of telemedicine among Ethiopian physicians. While the model explained acceptance behavior of physicians in a resource constrained environment, it also explained twenty-eight percent of the variance in the intention to adopt the technology and fifty-eight percent in perceived ease of use. This research presentation challenges the field to examine what are the critical disease conditions that can be modeled to address critical disease conditions in these environments.

#### 3 - A Simulation Study on the Decongestion of Urban HIV Clinics in Zambia

Kathryn Smith, NCSU, Raleigh, NC, United States, knsmith4@ncsu.edu, Karen T Hicklin, Elizabeth McCarthy, Julie Simmons Ivy

Congestion and long patient wait times affect HIV clinics in developing countries. In order to attempt to reduce congestion and wait times, interventions to increase the number of stable patients receiving three month drug supplies and reduce drug stockouts were implemented and tested at several clinics in Zambia for a three month period. To analyze the effects of these, and other possible interventions, a discrete event simulation (DES) model of a generic HIV clinic was created.

## ■ TB07

Willem Burger Zaal

### Policy/Incentive Issues in Healthcare Operations

Invited: Public Health and Policy Making

Invited Session

Chair: Tinglong Dai, Johns Hopkins University, Johns Hopkins University, Baltimore, MD, 21202, United States, dai@jhu.edu

#### 1 - Rational Inattention under Offer Batching

Tinglong Dai, Johns Hopkins University, 100 International Dr, Baltimore, MD, 21202, United States, dai@jhu.edu, Ronghuo Zheng

In this study, motivated by an organ procurement organization's offer-placement process, we model a two-sided matching problem in which costly investigation effort is required to acquire reliable quality information. We discuss a broad class of applications of our modeling framework, and provide both structural properties and computational insights.

#### 2 - Machine Learning for Planning Capacity and Demand in Primary Care Mental Health Services

Laura Andrews, Cardiff University, Cardiff, United Kingdom, andrewslg@cardiff.ac.uk, Daniel Gartner

Aneurin Bevan Health board is one of the largest healthcare organizations in the United Kingdom. Mental health services within the organization are faced with large demand. In this study, we use a sequential pattern mining algorithm to predict patients' clinical pathways and follow-up patterns. In a second stage, performance metrics are traded off using discrete-event simulation.

#### 3 - Implementing An Agent-based Framework to Evaluate Competition in Private Healthcare Markets

Abdullah Alibrahim, University of Southern California, 612 S Flower St, Apt 708, Los Angeles, CA, 90017, United States, alibrah@usc.edu, Shinyi Wu

Initiatives to improve healthcare quality and affordability have seemingly counteracting effects. Market share shifts due to coordinated healthcare provision might negate the effects of concentrating purchasing for care and coverage. An agent-based simulation model is built based on a theoretical framework that captures consumer, provider, and insurer decisions in private healthcare market. The structural, behavioral, and interrelated relationships are operationalized and results are validated in comparison to applicable empirical econometric relationships.

## ■ TB08

Ruys Zaal, Fourth Floor

### Healthcare Operations Management Applications

Invited: Health Operations Management

Invited Session

Chair: Nan Kong, Purdue University, Purdue University, West Lafayette, IN, 47906-2032, United States, nkong@purdue.edu

#### 1 - Reconfiguring Accident and Emergency Healthcare Facilities

Houyuan Jiang, University of Cambridge, Judge Business School, Trumpington Street, Cambridge, CB2 1AG, United Kingdom, h.jiang@jbs.cam.ac.uk, ManMohan Sodhi

Motivated by the cost and service pressures in England, the Keogh report of 2013 presented some principles for reconfiguring the emergency department (ED) system, while calling for models and tools to evaluate such reconfiguration. We present an approach to understand cost implications and to identify opportunities for reconfiguration of ED facilities nationwide. Using stylized models, we identify conditions for separating specialty from general ED to reduce costs without sacrificing service requirements. We identify conditions which support a merger of two EDs. Our work can help the implementation of the Keogh recommendations related to elderly services or urgent clinics for minor injuries.

#### 2 - Optimizing Patient-centered Care Interventions to Reduce Readmissions

Jingshan Li, Professor, University of Wisconsin-Madison, Madison, WI, 53706, United States, jingshan.li@wisc.edu, Hyokyung Lee, Sujee Lee, Philip A Bain

Hospitals have devoted substantial efforts to reducing readmissions. In this talk, first, the predictive models are used to identify the most critical factors that affect readmission and predict each patient's readmission risk. Then, process intervention models are introduced to evaluate the potential readmission probabilities. Finally, patient-centered optimization models are used to find the most cost effective intervention policies so that the readmission rate can be minimized. Two case studies are introduced: patients with chronic obstructive pulmonary disease (COPD) and total joint replacement (TJR) surgeries.

#### 3 - Next Day Stochastic Operating Room Scheduling with Limited Historical Data

Enis Kayis, Assistant Professor, Ozyegin University, Ni antepe Mah. Orman Sok.No:34-36, Alemda – Çekmeköy, Istanbul, 34794, Turkey, enis.kayis@ozyegin.edu.tr, Omer H Sevindik

Effective operating room (OR) scheduling when surgery durations are uncertain requires accurate surgery duration estimates. True surgery duration distributions are not known in practice and hence estimates are used as a proxy. Unfortunately, these estimates are developed using limited past data. In this paper, we quantify and analyze the effect of limited past data on generating OR schedules and discuss the efficiency of several estimation methods one can employ to increase the quality of OR schedules. We find that the number of data points may not be practically available in most settings to generate near-optimal schedules.

#### 4 - Improving Access of Low Back Pain Patients through Prioritization at a Neurosurgery Clinic

Esma S. Gel, Arizona State University, School of Computing, Informatics and, Decision Systems Engineering, Tempe, AZ, 85287-8809, United States, esma.gel@asu.edu, Derya Kilinc, Bernard Bendok

Low back pain (LBP) is often cited to cause significant health impairments for a large fraction of the population. Studies point to the unnecessary use of costly imaging studies and surgical assessment. This mismatch results in critical access problems for patients that truly need surgical interventions within a reasonable timeframe. We present findings from a year-long project to improve access of LBP patients at a neurological surgery clinic. Our analysis points to the importance of prioritizing surgical patients and demonstrates the potential improvements in patient access.

## ■ TB09

Van Rijckevorsel Zaal, Fourth Floor

### Scheduling and Planning VI

Contributed Session

Chair: Sandeep Rath, University of North Carolina at Chapel Hill, CB #3490, McColl Building, McColl 4705, Chapel Hill, NC, 27599, United States, sandeep@unc.edu

#### 1 - Optimizing Operations in a Surgical Theater

Flavio S Fogliatto, Professor, Federal Univ of Rio Grande do Sul, Av. Osvaldo Aranha, 99/5o andar, Porto Alegre, RS, 90040020, Brazil, ffogliatto@producao.ufrgs.br, Michel J. Anzanello

Performing surgeries is a central activity in most hospitals, calling for proper management of operations in the surgical theater. One key element is the scheduling of procedures: if properly conducted it maximizes the number of surgeries assigned to surgical rooms and smooths the demand for resources, before and after procedures take place. Here we discuss the planning of activities in surgical theaters at a low aggregation level. We present a proposition to handle the scheduling problem, and test it in a surgery theater comprised of 11 rooms, assignable to 15 surgical specialties.

#### 2 - Using Buffer Capacity in Operating Room Planning

Carla Van Riet, KU Leuven, Naamsestraat 69, Leuven, 3000, Belgium, carla.vanriet@kuleuven.be, Erik Demeulemeester

A surgical schedule can rarely be executed as planned, leading to undesired cancellations of surgeries and staff overtime. One way to avoid this is to use buffers in the schedule. Unfortunately, this reduces the amount of capacity available for planning elective patients. In this talk, we show whether and in which cases it is reasonable to install capacity buffers, which type of buffer results in the best performance and how buffers influence the master surgery schedule. We are collaborating with a large university hospital in Belgium.

#### 3 - Operating Theater Scheduling Optimization

Paolo Tubertini, Assistant Professor, University of Bologna, Viale Risorgimento 2, Bologna, Italy, paolo.tubertini@unibo.it, Valentina Cacchiani

Waiting list reduction for elective surgery is a strategic goal for Emilia-Romagna Regional administration. In recent years the management of surgical activities is moving towards resources integration, emphasizing the need of decision support systems for optimizing the utilization of Operating Theaters shared resources such as induction and recovery rooms. We implemented and tested a Mixed Integer Programming model and a heuristic algorithm for the weekly scheduling of elective activities on real world instances.

#### 4 - Integrated Anesthesiologist and Room Scheduling For Surgeries: Methodology and Application

Sandeep Rath, Assistant Professor, University of North Carolina at Chapel Hill, CB #3490, McColl Building, McColl 4705, Chapel Hill, NC, 27599, United States, sandeep@unc.edu, Kumar Rajaram, Aman Mahajan

We consider the problem of minimizing resource usage and overtime costs across multiple parallel resources such as anesthesiologists and operating rooms. We develop a data driven robust optimization method to solve this problem. We validate and implement this model as a decision support system at the UCLA Ronald Reagan Medical Center This has increased the average daily resource utilization by over 3.5% and has led to an average daily cost savings of around 7% or estimated to be \$2.2mn per annum. The insights based on this model have also significantly influenced decision making at the operating services department at this hospital.

## ■ TB10

Plate Zaal, Fourth Floor

### Health Operations I

Contributed Session

Chair: Steven Mark Shugan, University of Florida, 2030 NW 24th Avenue, Gainesville, FL, 32605, United States, steven.shugan@warrington.ufl.edu

#### 1 - Operations Management and Mathematical Approaches to Implement Oncology Care Model at Lahey Cancer Institute

Mehmet Erkan Ceyhan, Lahey Hospital and Medical Center, 41 Mall Road, Burlington, MA, 01839, United States, erkanceyhan@gmail.com, Linda Weller-Ferris

The Center for Medicare & Medicaid Innovation is developing new payment and delivery models designed to improve the effectiveness and efficiency of cancer care. Oncology Care Model (OCM), which aims to provide higher quality, more highly coordinated oncology care at the same or lower cost. The practices participating in OCM have committed to providing care coordination, navigation, and national treatment guidelines for care. Lahey Health Cancer Institute has been selected to participate with their five infusion and outpatient clinics. We are

going to demonstrate mathematical modelling needs to improve efficiency and care coordination in OCM framework.

#### 2 - Modeling the Behavior of Patients Who Leave the ER without Being Seen

Ehsan Bolandifar, Assistant professor, Chinese University of Hong Kong, 9/F, Cheng Yu Tung Building, No., 12, Chak Cheung Street, Shatin, N.T., Hong Kong, Hong Kong, ehsan@cuhk.edu.hk, Tava Olsen, Nicole DeHoratius

Abandonment in queues has long been recognized as having a significant impact on system performance. Nevertheless, our empirical understanding of the key drivers for abandonment, particularly in observable systems, is limited. To better inform our understanding of abandonment and guide our modeling of this behavior, we study three operational drivers of abandonment, namely, waiting time, queue-length, and service rate. We examine the shape of the hazard function for LWBS behavior and found the Weibull distribution, when parameterized by appropriate covariates, does provide a good fit. We use these findings together with a numerical study to make recommendations for simulating LWBS behavior.

#### 3 - Past, Present, and Future of the Long Term Care Services: A Case Study in Vancouver Island

Mehdi Ghotboddini, Dr., VIHA, Victoria, BC, H3H 1H1, Canada, mehdi\_ghotboddini@yahoo.com, Chloe Wu, William Collishaw

An integrated simulation and predictive model is developed to investigate the impact of Residential Care (RC) admission policy in Vancouver Island, British Columbia, Canada, on the patients' waiting time and waiting cost. To this aim, the waiting costs for the community and hospitals waitlists are evaluated in detail. Various levers of high occupancy rates in RC facilities are studied. And then the future demand for Long Term Care services is predicted. Results demonstrate that the turnaround rates and the LTC eligibility criteria must be revised.

#### 4 - When Private and Public Hospitals Compete

Steven Mark Shugan, McKethan-Matherly Eminent Scholar Chair/Professor, University of Florida, Department of Marketing, P.O. Box 117155, Gainesville, FL, 32611, United States, steven.shugan@warrington.ufl.edu, Jinwan Moon

Public and private hospitals often compete. Our competitive model reveals that public hospitals target a broad market while private hospitals target niche markets, obtaining higher prices. Given higher margins, private hospitals obtain greater marginal benefits from marketing and invest more in marketing than public hospitals. Moreover, private hospitals increase marketing efforts given lower quality standards, less competition, and greater marketing efficiency because all allow greater differentiation. Surprisingly, when markets are less price sensitive, private hospitals also broadly targeting.

## ■ TB11

Van der Vorm Zaal, Fourth Floor

### Policy & Systems I

Contributed Session

Chair: Barbara Wiecekowska, Ministry of Health-Poland, Miodowa 15, Warsaw, 00-952, Poland, dep-as@mz.gov.pl

#### 1 - Patient Choice of Hospital Levels in China

Yi Chu, PhD Student, Industrial Engineering, ZJ 17#, Tsinghua University, Beijing, 100004, China, chuy14@mails.tsinghua.edu.cn

The research is aimed at helping Chinese government to guide patients to the proper level of health care provider. We mainly focus on the following three aspects: (1) factors that affect patient choice of levels of medical service providers in China, (2) compare health seeking behavior patterns in different areas in China, (3) compare health seeking behavior patterns between different disease types. Conditional logit model is used to analyze survey data from China Health and Retirement Longitudinal Study. We find the choice pattern varies among patients, implicating that policies should allow flexibility and be carefully designed for specific groups of people.

#### 2 - National-level Prediction in Length of Hospital Stay for Cardiology Patients in Taiwan

Po-Chia Chen, PhD Candidate, PhD Program in Management, College of Management, National Taipei University of Technology, 1, Sec. 3, Zhongxiao E. Rd., Taipei 10608, Taipei, Taiwan, zephyranger@hotmail.com, Pei-Fang Tsai, Kai-Ying Chen

This study is to develop a national-level prediction model in length of stay (LOS) for cardiology inpatients with coronary atherosclerosis, heart failure, and acute myocardial infarction. A total of 216,635 cases discharged between January 1, 2010 and December 31, 2012 from the National Health Insurance Research Database of Taiwan were analyzed. Factors found to have a significant effect on LOS were sex, age, hospital location, level of hospital accreditation, main diagnosis, comorbidity, intervention, and the reimbursement method. The accuracy of the predicted LOS was 62.44%. An empirical analysis of an academic medical center in Taipei was to demonstrate the application of the model.

### 3 - Relations Between Importance and Zone of Tolerance of Patient Expectation: An Empirical Research of Hospital Service Quality

Wei Hsu, Assistant Professor, National Taipei University of Nursing & Health Sciences, No. 89 Neijiang St., Taipei City, 10845, Taiwan, weihsu@ntunhs.edu.tw, Yun-Ting Huang, Wen-Ping Fan

The patient expectation, bounded by upper and lower levels of the Zone of Tolerance (ZOT), plays a critical role of defining what hospital service quality. However, there is a lack of literature to investigate the relations between importance and ZOT in a nonprofit organization. This study intends to investigate the relations between the importance and ZOT of service quality dimensions and attributes of hospital services, based the SERVQUAL dimensions and a sample of responses by 304 patients. The results showed that the situation, that higher importance with narrower and higher ZOT, exists in nonprofit organizations, especially significant on 'Tangibles' and 'Responsiveness.'

### 4 - Healthcare Needs Maps in Poland – A First Step Toward Evidence Based Management in Healthcare System

Barbara Wi ckowska, Ministry of Health, Miodowa 15, Warsaw, 00-952, Poland, dep-as@mz.gov.pl  
Barbara Wi ckowska, Warsaw School of Economics, al. Niepodleglo ci 162, Warsaw, 02-554, Poland, dep-as@mz.gov.pl, Beata Kon

Evidence based management was not widely used in recent years in Polish healthcare system. Even if it was used, it was based on individually collected data (coming from chosen providers/area). Without sufficient information only socially accepted policies and decisions were being implemented. Those important but controversial ones were not. To change this situation, healthcare needs mapping was introduced in Poland. Its aim is to provide data and thereby to enforce indispensable changes in Polish healthcare system. In presentation we discuss some examples of recent results.

## ■ TB12

Mees Zaal, Fourth Floor

### Health and Humanitarian Logistics

Invited: Health and Humanitarian Systems

Invited Session

Chair: Harwin deVries, INSEAD, Fontainebleau, 77210, France, harwin.devries@insead.edu

### 1 - The Benefits of Combining Early Aspecific Vaccination with Later Specific Vaccination

Lotty Evertje Duijzer, Erasmus University-Rotterdam, P.O. Box 1738, Rotterdam, 3000 DR, Netherlands, duijzer@ese.eur.nl, Willem L. Jaarsveld, van, Rommert Dekker

We study a decision maker who has a budget available to spend on vaccines. We study the trade-off between an early available aspecific vaccine and a later specific vaccine that is more tailored to the current outbreak. We show that it is often optimal to use a hybrid strategy, i.e. a strategy that partly invest in the early aspecific vaccine and partly in the late specific vaccine. Numerical results show that hybrid strategies can reduce infections by more than 50%.

### 2 - Optimizing Population Screening for Infectious Diseases

Harwin de Vries, INSEAD, Boulevard de Constance, Fontainebleau, 77210, France, harwin.devries@insead.edu, Albert P. M. Wagelmans, Joris Van De Klundert

Population screening by mobile units is crucial to control several infectious diseases. We consider the following planning problem: given a set of populations at risk, the expected evolution of the epidemic in these populations, and a fixed number of mobile units, which villages should be screened when? We present descriptive models for the development of the burden of disease over time which take screening explicitly into account, use these to develop and analyze several classes of planning policies, and numerically analyze them in the context of the control of the HAT disease in D.R. Congo.

### 3 - Analyzing the Effects of Combining Cost and QALY in the Value Function of a POMDP Model for Cervical Cancer Screening

Raha Akhavan-Tabatabaei, Associate Professor, Sabanci University, Sabanci University, Orta Mahalle, Tuzla, Istanbul, 34956, Turkey, akhavan@sabanciuniv.edu, Malek Ebadi, Hans Frenk

Maximizing a health-related measure of utility such as QALY, is a popular choice of value function for MDP models that recommend optimal and dynamic cancer screening policies. This choice however, assumes that the financial cost of testing is negligible. In this study, using the literature of health economics, we first address the challenge of combining cost and QALY into a single scale. Then, we analyze its effect on the screening recommendations of a POMDP model.

## ■ TB13

Van Weelde Zaal, Fourth Floor

### Predictive Analytics for Biomedicine and Clinical Decision

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Eva Lee, Georgia Tech, H. Milton Stewart School of, Atlanta, GA, 30332, United States, eva.lee@isye.gatech.edu

### 1 - Machine Learning: Multi-site Evidence-based Best Practice Discovery

Eva Lee, Georgia Tech, Industrial & Systems Engineering, Ctr. for Operations Research in Medicine, Atlanta, GA, 30332-0205, United States, evakylee@isye.gatech.edu

This study establishes interoperability among electronic medical records from 737 healthcare sites and performs machine learning for best practice discovery. A mapping algorithm is designed to disambiguate free text entries and to provide a unique and unified way to link content to structured medical concepts despite the extreme variations that can occur during clinical diagnosis documentation. Redundancy is reduced through concept mapping. A SNOMED-CT graph database is created to allow for rapid data access and queries. These integrated data can be accessed through a secured web-based portal. A machine learning model (DAMIP) is then designed to uncover discriminatory characteristics that can predict the quality of treatment outcome. We demonstrate system usability by analyzing Type II diabetic patients. DAMIP establishes a classification rule on a training set which results in greater than 80% blind predictive accuracy on an independent set of patients. By including features obtained from structured concept mapping, the predictive accuracy is improved to over 88%. The results facilitate evidence-based treatment and optimization of site performance through best practice dissemination and knowledge transfer.

### 2 - Analyzing Longitudinal and Multi-omic Microbiome Data

Paul Brooks, Virginia Commonwealth Univ., Dept of Stat., Sci. and OR, P.O. Box 843083, Richmond, VA, 23284, United States, jpbrooks@vcu.edu

Advances in sequencing technology have facilitated comprehensive surveys of the human microbiome, the community of microorganisms that reside in various body habitats. Longitudinal and multi-omic measurements provide a glimpse of the dynamics of host-microbiome interactions which can provide insight into human health and disease. These high-throughput measurements pose unique challenges for data analysis, motivating the development of new methods. In this talk we describe new methods and strategies for microbiome data.

### 3 - Incorporating Dose-prediction within a Personalized Treatment Paradigm

Xin Wei, Georgia Institute of Technology, Atlanta, GA, United States, xwei36@gatech.edu, Eva Lee

This work is joint with Grady Memorial Hospital. The management of gestational diabetes mellitus (GDM) focuses on close monitoring of a patient's blood glucose level while the clinician experiments with dosing strategy based on some clinical guidelines and his/her own experience. This work proposes a drug-effect-based personalized approach to improve treatment outcome for GDM patients. First, a pharmacokinetic and pharmacodynamics (PK/PD) model is established to uncover and predict drug effect based on analysis of anti-diabetic drug dosage and the blood glucose level recorded in the titration period of each patient. This personalized evidence is then incorporated within a treatment plan optimization model to generate optimal dosing strategy. In a retrospective study, personalized drug effect and disease progression are established using the first 2-3 weeks of treatment data. The optimized dosing strategy gives better glycemic control than those used in real practice; it also uses lower drug dosage. The personalized predictive treatment planning system improve clinical decision, facilitating cost-effective outcome-driven treatment.

**Thursday, 12:00PM - 2:00PM**

Willem Burger Zaal

**Lunch Plenary****The INFORMS contribution for the Health Systems and Hospitals of the Future**

Eric de Roodenbeke, CEO of the International Hospital Federation, Erik Gerritsen, Government of the Netherlands

Over the past years, The Dutch Health System has received considerable international praise. At the same time however, there are concerns about the sustainability, and the adaptations that are needed to meet future societal needs. In most scenarios, information technology and analytics play an important enabling role to provide solutions for the challenges ahead. Much of the discussion on making adaptations to health systems, whether in The Netherlands or abroad, focus around the pivotal role of hospitals. In addition to other advances, information technology will change their relationships with patients, with primary care, and is already bringing some of the services from the real physical world to the internet. There is a role to play for Operations Research and Analytics to design these transitions and develop their cost-effectiveness. Two highly distinguished guests will share their views on these developments. Erik Gerritsen, Secretary General of the Dutch Ministry of Health, Welfare and Sports will position the Dutch health system and unveil the plans to meet the future challenges. Eric de Roodenbeke, CEO of the International Hospital Federation, will discuss the present and future roles of hospitals, and share his views on the role of information technology and analytics. After presenting their views, the plenary speakers will involve the audience through a series of propositions regarding the contribution the INFORMS community can make to promote effective solutions for the identified challenges.

**Thursday, 1:30pm - 3:00pm****TC01**

Van Cappellen Zaal, Ground Level

**Healthcare Informatics**

Sponsored: Health Applications

Sponsored Session

Chair: Rema Padman, Carnegie Mellon University, Pittsburgh, PA, 15213, United States, rpadman@cmu.edu

**1 - Addressing Health Disparities using Smartphones**

Sriram Iyengar, Texas A&amp;M Health Science Center, Houston, TX, United States, iyengar@medicine.tamhsc.edu

Health disparity populations encounter great difficulties in understanding clinical information such as medical advice from providers about the nature, prevention, and management of their illnesses. The widespread penetration of smart phones even among low social-economic populations in the US offers an opportunity to remedy this situation. We describe how Persuasive Technology and Felder-Silverman theory can be applied to design apps that deliver complex medical information effectively, overcoming barriers of literacy/education deficits, age, and minority status.

**2 - Advancing Healthcare Delivery through an Integrated Research Electronic Health Record Model**

Lydia Drumwright, University of Cambridge, Cambridge, United Kingdom, lnd23@medschl.cam.ac.uk

The intrinsic belief that electronic health record (EHR) systems can change the delivery of care has inspired a wave of adoption of fully integrated EHR systems across high-income countries. While providing potential gains in patient safety, current EHR systems in isolation are not likely to dramatically change healthcare delivery. In order to support the full potential of an EHR, translational research must be embedded in the infrastructure. In October 2014, our hospital trust started using a fully integrated EHR, including a research model to maximise intelligent use of routinely collected data. Herein, we will demonstrate how specific exemplar projects are enabled by this system.

**3 - User Perspectives on using M-health Technologies to Support Opioid Addiction Recovery**

Esra Alagoz, University of Wisconsin, Madison, WI, United States, ealagoz@wisc.edu

The most common outcome of treatment for opioid dependence is early relapse. To reduce early relapse, we developed and currently testing a smartphone innovation called A-CHESS. In this presentation, we will present our findings on patient perceptions of the effects of using A-CHESS, the most and least useful services in A-CHESS, gender-specific effects, and how patients feel about various A-CHESS services over time.

**4 - Analysis of Game Telemetry from a Pediatric Health Intervention**

Rema Padman, Carnegie Mellon University, The H. John Heinz III College, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, rpadman@cmu.edu, Disha Gupta, Ketan Deshmukh, Rema Padman

Pediatric obesity is a growing epidemic, with unhealthy eating habits and poor physical activity being major contributors. While video and mobile games show a positive impact on behavior change in children, the mechanisms underlying game play that impact outcomes of interest are poorly understood. We examine the impact of a novel mobile gaming app on design of behavioral interventions by learning from the rich and unique game telemetry generated from a randomized controlled trial of app use by school children. We build and analyze chronological sequences of game plays to understand key patterns in game mechanics that players utilize as they navigate the game, and possible implications of the results.

**TC02**

Arcadis Zaal, First Floor

**Emergency Medical Services III**

Contributed Session

Chair: Mohammed Skiredj, École Nationale Supérieure, 10 Rue Jose Frappa, Saint-Étienne, 42000, France, mohammed.skiredj@emse.fr

**1 - Configuring Service Production Function for Emergency Medical Services**

Ram Babu Roy, Assistant Professor, Indian Institute of Technology Kharagpur, Kharagpur, 721302, India, rambabu@see.iitkgp.ernet.in, Sreekanth V K, Paul M Lillrank

The service production function for Emergency Medical Services comprises three configurations: self-service, collaborative service, and service factory. Defining the roles and responsibilities of customer and provider optimally in each configuration is crucial for value co-creation. Game theoretic concepts are used to design the contracts governing these service configurations.

**2 - A Minimum P Envy Mathematical Model for Locating Emergency Medical Service Centers Solved by Robust Meta Heuristics**

Roya Soltani, Islamic Azad University, Science and Research Branch, Shahrake Gharb, Darya Blv, Tehran, 1466948434, Iran, Islamic Republic of, roya.soltani@gmail.com, Mohammad Khalilzadeh, Ali Shahid Sales

For all customers to have an equal chance to obtain services from EMS centers, inequity among all customers must be reduced. For this purpose, we make use of the minimum envy location problem and expand it to simultaneously minimize the total weighted envy cost, service costs by ambulances at EMS centers, the establishment costs of EMS centers and purchasing costs of ambulances. Since the problem is NP-hard, metaheuristics with tuned parameters by Taguchi method are used to find the location of EMS centers, the number of ambulances assigned to each center and assignment calls of demand zones to EMS centers. The model is implemented to some problem instances and the results are analyzed.

**TC03**

Zeelenberg Zaal, Second Floor

**Public Health: Models and Empirics**

Invited: Public Health and Policy Making

Invited Session

Chair: Joel Goh, Harvard Business School, Boston, MA, 02163, United States, joelgoh@alumni.gsb.stanford.edu

**1 - Can Patient Arrivals to the Emergency Department be Modelled by Simple Waves?**

Donald Lee, Yale School of Management, 165 Whitney Ave, Box 208200, New Haven, CT, 06520, United States, donald.lee@yale.edu, Ningyuan Chen, Sahand Negahban

Exploiting the fact that real world arrival processes exhibit cyclic (though not necessarily periodic) behaviour, we propose a surprisingly simple procedure for obtaining a compact and analytic description of the underlying arrival process from data. Such a model is clearly useful for both simulation and modeling purposes, and the procedure itself comes with clean theoretical guarantees. We apply it to arrivals data from an emergency department to examine differences in arrival patterns by illness severity.

## 2 - Deployment Guidelines for Community Health Workers in Sub Saharan Africa

Jonas Oddur Jonasson, MIT Sloan School of Management, 30 Memorial Drive, E62-588, Cambridge, MA, 02142, United States, [joj@mit.edu](mailto:joj@mit.edu), Carri Chan, Sarang Deo, Jeremie Gallien

Community health workers (CHWs) are increasingly important to the delivery of health care in many African countries. Leveraging an extensive dataset featuring time, clinical findings and GPS information for CHW visits in Ghana, we develop a stochastic model describing the health dynamics of a population served by a time-constrained CHW. This model supports the design of managerial guidelines for patient prioritization and catchment area assignment in a CHW operation.

## 3 - Evidence of Upcoding in Pay-for-Performance Programs

Hamsa Sridhar Bastani, Stanford University, 10 Comstock Circle, Apt 304, Stanford, CA, 94305, United States, [hsridhar@stanford.edu](mailto:hsridhar@stanford.edu), Joel Goh, Mohsen Bayati

Medicare has sought to improve patient care by penalizing providers for hospital-acquired infections (HAIs). However, these efforts may be undermined if providers upcode, i.e. mis-report HAIs (possibly unintentionally) to increase reimbursement. Identifying upcoding is challenging due to unobservable confounders. We exploit state-level variations in adverse event regulation and instrumental variables to estimate that over 10,000 infections (nearly 20%) are upcoded each year, resulting in an added cost of \$200 million. Our findings suggest that increasing financial penalties alone may not reduce HAI incidence. We make several policy recommendations accordingly.

## 4 - The Cost of Workplace Stressors: Comparisons Between The United States and Europe

Joel Goh, Harvard Business School, Morgan Hall 495, Soldiers Field Road, Boston, MA, 02163, United States, [jgoh@hbs.edu](mailto:jgoh@hbs.edu), Jeffrey Pfeffer, Stefanos Zenios

The negative health effects of psychosocial work stressors such as long work hours, low job control, and economic insecurity are well-established. Nonetheless, an open question that organizational decision makers and public policy has yet to answer is the extent to which these negative outcomes and costs can be realistically remediated. In this research, we apply a mathematical model to estimate the extent to which the U.S. toll is preventable by comparing the estimated health consequences of work environments in the United States with similar countries in Europe.

## TC04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning VI

Contributed Session

Chair: Sheldon H Jacobson, University of Illinois, Dept of Computer Science, 201 N Goodwin Avenue MC258, Urbana, IL, 61801-2302, United States, [shj@illinois.edu](mailto:shj@illinois.edu)

## 1 - Person-Centric vs. Problem-Centric: Data-driven Heuristics for using Machine-learning to Improve Healthcare Outcomes

John Benjamin Coles, CUBRC Inc., 194 Cadman Drive, Williamsville, NY, 14221, United States, [jbcoles@buffalo.edu](mailto:jbcoles@buffalo.edu), Brett Cropp, Kacob Ekstrum

In the world of big data, health outcomes research is still in the process of shifting from a hypothesis, problem-centric approach to a person-centric, data-driven approach. In this talk we highlight how data-driven approaches to improving health outcomes open the door to cross-sector collaboration in improving health outcomes. Specifically, we will discuss how heuristics and semi-automated machine learning techniques are critical to identifying the right subset of information to develop predictive models.

## 2 - Prediction of Healthcare Resources Utilization using Multi-output Regression Models

Liwen Cui, Tsinghua University, Room 615, Building Shunde, Room 615, Beijing, 100084, China, [cuilw13@mails.tsinghua.edu.cn](mailto:cuilw13@mails.tsinghua.edu.cn), Xiaolei Xie, Zuojun Shen, Rui Lu, Haibo Wang

Previous literature mainly focuses on predicting the inpatient cost through one-output models, which suffers from several drawbacks. We provide a unified tool to predict the total cost and length of stay in a hospital simultaneously. We use modern machine learning models and evaluate their performance based on the electronic healthcare record (EHR) dataset containing more than 750,000 patients. We find that multi-output models halve training time, while provide similar or even better prediction results compared to one-output models.

## 3 - Health Analytics Lead to More Questions

Ramesh Sharda, Oklahoma State University, Spears School of Business, Institute for Research in Info. Systems, Stillwater, OK, 74078-0555, United States, [ramesh.sharda@okstate.edu](mailto:ramesh.sharda@okstate.edu), Pankush Kalgotra

As we amass more data, we have an opportunity to analyze a pseudo population to better understand differences in health across population groups. The way patients belonging to different population groups develop comorbidities can have a major impact on their health outcomes. We draw on the network theory and develop multiple comorbidity networks for different population groups based on gender, race, etc. using Cerner database in Center for Health Systems Innovation. Then, we compare their structural properties, which leads to developing multiple questions that need to be explored in the future clinical, economic and policy research.

## 4 - Estimating Causality using Balance Optimization Subset Selection

Sheldon H. Jacobson, University of Illinois, 201 N. Goodwin Avenue, MC258, Urbana, IL, 61801, United States, [shj@illinois.edu](mailto:shj@illinois.edu), Hee Youn Kwon, Jason Sauppe

Controlling estimator bias is a challenge when assessing causality, which occurs when estimating a treatment effect from observational data in medical studies. We investigate cases that may generate bias in the context of Balance Optimization Subset Selection (BOSS), and discuss how to mitigate it. While doing so, a balance hierarchy is created, which leads to particular imbalance measure that correspond to particular response functions. New imbalance measures based on the Cramer-von Mises test statistic are introduced. The cases of insufficient data and suboptimality that can arise in causal analysis with BOSS are discussed.

## TC05

Schadee Zaal, Third Floor

### Patients, Physicians, and Their Interactions

Invited: Health Operations Management

Invited Session

Chair: Joel Goh, Harvard Business School, Harvard Business School, Boston, MA, 02163, United States, [joelgoh@alumni.gsb.stanford.edu](mailto:joelgoh@alumni.gsb.stanford.edu)

## 1 - Conspicuous by its Absence: Diagnostic Expert Testing under Uncertainty

Tinglong Dai, Johns Hopkins University, 100 International Dr, Baltimore, MD, 21202, United States, [dai@jhu.edu](mailto:dai@jhu.edu), Shubhranshu Singh

A diagnostic expert helps clients assess their conditions and recommends courses of action. When the expert's diagnosis is imperfect, costly gnostic testing may be required to reveal the clients' true conditions. For an expert concerned about both the clients' utility and her own reputation as a highly skillful professional, there is an opportunity for the expert to choose the diagnostic process to influence the clients' perception. Our paper represents an initial attempt to formally link diagnostic uncertainty and information asymmetry, and provides implications for the phenomenon of under-testing in the US healthcare system, which, despite its prevalence, receives little attention.

## 2 - A Robust-stochastic Approach to Data-driven Patient Scheduling in Emergency Departments

Shuangchi He, National University of Singapore, 1 Engineering Drive 2, Dept. of Industrial and Systems Engineering, Singapore, 117576, Singapore, [heshuangchi@nus.edu.sg](mailto:heshuangchi@nus.edu.sg), Melvyn Sim, Meilin Zhang

Emergency care necessitates adequate and timely treatment, which has unfortunately been compromised by crowding in emergency departments (EDs). We study patient scheduling in EDs in order for mandatory targets imposed on patients' door-to-provider times and lengths of stay to be collectively met with the greatest probability. Exploiting patient flow data, we propose a hybrid robust-stochastic approach that provides a computationally amiable formulation and yields satisfactory solutions to the patient scheduling problem. The hybrid formulation enables us to develop a dynamic scheduling algorithm for making recommendations about the next patient to be seen by each available physician.

## 3 - Assessing the Cost of Physician Burnout in the United States

Joel Goh, Harvard Business School, Morgan Hall 495, Soldiers Field Road, Boston, MA, 02163, United States, [jgoh@hbs.edu](mailto:jgoh@hbs.edu), Shasha Han, Christine A Sinsky, Tait D. Shanafelt, Liselotte N. Dyrbye, Mickey Trockel, Lynne C. Fiscus

Occupational burnout is a psychological state that is characterized by a loss of motivation or enthusiasm at work and feeling of cynicism. Burnout in physicians is known to be associated with an increased propensity to reduce in their work effort and an increased frequency of medical errors. Understanding the costs of physician burnout can guide clinical leadership in making better operational choices or investing in burnout mitigation interventions. In this research, we develop a mathematical model and calibrate it using data to assess the annual cost of physician burnout in the United States.

## ■ TC06

Van Beuningen Zaal, Third Floor

Invited: Tutorial

### Data and Modeling Challenges in Low and Middle Income Settings

Invited: Disparities in Health, Low and Middle Income Settings, Global Health

Invited Session

Chair: Hari Balasubramanian, University of Massachusetts-Amherst, 160 Governors Drive, Amherst, MA, 01003, United States, hbalasubraman@ecs.umass.edu

#### 1 - Data and Modeling Challenges in Low and Middle Income Settings

Hari Balasubramanian, Univ of Massachusetts-Amherst, 160 Governors Drive, Amherst, MA, 01003, United States, hbalasubraman@ecs.umass.edu

In this tutorial, we will discuss the operational challenges in coordinating clinical and social needs for patients in low and middle income settings. We will use a unique longitudinal dataset from Camden, New Jersey to illustrate topics such as the statistical prediction of individual trajectories and the staffing implications for a multidisciplinary care team consisting of nurses, community health and social workers. The tutorial will make use of a short video, detailed analysis of the dataset as well as interactive discussion with the audience to explore methodologies for such problems.

## ■ TC08

Ruys Zaal, Fourth Floor

### Patient Scheduling and Assignment

Invited: Health Operations Management

Invited Session

Chair: Aleida Braaksma, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States, braaksma@mit.edu

#### 1 - Multimodularity in the Stochastic Appointment Scheduling Problem with Discrete Arrival Epochs

Christos Zacharias, University of Miami, 5250 University Drive, Room 401 K/E, Coral Gables, FL, 33146, United States, czacharias@miami.edu, Tallys Yunes

We address the problem of designing appointment scheduling strategies that account for patients' no-show behavior, non-punctuality, emergency walk-ins and random service times. We maintain the discrete nature of the appointment scheduling problem by considering arrival epochs with discrete supports. We demonstrate that the optimal scheduling strategy minimizes a multimodular function, and that a polynomial-time local search algorithm terminates with a globally optimal solution.

#### 2 - Online Appointment Scheduling with Consideration of Service Durations and Time Preferences

Anne Zander, Karlsruhe Institute of Technology, Karlsruhe, Germany, anne.zander@kit.edu, Uta Mohring

We consider an online appointment system that lets patients choose an appointment out of a set of time slots. We want to decide which time slots to offer to a specific patient in order to maximize schedule utilization while satisfying a fairness measure. Hereby, we take different service durations and time preferences of patients into account. We model the problem as a Markov decision process and present a heuristic for realistic problem instances that solves a stochastic ILP for each requesting patient. In a simulation the heuristic is tested and compared to simpler strategies.

#### 3 - Advance Multi-appointment Scheduling with Resource Compatibility Restrictions

Ingeborg Bikker, University of Twente, Drienerlolaan 5, Enschede, 7522 NB, Netherlands, i.a.bikker@utwente.nl  
Antoine Saure, Xiang Claire Ma, Nathan Horvath, Scott Tyldesley, Martin L. Puterman

To provide radiotherapy patients with timely access to care, we consider an advance scheduling problem in which patients require a series of radiation appointments on one of several treatment units. Unit requirements vary per patient type. In practice, appointments are typically planned in the first available slot of a suitable unit, leaving no space for urgent patients. We formulate a Markov decision process to identify good policies for scheduling appointments on units, while reducing access times in a cost-effective manner. We use value function approximation and column generation to derive approximate solutions, and simulate their performance for a case of the British Columbia Cancer Agency.

#### 4 - Real-time Assignment of Inpatients to Beds

Aleida Braaksma, Massachusetts Institute of Technology, Sloan School of Management, 100 Main Street (E62-459), Cambridge, MA, 02142, United States, braaksma@mit.edu, Bethany Daily, Peter Dunn, Retsef Levi, Ben Orcutt, Elizabeth Ugarph, Ana Cecilia Zenteno

Assigning newly admitted patients to beds involves multiple constraints. Suboptimal patient-to-bed assignment may cause excessive patient wait times, crowding in upstream areas, and prolonged length-of-stays. We develop algorithms for real-time assignment of patients to beds, aiming at shortening patient wait times and decreasing upstream congestion. Through data-driven simulation, we quantify the benefits of the developed algorithms. Implementation of our results at Massachusetts General Hospital has resulted in significant decreases in patient wait times for beds, in addition to multiple other benefits.

## ■ TC09

Van Rijckevorsel Zaal, Fourth Floor

### Scheduling and Planning VII

Contributed Session

Chair: Nikky Kortbeek, University of Twente, Neeltje Snijdershof 29, Wijk aan Zee, 1949BS, Netherlands, n.kortbeek@utwente.nl

#### 1 - Enhanced Patient Dispatching Rules for Triage Process in Emergency Departments

Guvenc DIK, PhD Candidate, Queensland University of Technology, 2 George St, Brisbane, 4000, Australia, guvenc.dik@hdr.qut.edu.au

The emergency department (ED) is a dynamic and complex system. Triage determines initial clinical needs and prioritizes order in which patients are to be seen based upon their presentations. A scheduling model for patient flow is developed and enhanced dispatching rules for the triage process are investigated using stochastic treatment times. Results show that the maximum waiting and length-of-stay times of ED patients are decreased with enhanced dispatching rules.

#### 2 - A Mixed Integer Linear Programming Approach for the Patient Admission Scheduling Problem

Janaina Marchesi, PUC-Rio, Rio de Janeiro, Brazil, janainamarchesi@gmail.com, Leonardo Bastos, Silvio Hamacher

This paper addresses the Patient Admission Scheduling (PAS) problem corresponds to the assignment of elective patients to beds given the medical needs and the patient preferences. The best solutions in literature were provided by heuristic methods and no optimal solution has been found. Hence, this paper presents a mixed-integer linear model to solve the PAS with a new modelling approach for the constraints found in the literature to achieve optimal results for the tested instances.

#### 3 - Developing a Simulation Framework for the Integrated Hospital Scheduling Problem

Joren Marynissen, KU Leuven, Naamsestraat 69, Leuven, 3000, Belgium, joren.marynissen@kuleuven.be, Erik Demeulemeester

The integrated hospital scheduling problem focuses on scheduling patients who need multiple appointments. These problems originated in the integrated healthcare literature and try to devise a schedule in which the patient receives the full treatment as soon as possible. For this problem, we developed a new simulation package (SimInt) that is capable of testing multiple scheduling strategies and measuring the impact of these strategies on the operational processes. The package was tested using data from a cardiology department in a large university hospital.

#### 4 - Integral Capacity Management in St Maartenskliniek – Science in Practice

Nikky Kortbeek, CEO / Researcher, Rhythm, spin-off University of Twente, Neeltje Snijdershof 29, Amsterdam, Netherlands, n.kortbeek@utwente.nl

Over the past decade, the results of the research center CHOIR of the University of Twente have shown that developing and applying OR/MS techniques can lead to a better understanding and functioning of healthcare delivery. Following its mission to maximize practical impact, it founded the spin-off company Rhythm in 2014. Please join a short trip along some of the addressed research topics and their applications. This storyline serves as a living of example of CHOIR's innovation cycle: new insights continuously leading to new questions, in turn leading to new research and new solutions. The scientific results culminate in the practical case of the St Maartens Clinic. In this innovative Dutch hospital, integral planning & scheduling of surgeons, operating rooms, diagnostics and beds based on OR/MS techniques is set as the new standard.

## ■ TC10

Plate Zaal, Fourth Floor

### Health Operations II

Contributed Session

Chair: Robert A. Myers, Wright State University,  
8647 US Route 127, West Manchester, OH, 45382, United States,  
robert.a.myers@wright.edu

#### 1 - Modelling Care Seeking

Steffen Bayer, University of Southampton, Highfield Campus,  
Southampton, SO17 1BJ, United Kingdom, s.c.bayer@soton.ac.uk

This presentation presents a hybrid modelling framework to build models capable of simulating care-seeking behaviour. The framework is implemented in Anylogic and applied to a diverse set of examples of care-seeking behaviour: vaccination, screening attendance and provider choice for less serious healthcare concerns (e.g. GP vs. emergency room visit).

#### 2 - Decision Support for Improving Interoperability of Major Disasters: Main Tasks, Materials, Equipment, EU Civil Protection Modules and Responders

Marion Rauner, Associate Professor Dr., University of Vienna,  
Oskar-Morgenstern-Platz 1, Vienna, A-1090, Austria,  
marion.rauner@univie.ac.at, Helmut Niessner, Karen Neville,  
Pope Andrew, Simon Woodworth, Odd Steen, Niklas Holmberg

The S-HELP Decision Support System was developed in a fp7 EU project for improving preparedness, response, and interoperability of health services and other main stakeholders involved in emergency situations (<http://www.fp7-shelp.eu/project>). We, the team of the University of Vienna, investigated emergency interventions/tasks performed by emergency responders (skills taxonomy) using emergency material/equipment and EU Civil Protection Modules (resources taxonomy). Differences among selected European emergency responder systems and disaster types were analyzed.

#### 3 - Outpatient Appointment Scheduling Considering Interruption

zihao jiao, Beijing Institute of Technology, Beijing, China,  
zihaojit@163.com

Due to lacking of medical resources, there exist unfairness and phenomenon making low efficient treatment caused by no-show and interruption especially when occupancy happened in outpatient department under the traditional HS appointment scheduling systems. From the perspective of patient, medical institutes and society and based on the model proposed by Hassin and Mendel (2008), we give a robust scheduling model considering these factors, which are always happened in countries which maintain no enough medical resources, then we give a data insight about influence of the parameters on optimal appointment intervals.

#### 4 - Nurses' Work with Interruptions: An Objective Model for Testing Interventions

Robert A. Myers, Wright State University, 3640 Colonel Glenn  
Highway, 207 Russ Engineering Center, Dayton, OH, 45435,  
United States, robert.a.myers@wright.edu, Pratik J Parikh

We present a model of nurses' work, comprehending both detrimental and beneficial interruptions, and generating insights into the onset of interruptions and the evaluation of interventions. Our data driven model was informed by observation of nurses in a trauma center, including 259 interruptions during 580 nursing activities. The resulting stochastic non-stationary model, with source and activity-dependent interruptions, is instantiated as a simulation and demonstrated using interventions emulating 'do not disturb' strategies and a more focused 'triaging' of phone calls.

## ■ TC11

Van der Vorm Zaal, Fourth Floor

### Policy & Systems II

Contributed Session

Chair: Rakesh Kumar Sarin, University of California-Los Angeles,  
Anderson School, Suite B519, 110 Westwood Plaza Box 95148,  
Los Angeles, CA, 90095-1481, United States,  
rakesh.sarin@anderson.ucla.edu

#### 1 - What Future for Healthcare Expenditures? A Time Series Analysis

Sofia Gomes, FEUP / INESC-TEC, Porto, Portugal,  
up200401798@fe.up.pt

The long-term causality relation between healthcare expenditure, economic growth, healthcare workforce and demographic variables is assessed by means of a cointegration analysis. Using data from Portugal for the period 1960-2014, the projection of future expenditures based on our results and on what is the expected evolution of those drivers reveals a rising trend in health expenditures, which may generate heightened challenges to governments and managers on the future delivery of healthcare.

#### 2 - Evaluating Sugary Drinks Tax using Dynamic Addiction Model

Masakazu Ishihara, New York University, Tisch Hall 818,  
40 West 4th Street, New York, NY, 10012, United States,  
mishihar@stern.nyu.edu, Jong Yeob Kim

This paper presents a dynamic structural model to evaluate the effect of a fat tax on soda purchases. High consumer responsiveness to the frequent price promotions in the soda category suggests that price-based instrument can be an effective policy tool in combating obesity. Our modeling framework incorporates unobserved heterogeneity, stockpiling behavior, and rational addiction and endogenous consumption that depend on past consumption history. We conduct counterfactuals based on realistic policy scenarios and evaluate how different tax policies affect soda purchases.

#### 3 - Strategic Forecasting and Alternative Payment Models: How Scenario-based Planning can Predict Health Care Fraud

David Sulek, Principal/Director, Booz Allen Hamilton, 901 15th  
Street NW, Suite 400, Washington, DC, 20005, United States,  
sulek\_david@bah.com, Kelsey Carpenter, Ari Friedman

Fraudulent actors in the health care market are constantly adapting, however analysts typically look to the past to predict future instances of fraud. This method of detection is not always effective, and could be augmented by a strategic forecasting model that uses futuristic scenario-based planning to discover areas of weakness. To demonstrate the power of scenario-based planning, the presentation will highlight a future where Accountable Care Organizations face constant attacks from fraudulent actors with and without the Patient Protection and Affordable Care Act in place.

#### 4 - Universal Healthcare: Economics and Morality

Rakesh Kumar Sarin, Paine Professor of Management, University  
of California-Los Angeles, Anderson School, Suite B519,  
110 Westwood Plaza Box 95148, Los Angeles, CA, 90095-1481,  
United States, rakesh.sarin@anderson.ucla.edu

I make a case for universal healthcare as a rational economic and moral policy. The argument relies on the "original position" advanced by Rawls in his celebrated Theory of Justice. My conclusion, however is different than what Rawls proposed. I use the framework of decision theory when one is ignorant about the future state. Under the "veil of ignorance" a rational economic person will prefer a minimum level of universal healthcare and beyond which will maximize average utility. Such a policy though motivated by economic reasoning does have a moral force. I will use a few cases from medical decision making and healthcare policy to illustrate the distinction between Rawls Maximin rule and my proposed rule.

## ■ TC12

Mees Zaal, Fourth Floor

### Utilizing Data to Enhance Care Delivery

Invited: Health and Humanitarian Systems

Invited Session

Chair: Julie Simmons Ivy, North Carolina State University,  
Raleigh, NC, 27695-7906, United States, jsivy@ncsu.edu

#### 1 - Simulation to Validate an Optimization Based Workload Score Used to Triage Patients

Maria Esther Mayorga, North Carolina State University,  
400 Daniels Hall, Dept. of Industrial & Systems Engineering,  
Raleigh, NC, 27695, United States, memayorg@ncsu.edu,  
Osman Yalin Ozaltin, Joseph Kapena Agor, Kendall E. McKenzie,  
Jeanne Marie Huddleston

A simulation model was built in SIMIO8 to assist in triaging patients into The Mayo Clinic in Rochester, MN to balance workload among the hospital services. Delphi surveys, conjoint analysis, and optimization methods were used in the creation of a score to better represent provider workload. Preliminary results yielded a 12.1% decrease in the proportion of time a service was at or above "max utilization" and a decrease in the average difference among these proportions by 8.3% (better balance).

#### 2 - Translating Prediction to Decision: Risk Prediction and Visualization of Sepsis at the Bedside

Muge Capan, Christiana Care Health System, 902 N Market  
Street, Apt 527, Wilmington, DE, 19801-3082, United States,  
mccapan@ncsu.edu, Julie Simmons Ivy, Kristen E. Miller,  
Nisha Nataraj, Osman Ozaltin, Jeanne Marie Huddleston,  
Ryan Arnold

Rising incidence and mortality rate make sepsis, a spectrum of acute organ dysfunction secondary to an infection, an effective killer and healthcare burden. While utilizing electronic health records promises enhanced prediction of sepsis-induced deterioration of inpatients, translating findings into decisions at the bedside remains a challenge. We present a framework to reengineer the identification and presentation of risk associated with developing sepsis in infectious patients and in-hospital mortality in septic patients.

### 3 - Analyzing Septic Care Management through Discrete Event Simulation

Nishant Singh, North Carolina State University, 717 Resplendent Place, Raleigh, NC, 27603, United States, nsingh6@ncsu.edu, Julie Simmons Ivy, Maria Esther Mayorga

Infection and SEPSIS is one of the leading causes of death worldwide. Strict treatment guidelines exist in hospitals that feature complex systems involving multiple personnel and forms of technology. Many of these guidelines are time-based and tend to cause strain to the system. We used discrete event simulation to study the temporal management of resources and to provide recommendations to clinicians practicing in resource-limited settings.

## ■ TC13

Van Weelde Zaal, Fourth Floor

### Personalized Medicine via Cutting Edge Machine Learning

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Dimitris Bertsimas, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, dbertsim@mit.edu

#### 1 - Personalized Diabetes Management using Electronic Medical Records

Daisy Ying Zhou, Massachusetts Institute of Technology, Cambridge, MA, United States, zhuo@mit.edu, Nathan Kallus, Alex Weinstein, Dimitris Bertsimas

Current clinical guidelines for managing type 2 diabetes do not differentiate on patient-specific factors. We propose a personalized, data-driven prescriptive algorithm. For each visit among 10,806 type 2 diabetes patients from the electronic medical records, we analyzed the range of outcomes (HbA1c) under alternative care using a k-nearest neighbor approach. The algorithm prescribes the regimen with best outcome if the improvement from switching regimens exceeds a threshold. We evaluated the effect of recommendations on matched patient outcomes from unseen data. Among the 48,140 patient visits in the test set, the algorithm's recommendation mirrored the observed standard of care in 68.2% of visits. For patient visits in which the algorithmic recommendation differed from the standard of care, the mean post-treatment HbA1c under the algorithm was lower than standard of care by  $0.44 \pm 0.03\%$  ( $p < 0.001$ ).

#### 2 - Personalized Medicine for Traumatic Brain Injury

Jack Dunn, Massachusetts Institute of Technology, Cambridge, MA, United States, jackdunn@mit.edu, Dimitris Bertsimas, Yuchen Wang, Tom Trikalinos

Traumatic brain injury in children can be identified through CT imaging, which carries risks of radiation-induced malignancies. The current US practice uses a CART-based screening procedure to identify children at very low risk of brain injury that should not receive a CT scan. We apply new cutting-edge machine learning methods (Bertsimas and Dunn, Optimal Trees, Machine Learning, 2017) to this same problem, and show that our resulting models achieve the same sensitivity as the current practice (99%) while reducing the number of CT scans conducted by 25-50%.

#### 3 - Personalized Medicine for Coronary Heart Disease

Agni Orfanoudaki, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, agniorf@mit.edu, Dimitris Bertsimas

Coronary Heart Disease is the most common type of heart disease and the leading cause of death in the United States for women and men. However, a common approach to determine which treatment to prescribe to which patient has not been established yet. On that basis, we recognized the substantial benefit that algorithmic approaches and machine learning could bring in this field. We developed a personalized prescriptive algorithm that uses the electronic medical records of 21,617 patients to maximize the expected time to an adverse event (MI/Stroke) after diagnosis. Overall, the algorithm agrees with the current practice in 73.5% of the cases and achieves 12% improvement in the expected time.

#### 4 - Personalized Treatments for Breast Cancer

Emma Gibson, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, emgibson@mit.edu, Dimitris Bertsimas, Agni Orfanoudaki

There are many treatment options available to breast cancer patients, but it is often difficult to predict how successful these treatments will be for individual cases. We have developed a personalized treatment algorithm to select and evaluate treatment options based on individual diagnostic factors and existing medical conditions. When applied to cases in the SEER-Medicare dataset, our algorithm recommended alternative treatment options for approximately 10% of test subjects, resulting in an average estimated increase in survival time of 8 months within the first 8 years after diagnosis.

## Thursday, 3:30pm - 4:30pm

### ■ Plenary

Willem Burger Zaal

#### Brian Denton Plenary

Plenary Session

#### 1 - Operations Research in Medicine: Past, Present and Future

Brian T. Denton, University of Michigan, Ann Arbor, MI, 48109-2117, United States, btdenton@umich.edu

Operations Research (OR) methods such as decision analysis, simulation, stochastic models, and optimization, have a long and rich history of use for research and practice in medicine over the last several decades. Applications include cancer screening, diabetes treatment, glaucoma monitoring, organ transplants, radiation therapy, and many others. In this talk I will discuss some of the ways OR has had an impact on medicine in the past, drawing on several specific examples in the area of chronic diseases. Next, I will discuss some contemporary applications and discuss the research challenges and the opportunities these problems present to drive the development of new OR methods. Finally, I will conclude by summarizing some of the exciting new directions where OR can play a much needed role in the future including personalized medicine, biomarkers for early detection of diseases, and the development of artificial and regenerated organs.

## Friday, 8:00am - 9:30am

### ■ FA01

Van Cappellen Zaal, Ground Level

#### How Technology and Analytics Create Value in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Yasin Ceran, Santa Clara University, Santa Clara University, Santa Clara, CA, 95050, United States, yceran@scu.edu

#### 1 - High Resolution Optical DNA Mapping for Identification of Genomic Variations

Yasin Ceran, Santa Clara University, 2730 Park Ave., Apt 4, Santa Clara, CA, 95050, United States, yceran@scu.edu, Murat Baday

Optical mapping and newer genome mapping technologies based on nicking enzymes provide low resolution but long-range genomic information. The optical mapping technique has been successfully used for assessing the quality of genome assemblies and for detecting large-scale structural variants and rearrangements that cannot be detected using current paired end sequencing protocols. Here, we review several algorithms and methods for building consensus optical maps and aligning restriction patterns to a reference map, as well as methods for using optical maps with sequence assemblies.

#### 2 - The Interplay among Health Information Technology, Continuity of Care and Patient Readmissions

Changmi Jung, Johns Hopkins University, 100 International Dr, Rm 1323, Baltimore, MD, 21202, United States, changmi@jhu.edu, Sezgin Ayabakan

In health care, continuity of care has long been the core discussion element of improvement of care quality and patient health outcomes. Emerging health information technologies (HITS) are reducing the gap in the degree of available information, and thus, empowering more seamless care. In this study, we examine the effect of HIT on the patient readmissions and the extent of continuity of care. We utilize the state of Maryland's 2013 - 2016 FY inpatient admission records and present our preliminary findings.

#### 3 - To Predict or Not to Predict: The Case of Inpatient Admissions to the Emergency Department

Idris Adjerid, University of Notre Dame, 358 Mendoza College of Business, Notre Dame, IN, 46556, United States, iadjerid@nd.edu, Sriram Somanchi

The potential of data rich algorithms and systems to augment or even replace clinician judgment and fundamentally change the nature of healthcare is of significant debate. Yet, the challenges associated with incorporating these approaches into clinical settings are largely ignored in current research. We offer an approach that can help optimize prediction value in healthcare by balancing the accuracy of various prediction efforts against their associated costs.

## ■ FA02

Arcadis Zaal, First Floor

### Scheduling and Planning X

Contributed Session

Chair: David A Stanford, University of Western Ontario, Dept of Statistical & Actuarial Sciences, 1151 Richmond Street N, London, ON, N6A 5B7, Canada, stanford@stats.uwo.ca

#### 1 - Scheduling Strategies of Elective Surgeries in Order to Minimize Waiting Times for Emergencies

Roberto Bargetto, PhD Student, Ecole Nationale Supérieure des Mines de Saint-Etienne, 158 cours Fauriel, Saint-Etienne, 42000, France, roberto.bargetto@emse.fr, Federico Della Croce, Thierry Garaix, Xiaolan Xie

In hospitals, serve Emergency Surgeries (ESs) with the right timing lead to high quality of care. When ESs are performed in the Operating Rooms (ORs) used for the elective surgeries, the time when an OR becomes available (an elective ongoing surgery is completed) determines the Waiting Time (WT) for the incoming ES. A strategy to minimize the WT for ESs is proposed in [1], we study some variants of the problem presented in [1] and test different scheduling strategies as well. [1] Van Essen et al. Minimizing the waiting time for emergency surgery. *Oper Res Health Care*, 1(2-3):34-44, 2012.

#### 2 - Discovering Patterns in Self-reported Care Experience Data and Clinical Outcome Data to Improve Patient Experience

Qianyu Hu, Pennsylvania State University, State College, PA, United States, qzh5042@psu.edu, Deepak Agrawal, Yi-Shan Sung, Ning Liu, Soundar Kumara

Over past 25 years, patient satisfaction has gained increasing attention. Research has shown that patient experience is critical to improving clinical outcomes and should be measured in addition to standard quality and safety metrics. Therefore, providing a better patient experience, measuring and reporting is regulatory. However, literature is divided on this. Therefore, it is imperative to study the relationship between patient satisfaction and clinical outcomes. We use HCAHPS survey data to examine the relationship between patient perspective and clinical outcomes, to provide quality care.

#### 3 - The Affine Accumulating Priority Queue: A Model Which Prioritizes Based Upon Acuity and Waiting Time

David A. Stanford, Professor, University of Western Ontario, Western Science Centre 262, 1151 Richmond Street N, London, ON, N6A 5B7, Canada, stanford@stats.uwo.ca, Maryam Mojalal, Richard J Caron, Peter G Taylor, Ilze Ziedins

Previous Accumulating Priority Queue models in the literature have assumed that all arriving customers start to accumulate credits from a starting value of 0. The affine APQ model introduces a new element in terms of an initial class-dependent credit level, from which the accumulated priority grows linearly over time. In this presentation, we consider a two class APQ, and show initially how the initial priority score impacts the duration of the accreditation interval. We then assess the impact of the initial priority score on the waiting time distributions for the low and high priority classes. If time permits, numerical examples will be used to illustrate these concepts.

## ■ FA03

Zeelenberg Zaal, Second Floor

### Operations Management and Systems Engineering Models for Policy

Invited: Public Health and Policy Making

Invited Session

Chair: Edward Anderson, University of Texas-Austin, IROM Department, Austin, TX, 78712, United States, Edward.Anderson@mcombs.utexas.edu

#### 1 - Improving Access Delays from Request to Surgery with Multiple Patient Types

Mark P Van Oyen, University of Michigan, 1205 Beal Avenue, Ann Arbor, MI, 48109-2117, United States, vanoyen@umich.edu, Esmaeil Keyvanshokoo, Maya Bam, Brian T. Denton, Pooyan Kazemian

A stream of research by the authors treats real-time heuristic surgery scheduling policies to manage waits for an appointment, which are stratified by patient type. In addition, an optimization based methodology is able to specify (1) the date for the clinic visit, and (2) the surgery date with the same surgeon seen in clinic. It incorporates stochastic patient arrival mix and volumes and surgery durations (with surgical cancellation information gained in the clinic visit). We present model results based on historical patient data for patient access delay and overtime.

#### 2 - Multi-objective Criteria Scheduling in Healthcare

Amy Cohn, University of Michigan, 1205 Beal Avenue, Department of IOE, Ann Arbor, MI, 48109, United States, amycohn@umich.edu

When scheduling in healthcare, there are many rules and regulations that lead to complex combinatorial optimization problems, often well-suited for mixed integer programming methods. An additional challenge, however, is the frequent need to address multiple objective criteria, which are often qualitative as well. I will discuss examples from both resident scheduling and patient scheduling in endoscopy to motivate discussion about this challenging topic.

#### 3 - Rise and Shock: Optimal Defibrillator Placement in a High-rise Building

Timothy C.Y. Chan, PhD, University of Toronto, Dept. of Mechanical and Industrial Engineering, Toronto, ON, M5S 3G8, Canada, tcychan@mie.utoronto.ca

Cardiac arrests in high-rise buildings experience lower survival and longer delays until paramedic arrival. Use of defibrillators can improve survival, but "vertical" placement has not been studied. By modeling cardiac arrest occurrences using floor-specific Poisson processes, we determine the average distance from defibrillator to arrest for two possible defibrillator locations: lobby and elevator. We derive a simple and intuitive analytical result that characterizes when each location is optimal. We also examine maximum and standard deviation of the response distance.

## ■ FA04

Hudig Zaal, Third Floor

### Data Analytics and Machine Learning VII

Contributed Session

Chair: Ozden F. Gur Ali, Koc University, College of Administrative Sciences, Rumeli Feneri Yolu Sariyer, Istanbul, 34450, Turkey, oali@ku.edu.tr

#### 1 - Decision Pattern Mining in Chronic Disease Prescriptions using Electronic Medical Records

Praowpan Tansitpong, Lecturer, Mahidol University International College, 999 Bhuddhamonthon 4 Rd., Salaya, Nakhonpathom, 73170, Thailand, praowpan.tan@mahidol.ac.th, W. Art Chaovaitwongse, Apirak Hoonlor

This study investigates diversity in diabetes and hypertension prescriptions and estimates cost and revenue gained by health providers by mapping level of health benefit plans with clusters derived from hierarchical classification and inventory categorization technique.

#### 2 - Gestational Diabetes Mellitus Predictive Analytics using Electronic Medical Records

Haiyan Yu, University of Electronic Science and Technology of China, Chengdu, P.R.C, China, yhy188@tju.edu.cn, Chongqing University of Posts and Telecommunications, Chongqing, China, Hang Qiu

Gestational diabetes mellitus is one of the most common medical complications of pregnancy. Maternal characteristics collected and stored in Electronic Health Record (EHR) are known to increase risk of GDM. With EHR of pregnant women, digital health technologies such as machine learning and data mining provide a role for forecasting the occurrence of GDM. We have 33,935 pregnant women patients in total within the investigated four years. After the hard work of data cleaning, we use a filtering strategy to preselect patients as our candidate samples. Our proposed a prediction method based on EHR data to predict GDM is superior to OGTT in the horizontal period of gestational weeks.

#### 3 - Dynamic Risk Prediction Models Used for Patient Deterioration

Angie Shen, Duke University, Durham, NC, United States, angieshen6@gmail.com, Benjamin A. Goldstein, Rebecca C. Steorts

We use Electronic Health Records (EHR) data to develop a dynamic risk prediction model for patient deterioration. We propose a semi-parametric time-varying Cox regression model to incorporate a broad set of available predictors: vitals, labs and demographics. We evaluate the model over-time - showing the model performs consistently - and over time horizons - showing the model performs best in the near term. We illustrate different consideration in setting the data up in a counting process format to utilize the time-varying feature of EHR data.

#### 4 - Dealing with Data Generation Mechanism Biases in Burden of Disease Calculations with Big Data

Ozden F Gur Ali, Associate Professor, Koc University, College of Administrative Sciences, Rumeli Feneri Yolu Sariyer, Istanbul, 34450, Turkey, oali@ku.edu.tr

Availability of electronic health records, prescriptions, or death registries for population level studies can provide detailed information about disease prevalence, comorbidities, associated risk factors and sequelae of diseases when analyzed properly. On the other hand, observational data is prone to a number of biases, including in selection, reporting or coding. Further, integration of this information with those from other sources, including academic literature and population health surveys is desired, culminating in predictions with uncertainty intervals. We present our work on predictive models for burden of disease calculations.

#### ■ FA05

Schadee Zaal, Third Floor

#### Resource Planning in Hospitals

Invited: Health Operations Management

Invited Session

Chair: Jan Schoenfelder, Universitäres Zentrum für Gesundheitswissenschaften am Klinikum Augsburg (UNIKA-T), Universitäres Zentrum für Gesundheitswissenschaften, Friedberg, 86316, Germany, jan.schoenfelder@unikat.uni-augsburg.de

#### 1 - A Column Generation Approach to Flexible Nurse Scheduling under Uncertain Demand

Jan Schoenfelder, Bahnhofstrasse 6, Friedberg, 86316, Germany, jan.schoenfelder@wiwi.uni-augsburg.de

We model a hospital's scheduling decisions for (partially) cross-trained nurses under uncertain demand. While we approximate the true demand distribution by formulating a deterministic equivalent formulation, we are able to incorporate a refined set of possible demand realizations by employing a column generation approach. Based on data collected from three hospitals, we derive insights into the potential benefit that may or may not be gained from employing the cross-trained nurses. Furthermore, we analyze the schedule improvements that result from incorporating possible nurse reassignments into the initial scheduling decisions.

#### 2 - Case Mix Planning under Uncertainty

Sebastian Hof, University of Augsburg, Augsburg, Germany, sebastian.hof@unikat.uni-augsburg.de

Strategic decisions on the case mix are an opportunity for hospital providers to respond to financial pressure. The objective of this work is to evaluate which kinds of uncertainties should be considered in strategic case mix planning. Different stochastic problems considering different aspects of stochasticity are formulated and translated into their deterministic equivalents. The derived recommendations are evaluated simulating operational data. As a result, stochastic influences are ordered by their impact. Concluding, optimal strategies are compared to rules of thumb used in deterministic planning. We apply the analysis to data of a German hospital and show preliminary results.

#### ■ FA06

Van Beuningen Zaal, Third Floor

#### Disparities

Invited: Disparities in Health, Low and Middle Income Settings, Global Health

Invited Session

Chair: Paul Michael Savage, Iona College, 715 North Avenue, New Rochelle NY 10801 United States psavage@iona.edu

#### 1 - Dental Care Disparities for Low Income Children

Nicoleta Serban, Georgia Institute of Technology, 755 Ferst Drive Ne, Groseclose 438, Atlanta, GA, 30332, United States, nserban@isye.gatech.edu, Shanshan Cao, Monica Gentili, Paul Griffin, Susan Griffin

For children, tooth decay remains one of the most preventable chronic conditions. One reason for this is a lack of access to dental services. We evaluate access to dental care for children in the state of Georgia. We used optimization models matching need with supply of dental preventive services for children under access constraints. We used the models to evaluate the impact of oral health policies for improve access. We found that more than half of the pediatric population in the state of Georgia do not have access to preventive dental care. Moreover, those eligible for public insurance need to travel very large distances. These extreme disparities call for substantive changes in oral health policy.

#### 2 - Business Application of Machine Learning for Healthcare Transformation

Paul Michael Savage, Iona College, 715 North Avenue, New Rochelle, NY, 10801, United States, psavage@iona.edu

Machine Learning and the building of massive data-lakes associated with Population Health are transforming the decision support resources of Governance and Executive Leaders. The US Healthcare economic model is embracing 'Risk' & Disparity, based upon several simultaneous quantitative and qualitative metrics along with significant data enhancements which represent multiple analytical dimensions. These require a new understanding of modeling, forecasting and defining strategic business initiatives. The constraints and analytic capabilities will be explored.

#### ■ FA08

Ruys Zaal, Fourth Floor

#### Scheduling Optimization for Healthcare Management

Invited: Health Operations Management

Invited Session

Chair: Gang Du, PhD, East China Normal University, No. 500 Dongchuan road, Shanghai, 200241, China, gdu@dbm.ecnu.edu.cn

Co-Chair: Jianjun Wang, Dalian University of Technology, 2 Linggong Road, Dalian, 11624, China, drwangjj@dlut.edu.cn

#### 1 - Multi-objective Ant Colony Optimization Method on Operating Room Scheduling Problem

Aijun Liu, Xidian University, No.2, South Taibai Road/Street, Hi-Tec, Xi'an, China, liuajun2013@gmail.com

This research described the operating room scheduling problem with multiple objectives. A surgery planning mathematical model was developed with the objectives of minimizing the surgery cancellation risk and illness deterioration risk. An ant colony algorithm was designed to solve the multi-objective optimization problem. To take advantage of ant colony algorithm solving routing problem, Hybrid strategy is considered in the coding scheme. The approach used a variation of the adaptive grid and  $\lambda$ -dominated to produce well-distributed Pareto fronts. Experiment results show the proposed algorithm is effective and practical.

### 2 - A Distributionally Robust Optimization Approach for Solving Surgery Blocks Allocation Problems

Yu Wang, Shenyang Agricultural University, 133 Dongling Road, Shenyang, China, wangyuguomei@163.com, Yu Zhang

Managing operating room resources efficiently is a difficult task as patients' surgery duration has high variability. We propose a distributionally robust optimization approach for solving surgery blocks allocation problems. An ambiguous set consisting of means, absolute variance and support is built based on historical real-life data. Both exact and approximate solutions are obtained by deriving linear integer counterparts. Upper and lower bounds of the robust problem are also found. A three-point distribution heuristic is provided to find the near-optimal worst case solution. The developed approach is tested on real-life instances and demonstrates their ability.

### 3 - The Decision-Making of Large Medical Equipment Scheduling: From the Perspectives of Economic Benefit and Operational Efficiency

Gang Du, East China Normal University, 500 Dongchuan Road, Shanghai, 200241, China, gdu@dbm.ecnu.edu.cn, Xiaoling Ouyang

This article aims to propose a decision scheme for hospitals to address the time scheduling problem concerning multiple types of patient diagnostic equipment. We propose five solutions and finally determine the best one by constructing a finite horizon Markov decision process model. Results indicated that for the case of two PET-CT machines, although the optimal strategy of profit is better than the heuristic strategy, other performance indicators presented by optimal strategy and other suggestive strategies are similar. For the case of two scanners, other performance levels of all types of patients have reduced significantly.

### 4 - A Scenario-based Robust Optimization Approach for Surgeries Scheduling with a Single Specialised Human Resource Server

Jianjun Wang, Dalian University of Technology, 2 Linggong Road, Dalian, 11624, China, drwangjj@dlut.edu.cn, Chunlai Liu

This paper addresses a surgeries scheduling problem with a single server in charge of key medical facility. A surgery can be processed with a precedent setup by the server on one of available operating rooms. The setup can be processed at only one surgery at any time. Thus, it is critically important to simultaneously consider the setup precedence and operating room scheduling decisions. A robust model is presented for the problem to minimize the makespan associated with an uncertainty set for surgery durations. In order to evaluate the performance of the proposed robust model, a commercial optimization solver and several constructive heuristics which solve larger size instances are provided.

## FA09

Van Rijckevorsel Zaal, Fourth Floor

### Scheduling and Planning IX

Contributed Session

Chair: Majid Taghavi, Dalhousie University, 126 Abbington Ave., Bedford, NS, B4B 0R2, Canada, taghavi@dal.ca

#### 1 - Developing an Optimization-based Tool to Support Health Workforce Planning

Marta Monteiro, Centre for Management Studies, Instituto Superior Técnico, 1 Av Rovisco Pais, Lisbon, 1049-001, Portugal, martacmonteiro92@gmail.com, Dar'ya Khoroshylova, Teresa Cardoso-Grilo, Teresa Cardoso-Grilo, Mónica Oliveira, Ana Póvoa

Strategic planning of the health workforce currently represents a health policy priority in many European countries as the often existing imbalances in the demand and supply of health human resources (HHR) translate efficiency, quality and cost problems. This study proposes a tool based on multi-objective optimization models to inform decisions related to the opening of vacancies in medical schools and across medical specialties when multiple health, cost and HHR-specific objectives are pursued. A Portuguese case study is analysed, showing that substantial adjustments need to be done to the number of vacancies and to their allocation to specialties to anticipate future health system changes.

#### 2 - Analyses of the Phase I Postanesthesia Care Unit Baseline Capacity and Effect of Disruptions to its Beds or Nurse Availability on Operating Room Workflow

Danial Khorasanian, Isfahan University of Technology, Isfahan, 8415683111, Iran, Islamic Republic of, d.khorasanian@in.iut.ac.ir, Franklin Dexter, Ghasem Moslehi

When there is not a free bed or nurse in the phase I postanesthesia care unit ("PACU"), the patient recovers in the operating room, preventing the start of subsequent case(s), until capacity is available in the PACU. We report some real examples of situations in which the capacity of the PACU decreases unexpectedly, and analyze their implications on the operating room workflow. For this purpose, first, the baseline capacities of PACU beds and nurses are determined for some simulated data. Then, the characteristics of some situations with less capacity than the baseline are investigated, caused by disruptions of either decreasing the number of beds or nursing hours in the PACU.

### 3 - A Model for Allocation of Medical Specialists in a Private Hospital Network

Nantana Suppavitnarm, Chulalongkorn University, 2 Soi Soonvijai 7 New Petchburi Road, Bang Kapi, Huai Khwang District, Bangkok, 10310, Thailand, noon.su@gmail.com, Krit Pongpirul

As human diseases are getting more complex, the need for medical specialist consultation is more pronounced. This study aims to construct allocation models using a multi-objective programming approach to all demand sites within the Bangkok Dusit Medical Services (BDMS) network. Our models consist of 13 specialist types in 4 main disease groups of the BDMS network. The models feature 3 objectives: 1) Minimizing cost, 2) Meeting physician engagement and 3) Providing proper quality of care. It was found that the more the requirements, the less the capability of the model to solve for specialist allocation. The model should then be as most flexible as possible to succeed the allocation process in all areas.

### 4 - Planning the Number and Distribution of Specialist Palliative Care Personnel for Nova Scotia

Majid Taghavi, Assistant Professor, Dalhousie University, 5850 College St, Tupper Medical Building, Halifax, NS, B3H 4R2, Canada, taghavi@dal.ca, Grace Johnston

The population is ageing in many countries, and this means that an increasing number of adults will need a palliative approach at the end of their lives. In the past, palliative care was considered mainly for persons dying of cancer, but increasingly a palliative approach is being advised for individuals with organ failure and frailty. In this research, we propose a stochastic programming approach to find the optimal number of physicians, nurses, and social workers for Nova Scotia palliative care system over next 20 years. The model is capable of handling similar workforce planning problems in healthcare.

## FA10

Plate Zaal, Fourth Floor

### Emergency Medical Services IV

Contributed Session

Chair: S. Parthasarathy, Indian Institute of Technology-Madras, Sardar Patel Road, Adyar, Chennai, 600036, India, parthasarathy.subburaj@gmail.com

#### 1 - Ambulance Driver Timetabling

Mohammed Skiredj, PhD Student, École Nationale Supérieure des Mines de Saint-Étienne, 158 Cours Fauriel, Saint-Étienne, 42023, France, mohammed.skiredj@emse.fr, Thierry Garaix, Xiaolan Xie

This work addresses the timetabling problem for ambulance crews. The day before, based on the set of booked requests the working period of each driver is computed. The previous planning built two weeks ago using demand forecast has to be preserved as far as possible. The new timetable has to be robust against additional requests over the course of the day, avoiding overtime and delays for requests. This approach is compared to several current planning strategies from two ambulance companies.

#### 2 - Ambulance Dispatching and Relocation – The Portuguese Case

Inês Marques, Universidade de Lisboa, Avenida Rovisco Pais, Lisboa, 1049-001, Portugal, ines.marques.p@tecnico.ulisboa.pt, Ana Sofia Carvaino

Emergency Medical Service (EMS) is one relevant health care service since it plays a very important role for any person in an emergency. And daily, thousands of emergencies occur affecting the life of many people. EMS has to manage and mobilize several resources, e.g. expensive and high specialized material equipment and highly skilled staff, whereas providing an effective response to the uncertain emergencies that may occur. In Portugal, the ambulance dispatching and relocation has been a handmade task. This work studies the Portuguese case of EMS and applies optimization approaches to help the decision maker in these tasks.

#### 3 - Using Big Data for the Mobile Facility Routing Problem in Healthcare Delivery

Soheil Davari, Lecturer at Hertfordshire Business School, University of Hertfordshire, Hatfield, Hertfordshire, Hatfield, AL10 9AB, United Kingdom, s.davari@herts.ac.uk, Konstantinos Ampountolas

We will present a mobile facility routing problem with a continuous-time planning horizon using real-time data from a server. A set of vehicles are scheduled and routed in order to provide healthcare services to people considering capacity restrictions and budget issues. We modelled this problem as an infinite dimensional bi-objective mixed-integer programming model and proposed heuristics to solve it. The performance of the heuristics in terms of their solution quality and run-time have been compared. A case study in Glasgow, Scotland is provided as well.

#### 4 - Ambulance Re-positioning Algorithms using Core and Outlier Based Clustering

S. Parthasarathy, Indian Institute of Technology Madras, Sardar Patel Road, Adyar, Chennai, 600036, India, parthasarathy.subburaj@gmail.com, Amit R.K.

In today's world with growing development in science and technology, unfortunately, emergencies have also grown. In this paper we propose algorithms for re-positioning ambulances between different demand nodes in the city of Chennai (India) for improving the operational efficiency of emergency medical services. We also developed a new clustering technique, 'core and outlier based clustering', based on which the ambulances were clustered before adopting the relocation algorithms. Dynamic assignment of base locations to the ambulances has been employed as against the static ones. Further, we show that the proposed algorithms outperform the existing system and improves the efficiency.

### ■ FA11

Van der Vorm Zaal, Fourth Floor

#### Simulation

Contributed Session

Chair: Saied Samiedaluie, University of Alberta, 3-40C Business Building, Alberta School of Business, Edmonton, AB, T6G 2R6, Canada, samiedal@ualberta.ca

#### 1 - Simulation Modeling for Burnout in Caregivers of Patients with Chronic Disease

Oussama Batata, PhD Student, École Nationale Supérieure des Mines de Saint-Étienne, 158 cours Fauriel, Saint-Etienne, 42023, France, oussama.batata@emse.fr, Vincent Augusto, Xiaolan Xie

In France, the burnout of caregivers (family, friends...) of patients is becoming an important issue. The literature is poor regarding to the prevalence and predictors of burnout in the caregivers. In our work, we propose a predictive model based on burnout predictors for following health states of caregivers. The simulation of our model is included the variety of respite solutions for caregiver. In order to investigate the impact of these solutions over time, we carry out an experiment plane.

#### 2 - System Modelling for Improving Operational Performance and Patient Experience in Cancer Diagnostic Services

Richard Guerrero-Ludueña, Research Fellow, University of Southampton, University of Southampton, Faculty of Health Sciences, Southampton SO17 1BJ, UK, Southamton, SO17 1BJ, United Kingdom, R.E.GuerreroLuduenaa@soton.ac.uk, and University of Barcelona, Faculty of Biology, Av. Diagonal, 645 08028 Barcelona, Barcelona, 08028, Spain, R.E.GuerreroLuduenaa@soton.ac.uk

System modelling was used to improve operational performance and patient experiences in cancer diagnostic services in the UK. Information was collected from interviews with cancer services representatives, review of national guidance on cancer diagnosis and waiting times, open data, and data provided by hospitals. A conceptual model of the current cancer diagnostic system was developed. Finally, a simulation model was used to identify resources constraints and to evaluate potential service redesigns.

#### 3 - An Agent Based Simulation Model on Diabetes Prevention Strategies in China

Bowen Pang, Tsinghua University, Tsinghua Univ. Zijing 14#, Beijing, 100084, China, pzkaixin@foxmail.com, Xiaolei Xie, Jonathon Nelson, Yan Li, José A. Pagán

There are approximately 114 million people with diabetes and upwards of 500 million people with prediabetes in China, which prevents an enormous challenge to the society. We develop an agent based model (ABM) to simulate diabetes and its complications. After validation, the interventions such as quit smoking, improve physical activities and promote healthy diet are simulated and their impacts are investigated, respectively.

#### 4 - Developing a Simulation Model to Address Health Policy Questions Relating to Contraception Access

Saied Samiedaluie, Assistant Professor, University of Alberta, 3-40C Business Building, Alberta School of Business, Edmonton, AB, T6G 2R6, Canada, samiedal@ualberta.ca, Steven Shechter, Wendy Norman, Rollin Brant, Stirling Bryan

Almost half of pregnancies in Canada are unintended. Cost is among the important barriers to effective family planning methods and services. Extending government subsidy for contraception has proven to be a cost-effective intervention in many countries. In this research, we develop a simulation model to predict the related health and economic cost and benefit streams likely to result from any policy change in this area, such as provision of universal subsidy for contraception.

### ■ FA12

Mees Zaal, Fourth Floor

#### Analytics Approaches to Personalizing Healthcare Delivery

Invited: Personalized Medicine

Invited Session

Chair: David Scheinker, Stanford Engineering & Lucile Packard Children's Hospital, Stanford, CA, 94305, United States, dscheink@stanford.edu

#### 1 - Predicting Life Threatening Events Among Hospitalized Patients Through the Application of Convolutional Neural Networks to Physiologic Waveform Data

Andrew Shin, MD, Stanford University, Stanford, CA, United States, drewshin@stanford.edu, Daniel Miller, Lynda Knight, Vamsi Yarlagadda, David Scheinker

Hospitalized patients often exhibit signs of clinical deterioration 24-48 hrs prior to experiencing a life-threatening event. Detecting these signs can enable early identification of patient decline, allowing preventative measures to be taken. We hypothesize that the continuous physiologic waveform data streams generated by the patient's bedside monitor may be leveraged to predict patient decline prior to a life-threatening event. We present some clinical background and our initial results in the application of convolutional neural networks (CNNs) to physiological waveform data signals.

#### 2 - Patient Centric Therapy Decisions

Alejandro Martinez, Stanford University, Palo Alto, CA, United States, ale.martinez@stanford.edu

Patients, their families and providers are often faced with a choice of therapies. Considering patient specific risk factors and outcome preferences will lead to better decisions. We provide a rigorous framework for doing so. We use this framework to develop and test a tool for prostate cancer decisions.

#### 3 - Optimizing Surgical Patient Flow with Patient-Specific Analytics

David Scheinker, Stanford - Lucile Packard Children's Hospital, Huang Engineering Center, 475 Via Ortega, Stanford, CA, 94305, United States, dscheink@stanford.edu

The US healthcare system results in worse outcomes, by some measures, than the systems of comparable countries but costs significantly more. There is pressure on healthcare providers to improve quality and cut costs. Since the operating room environment provides highly specialized care, requires significant resources, and contributes significantly to a hospital's bottom line, it is a natural area of focus. We present several projects at a pediatric academic medical center that use machine learning and mathematical programming to incorporate patient-specific data into forecasting, scheduling, and management decisions.

#### 4 - Analytics for EHR-Integrated Pediatric Cardiology Home Monitoring Data

Jonathan P. Palma, MD, MS, Stanford Children's Health, Palo Alto, CA, United States, JPalma@stanfordchildrens.org

Infants with congenital heart disease causing single-ventricle physiology require multiple stages of surgery to prevent the development of heart failure. We describe the automation of the Single Ventricle Interstage Home Monitoring Program at Stanford Children's Health using a patient facing mobile application based on consumer technology (Apple CareKit). The app allows patients to record pertinent clinical information, and achieves electronic health record (EHR) integration of the home monitoring data. EHR-integration enhances the personalization and quality of care through new data visualizations and advanced analytics approaches designed to extract useful signal from the data.

## ■ FA13

Van Weelde Zaal, Fourth Floor

### Incentives in Healthcare

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Itai Ashlagi, Stanford University, Stanford, CA, 94305, United States, iashlagi@stanford.edu

#### 1 - Identifying Network Effects in Epidemic Propagation

Kimon Drakopoulos, USC, Los Angeles, CA, United States, drakopou@marshall.usc.edu, Fanyin Zheng

The analysis of epidemic propagation among populations has been the focus of several studies in different fields including epidemiology, public policy and operations. Existing work assumes an underlying network structure that governs the rate at which epidemics propagate. In this work, we develop and use tools in network econometrics on a rich dataset containing 7 years of data on the propagation of influenza in the United States, environmental factors, vaccination interventions as well as economic indicators. Our results provide a framework for identifying network effects in panel data with serial correlation and shed light on the effect of inter-state traveling on the propagation of influenza.

#### 2 - Do Mandatory Overtime Laws Improve Quality?

##### Staffing Decisions and Operational Flexibility of Nursing Homes

Susan F Lu, Purdue University, Krannert 441, West Lafayette, IN, 47907, United States, lu428@purdue.edu, Lauren Xiaoyuan Lu

During the 2000s, over a dozen U.S. states passed laws that prohibit health care employers from mandating overtime for nurses. Using a nationwide panel dataset from 2004 to 2012, we find that these mandatory overtime laws reduced the service quality of nursing homes, as measured by an increase in deficiency citations. This outcome can be explained by two undesirable changes in the staffing hours of registered nurses: decreased hours of permanent nurses and increased hours of contract nurses per resident day.

#### 3 - Dynamic Matching in Kidney Exchange

Itai Ashlagi, Stanford University, Department of Management Sci. and Engr., Stanford, CA, 94305, United States, iashlagi@stanford.edu

We study matching policies in a random dynamic market where some agents are easier to match than others. This asymmetry creates an imbalance: hard-to-match agents wait for partners, while easy-to-match agents are matched almost immediately upon arrival to the market. Matching agents greedily, leads to low waiting times, but leaves more agents without a compatible partner. A greedy policy nevertheless dominates other natural matching policies.

## Friday, 10:00am - 11:30am

## ■ FB01

Van Cappellen Zaal, Ground Level

### Data Analytics for Healthcare Management

Sponsored: Health Applications

Sponsored Session

Chair: Juhee Kwon, City University of Hong Kong, 6-274, Lau Ming Wai, Kowloon, Y7601, Hong Kong, juhekwon@cityu.edu.hk

#### 1 - Changes in Shoulder Muscle Activity After Breast Cancer

##### Surgery: A Pattern Analysis of Electromyographic Data

Young Ok Kwon, Sookmyung Women's University, Seoul, Korea, Republic of, yokwon@sm.ac.kr

Alterations in scapular muscle activation and restricted shoulder mobility, which are common with breast cancer patients, have been found to affect upper limb function. This study seeks to uncover factors that can determine scapular muscle-activation ratios by examining the patterns of electromyographic data. A Gaussian filter is applied to smooth the data and then activity differences between affected and unaffected sides are explored. The results show that altered muscle activity patterns are different with shoulder motion, surgery type, and duration after surgery. This biomechanical evidence may support the need of the precision exercise program according to the breast cancer treatment.

#### 2 - Creating and Evaluating the Use of Internet of Things and Analytics for Home-dwelling Elderly

Sharon Tan, National University of Singapore, Singapore, tanstl@comp.nus.edu.sg

This study uses IoT and analytics to monitor the activities of home-dwelling elderly daily living to identify relevant behaviours and behavioral changes that can be correlated with risks of mild cognitive impairment and frailty. Appropriate ICT-based interventions (e.g. data visualization and alerts to caregivers) are then applied to mitigate these risks. To evaluate the outcomes of our technology intervention, psychosocial data related to the elderly's quality of life, social activity participation and activities of daily living will be collected and analyzed.

#### 3 - Does Health Information Technology Affect End-of-life Medicare Spending?

Juhee Kwon, City University of Hong Kong, Hong Kong, Korea, Republic of, juhee.kwon@cityu.edu.hk, M. Eric Johnson

Treating chronic disease is enormously expensive. U.S. patients with chronic illnesses in their last two years of life account for about 32% of total Medicare spending. We seek to identify how the adoption of healthcare IT is associated with Medicare spending in the last 2 years of life. We find that EHRs significantly reduce end-of-life Medicare spending and result in increased patient satisfaction scores. However, we do not find any effect on readmission and mortality rates.

## ■ FB02

Arcadis Zaal, First Floor

### Scheduling and Planning X

Contributed Session

Chair: Kjartan Kastet Klyve, Prinsens Gate 61, Trondheim, 7011, Norway, kjartankk@gmail.com

#### 1 - A Markov Decision Process-based System for Scheduling Physiotherapy Treatment Appointments

Sergio Maturana, Professor, Pontificia Universidad Catolica de Chile, Dept Industrial and Systems Engineering, Vicuna Mackenna 4860, Santiago, MACUL, Chile, smaturan@ing.puc.cl, Ignacio Lazo

Scheduling physiotherapy treatment appointments in a hospital faced with a very high demand is complex. The current system in a Chilean hospital results in many patients waiting long times before their treatments can begin. We propose a scheduling system, based on a Markov Decision Process, to determine how to assign the patients to the physiatrist and how to distribute the patient's sessions within a planning horizon in order to reduce waiting times and assure that sessions are evenly spread.

#### 2 - Integrated Scheduling of Tasks and Gynecologists to Improve Patient Appointment Scheduling

Noelle Maria van de Vrugt, PhD, University of Twente, Drienerlolaan 5, Postbus 217, Enschede, 7500AE, Netherlands, n.m.vandevrugt@utwente.nl, Samuel T. Luen-English, Erwin Hans, Johann Hurink, Richard J Boucherie

The gynecology department of the Jeroen Bosch Hospital experienced difficulties with scheduling outpatient appointments at the medically preferred times. To overcome this unbalanced scheduling we develop a Mixed Integer Linear Programming approach that simultaneously assigns task types and gynecologists to shifts. Additionally we present two heuristics for practical implementation. Our methods improve upon the manually created schedules significantly and can easily be implemented in practice.

**3 - Optimization-based Nurse Scheduling for Real-life Instances**

Kjartan Kastet Klyve, PhD Student, Norwegian University of Science and Technology, Prinsens gate 61, Trondheim, 7011, Norway, kjartan.klyve@ntnu.no, Henrik Andersson, Marielle Christiansen, Anders Nordby Gullhav, Francesco Rugiano Beckmann

We provide a mathematical model used for optimization-based nurse scheduling at a maternity ward at St. Olavs Hospital, Trondheim, Norway. The planning problem at the ward involves allocating work shifts and off-days to 69 employees for a period of 27 weeks, while respecting several scheduling rules and focusing on employees' influence in the process. In fact, all preferences the ward manager could explicitly formulate are included in the mathematical model. A computational study shows very promising results and the model will be the core in a customized decision support tool.

**■ FB03**

Zeelenberg Zaal, Second Floor

**COST Action ENC-KEP: State of the Art in European Kidney Exchange Programs**

Invited: Public Health and Policy Making

Invited Session

Chair: Joris Van de Klundert, Erasmus University-Rotterdam, Ridderkerk, 2983 HE, Netherlands, vandeklundert@bmg.eur.nl

**1 - An Overview of KEP Practices in Europe**

Peter Biro, Hungarian Academy of Sciences, Budapest, Hungary, biro.peter@krtk.mta.hu

In this talk we will give an overview on the initial descriptions of these programmes, provided by the local coordinators. We will survey the main characteristics of the programmes, their performance and the main questions, challenges identified.

**2 - Kidney Exchange in NL, State of the Art and Future Directions**

Haase Bernadette, Netherland Transplant Stichting, Leiden, Netherlands, b.haase@transplantatiestichting.nl

In this presentation, we review our history and practices, and outline our plans for future advancements. While the emphasis of the presentation will be on the practical aspects of the program, we also discuss existing and future matching algorithms in the Dutch exchange program, as implemented in software that forms the foundation for the kidney exchange programs in various other countries.

**3 - Algorithms for Paired and Altruistic Kidney Donation in the UK**

David Manlove, University of Glasgow, Glasgow, United Kingdom, David.Manlove@glasgow.ac.uk

In this talk I will describe the matching problem and outline the algorithmic techniques that have been used to provide solutions. As of March 2016, 1058 potential transplants have been identified and 658 of these have proceeded to surgery.

**■ FB04**

Hudig Zaal, Third Floor

**Data Analytics and Machine Learning VIII**

Contributed Session

Chair: Faruk Akin, Koç University, Rumelifeneri Mah., Rumelifeneri Yolu, Sariyer, Istanbul, 34450, Turkey, fakin14@ku.edu.tr

**1 - A Delay-differential Equation Model of an Intensive Care Unit with State-dependent Service Rates and Return Probabilities**

Eman Almehdawe, Assistant Professor, University of Regina, 3737 Wascana Parkway, Faculty of Business, Regina, SK, S4S 0A2, Canada, Eman.Almehdawe@uregina.ca, Armann Ingolfsson

We investigate a fluid model of an Intensive Care Unit (ICU), in which patients are discharged at an adjustable speed, which influences the proportion of patients that require re-admission to the ICU after a delay. We formulate the model as a delay-differential equation. We study the transient and steady-state behavior of the system occupancy in four different regimes and we obtain conditions under which speedup reduces average occupancy.

**2 - Bending Healthcare Costs CABG with Improved Processes**

Feryal Erhun, University of Cambridge, University of Cambridge, Trumpington Street, Cambridge, CB2 1AG, United Kingdom, f.erhun@jbs.cam.ac.uk

Coronary artery bypass graft (CABG) surgery is a well-established, commonly performed treatment for coronary artery disease—a disease that affects over 10% of US adults and is a major cause of morbidity and mortality. In 2005, the mean cost for a CABG procedure among Medicare beneficiaries in the USA was \$32,201±\$23,059. The same operation reportedly costs less than \$2,000 to produce in India. The goals of this study are to (1) identify the difference in the costs incurred to perform CABG surgery by three Joint Commission accredited hospitals with reputations for high quality and efficiency and (2) characterize the opportunity to reduce the cost of performing CABG surgery.

**3 - Admission Control in an Intensive Care Unit with Readmission**

Faruk Akin, PhD Candidate, Koç University, Rumelifeneri Mah., Rumelifeneri Yolu, Sariyer, Istanbul, 34450, Turkey, fakin14@ku.edu.tr, E. Lerzan Örmeci

We consider an Intensive Care Unit and focus on the effects of early discharge decisions. The system may admit, reject or admit by early discharging a current patient in the ICU. Each discharged patient may join the environment and cause readmission, where we assume that early discharged patients are more likely to join the environment than regularly discharged patients. Arrival processes occur according to a Poisson process with a constant rate while the rate of recurring patients depends on the number of patients in the environment. Length of stay for all patients is an exponentially distributed random variable with the same rate. We investigate the structure of the optimal admission control policy.

**■ FB05**

Schadee Zaal, Third Floor

**Healthcare Analytics**

Invited: Health Operations Management

Invited Session

Chair: Zlatana Dobrilova Nenova, University of Pittsburgh, Pittsburgh, PA, 15217, United States, znenova@katz.pitt.edu

**1 - The Impact of No-show Prediction in Appointment Scheduling**

Shannon Harris, The Ohio State University, 1005 W 5th Avenue, Unit 535, Columbus, OH, 43212-3085, United States, harris.2572@osu.edu, Michele Samorani

Patient no-shows are very disruptive in outpatient appointment scheduling, as they lead to clinic underutilization, long patient waits, and doctor overtime. Existing studies suggest that predicting the individual patients' no-show probability may lead to a higher-quality schedule, but they fail to quantify the impact of the prediction performance on the schedule quality. Our study aims at filling this research gap by analytically measuring the improvement in the schedule quality resulting from an improvement in the no-show predictive performance. Our results can help practitioners determine how many resources to invest in predictive analytics.

**2 - Managing Emergency Physicians in a Multi-facility Management Network**

Krista Foster, University of Pittsburgh, 1622 Beechwood Boulevard, Apt 1, Pittsburgh, PA, 15217, United States, kmf88@pitt.edu, Jennifer S Shang

U.S. hospital-based emergency departments (EDs) are mandated by law to receive and treat patients regardless of patients' demographic, socioeconomic, insurance, or medical conditions. Thus, an ED's actual demand depends on external factors and is uncertain when personnel scheduling decisions are made. Furthermore, the growing trend of ED consolidation in the US has intensified the complexity of managing ED staff such as doctors, nurses, and advanced practice providers. We develop a model to optimally schedule these different types of ED personnel.

### 3 - Optimal Appointment Policy Selection for Chronic Kidney Disease Patients

Zlatana Dobrilova Nenova, University of Pittsburgh,  
2720 Shady Avenue, Apt 2, Pittsburgh, PA, 15217, United States,  
znenova@katz.pitt.edu, Jerrold H. May, Luis G. Vargas

We develop a Markov Decision Model, which optimizes the frequencies of regular appointments for patients with chronic kidney disease (CKD) over a pre-specified time horizon. The appointment selection depends on patients' CKD stage, comorbidities and age. The action space reflects a policy suggested by the National Institute for Health and Care Excellence. The model bases its decisions on trajectory forecasts from a case-based reasoning model drawing on a large-scale case base, a survival model, and appointment disutility estimates.

### ■ FB06

Van Beuningen Zaal, Third Floor

#### Global Health/Low Income Settings

Invited: Disparities in Health, Low and Middle Income Settings,  
Global Health

Invited Session

Chair: Kamalini Ramdas, London Business School, London, NW1 4SA,  
United Kingdom, kramdas@london.edu

#### 1 - Something from Nothing: Financial, Operational, and Social Benefits of Need-based Free Healthcare

Sobhan Asian, RMIT University, Melbourne, Australia,  
sobhan.asian@rmit.edu.au, Vikrant Vaze, Srinagesh Gavirneni,  
Omkar D. Palsule-Desai

Need-based free healthcare is an emerging business model that is delivering greater social benefits concurrently with higher financial gains due to its underlying innovative operational, marketing, and philanthropic features. Using Aravind Eye Hospital in India as the setting, we evaluate the role of operational learning, spill-over effects of marketing, and customer segmentation in enabling the success of this philosophy that is increasingly attractive in communities with rampant inequality commonly found in developing countries.

#### 2 - How Does Multichannel Delivery Impact Access to a Care Network? Evidence from Telemedicine in South India

Kraig Delana, London Business School, PhD Program Office,  
London, NW1 4SA, United Kingdom, kdelana@london.edu,  
Kamalini Ramdas, Sarang Deo

We empirically examine the impact of introducing a new healthcare delivery channel, specifically, vision centers in rural India where patients consult remotely with an ophthalmologist at an eye hospital via telemedicine. Our objective is to understand how this new channel impacts patient access and outcomes across the care network. We find that vision centers substantially improve access to care, leading to a 5% increase in network visits, of which more than 70% are from new patients. This increase in access prevails despite a 4% decrease in hospital visits. Improvement in outcomes varies by patient needs, with less-complex patients benefiting more.

#### 3 - Blueprinting Maternity Care Services in Rural India

Amrita Amrita, Indian Institute of Technology Kharagpur,  
Kharagpur, Paschim Medinipur, 721302, India,  
amrita@iitkgp.ac.in, Indranath Banerjee, Ram Babu Roy

One third of the 303,000 global maternal deaths, in 2015, happened in developing countries especially Nigeria and India. It is urgent to figure out how the rural women are utilizing the services by tasks. Average service utilization data does not help in understanding actual utilization. The study analyzes 306 primary data in two rural regions to compare the maternity care service-utilization by tasks and proposes a service blueprint for co-creating the value for rural maternity care services.

### ■ FB08

Ruys Zaal, Fourth Floor

#### Smart Healthcare Service Management

Invited: Health Operations Management

Invited Session

Chair: Lindu Zhao, Southeast University, Nanjing, 210096, China,  
ldzhao@seu.edu.cn

Co-Chair: Xiangpei Hu, PhD, Dalian University of Technology,  
No. 2 Linggong Road, Ganjingzi District, Dalian, 116024, China,  
drhxp@dlut.edu.cn

#### 1 - Survival Probability Analytics Based Solutions for Prehospital Emergency Care Coordination

Ke Wang, Southeast University, Nanjing, 211189, China,  
kirk66@163.com, Lindu Zhao

Taken sudden cardiac death in home health care as example, this paper proposes survival probability analytics based solutions for prehospital emergency care coordination. A multi-stage, multi-agent, multi-level and coordinated care model driven by telemedicine is optimized and proved to improve survival rate significantly.

#### 2 - Membership of Medical Service Supply Chain Based on Health Data Bank

Lisa Xie, Southeast University, 2 Southeast University Road,  
Nanjing, 211189, China, lisa.abcd1234@foxmail.com, Lindu Zhao

In the medical service supply chain where there is a health data bank, by processing health data from health data providers, the Health Data Bank can provide an optimal plan that health data users need. This paper aims to use game theory to study the relationship between health data providers and users in the above supply chain.

#### 3 - Coordinate Pricing of Drugs Home Delivery under "Order Online, Delivery by Pharmacies" Strategy

Lindu Zhao, Southeast University, 2 Sipailou, Nanjing, China,  
ldzhao@seu.edu.cn, Ge Yang

To realize low-cost and qualified pharmaceutical home delivery, especially for the acute patients, this paper studies the coordinate pricing of normal delivery and urgent express under "Order online, Delivery by pharmacies" strategy. Based on the time sensitivity of patients utility and delivery cost, we design the optimal profits sharing contract.

#### 4 - A New Order Fulfillment Model of Online Pharmacy Store

Minfang Huang, North China Electric Power University, 2 Beinong  
Road, Beijing, 102206, China, hmf1006@163.com, Xiangpei Hu

Drug online retailing has become popular with China's health-care reform, which directly results in the separation of drug prescribing and drug selling. How to deliver drugs timely and efficiently is a logistic challenge for drug online retailers. We propose to combine online and offline pharmacy stores. Customers can make orders online while pick up their drugs at stores. Thus, we propose an order fulfillment model in which a community pharmacy operates both as an experiencing site of pharmaceutical service and a distribution station. We know the effectiveness of the model as it helps better fulfill orders and improve customer experience.

### ■ FB09

Van Rijckevorsel Zaal, Fourth Floor

#### Scheduling and Planning XII

Contributed Session

Chair: Masoumeh Kazemi Zanjani, Concordia University, 1515 St  
Catherine Street W, (EV4.243), Montreal, QC, H3G 1M8, Canada,  
kazemi@encs.concordia.ca

#### 1 - Cyclic and Acyclic Rosters for General Medicine Physicians

Thomas Adams, University of Auckland, Level 3, Uniservices  
House, 70 Symonds Street, Auckland, 1142, New Zealand,  
tada955@aucklanduni.ac.nz

Cyclic rosters guarantee an equitable distribution of shifts in the long term, but not if a small and fractional number of cycles are performed. This type of situation arises when rostering general medicine physicians at Auckland Hospital. The difference between cyclic and acyclic rosters, and the effects of the hospital's roster rules are examined in this setting.

**2 - Adaptive Acyclic Specialist Rostering with Integer Programming**

Monique Bakker, PhD Candidate, City University of Hong Kong, 88 Tat Chee Avenue, Flat B 2/F Mo Kwan House, Hong Kong, Hong Kong, moniquebakker121@gmail.com, Jin Wang, Kwok-Leung Tsui

We address the problem of assigning heterogeneous medical specialists to daily activities, subject to variability in their availability and a large set of real-life constraints. We use a patient-centric multi-appointment flow perspective: a unique on-par objective function minimizes deviations from average values, for the number of instances of each activity-specialist combination. Formulated as Integer Programs, all problem instances are solved to optimality in under 6 seconds on a normal desktop computer, with a commercial solver. The resulting rosters outperform traditional, manually constructed cyclic rosters in our simulation, in terms of patient access time and service levels.

**3 - Physician Scheduling under Uncertainty in Ambulatory Polyclinics**

Masoumeh Kazemi Zanjani, Associate Professor, Concordia University, 1515 St Catherine Street W, (EV4.243), Montreal, QC, H3G 1M8, Canada, kazemi@encs.concordia.ca, Mohammad Tohidi, Ivan Contreras

We propose a multi-stage stochastic program (SP) for integrated physician and clinic scheduling in polyclinics under random patient flow, treatment times, and physicians absenteeism. Assigning on-call physicians to shifts and extending shift duration are among the recourse actions envisaged to protect the schedule against uncertainty. It is demonstrated that the model is equivalent to a two-stage SP with a large number of scenarios. Sample-Average Approximation is thus implemented to obtain a feasible schedule. The proposed scheduling tool is applied to a real polyclinic in Montreal, Canada.

**FB10**

Plate Zaal, Fourth Floor

**Quality and Safety I**

Contributed Session

Chair: Chin Hon Tan, National University of Singapore, 1 Engineering Drive 2, Department of Industrial and Systems Engineer, Singapore, 117576, Singapore, isetch@nus.edu.sg

**1 - Does Magnitude of Penalties Matter? An Empirical Investigation in the Healthcare Context**

Gopalakrishnan Narayanamurthy, IIM Kozhikode, FPM Office, IIM Kozhikode, IIMK Campus P. O., Kunnammangalam,, Kozhikode, 673570, India, gnarayan@umn.edu, Rachna Shah

In general, facilities are inspected by regulatory agencies to check the compliance status on certain specific pre-defined standards. Based on the scope and severity of the non-compliance observed, inspectors impose penalties to threaten and push the facility towards compliance. In this study, an attempt is made to disentangle the impact of having a penalty and that of the magnitude of penalty on the future quality of care delivered. Through this attempt, we will be able to understand the role played by the magnitude of penalty imposed.

**2 - Reducing Potential Human Errors in Hospitals using FMEA Method under Fuzzy Environment**

Reza Fattahi, PhD Student, Islamic Azad University, Science and Research Branch, Tehran, Iran, Islamic Republic of, e.reza.fattahi@gmail.com, Roya Soltani, Ehsan Rashidzadeh, Seyedhadi Hosseini

Failure mode and effects analysis (FMEA) is an appropriate method to assess risks in hospitals. One of the main problems regarding hospitals is the hazards caused by potential errors of doctors and personnel. In this research, the potential human errors in hospitals are reduced by a new FMEA method under fuzzy environment. Eventually, hospital of Kerman is considered as a case study to demonstrate applicability and benefits of the proposed fuzzy FMEA method.

**3 - Assessment of Quality of a Health Care Delivery System in a Hospital in India: A Bayesian Causality Model**

Abhik Patra, Research Scholar, Indian Institute of Technology Kharagpur, Department of Industrial and Systems Engineering, IIT Kharagpur, Kharagpur, 721302, India, abhikmechanical@gmail.com, Pradip Kumar Ray

The quality of the healthcare delivery system in a hospital is based on the stakeholder perspectives and their interaction effect. The objective of the study is to explore the stakeholder's interaction effect on the quality of care based on the conditional probability in the Indian context. Data collected through interview of stakeholders are analysed to identify critical quality attributes and their dimensions affecting the healthcare delivery system of hospitals in India. A Bayesian causality model is prepared to assess the quality of care as provided by a particular hospital.

**4 - Reagent Lot Verifications in Clinical Laboratories**

Chin Hon Tan, National University of Singapore, 1 Engineering Drive 2, Department of Industrial and Systems Engineering, Singapore, 117576, Singapore, isetch@nus.edu.sg

It was recently reported that a systematic drift in a hormonal test was undetected across many years, resulting in missed diagnoses and inappropriate clinical decisions over that period. It was discovered that this happened because existing procedures are unable to capture significant differences that arise as a result of non-significant shifts that accumulate over time. This project aims to prevent the occurrence of similar incidents by improving the existing procedures used to validate reagent lot-to-lot changes in clinical laboratories.

**FB11**

Van der Vorm Zaal, Fourth Floor

**Insurance I**

Contributed Session

Chair: Rohit Verma, Cornell University, 338 Statler Hall, Ithaca, NY, 14853, United States, rv54@cornell.edu

**1 - A Dynamic Programming Approach for Auditing Health Insurance Claims**

Fletcher Lu, Associate Professor, University of Ontario Institute of Technology, Faculty of Business and IT, 2000 Simcoe Street North, Oshawa, ON, L1H 7K4, Canada, fletcher.lu@uoit.ca

We studied applying a dynamic programming approach with Markov Decision processes to health insurance claims records provided by two insurance companies to search for invalid health claims. Our objective was to both efficiently uncover new fraud claim patterns and improve the efficiency of their existing fraud searches. Our modifications to their processes and uncovered new fraud cases were validated using a year of private prescription drug insurance claims involving over 5 million records. Our improvements resulted in tens of thousands of dollars in recovered funds.

**2 - Designing Service Machine for Reducing Information Asymmetry in Health Insurance**

Mohd Zuhair, Research Scholar, IIT Kharagpur, Kharagpur, 721302, India, md.zuhair.cs@gmail.com, Ram Babu Roy, Paul M Lillrank

Service machine is a metaphor for implementing the machine design concepts into service production system. Health insurance service in India is inefficient primarily due to information asymmetry. It affects access, variety and specialization in health insurance service. We propose the application of service machine concept to reduce the information asymmetry.

**3 - A Research on Patients' Willingness to Pay of Outpatient Co-payment and Hierarchical Health-seeking Behavior**

Wen-Ping Fan, National Taipei University of Nursing and Health Services, Taipei City, Taiwan, weihsu@ntunhs.edu.tw, Wei Hsu, Yun-Ting Huang

Previous studies had diverse suggestions on the influence of higher co-payment to hierarchical health-seeking behavior. This study investigated patients' Willingness to Pay (WTP) of the outpatient co-payment for implementing hierarchical medical system and tested the impact of WTP to hierarchical health-seeking behavior by 971 patients of an academic medical center in Taiwan. The result showed that the average WTP of the outpatient co-payment for academic medical centers amounted to NT\$443.59 (around US\$ 15), higher than the current amount (NT\$ 360, around US\$ 12). The WTP of the outpatient co-payment had significantly positive impact to hierarchical health-seeking behavior.

**4 - Technology, Cost and Health-insurance Policy Impact Customers' Perceptions of on Quality of Care**

Rohit Verma, Dean of External Relations and Professor, Cornell University, MVR 3250, Ithaca, NY, 14853, United States, rv54@cornell.edu, Lu Kong, Hessam Sadatsafavi

NY state residents' perceptions of healthcare survey was conducted. Key findings - The majority of respondents have a positive view of computer use by physicians; they prefer to use an outpatient clinic outside of hospital to receive outpatient care. Among all concerns regarding U.S. healthcare, the cost of care (39%) is the biggest concern, followed by government policy regarding healthcare (27%), and specialized treatment (8%); quality of hospitals is the least concerned (less than 1%) problem.

## ■ FB12

Mees Zaal, Fourth Floor

**Harnessing Information and Communication Technology for Healthcare**

Invited: Personalized Medicine

Invited Session

Chair: Shinyi Wu, University of Southern California, Los Angeles, CA, 90089, United States, shinyiwu@usc.edu

**1 - Cluster Analysis of Objectively Measured Physical Activity Patterns in Women**

Yoshimi Fukuoka, University of California, San Francisco, San Francisco, CA, 94118, United States, Yoshimi.Fukuoka@ucsf.edu, Mo Zhou, Eric Vittinghoff, William Haskell, Ken Goldberg, Anil Aswani

The aims of this report are to identify clusters of women living in California based on accelerometer measured raw metabolic equivalent values (METs) and a normalized version of the METs  $\geq 3$  data and to compare sociodemographic and cardio metabolic risks among these identified clusters. 215 women wearing an accelerometer for at least 8 hours per day for the last 7 days prior to the randomization visit were analyzed. A K-means clustering method, the Lloyd's algorithm, was used. To choose the number of clusters, we used the elbow method, looking at the percentage of variance explained as a function of the number of clusters.

**2 - Adaptive Message Optimization for Fitness Tracking**

Yonatan Mintz, UC Berkeley, 1822 Francisco St., Apt 10, Berkeley, CA, 94703, United States, ymintz@berkeley.edu, Anil Aswani, Philip Kaminsky, Elena Flowers, Yoshimi Fukuoka

Exercise programs with personal reminders are some of the most effective ways to treat sedentary lifestyles. Despite the prevalence of personal fitness tracking, many individuals have a hard time adhering to these programs since they may recommend a person exercise during times inconvenient for their schedule or provide ineffective motivation. In this talk, we address this problem by leveraging the data and infrastructure of mobile fitness tracking to personalize exercise programs for participating individuals. We develop a multi-armed bandit approach to adaptively learn each participant's exercise preferences to personalize their exercise programs and increase adherence.

**3 - Efficient Discovery of Responses of Proteins to Compounds using Active Learning**

Yan Li, IBM, Yorktown Heights, NY, United States, yanli890410@gmail.com

High-throughput compound screening is time and resource consuming. We use active learning methods to assist the selection process by focusing on areas of chemical space that have the greatest chance of success while considering structural novelty. One critical feature of these techniques is their ability to learn through sequential feedback. Through simulated experiments, we show that active learning algorithms have the potential to reduce costs and save precious materials.

**4 - Analysis of a Health Program Effects on Older Diabetes Patients**

Shinyi Wu, University of Southern California, 3715 McClintock Avenue, GER 240 C, Los Angeles, CA, 90089, United States, shinyiwu@usc.edu

Mobile technology is increasingly adopted by older adults but the potential to improve their health is underutilized. This presentation describes a program that tested using this technology with a homegrown diabetes self-care app for older adults. In an experimental trial, 237 adults aged 55 and above with type 2 diabetes participated in 8-week sessions with college students coaching them in learning the technology and chronic disease self-management at a general hospital in Taiwan. The app usage patterns and the program effects are analyzed with implications for data science.

## ■ FB13

Van Weelde Zaal, Fourth Floor

**Big Data Analytics in Health Care**

Invited: Healthcare Data Analytics and Machine Learning

Invited Session

Chair: Amir Rastpour, Western University, Ivey Business School, London, ON, N6G0N1, United States, arastpour@gmail.com

**1 - Eliciting Lipid Management Guidelines' Valuation of Future Life by Inverse Optimization**

Emine Yaylali, Istanbul Technical University, Istanbul, Turkey, emineyaylali@itu.edu.tr, Murat Kurt, Osman Yalin Ozaltin

Discounting is essential to designing long-term policies. We use inverse optimization to elicit discount factors that offset appropriately the benefits and side-effects of statins from future to present for Type 2 diabetes patients. Our approach aims to make national lipid management guidelines non-dominated solutions of a Markov decision process with respect to QALYs and long-term cardiovascular risk. Using real data we present the results for several national guidelines and make comparisons.

**2 - Finding Empirical Evidence for the Impact of Surgery Sequencing on Non-operative Time**

Brecht Cardoen, KU Leuven, Naamsestraat 69, Leuven, 3000, Belgium, Brecht.Cardoen@kuleuven.be, Mehmet A Begen, Carla Van Riet, Johannes De Smedt

We explore to what extent the sequencing of surgeries might impact the non-operative time in the OR, as this might have consequences for surgery scheduling practice to improve performance measures. We report on insights from data of a large Belgian hospital and differentiate between an outpatient and inpatient setting.

**3 - Wait Times for Five Most Prevalent Cancer Types in Ontario**

Amir Rastpour, Ivey Business School, 1255 Western Road,, London, ON, N6G0N1, Canada, rastpour@ualberta.ca, Mehmet A. Begen, Greg Zaric

We use administrative data from The Ontario Cancer Data Linkage Project (cd-link) to analyze how waiting times, the period from diagnosis to the first treatment (surgery, chemotherapy, radiotherapy), have changed from 2002 to 2012 for patients with five most prevalent cancer types in Ontario. Our initial findings show that, although the mean and median waiting times have increased for some cancer and treatment types, the coefficient of variation has consistently improved over time, indicating that the predictability of the treatment time has improved over the study period.

**Friday, 11:35am - 1:05pm**

## ■ FC01

Van Cappellen Zaal, Ground Level

**Health Care Analytics and Operations Management**

Sponsored: Health Applications

Sponsored Session

Chair: Daniel Gartner, Cardiff University, School of Mathematics, Cardiff, CF10 3XQ, United Kingdom, GartnerD@cardiff.ac.uk

**1 - Whole Blood or Apheresis Donations? A Multi-objective Stochastic Optimization Approach**

Sally C Brailsford, University of Southampton, School of Management, Southampton, S017 1BJ, United Kingdom, s.c.brailsford@soton.ac.uk, Andres F Osorio, Honora K Smith

Blood supply chain managers face the difficult strategic problem of choosing the best combination of technologies for collection and processing, as well as the difficult operational problem of assigning donors to collection methods. The use of deterministic demand forecasts is rarely adequate and a robust decision must consider variability in demand as well as potentially conflicting objectives. This paper presents a multi-objective stochastic ILP model to support such decisions, illustrated using real data from Bogota, Colombia.

## 2 - Jumping the Line, Charitably: Analysis and Remedy of the Donor-priority Rule

Tinglong Dai, Johns Hopkins University, 100 International Dr, Baltimore, MD, 21202, United States, dai@jhu.edu  
u, Ronghuo Zheng, Katia P. Sycara

The growth of organ transplant waiting lists significantly outpaces the supply of donated cadaveric organs, stimulating discussions of a myriad of initiatives aiming to boost organ donation. Among these initiatives, the donor-priority rule grants a registered organ donor priority in receiving a transplant. In this paper, we adopt a strategic queueing theoretic framework and quality-adjusted life expectancy (QALE) criteria to model individuals' decisions to join the donor registry under the donor-priority rule. We also propose a simple freeze-period mechanism, and prove that it can increase the supply of donated organs without compromising the average quality of the donor pool.

## 3 - Scheduling Interval Optimization in Healthcare Clinics Considering No-shows and Cancellations

Anne Leeftink, University of Twente, P.O. Box 217, Enschede, 7500AE, Netherlands, a.g.leeftink@utwente.nl, Gabriela Martinez, Esra Sisikoglu, Erwin Hans, Mustafa Y Sir, Kalyan Pasupathy

To improve the operational efficiency of healthcare clinics, we determine the optimal scheduling interval such that the impact of no-shows and cancellations is minimized, against the cost of rejecting patients. We show that the no-show and cancellation rates increase with the scheduling interval, and that the temporal behavior of cancellations follows a bimodal distribution. This time-dependent behavior is taken into account in our queueing solution approach.

## 4 - Metaheuristic Approaches for Order Set Optimization

Daniel Gartner, Lecturer of Operational Research, Cardiff University, Senghennydd road, Cardiff, CF244AG, United Kingdom, GartnerD@cardiff.ac.uk, Yiye Zhang, Rema Padman

Order sets are a critical component in hospital information systems and expected to reduce physical and cognitive physician workload, substantially. Order sets represent clustered order items such as medications prescribed at hospital admission which are administered to patients during their hospital stay. In this paper, we develop a mathematical program and three heuristic solution procedures to generate order sets. We show theoretical properties of the problem and compare a major hospital's current order set usage with optimal and heuristic solutions on a variety of performance metrics.

## FC03

Zeelenberg Zaal, Second Floor

## Challenges & Research Directions in Kidney Exchange Programs

Invited: Public Health and Policy Making

Invited Session

Chair: Itai Ashlagi, Stanford University, Stanford, CA, 94305, United States, iashlagi@stanford.edu

## 1 - Global Kidney Exchange and Deceased Donor-initiated Nonsimultaneous Extended Altruistic Donor Chains

Michael A Rees, Chief Executive Officer, Alliance for Paired Donation, P.O. Box 965, Perrysburg, OH, 43552, United States, Michael.Rees2@utoledo.edu

This presentation examines two new approaches aimed to expand the benefits of kidney exchange. Global Kidney Exchange offers the opportunity to utilize the mechanism of kidney exchange to overcome financial barriers to kidney transplantation. Deceased donor-initiated nonsimultaneous extended altruistic donor (NEAD) chains expand kidney exchange by starting NEAD chains with deceased donor kidneys. This presentation will explore the ethics and efficacy of these novel approaches to produce more kidney transplants and reduce the personal and economic burden caused by ESRD.

## 2 - Misaligned Incentives in Kidney Exchange

Itai Ashlagi, Stanford University, Department of Management Sci. and Engr., Stanford, CA, 94305, United States, iashlagi@stanford.edu

While a market for kidney exchange has grown in recent years the number of transplants from kidney exchanges has stagnated in the last few years. Focusing on the U.S. market, we use administrative records to document that: (1) the market is fragmented across many competing exchange programs, (2) participants in the largest exchange program are adversely selected, (3) smaller exchange programs conduct inefficient exchanges. We propose a supply and demand model to explain how these outcomes can arise as equilibrium behavior, due to the social and private incentives of hospitals being misaligned. We use the model and data to develop simple and efficient alternative mechanisms.

## FC04

Hudig Zaal, Third Floor

## Data Analytics and Machine Learning IX

Contributed Session

Chair: Maria Alejandra Wilches Mogollon, Universidad de los Andes, Cra 1 Este 19A - 40, Bogotá, 111711, Colombia, ma.wilches529@uniandes.edu.co

## 1 - Incidence and Mortality of Public Hospitalizations for Stroke in Brazil Between 2009 and 2015

Silvio Hamacher, Associate Professor, PUC-Rio, Rio de Janeiro, Brazil, hamacher@puc-rio.br, Igor Peres, Janaina Marchesi, Leila Dantas

Stroke is the third major cause of death in the world. This study evaluates the incidence and mortality rates in Brazil between 2009 and 2015, using hospitalizations data. We made a descriptive and statistical analysis using chi-square test and multiple logistic regression. The stroke hospitalizations increased 17% and the mortality decreased 2%. The incidence increased by 14%, 19% and 30% for the adult, elderly and elderly over 85 years, respectively, which is related to the population's aging.

## 2 - Digital Divide in Online Health Utilization in China – A Case Study of Geographic Health Analytics

Haijing Hao, Assistant Professor in Health Information Systems, University of Massachusetts-Boston, 12 Inman Street Apt 31, Cambridge, MA, 02139, United States, haijing.hao@umb.edu, Haibo Hao

The present study intends to explore what factors may have an impact on online health utilization in China by examining various economic-related variables. We use Tableau mapping features to illustrate the geographical visualization and also run quantitative fixed effect regression models. Our preliminary results show that percentage population that can access the Internet of a province in China has a statistical significant impact on the online health utilization of that province.

## 3 - Quantifying Uncertainty about Future Antimicrobial Resistance with Structured Expert Judgment

Abigail Colson, Research Associate, University of Strathclyde, Glasgow, United Kingdom, abigail.colson@strath.ac.uk, Tim Bedford, Sumanth Gandra, Ramanan Laxminarayan, Itamar Megiddo, Alec Morton

Antibiotic resistance is a major global concern. Although many countries collect resistance surveillance data, the large number of factors that influence the emergence and spread of resistance makes it extremely difficult to translate historical data into future predictions. To bridge the gap between existing surveillance data and the needs of decision makers, we use Cooke's classical model of structured expert judgment to quantify uncertainty about future resistance rates for select pathogen-antibiotic pairs in several European countries.

## 4 - Improving Cervical Cancer Screening Policies in Colombia with Data Analytics

Maria Alejandra Wilches Mogollon, M.Sc. Student, Universidad de los Andes, Cra 1 Este 19A - 40, Bogotá, 111711, Colombia, ma.wilches529@uniandes.edu.co, Raha Akhavan-Tabatabaei, Daniel Felipe Otero, Ivan Mura

Medical records, demographic, socio-economic and clinical data help understand population dynamics and chronic disease epidemics, such as cervical cancer. Harnessing the wealth of information contained therein allows developing models to measure and compare the impact of public health policies. We apply data analytics techniques on Colombian data to tune the parameters of a stochastic model that allows comparing different cervical cancer screening policies, and then to define an epidemiological model that predicts the impact of screening policies for the whole population.

## ■ FC05

Schadee Zaal, Third Floor

### Location Planning for General Practitioners

Invited: Health Operations Management

Invited Session

Chair: Melanie Reuter-Oppermann, Karlsruhe Institute of Technology, Kaiserstraße 89, Karlsruhe, 76131, Germany, melanie.reuter@kit.edu

#### 1 - Mobile GP Units for an Improved Rural Health Care

Martin Comis, RWTH Aachen, Aachen, Germany, comis@math2.rwth-aachen.de, Christina Büsing, Catherine Cleophas

Demographic change lead to a severe shortage in general practitioners in many rural areas of Germany. As a counter-measure, the statutory health insurance pursues the setup of mobile medical units. Mobile medical units allow for an efficient medical coverage of sparsely populated, spacious areas. To maximize the impact of these units we solve a combination of a facility location, routing and scheduling problem. In order to study the effects of our solutions we developed an agent based simulation and evaluate the coverage of medical treatment on the basis of multiple performance indicators.

#### 2 - Deducing Short- and Long-term Strategies against General Practitioner Shortage Based on a Mixed-methods Approach

Kristina Jäkel, University Medical Center Schleswig-Holstein, Lübeck, Germany, kristina.jaekel@uni-luebeck.de

General practitioner (GP) shortage is an internationally alarming issue. In order to overcome this shortage several strategies are proposed. Waldshut (WT), a rural district in Southern Germany, faces this challenge, too. After conducting interviews and surveys about WT inhabitants' perceptions of healthcare needs, we deduced short- and long-term strategies for this district. Key issue will be an analysis of optimal location planning for future GP sites in this district.

#### 3 - Location Planning for General Practitioners in Germany

Melanie Reuter-Oppermann, Karlsruhe Institute of Technology, Karlsruhe, 76131, Germany, melanie.reuter@kit.edu

Similar to many other regions in Germany, the rural district of Waldshut faces the challenge of a current and future shortage of General Practitioners (GP). Therefore, we study the location planning for new collaborative practices in the region that are more attractive to young GPs. We present optimal solutions for different scenarios of future developments and possible constraints and objectives and discuss the possibility of using mobile practices. In addition, a GIS-based decision support tool is used to visualize the solutions, e.g. for decision makers.

## ■ FC06

Van Beuningen Zaal, Third Floor

### Disease Mitigation Planning

Invited: Disparities in Health, Low and Middle Income Settings, Global Health

Invited Session

Chair: Emily L. Tucker, PhD Student, University of Michigan, 1205 Beal Ave, Ann Arbor, MI, 48109, United States, eltuck@umich.edu,

#### 1 - The Design of a Responsive Vaccine Supply Chain by the Incorporation of Production Capacity into the Guaranteed Service Approach

Stef Lemmens, KU Leuven, Naamsestraat 69 Box 3555, VAT BE 0419.052.173, Leuven, 3000, Belgium, stef.lemmens@kuleuven.be, Nico Vandaele, Catherine Jenny Decouttere, Mauro Bernuzzi, Amir Reichman

Previous research has integrated multi-echelon inventory management into the design of a responsive supply chain by the use of the guaranteed service approach. We build further upon this work by integrating the production capacity to minimize the supply chain's inventories. The production capacity is modeled with a queuing network to handle the variability of the batch production processes as well as the demand variability. We apply our model to the rotavirus vaccine supply chain which is seen as complex on the manufacturing side as well as on the distribution side. Furthermore we show how this work is embedded in a scenario approach to evaluate a scenario according to multiple performance indicators.

#### 2 - Incentivizing Supply Chain Resiliency to Prevent Drug Shortages

Emily L. Tucker, PhD Student, University of Michigan, 1205 Beal Ave, Ann Arbor, MI, 48109, United States, eltuck@umich.edu, Mark S Daskin, Wallace J Hopp, Burgunda V Sweet

Drug shortages have become a public health crisis in the United States. Many shortages are caused by disruptions to lean supply chains of generic, difficult to manufacture drugs. Supply chain design and inventory decisions are directly affected by market conditions and FDA policies. We use a two-stage, multi-period stochastic programming model to determine how resiliency decisions of a profit-maximizing firm change based on underlying market conditions and discuss implications for public policy.

## ■ FC08

Ruys Zaal, Fourth Floor

### Operating Room Scheduling II

Invited: Health Operations Management

Invited Session

Chair: Willem van Jaarsveld, Erasmus University-Rotterdam, Rotterdam, NL-3000DR, Netherlands, vanjaarsveld@ese.eur.nl

#### 1 - Impact of Congestion on Healthcare Outcomes

Huan Zheng, SJTU, Management Science Department, 535 Fa Hua Zhen Rd, Shanghai, China, zhenghuan@sjtu.edu.cn, Haiyue Yu, Jifeng Luo, Panpan Wang

This paper empirically studies how congestions in hospitals affect health care outcome. We utilize the number of new patients admitted every day and the number of inpatients to measure the degree of congestions. A fixed effect model was used for analyzing the discharge records of 189,740 patients from a public hospital in Shanghai during 2011-2014. The connections between congestions in operations and the mortality rate, readmission and length of postoperative hospital stay will be reported.

#### 2 - Optimization for the Locations of Ambulances under Two-stage Life Rescue in Emergency Medical Service: A Case Study in Shanghai, China

Dapeng Yang, Tongji University, Siping Road 1500, Tongji Building, Shanghai, China, yangdapeng081219@126.com, Qiang Su, Ming Liu

Ambulance service planning is a branch of healthcare optimization. In this paper, we study the problem based on the demand for Emergency Medical Services (EMS) in Songjiang District, China, followed by the joint planning of EMS management, which typically consist of emergency location planning and patients assignment to hospitals considering patients' injury degree and the difference in emergency calls over a day. Our results show that the demand coverage and response time can be substantially improved by relocating the current facilities without the need for additional resources.

#### 3 - Capacity Allocation in a Service System: Parametric and Data-driven Approaches

Guanlian Xiao, Technische Universiteit Eindhoven, Eindhoven, Netherlands, xglian@gmail.com, Liping Liang, Hengqing Ye

We study the capacity allocation problem for a service system that serves its customers with a deterministic service time under a service level requirement. The service level is measured by the probability of customers waiting longer than a pre-specified duration. We model the system as an M/D/1 or a G/D/1 queue and examine two approaches to determining the capacity: a parametric approach based on the effective bandwidth theory and a data-driven approach based on the sample average approximation. We conduct a numerical study to investigate the effectiveness of these two approaches, and find that the data-driven approach is more streamlined, accurate, and widely applicable.

## ■ FC09

Van Rijckevorsel Zaal, Fourth Floor

### Scheduling and Planning XIII

Contributed Session

Chair: Marta Cildoz, Public University of Navarre, 6 Eunate Street, Obanos, 31151, Spain, marta.cildoz@unavarra.es

#### 1 - A Simulation Optimization Framework to Find Optimal Numbers of Medical Staffs in an Emergency Department

Mi Lim Lee, Honik University, Seoul, Korea, Republic of, mllee@hongik.ac.kr, Chuljin Park

A simulation optimization problem is considered to find the optimal numbers of medical staffs (i.e. nurses, interns, residents, and medical specialists) in an emergency department. While limiting the maximum waiting times of critical patients, we pursue maximizing the expected net profit of the emergency department. In order to solve the problem, a fully sequential ranking and selection framework is suggested with two steps: a set of strictly feasible solutions are determined first, and then the best solution is selected among them.

#### 2 - Optimization of Staffing Levels in an Emergency Department a Method Based on Graphical Evaluation and Review Technique

Farhood Rismanchian, Yonsei University, Seoul, Korea, Republic of, rismanchian.farhood@gmail.com

For the purpose of this study, we want to address the following questions: By how much should we increase the current staffing budget, and how should this additional budget be used in the allocation of human resources in order to attain the targeted length of stay (LOS)? A model is formulated in which we seek the maximization of the marginal reduction in the LOS per unit of investment. The various steps of the proposed method are illustrated through a case study, which involves modeling the patient flow for the ED of S Hospital in Seoul. The relationship between additional investment on the staff budget and the percentage of reduction in the average LOS has been derived and discussed.

#### 3 - Balancing Stress and Workload in Emergency Departments

Marta Cildoz, Public University of Navarre, Campus Arrosadia, Pamplona, 31006, Spain, marta.cildoz@unavarra.es, Fermin Mallor, Amaia Ibarra, Cristina M Azcarate

Some Emergency Departments (EDs), with the aim of equitably distributing patients to physicians, use simple rotational rules. However, the variability in the severity of patients randomly arriving to ED leads to both temporary physicians' workload imbalances and differences among their stress levels. In this study, we propose and investigate new rules to equitably assign patients to physicians taking into account not only patients waiting time by priority but also physicians' stress and workload.

## ■ FC10

Plate Zaal, Fourth Floor

### Quality and Safety II

Contributed Session

Chair: Henni Tenhunen, Aalto University, Aalto University, Espoo, 1, Finland, henni.tenhunen@aalto.fi

#### 4 - Analysis of Operation Process for Healthcare Workers with Wearable Sensors at an Elderly Day Care Facility in Japan

Masato Takanokura, Associate Professor, Kanagawa University, 3-27-1 Rokkakubashi, Kanagawa-ku, Faculty of Engineering, Yokohama, 221-8686, Japan, takanokura@kanagawa-u.ac.jp, Yuta Shimosako, Koki Karube, Munenori Kakehi, Tetsuo Yamada

The operation process was analyzed from healthcare workers in terms of the professional duty for elderly care. In addition, heart rate and physical activity were measured from the workers by wearable sensors during their operation. Physical workload was quantified by the operation process, heart rate and physical activity. A worker had a lot of tasks as the director of this facility. He had a higher workload than the other workers because of many moving tasks for facility management. The other workers showed that their workload was task-dependent. We proposed some improvements from the operation process for workers with wearable sensors such as reduction of unnecessary moving to telephone calls.

#### 4 - Time Observing Measurement to the Care Operating on Activities of Daily Living (ADLs) in Long-term Care Facility: A Pilot Experience in Taiwan

Chingya Huang, National Taipei University of Long-term Care, Taipei City, Taiwan, top80736@gmail.com

In order to make good handling of long-term care resources, Ministry of Health, Labour and Welfare of Japan had carried out the unique project of "The one-minute time-and-motion study" as a method for measuring the quantity of care

provided by custodial care staff. The study tended to use the one-minute time-and-motion as a method to investigate the quantity of care on activities of daily living (ADLs) provided by custodial care staff in a nursing home in Taiwan. It followed on a total of 50 residents and conducted more than 24 hours.

#### 3 - Implication of Codified Knowledge Sharing on Operational Failures in Healthcare

Mecit Can Emre Simsekler, Assistant Professor, KUSTAR, Industrial & Systems Engineering Department, Abu Dhabi, 127788, United Arab Emirates, emre.simsekler@kustar.ac.ae, Bilal Gokpinar

Focusing on codified knowledge sharing among healthcare personnel in the form of written guidance documents, we examined the role of codified knowledge on operational failures in healthcare. We used a unique dataset from hospitals in England and employed text-mining techniques to investigate the impact of documents on operational failures.

#### 1 - Value Drivers in Prenatal Testing Services

Henni Tenhunen, Doctoral Candidate, Aalto University, Institute of Healthcare Engineering, Management and Architecture (HEMA), P.O. Box 15500, FI-00076 AALTO, Finland, Espoo, Finland, henni.tenhunen@aalto.fi, An Chen, Karita Reijonsaari, Paul Lillrank

For the purpose of identifying value drivers in maternal care service context, we interviewed 27 screen-positive women who participated in prenatal testing in Finland. Results suggest that women's perceptions of the value of the service are strongly related to how well the pre-test counseling about the different options, the communications with the midwives, and the convenient service delivery alleviated negative emotions such as anxiety, worry, and lack of control.

## ■ FC11

Van der Vorm Zaal, Fourth Floor

### Insurance II

Contributed Session

Chair: Yiannis Dimitrakopoulos, University of Athens, 29A Kykladon Str., Athens, 11361, Greece, dimgiannhs@aueb.gr

#### 1 - Curbing Irrational Antibiotic Use: Understanding Patient and Physician Behavior

Berna Tuncay, Assistant Professor, Koc University, Istanbul, Turkey, betuncay@ku.edu.tr, Ozden F. Gur Ali

In this paper, we analyze physician prescribing behavior of antibiotics and how it varies with patient characteristics, diagnosis and geography. We evaluate the impact of a policy intervention to reduce irrational antibiotic use on physician visits by patients, physician prescribing and antibiotic drug sales. Patient insurance is used as an indicator of a change in patient behavior. We examine antibiotic prescribing behavior of physicians in terms of diagnosis, patient demographics, region, physician specialty and patient insurance information, and the observed policy effect in different patient and physician groups, using the Pharmaceutical Index and the Prescription Index by IMS Health.

#### 2 - Improving Discharge Process for Cashless Patients in Indian Multi-specialty Hospitals using Simulation Approach

Sudipendra Nath Roy, Doctoral Student, Indian Institute of Management Indore, Indian Institute of Management Indore, Prabandh Shikhar, Indore, 453331, India, fl3sudipendrar@iimind.ac.in, Bhavin J. Shah, Hasmukh Gajjar

Indian patients rely on health insurance to avail health service from a private health provider. Cashless insurance is becoming popular for the purpose. However, cashless patients often suffer from a serious delay in the discharge process. In this paper, we investigated the cashless discharge process in an Indian multi-specialty hospital using discrete event simulation. Our results suggest that 38% delay reduction can be possible by improving the practice from the hospital administration side.

#### 3 - Strategic Customer Behavior in Buying Insurance and Choosing Private Treatment

Yiannis Dimitrakopoulos, Post-Doc Researcher, University of Athens, 29A Kykladon Str., Athens 11361, Greece, Panepistimiopolis, Athens 15784, Greece, Athens, 11361, Greece, dimgiannhs@aueb.gr, Apostolos Burnetas, Antonis Economou

We analyze equilibrium behavior and optimal strategies for customers who decide whether to buy a medical insurance or not for receiving medical treatment in a private provider instead of joining the public healthcare system, considering their income, cost of treatment and the level of congestion in public facilities. We model the public system as a Markovian queue, whereas the private provider can be considered as a costly outside option with no waiting for treatment.

## ■ FC12

Mees Zaal, Fourth Floor

**Disease and Treatment Modeling IV**

Contributed Session

Chair: Alexandar Angelus, The University of Texas at Dallas, Richardson, TX, 75080, United States, alexandar.angelus@gmail.com

**1 - HPV Vaccination Uptake Policy Analysis with a System****Dynamics Approach**

Nasim S. Sabounchi, State University of New York at Binghamton, 4400 Vestal Parkway East, P.O. Box 6000, Systems Science and Industrial Engineering, Binghamton, NY, 13902, United States, sabounchi@binghamton.edu, A. Serdar Atav, Nasser Sharareh

This study demonstrates how psychological, parental perceptions, cultural, socio-economic and health policy factors influence the completion of the recommended series of HPV vaccinations among adolescent boys. Despite availability of HPV vaccines, in 2014, only 22 % of boys aged 13 - 17 had received all 3 doses. A system dynamics approach and the constructs of the Health Belief Model were adopted to develop a simulation platform and investigate the complex interactions of different key factors on the vaccine uptake. Our results help to identify the most effective interventions to improve HPV vaccination rates.

**2 - An Agent-based Model for Mumps: Does Separating Vaccinated and Unvaccinated Students in Schools Result in Better Health Outcomes?**

Liuai Hatter, Concordia University, 1515 Saint-Catherine Ouest, EV S3.330, Montreal, QC, H3G 2W1, Canada, liuaihatter@gmail.com, Ketra Schmitt, Hossein Moosavi

A rise in unvaccinated children and subsequent uptick in vaccine-preventable diseases has led to a vigorous public debate regarding vaccination status. To investigate different policies in managing mumps, we developed an agent-based model to simulate outbreaks and evaluated how key disease dynamics are impacted by a policy of separating vaccinated and unvaccinated children into different schools when used concurrently with physical distancing, school closure, and mandatory isolation strategies.

**3 - Introducing the Pneumococcal Conjugate Vaccine in India's National Immunization Programme: An Economic Analysis using Agent-based Modelling**

Itamar Megiddo, Chancellor Fellow, Lecturer, University of Strathclyde, Glasgow, United Kingdom, itamar.megiddo@strath.ac.uk, Itamar Megiddo, Chancellor Fellow, Lecturer, Center for Disease Dynamics, Economics & Policy, Washington, DC, United States, itamar.megiddo@strath.ac.uk, Eili Klein, Ramanan Laxminarayan

Pneumococcal pneumonia causes over 100,000 child deaths in India annually. Uncertainty regarding the impact of introducing the pneumococcal conjugate vaccine and its high cost have been a concern, particularly after the proposed GAVI alliance support ends. We evaluate disease transmission and the vaccine's disease and economic impact in an agent-based simulation model representative of the Indian population and healthcare system. Despite its high cost, introducing the vaccine averts a significant number of deaths and protects poor populations from financial risk.

**4 - On Optimal Timing of Influenza Vaccine Production under Yield Improvement Strategies**

Alexandar Angelus, Assistant Professor, The University of Texas at Dallas, Jindal School of Management, 800 West Campbell Road SM 30, Richardson, TX, 75080, United States, alexandar.angelus@utdallas.edu, Ozalp Ozer

We develop a multi-stage dynamic program to determine the optimal timing of large-scale influenza vaccine production, when the vaccine's uncertain yield can be improved both during the development phase and during the production phase. We determine the structure of the optimal stopping policy for launching vaccine production. That structure is found to depend on the relative effectiveness of the two yield improvement strategies. When yield improvement during development is more effective, the myopic 1-Step Look-Ahead policy is always optimal. We also prove that the optimal time to bring influenza vaccine to the market is decreasing in the effectiveness of yield improvement during production.

## ■ FC13

Van Weelde Zaal, Fourth Floor

**eHealth & Telemedicine**

Contributed Session

Chair: Fatima Zahra Barrane, Qatar University, Al Tarfa, Doha, 2713, Qatar, fzahra@qu.edu.qa

**1 - A Maturity Model for Healthcare 2.0**

Liezl Van Dyk, Professor, North-West University, North-West University, School for Industrial Engineering, Potchefstroom, 2531, South Africa, liezl.vandyk@nwu.ac.za

Fueled by "Industry 4.0" the use (and misuse) and google-search for "Healthcare 4.0" is steadily increasing (Google Trends). What exactly is "Healthcare 4.0"? Is it just another buzzword or will it significantly shape the optimization of healthcare operations and outcomes? Aim: To address these questions a Healthcare 4.0 maturity model is proposed to serve as reference model Methodology: This study build on previous work in the development of a Telemedicine Service Maturity Model. Additionally, literature, grey literature as well as other internet sources are reviewed concerning Industry 4.0, Healthcare x.0 and related terms.

**2 - Homophily Effect of Doctor Behavior Over Time in Online Healthcare Community: Evidence from China**

Panpan Wang, Shanghai Jiao Tong University, Shanghai, China, wpp\_cq@qq.com, Jifeng Luo

This research empirically investigate the patterns of physicians' adoption and usage behaviors in online healthcare community over time across locations. We have collected panel data on personal information, historical online activities and online reviews for 26499 doctors in 31 cities of China from a large Chinese healthcare website. We use logit model to study doctors' adoption behavior and multinomial logit model to analyze the use of 3 kinds of healthcare services. The homophily effect(i.e. demographic similarity and geographical proximity) of doctor behavior over time will be reported.

**3 - Acceptance and Use of Information Technology in Healthcare System. An Empirical Investigation**

Fatima Zahra Barrane, Post Doctorla Fellow, Qatar University, Al Tarfa, Doha, 2713, Qatar, fzahra@qu.edu.qa

The purpose of this paper is to understand the acceptance and use of information technology in the healthcare system. Our study is carried out in Qatar. To better understand the factors that influence the use of information technology in the healthcare system, we have chosen the Unified Theory of Acceptance and Use of Technology (UTAUT). Our main goals are to develop a conceptual framework specific to the use of information technology in the healthcare system, to identify the main similarities and differences according to the basic UTAUT model, to understand factors and barriers to the use of information technologies in the healthcare system.

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- WA02 ALIO Sponsored Session
- WA04 Data Analytics and Machine Learning I
- WA05 Stochastic Models for Hospital Operations Management
- WA06 Optimization Modeling for Medical Decision Making
- WA08 Data-driven Models in Health Care Operations
- WA09 Scheduling and Planning I
- WA10 Supply Chains I
- WA11 Medical Decision Making I
- WA12 Radiation Therapy Planning
- WA13 Machine Learning for Optimizing Healthcare Delivery

## Wednesday, 10:30am - 11:30am

- Plenary Dimitris Bertsimas- Personalized Medicine: A Vision for Research and Education

## Wednesday, 1:00pm - 2:30pm

- WB01 Empirical Healthcare Operations
- WB02 Healthcare Service Management
- WB03 Resource Allocation and Incentive Design in Healthcare settings
- WB04 Data Analytics and Machine Learning II
- WB05 Optimization Approaches for Healthcare Decision-Making under Uncertainty
- WB06 Optimization of Medical Decision Making for Chronic Diseases
- WB07 HAS Student Paper Competition
- WB08 Operations Research and informations Systems for Healthcare Efficiency
- WB09 Scheduling and Planning II
- WB10 Supply Chains II
- WB11 Medical Decision Making II
- WB12 Disease and Treatment Modeling I
- WB13 Data-Driven Algorithms for Healthcare Problems

## Wednesday, 2:30pm - 3:30pm

- WP01 Poster session

## Wednesday, 3:30pm - 5:00pm

- WC02 EMS Related Topics
- WC03 Operations Research for Chronic Care
- WC04 Data Analytics and Machine Learning III
- WC05 Managing Health Care Costs and Quality Under Uncertainty
- WC06 Panel Session: Developing Natural History Models for Medical Decision Making
- WC08 Mathematical Models of Sepsis and Hospital-Acquired Infections
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- WC10 Supply Chains III
- WC11 Medical Decision Making III
- WC12 Disease and Treatment Modeling II
- WC13 Public Health Preparedness: Answering (Largely Unanswerable) Questions with Operations Research

## Thursday, 8:30am - 10:00am

- TA01 Scheduling and Planning IV
- TA02 Emergency Medical Services I
- TA03 Data-driven Policies for Differentiated Care
- TA04 Data Analytics and Machine Learning IV
- TA05 Health Care Modeling
- TA06 Complications in Cost-effectiveness Analyses: Data Scarcity, Model Uncertainty, and Implementation Challenges
- TA07 Analyzing & Optimizing the Patient Path to Care
- TA08 Operating Room Scheduling I
- TA09 Scheduling and Planning V
- TA10 Supply Chains IV
- TA11 Organ Transplant
- TA12 Disease and Treatment Modeling III
- TA13 Advanced Data Analytics for Healthcare

## Thursday, 10:30am - 12:00pm

- TB01 IT Enabled Patient Empowerment and Engagement
- TB02 Emergency Medical Services II
- TB03 Panel Session - Operations Management: Current Practice and its Implications for Policy
- TB04 Data Analytics and Machine Learning V
- TB05 Coordination and Optimization in Healthcare
- TB06 Maximizing Health under Constraints in Developing Countries
- TB07 Policy/Incentive Issues in Healthcare Operations
- TB08 Healthcare Operations Management Applications
- TB09 Scheduling and Planning VI
- TB10 Health Operations I
- TB11 Policy & Systems I
- TB12 Health and Humanitarian Logistics
- TB13 Predictive Analytics for Biomedicine and Clinical Decision

## Thursday, 12:00pm - 1:30pm

- Lunch Plenary - Erik Gerritsen & Eric de Roodenbeke- The INFORMS Contribution for the Health Systems and Hospitals of the Future

## Thursday, 1:30pm - 3:00pm

- TC01 Healthcare Informatics
- TC02 Emergency Medical Services III
- TC03 Public Health: Models and Empirics
- TC04 Data Analytics and Machine Learning VI
- TC05 Patients, Physicians, and Their Interactions
- TC06 Data and Modeling Challenges in Low and Middle Income Settings
- TC08 Patient Scheduling and Assignment
- TC09 Scheduling and Planning VII
- TC10 Health Operations II
- TC11 Policy & Systems II
- TC12 Utilizing Data to Enhance Care Delivery
- TC13 Personalized Medicine via Cutting Edge Machine Learning

## Thursday, 3:30pm - 4:30pm

- Plenary Dr. Brian Denton- Operations Research in Medicine: Past, Present and Future

### Friday, 8:00am - 9:30am

- FA01 How Technology and Analytics Create Value in Healthcare
- FA02 Scheduling and Planning X
- FA03 Operations Management and Systems Engineering Models for Policy
- FA04 Data Analytics and Machine Learning VII
- FA05 Resource Planning in Hospitals
- FA06 Disparities
- FA08 Scheduling Optimization for Healthcare Management
- FA09 Scheduling and Planning IX
- FA10 Emergency Medical Services IV
- FA11 Simulation
- FA12 Analytics Approaches to Personalizing Healthcare Delivery
- FA13 Incentives in Healthcare

### Friday, 11:35am -1:05pm

- FC01 Health Care Analytics and Operations Management
- FC03 Challenges & Research Directions in Kidney Exchange Programs - Placeholder for Itai's Session
- FC04 Data Analytics and Machine Learning IX
- FC05 Location Planning for General Practitioners
- FC06 Disease Mitigation Planning
- FC08 Operating Room Scheduling II
- FC09 Scheduling and Planning XIII
- FC10 Quality and Safety II
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- FC12 Disease and Treatment Modeling IV
- FC13 eHealth & Telemedicine

### Friday, 10:00am - 11:30am

- FB01 Data Analytics for Healthcare Management
- FB02 Scheduling and Planning X
- FB03 COST Action ENC-KEP: State of the Art in European Kidney Exchange Programs
- FB04 Data Analytics and Machine Learning VIII
- FB05 Healthcare Analytics
- FB06 Global Health/Low Income Settings
- FB08 Smart Healthcare Service Management
- FB09 Scheduling and Planning XII
- FB10 Quality and Safety I
- FB11 Insurance I
- FB12 Harnessing Information and Communication Technology for Healthcare
- FB13 Big Data Analytics in Health Care

# MASTER TRACK SCHEDULE | MASTER TRACK SCHEMA

| WEDNESDAY, JULY 26    |       |  |   |  |  |   |
|-----------------------|-------|--|---|--|--|---|
| ROOM                  | TRACK | WA<br>8:30–10AM                                      | PLENARY<br>10:30–11:30AM  | WB<br>1–2:30PM   | POSTER SESSION<br>2:30–3:30PM  | WC<br>3:30–5PM  |
| Van Cappellen Zaal    | 1     | Empirical & Experimental Research in Healthcare Ops. | <p><b>Personalized Medicine: A Vision for Research &amp; Education</b></p> <p>Dimitris Bertsimas<br/>Massachusetts Institute of Technology, Cambridge, MA</p> <p>Willem Burger Zaal</p> | Empirical Healthcare Ops.  | <p><b>Poster Sessions</b></p> <p>Van der Mandele Zaal &amp; Jurriaanse Foyer</p> | No Session  |
| Arcadis Zaal          | 2     | ALIO Sponsored Session                               |   | Healthcare Service Mgmt.   |  | EMS Related Topics  |
| Zeelenberg Zaal       | 3     | No Session   |   | Resource Allocation & Incentive Design in HC Settings            |  | Operations Research for Chronic Care                          |
| Hudig Zaal            | 4     | Data Analytics & Machine Learning I                  |   | Data Analytics & Machine Learning II                             |  | Data Analytics & Machine Learning III                         |
| Schadee Zaal          | 5     | Stochastic Models for Hospital Operations Management |   | Opt. Approaches for Healthcare Decision-Making under Uncertainty |  | Managing Health Care Costs & Quality under Uncertainty        |
| Van Beuningen Zaal    | 6     | Optimization Modeling for Medical Decision Making    |   | Optimization of Medical Decision Making for Chronic Diseases     |  | Developing Natural History Models for Medical Decision Making |
| Willem Burger Zaal    | 7     | No Session   |   | HAS Student Paper Competition                                    |  | No Session  |
| Ruys Zaal             | 8     | Data-Driven Models in Health Care Operations         |   | OR & Information Systems for Healthcare Efficiency               |  | Mathematical Mod. of Sepsis & Hospital-Acquired Infections    |
| Van Rijckevorsel Zaal | 9     | Scheduling & Planning I                              |   | Scheduling & Planning II   |  | Scheduling & Planning III                                     |
| Plate Zaal            | 10    | Supply Chains I                                      |   | Supply Chains II   |  | Supply Chains III   |
| Van der Vorm Zaal     | 11    | Medical Decision Making I                            |   | Medical Decision Making II                                       |  | Medical Decision Making III                                   |
| Mees Zaal             | 12    | Radiation Therapy Planning                           |   | Disease & Treatment Mod. I                                       |  | Disease & Treatment Mod. II                                   |
| Van Weelde Zaal       | 13    | Machine Learning for Optimizing Healthcare Delivery  |   | Data-Driven Algorithms for Healthcare Problems                   |  | Public Health Preparedness                                    |

| THURSDAY, JULY 27  |       |  |  |   |  |  |
|--------------------|-------|--|--|---|--|--|
| ROOM               | TRACK | TA<br>8:30–10AM                              | TB<br>10:30AM–12NOON   | LUNCH PLENARY<br>12NOON–1:30PM  | TC<br>1:30–3PM                             | PLENARY<br>3:30–4:30PM   |
| Van Cappellen Zaal | 1     | Scheduling & Planning IV                     | IT Enabled Patient Empowerment & Engagement                              | <p><b>The INFORMS Contribution for the Health Systems and Hospitals of the Future</b></p> <p>Dr. Erik Gerritsen<br/>Government of Netherlands &amp;<br/>Dr. Eric de Roodenbeke<br/>CEO, International Hospital Federation</p> <p>Willem Burger Zaal</p> | Healthcare Informatics                     | <p><b>Operations Research in Medicine: Past, Present &amp; Future</b></p> <p>Brian T. Denton<br/>University of Michigan, Ann Arbor, MI</p> <p>Willem Burger Zaal</p> |
| Arcadis Zaal       | 2     | Emergency Medical Services I                 | Emergency Medical Services II  |   | Emergency Medical Services III             |  |
| Zeelenberg Zaal    | 3     | Data-driven Policies for Differentiated Care | Panel - Operations Mgmt.: Current Practice & its Implications for Policy |   | Public Health: Models & Empirics           |  |
| Hudig Zaal         | 4     | Data Analytics & Machine Learning IV         | Data Analytics & Machine Learning V                                      |   | Data Analytics & Machine Learning VI       |  |
| Schadee Zaal       | 5     | Health Care Modeling                         | Coordination & Optimization in Healthcare                                |   | Patients, Physicians, & Their Interactions |  |

| Room                 | Track | Topic   | Speaker   | Location   | Time   |   |
|----------------------|-------|---|---|--|--|---|
| Van Beurningen Zaal  | 6     | Complications in Cost-Effectiveness Analyses    | Maximizing Health Under Constraints in Developing Countries | <b>The INFORMIS Contribution for the Health Systems and Hospitals of the Future</b><br>Dr. Erik Gemben<br>Government of Netherlands &<br>Dr. Eric de Roodenrys<br>CEO, International Hospital Federation<br>Willem Burger Zaal | Data & Modeling Challenges in Low & Middle Income Settings |   |
| Willem Burger Zaal   | 7     | Analyzing & Optimizing the Patient Path to Care | Policy/Incentive Issues in Healthcare Operations            |  | No Session   |   |
| Ruys Zaal            | 8     | Operating Room Scheduling I                     | Healthcare Operations Mgmt. App.                            |  | Patient Scheduling & Assignment                            |   |
| Van Rijkswinkel Zaal | 9     | Scheduling & Planning V                         | Scheduling & Planning VI                                    |  | Scheduling & Planning VIII                                 |   |
| Plate Zaal           | 10    | Supply Chains IV                                | Health Operations I   |  | Health Operations II                                       |   |
| Van der Vorm Zaal    | 11    | Organ Transplant                                | Policy & Systems I  |  | Policy & Systems II  |   |
| Mees Zaal            | 12    | Disease & Treatment Modeling III                | Health & Humanitarian Logistics                             |  | Utilizing Data to Enhance Care Delivery                    |   |
| Van Weelde Zaal      | 13    | Advanced Data Analytics for Healthcare          | Predictive Analytics for Biomedicine & Clinical Decision    |  | Personalized Medicine via Cutting Edge Machine Learning    |   |
|                      |       |   |   |  |  | Operations Research in Medicine: Past, Present & Future<br>Brian T. Denton<br>University of Michigan, Ann Arbor, MI<br>Willem Burger Zaal |

**FRIDAY, JULY 28**

| Room                 | Track | Topic   | Speaker  | Location                                      | Time   |
|----------------------|-------|---|--|---|--|
|                      |       |   |  | FA  | FC   |
|                      |       |   |  | 8-9:30AM                                      | 11:35AM-1:05PM   |
| Van Cappellen Zaal   | 1     | How Technology & Analytics Create Value in HC                 | Data Analytics for Healthcare Management                         | <b>FB</b><br>10-11:30AM<br>Willem Burger Zaal | Health Care Analytics & Operations Management                |
| Arcadis Zaal         | 2     | Scheduling & Planning VIII                                    | Scheduling & Planning XI   |   | No Session   |
| Zwahlenberg Zaal     | 3     | Operations Management & Systems Engineering Models for Policy | State of the Art in European Kidney Exchange Programs            |   | Challenges & Research Directions in Kidney Exchange Programs |
| Hudig Zaal           | 4     | Data Analytics & Machine Learning VII                         | Data Analytics & Machine Learning VIII                           |   | Data Analytics & Machine Learning IX                         |
| Schadee Zaal         | 5     | Resource Planning in Hospitals                                | Healthcare Analytics   |   | Location Planning for General Practitioners                  |
| Van Beurningen Zaal  | 6     | Disparities   | Global Health/Low Income Settings                                |   | Disease Mitigation Planning                                  |
| Ruys Zaal            | 8     | Scheduling Optimization for Healthcare Management             | Smart Healthcare Service Management                              |   | Operating Room Scheduling II                                 |
| Van Rijkswinkel Zaal | 9     | Scheduling & Planning IX                                      | Scheduling & Planning XII  |   | Scheduling & Planning X                                      |
| Plate Zaal           | 10    | Emergency Medical Services IV                                 | Quality & Safety I   |   | Quality & Safety II  |
| Van der Vorm Zaal    | 11    | Simulation  | Insurance I  |   | Insurance II   |
| Mees Zaal            | 12    | Analytics Approaches to Personalizing Healthcare Delivery     | Harnessing Information & Communication Technology for Healthcare |   | Disease & Treatment Modeling IV                              |
| Van Weelde Zaal      | 13    | Incentives in Healthcare                                      | Big Data Analytics in Health Care                                |   | eHealth & Telemedicine                                       |