Medical Surge Capability: An Intelligent Framework for Improving Hospital Emergency Department Operations

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Abstract

Health systems are faced with significant challenges during and after natural or human-caused disasters. Surge planning is a critical component of every healthcare facility's emergency plan and response system. The process of managing and allocating scarce resources by tackling the vulnerability inherent to patients means that defining improvement priorities is one of the main challenges healthcare systems face when responding to a medical surge event (e.g., influenza, COVID-19). The consequences of these challenges include increased patient mortality, ambulance diversion, long wait times, and unavailability of beds. Although previous efforts in hospital operations management have been modestly successful in applying operations research techniques to analyze and optimize ED operations during a standard operating capacity and, literature provides a vast number of resources on surge response planning for hospital administrators, most of the planning guidelines are not suitable for the current pandemic scale. This project aims to develop computational models that help to answer how the constant level of hospital resources and the changing demand for medical care can be modeled. We propose an intelligent framework to improve ED operations following a four-stage process. *Stage one* – develop univariate and multivariate forecasting models to forecast daily ED patient arrivals, which will help hospital management efficiently plan and allocate limited ED resources. *Stage two* – investigate the current prolonged ED length of stay for COVID-19 patients, using ensemble methods. *Stage three* – developing a multi-scale simulation-optimization framework to investigate how resource allocation affects the ED's performance during a surge. The simulation model combines agent-based, discrete event, and system dynamics, where system dynamics address the spread of disease, agent-based models the behavior of patients and resources (i.e., doctors and nurses), and discrete event models the processes within the hospital emergency departments. The expected outcomes of the study are the multi-objective combination of indicators to optimize ED performance and studying the interactions between the different ED operations to improve service capacity. Our proposed activity will assist hospital administrators, and clinicians plan effectively to ramp up capacity in response to the current and future pandemic.

Keywords
Emergency Department, Medical Surge, COVID-19, Machine Learning, Simulation

Biographies
Egbe-Etu Etu is an Assistant Professor of Business Analytics at San Jose State University. He received his Ph.D. degree in Industrial and Systems Engineering from Wayne State University in 2021. His research interest focuses on developing computational models using artificial intelligence, machine/deep learning, and multi-scale simulation to solve problems and provide business intelligence in healthcare, manufacturing, transportation, and other domains. He is a member of the Industrial Engineering and Operations Management (IEOM), Institute of Industrial & Systems Engineering (IISE), and SAVE International. In 2020, he received the IEOM Annual Conference Best Paper Award in the Healthcare Systems track.

Leslie Monplaisir is a Professor in the Department of Industrial and Systems Engineering at Wayne State University (WSU). He is the Lead Researcher and Director of the Product Development and Systems Engineering Consortium (PDSEC) at WSU. His research interests include Lean Product Development, Design for lean Systems and Services and Design reuse, New Product Technology Decision modeling, Product Architecture Optimization, Design for Supply Chain, Global Product Platform Optimization, and Healthcare Technology System Design. He has authored over 100 publications in these areas with funded research from NSF, Veterans Administration, and Ford Motor Company. Dr. Monplaisir joined the College of Engineering at Wayne State University in the Department of Industrial and Manufacturing Engineering in 1996 from Florida A & M University, where he was a visiting assistant professor. He earned his Ph.D. in Engineering Management from the Missouri University of Science and Technology (MUST), a Master's in Computer Integrated Manufacturing from the University of Birmingham in Great Britain.

Celestine Aguwa is an Associate Professor Research in the Industrial and Systems Engineering Department at Wayne State University. His background includes lean, and value methodology in product development and advanced manufacturing, customer voice analysis in product recalls and, decision analysis modeling. He is currently working on several funded research projects in data analytics. He has cross-functional industrial experience at Ford Motor Company and extensive professional experience as an Architect. Dr. Aguwa has a Ph.D. and MSIE in Industrial and Manufacturing Engineering from the University of Pittsburgh and Massachusetts, Amherst. He also has a B.Arch. Degree in Architecture from the University of Nigeria. Dr. Aguwa has several awards, including a patent, and has written several published papers. He is a member of the IISE, SAVE International, and Institute of Operation Research and Management Sciences (INFORMS).

Suzan Arslanturk is an Assistant Professor in the Department of Computer Science at Wayne State University. She received her Ph.D. degree in Computer Science and Informatics from Oakland University in 2015. Her research interest and expertise fall in the broad area of health informatics that enables developing innovative machine learning and clinical solutions to enhance individual and population health outcomes. Her research endeavors and professional work focuses primarily on disease risk prediction, biomarker identification and disease subtyping using AI and statistical models. Her research is funded by NSF and Department of Defense.

Sara Masoud is an Assistant Professor of Industrial and Systems Engineering at Wayne State University. Her research focuses on dynamic data-driven application systems by utilizing machine learning, simulation, and optimization models in different applications such as agro-industry, transportation, health care, and manufacturing. She is a member of IISE and INFORMS and has received the IISE Annual Meeting Best Paper Award in Data Analytics and Information Systems Track.

Joseph Miller is an Emergency Medicine Physician at Henry Ford Hospital. He specializes in Emergency Medicine, Internal Medicine, and Clinical Research. Dr. Miller’s research interest focuses on emergency neurological conditions such as acute stroke, epilepsy, and traumatic brain injury. He also does research in hypertensive emergencies and teaches research methodology within the health system.