

AN INVESTIGATION OF HYBRID SIMULATION FOR BEHAVIORAL ANALYSIS IN HEALTHCARE

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ABSTRACT

Modeling and Simulation (M&S) studies are used in healthcare to gain insights into different systems of interest and assist decision-makers. There is a lack of studies that focus on developing frameworks and models that incorporate human factors. Due to the nature of behavioral analysis in healthcare, and in order to include underlying factors that may influence behavior patterns, this study aims to develop a conceptual M&S framework for behavioral analytics by applying hybrid approaches. M&S for behavioral analysis seeks to understand and explore the behavior of individuals and how they react to certain systemic interventions. This research proposes a hybrid M&S approach that relies on both qualitative and quantitative elements for the purpose of modeling operational and human behavioral aspects in healthcare systems. This work contributes to the literature on M&S for behavioral analysis, extending the applicability of soft OR methods in hybrid simulation studies.

1 MODELING AND SIMULATION IN HEALTHCARE

The introduction of M&S in operations research has gained attention in various sectors, with a broad focus on non-human behavior. However, human behavior and people's attitudes and perceptions play a significant role in affecting performance and productivity of organizations, and ultimately desired outcomes. Yet, the M&S literature rarely focuses on establishing unequivocally how to incorporate such human behavior within simulation models, particularly in healthcare industry where it is complicated to characterize and predict human behavior, which can demonstrate a lot of variations (Arisha and Rashwan 2016; Manzi 2020). Within the healthcare sector, it is therefore crucial to focus on M&S of patients' behavior, and to investigate how M&S can help in predicting desired healthcare outcomes and validating them.

Healthcare systems are complex systems with many stakeholders and a multitude of interconnected physical, operational and behavioral variables to take into account (Mustafee and Katsaliaki 2015). Healthcare system complexities pose certain challenges, which require considering a range of evolving behaviors that may vary over time and involve diverse human and operational factors (Kunc *et al.* 2016). As a result, any attempt to model individual entities and actors with simple modeling methods or analytical tools in such complex systems might lead to focusing on actors within the underlying system without understanding their dynamic interactions, and consequently failing to examine whole systems in a holistic way (Luke and Stamatakis 2012). However, due to the unique characteristics of such systems, using M&S for behavioral analysis could be complex and challenging. Therefore, this research argues that an appropriate M&S approach that takes behavioral aspects into account is needed to help modelers to develop valid and efficient models for such complex systems.

2 HYBRID MODELING AND SIMULATION APPROACH FOR BEHAVIORAL ANALYSIS IN HEALTHCARE

It has been suggested in a recent literature review of behavioral aspects in the application of OR in healthcare that users of OR M&S methods are highly prone to consider modeling if they are provided with a toolkit, rather than a single tool (Kunc *et al.* 2020). The complexity and uncertainty of human behavior in healthcare may imply that combining OR M&S techniques could enable the symbiotic relation of the strengths of individual techniques, while reducing their limitations, thereby potentially realizing synergies across techniques and facilitating greater insights to problem-solving. With the objective of reducing the gap between ‘real world systems’ and ‘computer simulation’, this research argues that a Hybrid Modeling approach can lead to a more realistic representation of the healthcare systems. Furthermore, this research suggests the combination of Soft OR techniques with M&S for behavioral analysis in healthcare and proposes a generic conceptual hybrid M&S framework for behavioral analysis in healthcare.

Incorporating human behavior in modeling studies, within various sectors, is not widely common. Specifically in the healthcare sector, the lack of incorporating behavioral factors when reporting findings from modeling may affect desired healthcare outcomes and influence results negatively. Despite the need for applying hybrid simulation for behavioral analysis, there is a dearth of studies which have applied Soft OR methods and M&S in an integrated way. We argue that this could be due to: (1) lack of understanding about Behavioral Operational Research, (2) the challenges associated with integrating M&S methods for analyzing such complex and uncertain systems, and (3) lack of literature on the benefits of mixing soft OR tools with M&S methods for simulation studies. Thus, there is a need for a potentially generic framework that provides step-by-step guidance on developing M&S for behavioral analysis. Such a framework could aid the development of models that are likely to be a better representation of the system under scrutiny. This is crucial for behavioral simulation as the real system is complex and uncertain.

The proposed M&S framework is aimed to help healthcare modelers to invoke behavioral analysis from the start by defining the characteristics of studied problems, and to combine multiple OR and M&S methods to benefit from the strengths of each one and reduce their limitations at the same stage or at different stages of the process. The proposed framework employs a more comprehensive approach to link health datasets and parameters with human behavior classification to address the complexity of human behavior and analyze it effectively. It is generally composed of multiple phases, and each phase is unique in addressing specific requirements. Identifying problem characteristics, based on behavior analysis and influencing factors, at an early stage, would lead to a more appropriate selection of a single simulation technique or hybrid M&S method. Therefore, a combination of soft OR and M&S methods is helpful in analyzing human behavior and addressing complexity and uncertainty of healthcare systems.

REFERENCES

- Arisha A, and W. Rashwan. 2016. “Modeling of Healthcare Systems: Past, Current and Future Trends”. In *Proceedings of the 2016 Winter Simulation Conference*, edited by T. Roeder, P. Frazier, R. Szechtman, E. Zhou, T. Huschka, and S. Chick. 1523–1534. Washington, DC: Institute of Electrical and Electronics Engineers, Inc.
- Kunc, M., P. Harper, and K. Katsikopoulos. 2020. “A review of implementation of behavioural aspects in the application of OR in healthcare”. *Journal of the Operational Research Society* 71(7), 1055-1072.
- Kunc, M., J. Malpass, and L. White. 2016. *Behavioral Operational Research Theory: Theory, Methodology and Practice*. London: Palgrave Macmillan.
- Luke, D., and K. Stamatakis. 2012. “Systems Science Methods in Public Health: Dynamics, Networks, and Agents”. *Annual Review of Public Health* 33(1): 357-376.
- Manzi, S. 2020. “The Importance of Human Behavior in Practice: Insights from the Modeling Cycle”. In *Behavioral Operational Research*, edited by L. White, M. Kunc, K. Burger, and J. Malpass, 183-201. Cham, Switzerland: Palgrave Macmillan.
- Mustafee, N., and K. Katsaliaki. 2015. “Simulation for Sustainable Health Care”. *Journal of Simulation* 10, 9(2):83–85.