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Dynamic Simulation in Health Care Comes of Age

For over half a century, the management science and industrial engineering community has applied simulation methods to problems in the delivery of health care services. Research in the 1970s used discrete event simulation (DES) to improve patient flows in emergency rooms and doctor s offices [1], to optimize the geographic location of ambulance stations to minimize response time, and to plan for staffing needs in various hospital departments. In 1976, the growth in these efforts prompted the devotion of an entire issue of *Operations Research* to the application of these methods in health care, and there were predictions that simulation would revolutionize health care delivery in ways similar to the tremendous improvements that had been seen through its application in manufacturing and network control [2]. However, given the poor state of the quality and high costs of US health care, it could be said that with some notable exceptions, the industrial revolution in health care delivery has not yet occurred. The Institute of Medicine, collaborating with the National Academy of Engineering, described what it termed the paradox of American health care, in which the best and the brightest produce multiple innovations in drugs and devices, but that virtually no talent and energy has been devoted to the operation of the health care system [3].

The most recent issues of *Value in Health* contain two reports by the ISPOR Simulation Modeling Emerging Good Practices Task Force. The first, Applying Dynamic Simulation Modeling Methods in Health Care Delivery Research The SIMULATE Checklist [4], provides a thoughtful overview of dynamic simulation methods, spells out a series of important definitions to ensure that future discussions have a common vocabulary, and develops a simple tool, the SIMULATE checklist, to assist modelers in making decisions about the need for a dynamic simulation method. It is an important first start, but work still needs to be done to enhance the value such a checklist has for an investigator. Some components of a problem essentially *require* that a dynamic modeling system be used (the need to represent component interactions, such as often seen in infectious disease models), whereas others may or may not require a dynamic system, but using a dynamic model may be useful or efficient (time and multilevel components are often very well modeled in microsimulation or state transition models).

The second article in this series, Selecting a Dynamic Simulation Modeling Method for Health Care Delivery Research Part 2: Report of the ISPOR Dynamic Simulation Modeling Applications in Health Care Delivery Research Emerging Good Practices Task Force [5], is a primer comparing the strengths and weaknesses of the three most common dynamic methods (system dynamics [SD], DES, and agent-based modeling [ABM]) and provides a series of easy-to-understand recommendations regarding the strengths and weaknesses of the various modeling methods. The article provides substantial and much needed guidance in the matching of particular simulation methods to the type of problem that is being addressed, the level of aggregation of outputs desired.

The specific boundaries between the SD, DES, and ABM simulation methods are growing very hard to define, and to some degree, the differences between these modeling types started as different software systems to represent dynamic problems rather than truly different methodologies. This overlap is demonstrated in the features table and Figure 4 in the article, which provides a summary of criteria for choosing a model type. There is more overlap than uniqueness in these criteria, and the relative superiority of one modeling type over another is hard to define explicitly. Modern object-oriented programming techniques have made the development of dynamic simulation tools substantially more accessible, and the simulation definitions that grew from specific software systems are becoming less important. Virtually any set of feedback loops typically described in an SD model can be represented by an appropriately constructed agent-based model, and entities within appropriately constructed DES models can contain algorithmic responses to the virtual environment that replicates the autonomous behavior of an agent in an ABM model. DES models can exhibit emergent behavior just as ABM models do, and accurate representations of complex realistic systems may require hybrid approaches that use components across multiple modeling types.

This work represents an important and timely statement to improve the methodological rigor by which models of health care systems are formulated and constructed. The potential that pioneers of the application of industrial methods in health care saw 50 years ago is yet to be fully realized. The appropriate application of the dynamic methods evaluated by this ISPOR task force to the incredibly complex problems we face in health care today holds tremendous potential to improve the cost, quality, and efficiency of health care systems. Hopefully, and with these methodological articles as helpful guideposts, dynamic simulation in health care may now come of age.

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