3.7 Ambulatory Healthcare Utilization in the United States: A System Dynamics Approach

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Rafael Diaz
Virginia Modeling, Analysis, and Simulation Center
Old Dominion University
rdiaz@odu.edu

Joshua G. Behr
Virginia Modeling, Analysis, and Simulation Center
Old Dominion University
jbehr@odu.edu

Mandar Tulpule
Virginia Modeling, Analysis, and Simulation Center
Old Dominion University
mtulp001@odu.edu

Abstract. Ambulatory healthcare needs within the United States are served by a wide range of hospitals, clinics, and private practices. The Emergency Department (ED) functions as an important point of supply for ambulatory healthcare services. Growth in our aging populations as well as changes stemming from broader healthcare reform are expected to continue trend in congestion and increasing demand for ED services. While congestion is, in part, a manifestation of unmatched demand, the state of the alignment between the demand for, and supply of, emergency department services affects quality of care and profitability. The central focus of this research is to provide an explication of the salient factors at play within the dynamic demand-supply tensions within which ambulatory care is provided within an Emergency Department. A System Dynamics (SD) simulation model is used to capture the complexities among the intricate balance and conditional effects at play within the demand-supply emergency department environment. Conceptual clarification of the forces driving the elements within the system, quantifying these elements, and empirically capturing the interaction among these elements provides actionable knowledge for operational and strategic decision-making.

1.0 INTRODUCTION

Ambulatory care includes a broad range of primary and preventive healthcare services that are delivered on an outpatient, or *ambulatory*, basis. Main venues for the treatment of ambulatory conditions include hospitals, federally qualified community health centers and clinics, urgent care facilities, and privately operated practices, which together are the major providers of healthcare services in the U.S. (U.S. Census Bureau, 2009). Ambulatory care provided by a hospital may be through either an Emergency Department (ED) or an Outpatient Department (OPD). Private practices that offer ambulatory care services may be classified as primary care, surgical specialties, or medical specialties (Burt & Schappert, 2004).

Research investigating how the intersection of social, technological, environmental, and financial factors impact access to healthcare may be broadly classified as health services research. The relationships among ambulatory treatment venue choice, patient characteristics, healthcare need, and the public health has been the domain of health services research for over half a century (e.g., Aday and Anderson (1974); Williams (1994); Gray et al. (2003)). The choice of ambulatory treatment venue may be influenced by a wide variety of factors including the nature of the condition or illness in conjunction with socio-economic and spatial factors, all of which influence the demand for ambulatory care services (Behr, Drivers of Emergency Department Utilization: A Systematic Study of the Individual's Decision Calculus to Select Healthcare Services, 2008).

It is clear that the nature of illness and chronic disease within our society creates the *demand* for treatment. The system of ambulatory care venues constitutes the *supply* of treatment meant to satisfy this demand. The capacity to supply treatment is finite and is a product of the availability of health care professionals and ambulatory care facilities. It is of national interest to match the demand for treatment with the availability and access to ambulatory treatment venues. Ensuring that all population segments, especially those that have traditionally been underserved, uninsured, or underinsured, have access to a reliable ambulatory care system is often the focus of public policy makers.

The complexity of factors, many of which are dynamically inter-related, may frustrate reaching demand-supply equilibrium. For example, demand for ambulatory care may be initially reduced by a condition of non- or under-insurance stemming from socio-economic conditions; potential patients may delay seeking ambulatory care (Behr & Diaz, 2010), yet delayed or non-treatment may be the catalyst for higher-acuity conditions that later may placed increased demand on the system. On the supply side, congestion in Emergency Departments may be a product of staffing and nursing issues and this, in turn, may impact timely treatment (Carr, Kaye, Wiebe, Gracias, Schwab, & Reilly, 2007). The interplay between demand and supply conditions the availability, affordability, congestion and quality of ambulatory care.

We assert that a meaningful understanding of the ambulatory care system may be derived from a holistic and encompassing approach that considers both demand and supply factors. Adequately identifying the salient supply-demand factors and realistically capturing the dynamics among critical factors are essential requirements in the development of a model of the ambulatory care system. Specifying within the model an appropriate combination of both demand and supply variables that captures the real-world system will then allow us to measure changes in variables that approach a sustainable healthcare system, one in which we have a viable balance between demand and supply.

The purpose of this study is to construct a high level, calibrated model for ambulatory healthcare utilization in the U.S. This research offers a System Dynamics (SD) simulation model that captures from an Emergency Department perspective the complexities associated with the interactions among these factors. This model demonstrates that it is possible to capture the supply and demand complexities that define our ambulatory care system.

The validity of the simulation model is demonstrated by comparing actual data from United States Ambulatory healthcare statistics with data produced by the simulation. Specifically, this study models the overall ambulatory healthcare demand and utilization trends in the United States between 1999 and 2006. The model and simulation mimics the current national-level dynamics of the ambulatory system with emphasis on emergency management and provides insights that may inform policy making.

Following this Introduction, Section 2 describes the research question, Section 3 presents an overview of our modeling and simulation approach and Section 4 presents and validates the results. Finally, the last Section discusses conclusion and the potential for the model to be extended to other applications.

2.0 USING SYSTEM DYNAMICS TO SIMULATE EMERGENCY DEPARTMENTS

The critical role of Emergency Departments in the delivery of healthcare in the United States makes them an important subject for research and analysis. Simulation may be employed as an approach that provides insight into the workings of an Emergency Department. Simulation provides the ability to test 'what if' scenarios without actually incurring the real cost and risk associated with injecting change into the current critical real-world system (Jun, Jaconbson, & Swisher, 1999). For example, authors have used System Dynamics to represent and study issues in Emergency Department crowding. Lane, Monefedlt, and Rosenhead (2000) use system dynamic modeling to investigate the reduction in bed capacity to the waiting times of patients and Behr and Diaz (2010) use Systems Dynamics to model sensitivity of Emergency Department utilization.

Existing reviews of the use of modeling and simulation to better understand Emergency Departments show that much research has been focused on well-defined aspects or particular operations within or related to the Emergency Department (Jun, Jaconbson, & Swisher, 1999). Many papers have a focus on the causes and solutions for specific emergency Department issues (Gunal & Pidd, 2009)

At a higher level, modeling and simulating the Emergency Department as part of a larger healthcare system is also possible. The present study aims to provide the reader a holistic view of the various factors that affect the Emergency Department utilization.

System Dynamics allows for a systemic view of the variables interactions at an aggregated level. However, there are disadvantage with the approach as loss of effects of stochastic variation and resolution down to individual patient or condition level. Nevertheless, healthcare provisions cannot be understood by looking at factors in isolation. System Dynamics is the tool of choice since it offers the ability to produce technically representative models that are persuasive to stakeholders.

3.0 RESEARCH QUESTION

Policy makers and hospital managers are faced with central decisions in relation to incentivizing and expanding healthcare infrastructure and increasing capacities. When and how to expand the supply of ambulatory healthcare services are difficult since such decisions may involve large personnel and capital commitments as well as have the potential to alter the demand for services at other existing ambulatory care venues. These decisions must be made in the context of market forces that require a health facility to sustain its economic viability. Therefore, understanding the nonlinear dynamics inherent in the interaction among supply and demand variables is critical to healthcare management sustainability.

The central focus of this research is to provide an explication of the salient factors at play within the dynamic demand-supply tensions within which ambulatory care is provided within an Emergency Department. In addition, this research answers question related to the relative importance of such factors in reaching near demand-supply equilibrium and the cost implications of approaching such a solution.

4.0 RESEARCH APPROACH

This research proposes a Modeling and Simulation (M&S) approach based on System Dynamics to represent and simulate ambulatory ED utilization. The four basic steps that gird our approach are as follows: 1) represent the general flow of patients seeking ambulatory care, 2) represent the main venues that serve ambulatory patients with a particular focus on service provided by Emergency Departments, 3) represent the driving forces that animate a patient's willingness to seek services from a particular treatment venue, and 4) simulate the system and validate results through comparative analysis with national data. In the following sections, the authors describe the salient features of the model that include the venues, patient population, selection process, capacity model, and revenues model.

4.1 Ambulatory treatment venues

Ambulatory care can be broadly classified into two categories, namely office-based primary care offered by independent physician practitioners and hospital-based healthcare centers. For practical purposes, in this study we consolidate the subcategories that compose each of these as either primary care physician (PCP) or Emergency Department (ED) venues. The PCP will consider the combined data for the three categories of office-based primary care physicians while the ED will consider the combined data for the emergency departments and the outpatient department. The insurance status of treatment seekers also distinguishes PCP and ED venues. Patients having no insurance (self-pay, no charge, or charity) have a greater tendency to visit the ED (inclusive of the OPD) realtive the PCP. Pitts, Niska, Xu, and Bur (Pitts, Niska, Xu, & Burt, 2008) indicate that 17.4% are uninsured patients as a percentage of total patients.

4.2 Patient Population

In the presented model, the patient population at any given time is assumed to be a fraction of the total population. In addition, we assume that the patient population is aging and the cumulative demand for ambulatory care is increasing. This is supported by knowledge of the aging U.S. baby boomer population. Hence, the cumulative healthcare needs of the society have been increasing. The argument is found to be valid for the data between 1999-2006. This assumption is supported by Burt and Schappert, (2004), and Cherry, Hing, Woodwell, and Rechtsteiner (2008).

An important determinant of treatment seeking behavior from ambulatory care providers is insurance status (Behr, 2008). In this model, we explicitly consider this status as a major factor. In general, the patient population is split into the two categories of insured (Private, Medicare, Medicaid, State children's health insurance program) and uninsured (self-pay, no charge, or charity). According to the U.S. Census Bureau, 1999-2008, 84.2% of the population had some form of insurance with the remainder (15.8%) classified as uninsured. Utilization of healthcare venues between the insured and the uninsured is uneven. Ambulatory visits by insured patients are 93.69%. This parameter (93.69%) is used to divide the patient population into insured and uninsured categories.

4.3 Combined weight for selection of Emergency Department

When seeking ambulatory care, individuals tend to select a venue (supply) that closely matches their needs (demand). The venue selection is based on a set of core factors including access, capacity, waiting time to be served, and financial status. The weight of each factor in the individual decision calculus to seek services from one venue relative another may be derived from surveying the population that seeks ambulatory care (2008). There are many scales and methodologies for quantifying these values. In our case, for practical purposes, we selected ED access and PCP capacity as the main drivers for selecting a given venue. Calibration values at the start of simulation runs accounted for representing factors other than those indicated above.

4.4 Combined weight for selection for ER by uninsured patients

The choice of venue by uninsured patients is computed in similar fashion as those computed for insured patients. However, three additional factors are considered: tendency to defer treatment, insurance status, and level of patient acuity.

Within the model, we imbue uninsured patients with a greater tendency to visit an ED relative a PCP. The rational for this assumption is that the 'Tendency to defer treatment' and the 'insurance status' factors will reduce the chance of the patient visiting either the PCP or the ED. Uninsured patients have a greater tendency to defer medical treatment due to financial constraints relative the insured and, thus, the uninsured are more likely to self treat. This tendency has been adopted in the model via the 'Tendency to defer treatment' factor. This can be represented in our model by means of the factor 'Patient acuity level'. The uninsured patient has the tendency to defer treatment, which may eventually lead to a higher acuity. A person with a medical condition requiring immediate stabilization is more likely to seek services from an ED relative a PCP. Thus, the two factors, 'Tendency to defer treatment' and 'insurance status,' promote a tendency to avoid an ED visit whereas the 'Patient acuity level' would promote the choice of the ED instead of the PCP.

4.5 Capacity Submodel

The capacity is modeled in terms of the capability of the system to treat a certain number of patients. The capacity is increased or reduced depending on the difference between available and target capacity. The available capacity and the number of patients visiting the facility is classically defined the 'Beds per person.' This represents units of capacity available per patient. This parameter influences the estimated waiting time at the facility 'ED waiting time factor' and is modeled as a regression with 'beds per patient.' As indicated before, the 'ED waiting time' factor is one of the aspects that contribute to the 'Combined weight for selection of ED'. The same model is implemented in case of PCP. The below Figure 1 below displays this model.

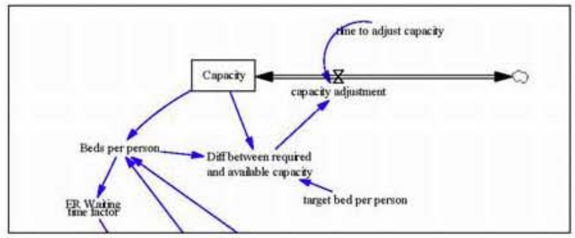

Figure 1 – Capacity submodel

4.6 Revenue submodel

The revenue submodel estimates the overall revenue generated by a particular venue as function of income per patient ('price') and the number of patients visiting the venue. The 'unpaid healthcare costs' are modeled as the 'price' and the number of uninsured patient visits. Figure 2 and 3 below show this simple revenue submodel and the accumulative stock for the 'unpaid healthcare costs.' The 'unpaid healthcare costs' is exponentially impacted by the tendency to defer treatment, which has been known to deteriorate and complicate the medical condition of the patient. A worsening of medical condition leads to higher costs.

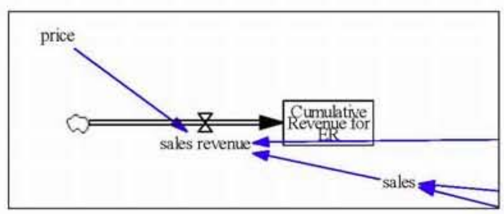

Figure 2 – Revenue model for healthcare venue

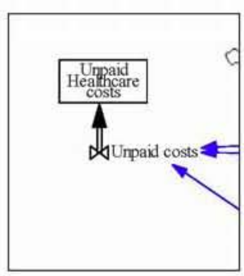

Figure 3 – Unpaid healthcare costs

5.0 RESULTS

The usefulness of the presented simulation model is reflected in its close approximation to the real-world system. That is, a model whose salient variables function in a fashion similar to patterns apparent in the real-world is often useful. As such, a classic method to measure the quality of the performance of the simulation model is to compare its output values with actual available statistics. If the real-world system has been properly modeled, then the differences between the two systems measures of performance ought to be minimal. The measures of performance selected to quantify the performance of the modeled system includes: Total Number of Visits to ED (divided between insured and uninsured patients), the Total Number of Visits to PCP (divided between insured and uninsured patients). The results are displayed in Table 1 below as a comparison of simulated and actual measures of performance.

Table 1 – Comparison of simulated and actual parameters

Year -2006	Simulated	Actual	% deviation
Total Number of Visits to ED	*217,642,000*	*221,399,000*	*-1.73%*
Number of Visits to ER - Insured patients	186,065,320	190,234,550	-2.24%
Number of Visits to ER - Uninsured patients	31,576,770	31,164,450	1.31%
Total Number of Visits to PCP	*904,368,000*	*901,954,000*	*0.27%*
Number of Visits to PCP -Insured patients	863,874,700	862,268,024	0.19%
Number of Visits to PCP -Uninsured patients	40,492,735	39,685,976	1.99%

It can be observed that the simulated and actual values closely match. This demonstrates that the level to which this model is calibrated to the actual system and also provides initial validation for the overall construction of the model.

6.0 DISCUSSION AND CONCLUSIONS

System Dynamics is a simulation approach that can be used to capture a holistic perspective of the ambulatory care system. In this paper, we developed a SD model that replicate the behavior of the ambulatory care system. The model considered both the supply and demand sides of the system. Further, it considers specific factors that influence individuals' decisions in selecting ambulatory care venues. Venues were categorized as either EDs for hospital-based care centers or PCPs for office-based primary care physicians. ED access and PCP capacity were selected as major drivers that conditioned the venue selection. Tendency to defer treatment, insurance status, and patient acuity level also are critical aspects that influence the performance of the model, although other components of the model, namely capacity and revenues submodels, were not fully analyzed in this paper.

The simulated model was executed for replicating the period from 1999 through 2006. Empirical results demonstrate that the model perform well. To measure the performance of the simulated data a comparisons were made relative real-world data. Deviation of the simulated data from real data was approximately 1.29%. Measures of performance included: total patients visits to EDs and PCPs for insured and uninsured.

Potential application of this simulation are manifold, including the following: 1) investigating the mix of intervention techniques that divert targeted patients to alternative venues, 2) the capacity and financial consequences of expanding or downsizing different venues, 3) the effects of delaying treatment, 4) providing ambulatory care to certain segment of the population, and 5) the consequences of congestion on demand and supply factors.

The simulation model demonstrates a handling of the complexities associated with an ambulatory care system. Managerial and policy-making decision environments systems require effective tools to support the decision process. Simulation-based decision support systems that embrace these technologies can assertively center on efforts and resource allocation that produce demonstrable sustainable solutions.

7.0 REFERENCES

[1] Aday, L., & Andersen, R. (1974). *A framework for the study of access to medical care.* Health Services Research.

[2] Behr, J. (2008). *Drivers of Emergency Department Utilization: A Systematic Study of the Individual's Decision Calculus to Select Healthcare Services.* Sentara Health Foundation. Norfolk, VA: Unpublished.

[3] Behr, J., & Diaz, R. (2010). A system dynamics approach to modeling the sesnititvity of inappropiate emerency department utilization. *Third International Conference on Social Computing, behavioral modeling, and prediction. SBP 2010.* Bethesda, MD: Advances in Social Computing - Springer.

[4] Burt, C. W., & Schappert, S. M. (2004). Ambulatory care visits to physician offices, hospital outpatient departments, and emergency departments: United States, 1999– 2000, National Center for Health Statistics. Vital Health Stat. *13* (157).

[5] Carr, B., Kaye, A., Wiebe, D., Gracias, V., Schwab, C., & Reilly, P. (2007). Emergency department length of stay: a major risk factor for pneumonia in intubated blunt trauma patients. *63* (9-12).

[6] Cherry, D. K., Hing, E., Woodwell, D. A., & Rechtsteiner, E. A. (2008). *National Ambulatory Medical Care Survey: 2006 Summary, National Health Statistics Reports.* Centers for Disease Control and Prevention, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES.

[7] Grey, B., Gusmano, M., & Collins, S. (2003). *AHCPR and the changing politics of health services research.* Health Services Research.

[8] Gunal, M., & Pidd, M. (2009). Discrete Event Simulation for Performance Modeling in Healthcare. *Unpublished,Lanchaster University Management School, Working Paper* .

[9] Jun, J. B., Jaconbson, S. H., & Swisher, J. R. (1999). Application of discrete-event simulation in health care clinics: A survey. *Journal of the Operational Research Society , 50* (2), 109-123.

[10] Lane, D. C., Monefedlt, C., & Rosenhead, J. V. (2000). Looking in the Wrong Place for Healthcare Improvements: A System Dynamics Study of an Accident and Emergency Department. *The Journal of the Operational Research Society , 51* (5), 518-531.

[11] Morgan, M. W., Zamora, N. E., & F., H. M. (2007). An Inconvenient Truth: A Sustainable Healthcare System Requires Chronic Disease Prevention and Management Transformation. *7* (4).

[12] Pitts, S. R., Niska, R. W., Xu, J., & Burt, C. W. (2008). *National Hospital Ambulatory Medical Care Survey: 2006 Emergency Department Summary, National Health Statistics Reports.* Centers for Disease Control and Prevention, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES.

[13] U.S. Census Bureau. (2009, December). *Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2009 (NST-EST2009-01).* Retrieved July 20, 2010, from census.gov: http://www.census.gov/popest/states/NST-ann-est.html

[14] U.S. Census Bureau. (1999-2008). *Health Insurance Historical Tables, Health Insurance Coverage Status and Type of Coverage by Nativity: 1999 to 2008.*

Retrieved July 20, 2010, from census.gov: http://www.census.gov/hhes/www/hlthins/data/historical/index.html

[15] Williams, D. (1994). *The concept of race in health services research..* Health Services Research.

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Dr. Rafael Diaz,
Dr. Joshua G. Behr,
& Mandar Tulpule

ModSim World Conference and Expo
October 15th, 2010
Virginia Beach, Virginia

1

Motivation

Driving Factors

- Ambulatory healthcare needs within the United States are served by a wide range of hospitals, clinics, and private practices.
- The Emergency Department (ED) functions as an important point of supply for ambulatory healthcare services.
- Growth in our aging populations as well as changes stemming from broader healthcare reform are expected to continue trend in congestion and increasing demand for ED services.
- While congestion is, in part, a manifestation of unmatched demand, the state of the alignment between the demand for, and supply of, emergency department services affects quality of care and profitability.

2

Study Focus & Purpose

Five Key Points

1. Construct a high level, calibrated model for ambulatory healthcare utilization in the U.S.
2. Apply System Dynamics (SD) approach to capture the complexities among the intricate balance and conditional effects at play within the demand-supply Emergency Department environment.
3. Demonstrates that it is possible to capture the supply and demand complexities that define our ambulatory care system.
4. Provide an explication of the salient factors at play within the dynamic demand-supply tensions within which ED ambulatory care is provided.
5. Provide actionable knowledge for operational and strategic decision-making.

3

Approach

Four-step Approach:

1. Represent the general flow of patients seeking ambulatory care.
2. Represent the main venues that serve ambulatory patients with a particular focus on service provided by Emergency Departments.
3. Represent the driving forces that animate a patient's willingness to seek services from a particular treatment venue.
4. Simulate the system and validate results through comparative analysis with national data.

4

Ambulatory Care

Key Points

- Ambulatory care includes a broad range of primary and preventive healthcare services that are delivered on an outpatient, or *ambulatory*, basis.
- Main venues for the treatment of ambulatory conditions include hospitals, federally qualified community health centers and clinics, urgent care facilities, and privately operated practices, which together are the major providers of healthcare services in the U.S. (U.S. Census Bureau, 2009).
- Ambulatory care provided by a hospital may be through either an Emergency Department (ED) or an Outpatient Department (OPD).
- Private practices that offer ambulatory care services may be classified as primary care, surgical specialties, or medical specialties (Burt & Schappert, 2004).

5

Health Services Research

Broadly Defined

- Research investigating how the intersection of social, technological, environmental, and financial factors impact access to healthcare may be broadly classified as health services research.
- The relationships among ambulatory treatment venue choice, patient characteristics, healthcare need, and the public health has been the domain of health services research for over half a century (e.g., Aday and Anderson (1974); Williams (1994); Gray et al. (2003)).
- The choice of ambulatory treatment venue may be influenced by a wide variety of factors including the nature of the condition or illness in conjunction with socio-economic and spatial factors, all of which influence the demand for ambulatory care services (Behr, Drivers of Emergency Department Utilization: A Systematic Study of the Individual's Decision Calculus to Select Healthcare Services, 2008).

6

Patient Population

Assumptions

- In the presented model, the patient population at any given time is assumed to be a fraction of the total population.
- In addition, we assume that the patient population is aging and the cumulative demand for ambulatory care is increasing.
- This is supported by knowledge of the aging U.S. baby boomer population. Hence, the cumulative healthcare needs of the society have been increasing.
- The argument is found to be valid for the data between 1999-2006. This assumption is supported by Burt and Schappert, (2004), and Cherry, Hing, Woodwell, and Rechtsteiner (2008).

7

Insurance Status

Insurance

- An important determinant of treatment seeking behavior from ambulatory care providers is insurance status (Behr, 2008).
- In this model, we explicitly consider this status as a major factor. In general, the patient population is split into the two categories of insured (Private, Medicare, Medicaid, State children's health insurance program) and uninsured (self-pay, no charge, or charity).
- According to the U.S. Census Bureau, 1999-2008, 84.2% of the population had some form of insurance with the remainder (15.8%) classified as uninsured.
- Utilization of healthcare venues between the insured and the uninsured is uneven:
    - *Ambulatory visits by insured patients are 93.69%. This parameter (93.69%) is used to divide the patient population into insured and uninsured categories.*

8

The Demand-Supply Equilibrium

The Balance

- It is clear that the nature of illness and chronic disease within our society creates the *demand* for treatment.
- The system of ambulatory care venues constitutes the *supply* of treatment meant to satisfy this demand.
- The capacity to supply treatment is finite and is a product of the availability of health care professionals and ambulatory care facilities.
- It is of national interest to match the demand for treatment with the availability and access to ambulatory treatment venues.
- Ensuring that all population segments, especially those that have traditionally been underserved, uninsured, or underinsured, have access to a reliable ambulatory care system is often the focus of public policy makers.

9

Complexity of the System may Frustrate the 'Match'

Interplay

- The complexity of factors, many of which are dynamically inter-related, may frustrate reaching demand-supply equilibrium.
- For example, demand for ambulatory care may be initially reduced by a condition of non- or under-insurance stemming from socio-economic conditions; potential patients may delay seeking ambulatory care (Behr & Diaz, 2010), yet delayed or non-treatment may be the catalyst for higher-acuity conditions that later may placed increased demand on the system.
- On the supply side, congestion in Emergency Departments may be a product of staffing and nursing issues and this, in turn, may impact timely treatment (Carr, Kaye, Wiebe, Gracias, Schwab, & Reilly, 2007).
- The interplay between demand and supply conditions the availability, affordability, congestion and quality of ambulatory care.

10

Sustainable Healthcare System

Capturing the Real World

- A meaningful understanding of the ambulatory care system may be derived from a holistic and encompassing approach that considers both demand and supply factors.
- Adequately identifying the salient supply-demand factors and realistically capturing the dynamics among critical factors are essential requirements in the development of a model of the ambulatory care system.
- Specifying within the model an appropriate combination of both demand and supply variables that captures the real-world system will then allow us to measure changes in variables that approach a sustainable healthcare system, one in which we have a viable balance between demand and supply.

11

Venue Selection

The Decision Calculus

- When seeking ambulatory care, individuals tend to select a venue (supply) that closely matches their needs (demand).
- The venue selection is based on a set of core factors including access, capacity, waiting time to be served, and financial status.
- The weight of each factor in the individual decision calculus to seek services from one venue relative another may be derived from surveying the population that seeks ambulatory care (2008).
- There are many scales and methodologies for quantifying these values. In our case, for practical purposes, we selected ED access and PCP capacity as the main drivers for selecting a given venue.
- Calibration values at the start of simulation runs accounted for representing factors other than those indicated above.
- The choice of venue by uninsured patients is computed in similar fashion as those computed for insured patients, but with three additional factors:
  1. tendency to defer treatment,
  2. insurance status, and
  3. level of patient acuity.

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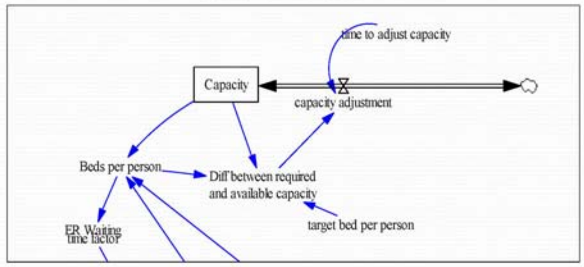
Capacity Submodal

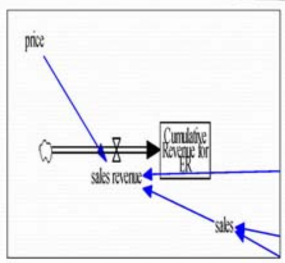


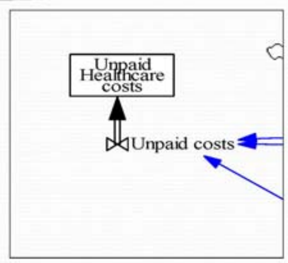
Key Points

- The capacity is modeled in terms of the capability of the system to treat a certain number of patients.
- The capacity is increased or reduced depending on the difference between available and target capacity.
- The available capacity and the number of patients visiting the facility is classically defined the 'Beds per person.'
- This represents units of capacity available per patient. This parameter influences the estimated waiting time at the facility 'ED waiting time factor' and is modeled as a regression with 'beds per patient.'
- The 'ED waiting time' factor is one of the aspects that contribute to the 'Combined weight for selection of ED'. The same model is implemented in case of PCP.

13

Revenue Submodal





Key Points

- Estimates the overall revenue generated by a venue as function of income per patient ('price') and the number of patients at that venue.
- The 'unpaid healthcare costs' are modeled as the 'price' and the number of uninsured patient visits.
- The 'unpaid healthcare costs' is exponentially impacted by the tendency to defer treatment, which has been known to deteriorate and complicate the medical condition of the patient – simply, a worsening of medical condition leads to higher costs.

14

Measures of Performance

A Comparative Approach

- The usefulness of the presented simulation model is reflected in its close approximation to the real-world system.
- That is, a model whose salient variables function in a fashion similar to patterns apparent in the real-world is often useful.
- As such, a classic method to measure the quality of the performance of the simulation model is to compare its output values with actual available statistics.
- If the real-world system has been properly modeled, then the differences between the two systems measures of performance ought to be minimal.
- The measures of performance selected to quantify the performance of the modeled system includes:
  1. Total Number of Visits to ED (divided between insured and uninsured patients),
  2. Total Number of Visits to PCP (divided between insured and uninsured patients).

15

Results

Comparison of Simulated and Actual

Year -2006	Simulated	Actual	% deviation
Total Number of Visits to ED	*217,642,000*	*221,399,000*	*-1.73%*
Number of Visits to ER -Insured patients	186,065,320	190,234,550	-2.24%
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Total Number of Visits to PCP	*904,368,000*	*901,954,000*	*0.27%*
Number of Visits to PCP -Insured patients	863,874,700	862,268,024	0.19%
Number of Visits to PCP -Uninsured patients	40,492,735	39,685,976	1.99%

Note: It can be observed that the simulated and actual values closely match. This demonstrates that the level to which this model is calibrated to the actual system and also provides initial validation for the overall construction of the model.

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Summary

Key Points

- System Dynamics is a simulation approach that can be used to capture a holistic perspective of the ambulatory care system.
- The model considers both the supply and demand sides of the system.
- The model considers specific factors that influence individuals' decisions in selecting ambulatory care venues.
- Venues are categorized as either EDs for hospital-based care centers or PCPs for office-based primary care physicians.
- ED access and PCP capacity are selected as major drivers that conditioned the venue selection.
- Tendency to defer treatment, insurance status, and patient acuity level also are critical aspects that influence the performance of the model.
- Other components of the model, namely capacity and revenues submodels, were not fully analyzed in this paper.

Future Applications

Four Potential Applications

1. Investigating the mix of intervention techniques that divert targeted patients to alternative venues,
2. The capacity and financial consequences of expanding or downsizing different venues,
3. The effects of delaying treatment, 4) providing ambulatory care to certain segment of the population, and
4. The consequences of congestion on demand and supply factors.

Conclusion

Three Takeaways

1. The simulation model demonstrates a handling of the complexities associated with an ambulatory care system.
2. Managerial and policy-making decision environments require effective tools to support the decision process.
3. Simulation-based decision support systems that embrace these technologies can assertively center on efforts and resource allocation that produce demonstrable sustainable solutions.