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EVALUATION OF INTERVENTIONS FOR PSYCHIATRIC CARE: A SIMULATION STUDY OF THE EFFECT ON EMERGENCY DEPARTMENTS

Thomas Roh

HDR, Inc.
8404 Indian Hills Drive
Omaha, NE 68114, USA

Valerie Quinones-Avila

University of Puerto Rico
1187 Calle Flamboyan
San Juan, PR 00926, USA

Ronna L. Campbell
Gabrielle Melin
Kalyan S. Pasupathy

Mayo Clinic
200 First St SW
Rochester, MN 55902, USA

ABSTRACT

Hospital-wide strategies for reducing mental health (MH) boarding in the emergency departments (ED) have focused on improving the onsite patient flow and resource management. A gap in literature is still residing on the lack of consideration for the MH transition process from the ED into external community and hospital inpatient psychiatric settings, as well as the external bed capacity limitations. Discrete event simulation was used to understand the mental health patient flow within the ED and to inpatient settings. It provided a forecast of system changes when three scenarios were tested to determine the percentage increase in beds necessary to reduce MH ED boarding time. These alternative approaches illustrate the applicability of the model as a decision support tool for evaluating solutions to MH ED boarding.

1 INTRODUCTION

With the deinstitutionalization of psychiatric care and reduction of state psychiatric hospitals, the number of beds available for the treatment of acutely or severely mentally ill patients in the United States (US) has had a staggering decline for the past half century (Trorrey et al. 2012). As much as 95 percent of the nation's public psychiatric hospital beds have disappeared (Trorrey et al. 2012). In individual states, as much as 56 percent of the state hospital beds have been closed during the five-year period from 2005-2010 (Trorrey et al. 2012). The idea behind the deinstitutionalization was driven in part by safely treating patients with medications in community facilities without having to consume hospital resources, provided that such treatment facilities existed. However, the current capacity of the community-based system is inadequate, since the community psychiatric care is being provided for fewer than half of the patients who need it.

Due to the absence of the needed treatment options, a growing number of patients with acute or chronically ill mental health crisis is overwhelmingly turning to hospital emergency departments (EDs) seeking care. This translates to an estimated 3.5 percent of all ED visits in the US being comprised of mental disorder patients (National Hospital Ambulatory Medical Care Survey 2010). In other studies, the proportion of mental health visits to all ED visits in the US has been reported as high as 6-9 percent (Hazlett et al. 2008; Larkin et al. 2005; Owens et al. 2007; Zeller et al. 2013). However, due to lack of

adequate and coordinated community services, inefficient administrative processes, and limited available supply of ED onsite (Zeller et al. 2013) and outside mental health beds, among other system causes, individuals presenting at the ED with mental health needs will often find themselves being held in the ED and the EDs find themselves being crowded with psychiatric patients.

Long after the decision to admit or transfer has been made, mentally ill patients often have no alternative but to endure long holding periods in the ED without the appropriate psychiatric treatment because the corresponding inpatient or community-based facilities are not available. This represents a phenomenon called "ED boarding", which is defined by the Joint Commission as " the practice of holding patients in the ED or another temporary location after the decision to admit or transfer has been made. Historical data suggests that mentally ill patients in the US can wait for several hours to as much as days for a psychiatric bed to open so that they can be admitted (Zeller et al. 2013). The prolonged times for finding a placement to actually transferring these patients to inpatient psychiatric beds are, thus, triggering increased ED length of stays. For instance, according to the National Hospital Ambulatory Medical Care Survey Emergency Department databases, due to the longer durations of mental health visits ending in transfer and visits of serious mental illness or substance use disorders, the average ED length of stay for mental health patients has been 42 percent higher (p-value <0.001) than that of non-mental health patients from 2001-2006 (Slade et al. 2010).

While inpatient boarding has been considered the primary cause of ED crowding (Beck et al. 2009; Moskop et al. 2009) the greater concern is the delay in treatment. When the number of patients exceeds the ED treatment space capacity, this creates backups that reverberate throughout the healthcare service system as a whole and prevents the patient from receiving the appropriate level of care at the right time and in the right place (Stone et al. 2012). It is important to find ways to reduce mental health ED boarding times because the arrival of mentally ill patients to hospital EDs throughout the US has been on the rise for more than a decade. As the EDs are unable to cope with the increased demands and limited psychiatric capacity, boarding will continue to get worse in the EDs, and, as such, so will quality of care, and, ultimately, health outcomes for these patients.

Studies relating to mental health boarding in the EDs have sought to determine average time for psychiatric evaluations to be completed in the ED (from the time referral was placed to completed evaluation) (Stone et al. 2012); average boarding time in the ED (from time of decision to admit until actual placement into inpatient psychiatric bed or transfer to an appropriate level of care) (Stone et al. 2012; Zeller et al. 2013); total average time spent in the ED (from time of arrival to actual discharge); factors associated with extended ED stays for this population (Zeller et al. 2013); and the negative effects of ED crowding (Bair, Song et al. 2010). Additional studies have measured the impact of implementing regional dedicated psychiatric emergency services on boarding times and hospitalization rates for psychiatric patients in the ED (Zeller et al. 2013).

Discrete event simulation has also been used to model patient flows within the EDs and for evaluating alternatives mainly directed towards reducing average patient ED LOS, ED boarding time, improving throughput, increasing resource utilization rate and controlling costs (Gul and Fuat Guneri 2012; Marshall et al. 2015a; Marshall et al. 2015b; Marshall et al. 2016). By developing a model of the operations of an ED, recent studies have focused on determining optimal resource allocation, such as patient demands, number of available staff, number of available beds or treatment areas and equipment; improving process changes, such as varying triage procedures, introduction of fast-track areas within EDs, rearrangements of existing process orders, and alternative staff scheduling at different arrival rates to reach these objectives (Gul and Fuat Guneri 2012). However, a gap in literature is still residing on the lack of consideration for external bed capacity limitations, specifically for mental health patients. Improving internal ED operations and patient flow can only go so far if there is no place where the patient can be sent for complete treatment. A question still remains whether adding additional bed capacity outside the ED could contribute to reducing ED boarding time for mental health patients.

The primary goal of this study was to model and simulate patient flow through the ED and study the effect on ED boarding time and inpatient throughput. Specifically,

1) What is the effect of increasing number of mental health patients on boarding time in the ED?
2) What is the effect of reducing ED to inpatient admissions of mental health patients on boarding time?
3) What is the effect of reducing the length of stay in the inpatient units on patient throughput?

2 METHODS

2.1 Study Design and Setting

The discrete event simulation models the mental health patient flow from the arrival to the Saint Mary's Hospital Emergency Department (SMH ED) to the discharge into inpatient psychiatric facilities. The SMH ED is part of the Mayo Clinic Rochester (MCR) campus in Minnesota. The ED receives some 79,000 cases per year and is open 24 hours a day. The ED staff is available at all times and includes doctors specializing in emergency medicine, internal medicine, surgery, and pediatrics; as well as social workers and on-call psychiatry consultant. As base case for this study, a total of 3 beds are designated for MH patients in the emergency room and one of the 9-bed observation unit can be repurposed for an extra MH patient when the ED is at overcapacity.

The inpatient psychiatric facilities considered in the model can be categorized as Mayo and non-Mayo sources. The MCR has a Psychiatry and Psychology Treatment Center that is located in the Generose Building on the campus of the Saint Mary's Hospital. A wide range of inpatient psychiatric services are provided to adults, adolescents and children in this modern facility. Generose manages four psychiatric units: a 16-bed Child, Adolescent, and Family Psychiatry unit (CAFP), a 25-bed Adult Psychiatric Acute Care Unit (PACP), a 14-bed Geriatric and Medical Psychiatry Unit (G/MPP) (7 Geriatric, 7 Older Adult and Medical Psychiatry), and a 16-bed Mood Disorders Unit (MDU). Generose receives admission request from inter-hospital transfers (SMH ED or MCR campus), internal unit transfers, and non-Mayo M.D. referrals or patient's self-referrals. The non-Mayo inpatient psychiatry facilities that were considered for the model were comprised of community behavioral health hospitals, Austin MCHS, Miller-Dwan Duluth, Hutchinson, Abbott Northwestern, U of M, New Ulm, and St. Joseph's Hospital.

2.2 Patient Cohort

Almost one year's worth of patient timestamp data was used as the base case. This included a total of 63,379 visits to the ED, of which 3,452 (5.44%) were considered mental-health related and 59,927 (94.55%) were non-mental health. A MH visit was operationalized as a visit pertaining to an individual whose first encounter with the Mayo Clinic was through the SMH ED and had a primary diagnosis of a mental health disorder (ICD-9 codes 291-319). A Non-MH visit was considered as a visit pertaining to an individual whose first encounter with the Mayo Clinic was also through the SMH ED, but did not have a primary diagnosis of a mental health disorder. The mean age of the study population was 45 years $\pm$ 25 years. The mean age for MH patients was 37 $\pm$ 19 years and for non-MH patients was 46 $\pm$ 25. The majority of the MH visits were comprised of high and moderate-acuity patients, according to the Emergency Severity Index (ESI) (Level 2: 49.8% and Level 3: 46.1%); compared to the non-MH visits, which mostly pertained to moderate-acuity patients (Level 3: 62%).

2.3 Data

The data consisted of the following timestamps: ED Arrival, ED Bed Placement, ED Departure, ED Disposition, Inpatient Bed Placement, and Inpatient Departure. Other patient characteristics that were

included were Age, Primary ICD-9 Diagnosis, and Disposition (Discharged, Admitted to an inpatient unit, or Transferred to another facility). Mental Health patients were identified as those with mental disorder Primary ICD-9 Diagnosis codes (290-319). Based on these timestamp data, disposition to discharge was computed as the 'boarding time'. The timestamp data was used to derive the arrival inputs for the simulation model. Non-MH patients were included in the model to use as a comparison to MH patients and also to include the effects of the shared bed resources. Since non-MH patients are not of primary interest and to simplify modeling and save time, non-MH patients' timestamps are fed directly into the model. Mental health patients' arrival rates to the Emergency Department were implemented with poisson distributions based on the ED arrival timestamps and the seasonal trends derived from them (Day of Week & Hour of Day Effect). Mental health patients' arrivals to the Psychiatric inpatient units that did not include an ED visit are discussed in the Validation section.

2.4 Patient Flow

The emergency care process starts with patients arriving to the SMH ED. Patients are then triaged by the medical staff for initial assessments, and evaluation is prioritized by urgency and by time of arrival. After the triage, the medical staff gathers the patients' demographic information and assigns the patient a medical record number. The ED Psychiatry Consultant later decides whether or not to diagnose the patient with a MH related primary diagnosis according to the ICD-9 codes. As soon as a bed becomes available, the MH patient is taken inside the ED and placed in a bed for stabilization and further intermediary assessments.

Next, the psychiatry consultant decides whether the patient is to be discharged from the ED (sent home) or admitted to an inpatient bed. MH patients can be admitted to Generose, the inpatient hospital. If there are no psychiatric beds available at Generose, MH patients can be discharged to either their home (if applicable) or to a non-Mayo inpatient psychiatric facility. If there are no available beds at Generose nor outside sources, sometimes the MH patients are sent to a unit in the Joseph (JO 2B) building at Saint Mary's Hospital, as a holding area until a bed becomes available. In contrast, non-MH patients can be admitted to a Mayo inpatient bed or discharged to their homes. Both MH and non-MH patients have to wait in the ED until the corresponding bed becomes available. The flow is shown in Figure 1.

The ED was modeled as a discrete-event system, from the time of decision to disposition was made by the physician to the actual transfer of the MH patient out of the ED. The term "decision to disposition" refers to the decision point to either admit the MH patient into Generose or discharge the patient to either a Non-Mayo inpatient psychiatric facility or home.

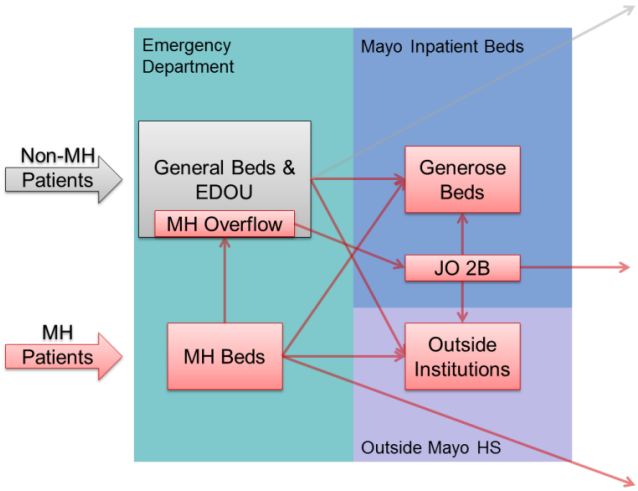

Figure 1. Simplified Patient Flow - EDOU: Emergency Department Observation Unit; Generose: Inpatient psychiatry unit; JO 2B: Joseph 2B (Additional inpatient psychiatry beds).

3 SIMULATION MODEL

The model consists of six distinct queues: Non-Mental Health, Mental Health, and the four inpatient unit queues. If a bed resource is available, the patient leaves the queue and seizes a bed. The patient will hold that bed until their service time has been completed. The service time was calculated using the past data and specific to the patient care area. ED non-mental health patients and ED Mental Health patients with a disposition of discharge exit the simulation at the end of their service time and release their seized bed. ED Mental health patients that need to be admitted enter one of the inpatient units' queues based on past assignments. The seized bed in the ED is not released until the patient can actually be placed in an inpatient unit bed. Mental Health patients that did not come through the Emergency Department are also coming into the inpatient unit queues and seeking a bed. Preference is given to ED patients. Once the admitted Mental Health patient seizes a bed and completes their time of care, they exit the system and release the resource. Figure 2 shows the patient pathways below.

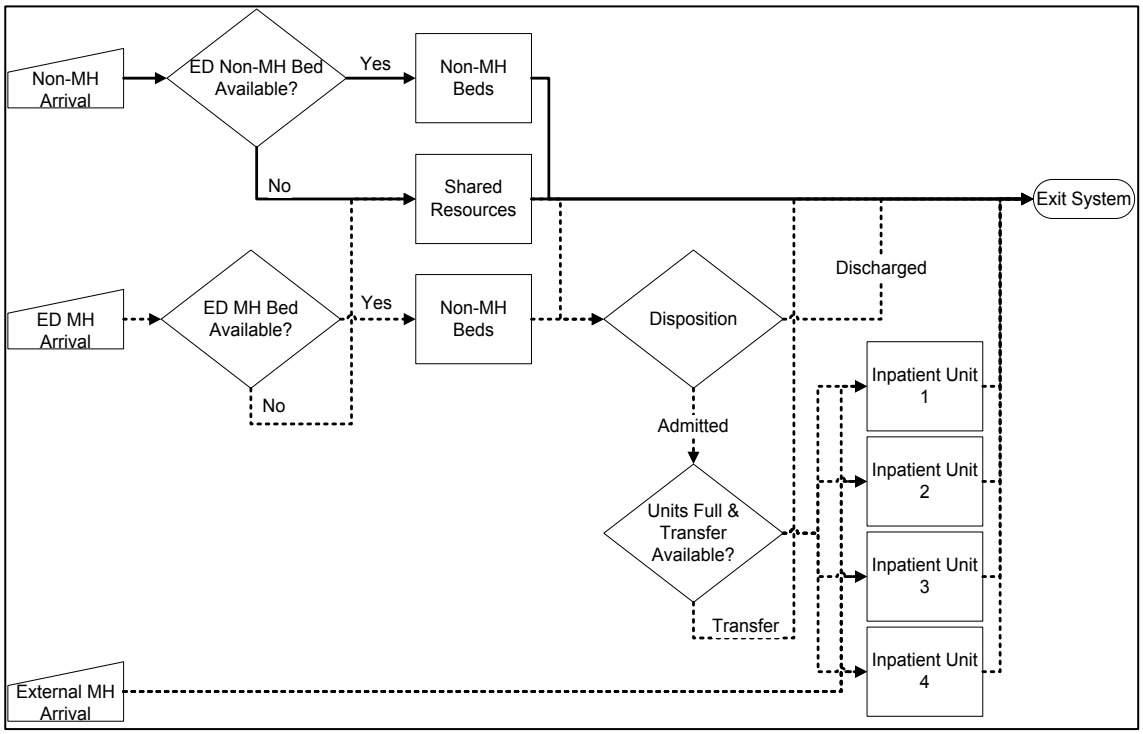

Figure 2: Patient Flow through the Mental Health Hospital System.

To model real life decompression of the system, two abandonment methods were used. Mental Health Patients in the Emergency Department that are waiting for a bed in one of the inpatient units have a chance of being transferred to another facility. The probability of that occurring was based on the total number of transferred patients from the data, and departure times were also adjusted to reflect seasonal trends. The second method allows Mental Health patients to stay in the Emergency Department for up to 8 hours. After which, it is assumed that these patients are "boarding" in the ED. The patients are assigned a length of stay that they would normally have in the inpatient units had they immediately been placed there. If the patient's assigned service time is exceeded by their "boarding" time, they release the Emergency Department resource, leave the inpatient unit queue, and exit the simulation. The service times for Non-MH patients are based on the actual timestamps. The patient arrives into the system at the exact historical time and is then delayed for service until the exact historical discharge time. The MH patient ED and inpatient unit service times were fitted with empirical distributions. All of the service time

distributions had notably long tails and theoretical distributions did not fit. The simulation model was setup and run using Arena simulation software.

3.1 Validation

All parameters were verified in the model to ensure that the simulation was performing what it was programmed to do. As previously mentioned the data points that were missing from the model were the external demand for the inpatient units. Since both the utilization rates and the length of stay in each inpatient unit was known, it was possible to derive the external demand. The external demand arrival parameters were tuned until the actual utilization rates fell within the simulated 95% confidence intervals. Table 1 shows the results of tuning the simulation. The estimated weekly external demand was approximately 29 patients per week.

Table 1: Actual vs. simulated utilization rates in the inpatient units with 95% CI.

Psychiatric Unit	Weekly Arrival Rate	Actual Utilization	Estimated Utilization	LCL	UCL
Pediatric	5.7	.88	.8757	.856	.896
Adult Acute	9.5	.96	.9538	.944	.964
Geriatric/Medical	6.2	.83	.8165	.797	.837
Mood Disorders	7.5	.9	.9011	.881	.921

The simulation run length was 11 months with 28 days as the warm-up period and 10 replications were run. The simulation output was compared against the actual data. To accurately model discharges from the psychiatric inpatient wards, the care schedule model had to be properly addressed. Psychiatric inpatient ward currently do not staff for patient care on the weekends. There is staff there to observe but not provide care. Therefore, patients were much less likely to be discharged on the weekend as reflected in the data with only a 15% chance of being discharged during Saturday and Sunday. To adjust for this aspect, the simulated patients with expected Saturday discharges were moved to Friday. This assumes practitioners will try to early discharge those they think that have a short time left. The simulated patients with Sunday discharges were moved to Monday. The assumption is that the practitioner would just hold the patient over the weekend and discharge them when they return to work. Fifteen percent of these expected weekend charges were discharged on the weekend. The last validation test was a comparison of the simulated mental health patients that went through the ED and the total psychiatric ward inpatients. Table 1 shows the results.

Table 2: Comparison of actual vs. simulated mental health inpatient throughput.

Output	ED-Psych Throughput	Total Psychiatric Ward Throughput
Actual	1417	2617
Simulated Mean	1529	2786
Simulated LCL	1355	1425
Simulated UCL	2621	2591

The actual throughput numbers fall within the 95% confidence intervals of the simulated so we can assume that the simulation's throughput numbers are valid. The model assumptions were validated with the practitioners that worked within the system.

4 RESULTS

Data for patient arrivals was segregated by hour of the day, then by day of the week. While non-MH patient arrivals showed similar patterns across days of the week, MH patient arrivals showed lot more variability across the days of the week. The mean arrival rate of MH patients was 10.3 visits/day when compared to 179.4 visits/day for non-MH patients. MH patients have lower arrival rates over the weekend than non-MH patients. The arrival distribution for MH patients also seems to be more variable when compared to non-MH patients.

Next the number of MH patients in the system was analyzed. An estimated 25% of the time there were more than 3 MH patients in the ED. The number of MH patients in the ED could increase up to 12 patients. In other words, while the SMH ED had a 3-bed capacity for MH patients, it was being crowded with MH patients for 25% of the time. As such, the average ED LOS for MH patients was significantly longer than that of non-MH patients, where mean ED LOS for MH patients (6.12hr-95% CI:5.83, 6.42) was nearly double than that of non-MH patients (3.51hr-95% CI:3.49, 3.52).

Transfers from the ED were categorized as "admitted" or "discharge" for each MH and non-MH patients. MH admissions refer to those patients that were transferred from the ED and admitted to a Generose ward. Non-MH admissions refer to non-MH patients that were transferred from the ED and admitted somewhere else within the Mayo Clinic facilities. MH discharges refer to the MH patients that were transferred from the ED to either their home or a Non-Mayo psychiatric bed. Non-MH discharges refer to non-MH patients that were transferred from the ED into either their home or somewhere outside the Mayo Clinic. The highest mean ED LOS pertained to MH admitted patients (6.13hrs-95%CI:5.76, 6.51), followed by that of MH discharged patients (6.12hrs – 95% CI:5.68-6.55). The lowest ED LOS pertained to non-MH discharged patients (3.51hr-95% CI:3.33-3.37), followed by that of non-MH admitted patients (4.15hr-95% CI:4.11-4.18). MH patients boarding in the ED also had significantly greater mean boarding times. MH patients' average boarding time (66.21min-95% CI:58.26-74.14) was double than that of non-MH patients (30.97min-95% CI:30.55,31.38). MH admitted patients had the largest mean boarding time (78.71min-95% CI:68.55-88.93) while Non-MH discharged patients had the lowest mean boarding time (21.75min-95% CI:21.32-22.17). For ED LOS, 95% CIs overlapped for MH admitted and MH discharged patients. For ED boarding times, 95% CIs overlapped tor MH admitted, MH discharged and Non-MH Admitted patients. Though we cannot conclude significant differences among these groups for these values, these groups were still considered for further analyses because they have different processes when transferred from the ED. Finally, there was a greater proportion of MH patients boarding more than 4 hours. 4% of MH admitted patients spent more than 4 hours boarding in the ED, and, similarly, this proportion represented a 4.5% for MH discharged patients. In comparison, only 1% of each non-MH admitted and non-MH discharged patients spent more than 4 hours boarding in the ED.

4.1 Interventions

To reduce the mental health "boarding time" in the "ED", two interventions were considered based on current initiatives going on within the community. The first focused on possible ways to reduce the number of mental health patients that were arriving to the ED as well as the effect of the increasing mental health ED traffic. The second would reduce the number mental health ED to hospital admissions by sending those patients to intermediary care after the ED intake process and diagnosis. Sensitivity analysis was used to give a full picture of the interventions' effects on "boarding time". This was performed by changing the arrival rate as shown on the x-axis in Figure 3, and re-running the simulation multiple times. The behavior is shown in Figure 3. In figure 3, a 0% change in arrival rate provides 0% change in mean boarding time. The change in arrival rate is shown in increments (and decrements of 10% represented by each dot) with the corresponding effect on mean boarding time. A 30% increase in arrival rate leads to a 100% increase in mean boarding time. Similar work was performed with the ED inpatient admission reduction, which is shown in Figure 4. Again, a 0% ED inpatient admission reduction

corresponds to a 0% change in mean boarding time. With a reduction in the ED inpatient admission, the mean boarding time increases. A 50% reduction leads to a 100% increase in mean boarding time.

Another possibility to improve access for mental health patients is to decrease the inpatient length of stay (LOS). This would have two effects: a decrease in ED boarding time and an increase of psychiatric inpatient ward patient throughput. Inpatient throughput was chosen as the metric of interest since the focus of these experiments was on improving mental health patient care for all (internal and external demand). A sensitivity analysis was conducted by varying the inpatient LOS to provide a clear picture of varying levels of LOS reduction. The experiments stopped at 40% since little could be gained from increasing the reduction past 40. Figure 5 shows the results.

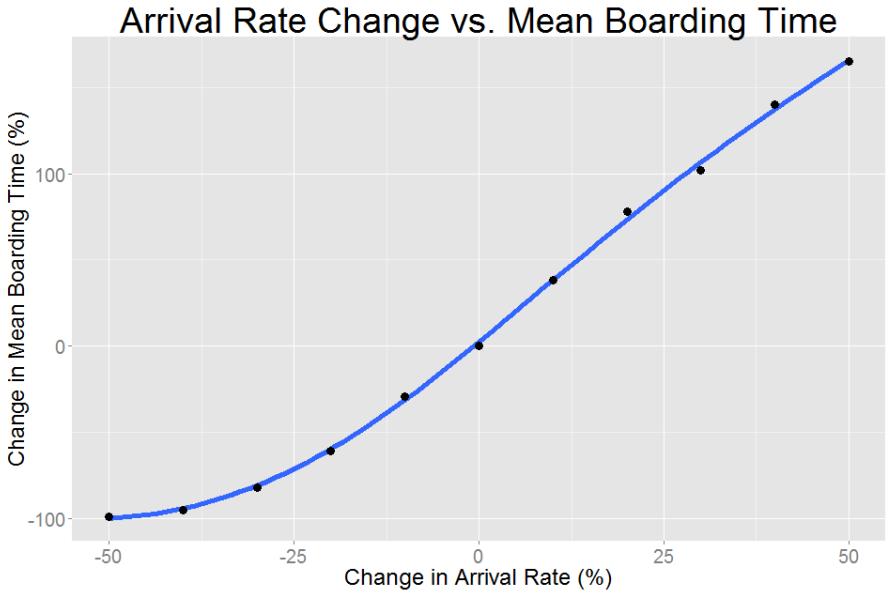

Figure 3. Arrival Rate Increase/Decrease Effects on Boarding Time.

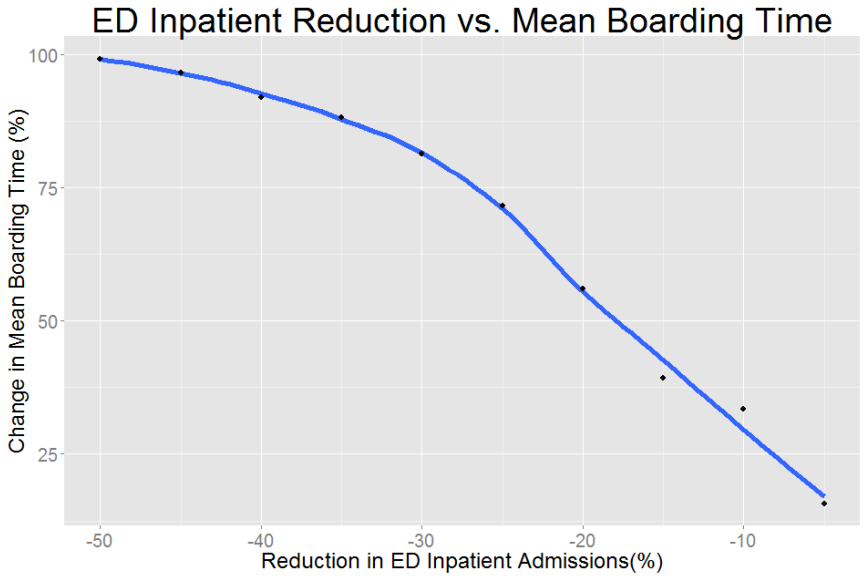

Figure 4. Admission Rate Reduction Effects on Boarding Time.

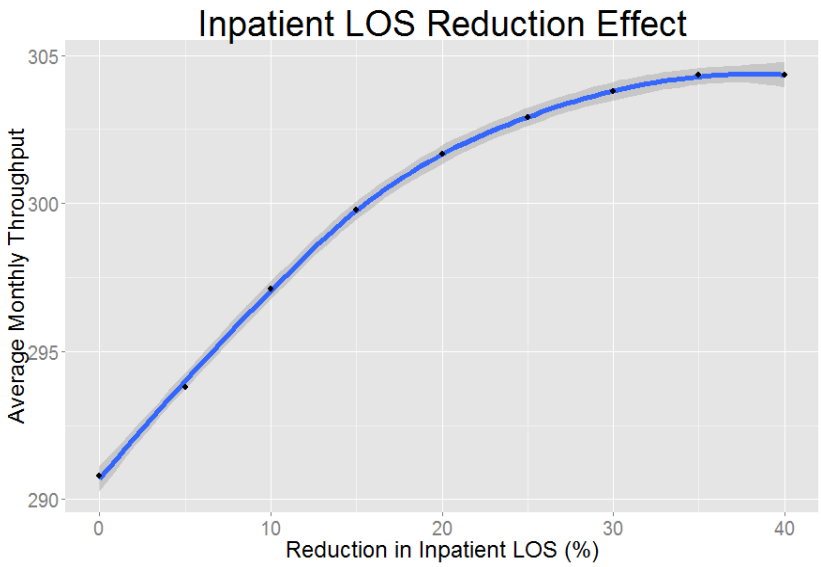

Figure 5. Effect of Inpatient LOS Reduction on Throughput.

5 DISCUSSION AND CONCLUSION

Mental health inpatient resources have significantly declined over the last few years in the United States. The state of Minnesota has followed that national trend which has resulted in long waiting times for inpatient treatment. This poses a threat to patient and community safety given the health risks associated with delayed treatment of mental health conditions (e.g. suicidal ideation, violent behavior). Inpatients units run at full capacity the majority of the time and have poor patient access. A side-effect of over-utilized inpatient units is that urgent care for mental health is pushed into the emergency department. Emergency departments are typically only suited for observation of mental health patients, not for treatment. In addition, it is also difficult to move these patients from the ED to the psychiatric units given the poor access. In turn, the "boarding" of mental health patients in the Emergency Department for several hours up to several days has become a problem.

The "boarded" patients cause stress on the resources in the Emergency Department and can affect the availability of these resources for other patients who need emergent care. Mental health patient care is suffering from a lack of available resources in the Mayo Clinic system. Given recent policies on mental health resourcing and poor financial incentives for treatment, it is unlikely that more resources will be allocated. Community programs such as mobile crisis units and more access to mental health outpatient care could help to decompress the Mayo ED and inpatient units. Internally, Mayo would receive the greatest benefit from reducing inpatient length of care in the psychiatric wards.

It is important to recognize that the mental health system at the Mayo Clinic in Rochester is one small part of a statewide problem. To truly understand the impact of the scarcity of Mental Health resources on the state, data from all institutions within the state would need to be gathered. With that data, it is possible to understand the flow of patients throughout the state and determine the number of resources needed. Different public policies could also be tested to see if it is possible to alleviate the load on the Minnesota health care system.

REFERENCES

Bair, A., W. Song, and Y. Chen. 2010. "The Impact of Inpatient Boarding on ED Efficiency: A Discrete-Event Simulation Study." *Journal of Medical Systems* 34(5):919-929.

Beck, E., H. Balasubramanian, and P. Henneman. 2009. "Resource Management and Process Change in a Simplified Model of the Emergency Department.".In *Proceedings of the 2009 Winter Simulation Conference (WSC)*, edited by M.D. Rossetti et al., 1887-1895. Piscataway, New Jersey: IEEE.

National Hospital Ambulatory Medical Care Survey. 2010. NHAMCS 2010 Emergency Department Summary Tables. www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2010_ed_web_tables.pdf, accessed August 12, 2018.

Gul, M. and A. Fuat Guneri. 2012. "A Computer Simulation Model to Reduce Patient Length of Stay and to Improve Resource Utilization Rate in an Emergency Department Service System". *International Journal of Industrial Engineering* 19(5):221-231.

Hazlett, S.B., M. L. McCarthy, M. S. Londner, and C. U. Onyike. 2008. "Epidemiology of Adult Psychiatric Visits to US Emergency Departments." *Acad Emerg Med* 11(2):193-195.

Larkin, G. L., C. A. Claassen, J. A. Emond, A. J. Pelletier, and C. A. Camargo. 2005. "Trends in U.S. Emergency Department Visits for Mental Health Conditions, 1992 to 2001". *Psychiatric Services* 56(6):671-677.

Marshall, D. A., L. Burgos-Liz, M. J. IJzerman, W. Crown, W. V. Padula, P. K. Wong, K. S. Pasupathy, M. K. Higashi, N. D. Osgood, and ISPOR Emerging Good Practices Task Force. 2015a. "Selecting a Dynamic Simulation Modeling Method for Health Care Delivery Research—Part 2: Report of the ISPOR Dynamic Simulation Modeling Emerging Good Practices Task Force." *Value in health* 18(2):147-160.

Marshall, D. A., L. Burgos-Liz, M. J. IJzerman, N. D. Osgood, W. V. Padula, M. K. Higashi, P. K. Wong, K. S. Pasupathy, and W. Crown. 2015b. "Applying Dynamic Simulation Modeling Methods in Health Care Delivery Research-The SIMULATE Checklist: Report of the ISPOR Simulation Modeling Emerging Good Practices Task Force." *Value in Health* 18(1):5-16.

Marshall, D. A., L. Burgos-Liz, K. S. Pasupathy, W. V. Padula, M. J. IJzerman, P. K. Wong, M. K. Higashi, J. Engbers, S. Wiebe, W. Crown, and N. D. Osgood. 2016. "Transforming Healthcare Delivery: Integrating Dynamic Simulation Modelling and Big Data in Health Economics and Outcomes Research." *Pharmacoeconomics* 34(2):115-126.

Moskop, J. C., D. P. Sklar, J. M. Geiderman, R. M. Schears, and K. J. Bookman. 2009. "Emergency Department Crowding, Part1 – Concept, Causes, and Moral Consequences, Part 2 – Barriers to Reform and Strategies to Overcome Them". *Annals of Emergency Medicine* 53:605-611 (part 1), 612-617 (part 2).

Overcoming Boarding Issues with Psychiatric ED Patients. 2013. Physician's Weekly. http://www.physiciansweekly.com/psychiatric-emergency-boarding/, accessed August 12, 2018.

Owens, P., R. Mutter, and C. Stocks. 2007. Statistical Brief #92: Mental Health and Substance Abuse-related Emergency Department Visits among Adults. Agency for Healthcare Research and Quality.

Slade, E. P., L. B. Dixon, and S. Semmel. 2010. "Trends in the Duration of Emergency Department Visits, 2001–2006." *Psychiatric Services* 61(9):878-84.

Stone, A., D. Rogers, S. Kruckenberg, and A. Lieser. 2012. "Impact of the Mental Healthcare Delivery System on California Emergency Departments." *Western Journal of Emergency Medicine* 31(1):51-56.

Trorrey, E. F., D. A. Fuller, J. Geller, and J. Carla. 2012. "No Room at the Inn: Trends and Consequences of Closing Public Psychiatric Hospitals". Research for Treatment Advocacy Center (July 19, 2012). http://www.treatmentadvocacycenter.org/storage/documents/no_room_at_the_inn-2012.pdf, accessed August 3, 2018.

Zeller, S., N. Calma, N., and A. Stone. 2013. "Effects of a Dedicated Regional Psychiatric Emergency Service on Boarding of Psychiatric Patients in Area Emergency Departments." *Western Journal of Emergency Medicine* 15(1):1-6.

AUTHOR BIOGRAPHIES

THOMAS ROH is a Data Scientist for the HDR Predictive Analytics team. He works to uncover hidden insights within data and quantify it to be used for informed decision making. Thomas led this modeling work while he was a senior health services analyst at Mayo Clinic's Kern Center for the Science of Health Care Delivery. His email address is thomas.roh@hdrinc.com.

VALERIE QUINONES-AVILA is in the Department of Health Services Administration at the University of Puerto Rico in San Juan. Valerie worked on this project while she was a summer intern at Mayo Clinic. Her email address is Valerie.quinones@upr.edu.

RONNA L. CAMPBELL is an Associate Professor of Emergency Medicine in the Mayo College of Medicine and a practicing physician in Mayo Clinic's emergency department. She served as the clinical lead for this work providing her expertise in psychiatric care in the emergency department. Her email address is campbell.ronna@mayo.edu.

GABRIELLE MELIN is an Assistant Professor of Psychiatry in the Mayo College of Medicine and a practicing psychiatrist. She provider her expertise in psychiatry for this work. She can be reaced at melin.gabrielle@mayo.edu.

KALYAN S. PASUPATHY is an Associate Professor of Health Systems Engineering in the Mayo College of Medicine and the scientific director of Mayo's Clinical Engineering Learning Laboratories. He leads the Information & Decision Engineering program within the Kern Center for the Science of Health Care Delivery and leads work in modeling and scientific study of mental health. His email is pasupathy.kalyan@mayo.edu.