Modeling Addiction: The Effects of Intervention Methods to Reduce the Opioid Epidemic

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Abstract: Drugs and alcohol have reached a new epidemic level affecting thousands of lives and families, not to mention the increasing cost to society reaching into the hundreds of billions of dollars. There are different types of programs available that provide recovery and assistance to individuals in order to reach a life of sobriety (inpatient, outpatient, Narcotics Anonymous, Alcoholics Anonymous, halfway houses, detoxification, medication, and self-recovery). However, the success rate of a rehabilitation center is difficult to quantify due to the inability to upkeep success reports, the diverse ways to measure performance, and the duty to safeguard patient information. The goal of this research was to quantify the success rate of drug intervention methods for opioid addiction. This research was narrowed down to opioid addiction due to its rising prevalence. A systems dynamic approach determined that of the factors altered, buprenorphine prescription rate, had the largest impact on individuals recovered from opioid addiction.

Keywords: Opioids, Systems Dynamics, Simulation, Socio-Technical Interventions

1. Introduction

In 2017, President Trump declared a national Public Health Emergency on the opioid crisis and directed "all executive agencies to use every appropriate emergency authority to fight the opioid crisis" ("It Didn't Happen Overnight': How The U.S. Opioid Crisis Got So Bad," 2018). Opioid usage is increasing and according to the 2018 Annual Surveillance Report of Drug-Related Risks and Outcomes by the CDC, 66.4% of drug overdose deaths involved opioids (CDC, 2018). A study projected that between 2015 and 2025 there will be a 147% increase in opioid overdose deaths (Chen et al., 2019). This crisis is not only affecting the lives of individuals but also the economy. In 2013, the economic burden to society was estimated to be $78.5 billion, which includes, healthcare, lost productivity, addiction treatment, and criminal justice involvement (Florence, Zhou, Luo, & Xu, 2016). These numbers confirm the need for action against the opioid crisis, but the question is how. The purpose of this study is to explore factors that can impact the number of individuals becoming addicted to opioids and the number of recovered addicts. This intervention model illustrates the impacts of increasing or decreasing certain prescriptions, funding, rehabilitation duration and rehabilitation cost.

1.1 Literature Review

There are a couple theories about the opioid crisis' origin. The first dates to the 1980s when physicians incorrectly believed that the possibility of becoming addicted to prescribed opioids was low. With this in mind, physicians began to prescribe opioids more freely. Another theory is the introduction of pain as the fifth vital sign. Vital signs are measures which doctors use to monitor a patient, such as heart rate, temperature, blood pressure. A final explanation to the crisis is the idea of patient satisfaction causing the physician to "over" prescribe pain medication (Salmond & Allread, 2019). This means that a patient's desire for pain medication may be easily achieved by the physician satisfaction attempt. Again, since doctors were not worried about potential addiction, prescriptions for opioids continued to increase. In fact, prescriptions in the United States

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increased from 76 million to 207 million from 1990 to 2013. Researchers attempt to combat the opioid crisis in several ways. The first is to find a way to reduce the supply of opioids and the second is to encourage clinicians to find a balance between patient's needs and potential abuse (Mercadante, 2019). These concepts address the idea of not accommodating to patient satisfaction.

Opioids are complicated to understand because drugs such as methadone and buprenorphine are typically used as a form of treatment for heroin addicts. However, buprenorphine is rarely associated with overdoses, but highly associated with arrests while methadone is number 8 on drug related overdose deaths (Piper, Shah, Simoyan, McCall, & Nichols, 2018). This causes a curiosity in the reasons as the why methadone is even prescribed. This concept of buprenorphine and methadone is addressed in Manchikanti's 3-tier plan.

Prescription opioid deaths increased by 18% from 2009-2016 (Manchikanti et al., 2018). This same research found that total opioids prescriptions declined from 251.8 million in 2013 to 196 million in 2017, (a 9% annual decrease). However, this decline in prescriptions is not accompanied with an expected decline in opioid abuse and death rates (Manchikanti et al., 2018). This study recommends the reframing of the prevention strategies. Currently, each state has a prescription drug monitoring program (PDMP). However, states have difficulties sharing information amongst each other and they are still underfunded (Manchikanti et al., 2018). One recommendation is to have a national PDMP. This would allow for one regulation amongst all 50 states, ensuring that all states are abiding by the same regulations. This study showed that state PDMP reduced the amount of opioids prescribed by 8% and overdose rate by 12% from 2006-2013 (Manchikanti et al., 2018). Manchikanti recommends a 3-tier approach to reduce opioid abuse. Tier 1 incorporates implementing a public education campaign on the use of opioids for both prescribing physicians and patients. Tier 2 suggest making nonopioids pain management techniques, such as physical therapy and interventional procedures, more accessible by eliminating or reducing copayments. Another suggestion is to make the access to buprenorphine, a less addictive treatment to pain, more accessible. France conducted a similar plan of action and increased the buprenorphine rate resulting opioid overdoses decreasing by 79% over 6 years. Tier 3 recommends making buprenorphine available as a pain management and medication assistant treatment by changing it from a Schedule III drug to a Schedule II (schedules refer to its abuse potential) and removing methadone (not allowing it to be prescribed), which is responsible for 3,000 deaths per year (Manchikanti et al., 2018).

Finally, according to the CDC, 0.8% of individuals seek help in varying locations, which include rehab, emergency rooms, self-help, and jail (CDC, 2018). In addition, 0.5% pursued assistance exclusive to inpatient and outpatient rehabilitation programs (CDC, 2018). According to the Addiction Center (2018), outpatient detox averages between 1-5 thousand dollars. Inpatient rehabs can vary drastically from $6,000 to $20,000 for more well-known rehabilitation centers lasting up to 30 days. Finally, for more intensive 60-90 day inpatient rehabilitation programs can be as much as $60,000 ("Understanding the Cost of Rehab," 2018).

The National Institute on Drug Abuse reported the state of Ohio had 32.90 opioid-related deaths per 100,000 people in 2016 (a total of 3,613 deaths). Ohio also had 85.8 opioid prescriptions per 100 persons in 2015 (NIH, 2018). For this research, Ohio is used as a baseline in order better evaluate the impact of rehabilitation programs and methods used to fight the opioid crisis.

2. Methodology

2.1 Population

There was no sample size for this specific research. The target audience for this research is individuals being prescribed opioids, addicts, and doctors. The state of Ohio was used to create a baseline for statistics such as population, population growth, death rate, and overdose rates. These numbers were used to create a synthetic population for evaluation. There was no differentiating between demographics, therefore all ages, races, ethnicities, and genders are utilized.

2.2 Instrumentation

Several studies and articles were reviewed to determine current statistics and findings regarding the opioid crisis and drug rehabilitation programs. A systems dynamic model was created in VENSIM© to represent the flow of individuals throughout the addiction process. Factors were incorporated to determine a potential method to reducing the number of individuals addicted to opioids.

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2.3 Variables

Table 1 represents the factors and the initial values that were used in the VENSIM model for evaluation. All the factors except for those altered in the design of experiments (DOE) remained constant.

Table 1. Factors and initial values for the simulation

Factor	Initial Value	Source
Standard Drug Attempt Rate	4.4%	("2018 Annual Surveillance Report of Drug-Related Risks and Outcomes — United States,"2018)
Buprenorphine Prescription Rate	Min: 11% Max: 58%	(Alderks, 2017)
Standard Death Rate	849.3 /100,000 population	("Deaths and Mortality," 2017)
Overdose/ User Death Rate	39.2 people/100,000 (Ohio)	("Ohio Opioid Summary," 2019)
Relapse Rate	40-60%	("Statistics on Drug Addiction," 2019)
Self-Recovery Rate	.2%	(Jackson)
User to Rehab Rate	.5%	("2018 Annual Surveillance Report of Drug-Related Risks and Outcomes — United States,"2018)
Rehab to Recovered Rate	1-Relapse Rate	
Rehab Cost	Min: $6,000 Max: $60,000	("Understanding the Cost of Rehab," 2018)
Funded Amount	Assumed about $4M	("Drug & Alcohol Rehab in Ohio," 2018)
Length in Rehab	30 days	
Non-User to User Rate	4.4%	("2018 Annual Surveillance Report of Drug-Related Risks and Outcomes — United States,"2018)

2.4 Procedure

We began the simulation with a pilot study to determine a baseline for the simulation. This baseline model required research and literature review of opioids, drug rehabilitation centers, addiction costs to society, and death rate to decide on initial values inputted into the model. After the literature review was completed, an initial systems dynamic model was created in VENSIM© to establish the flow of people regarding the opioid addiction. The system dynamic model is represented in Figure 1.

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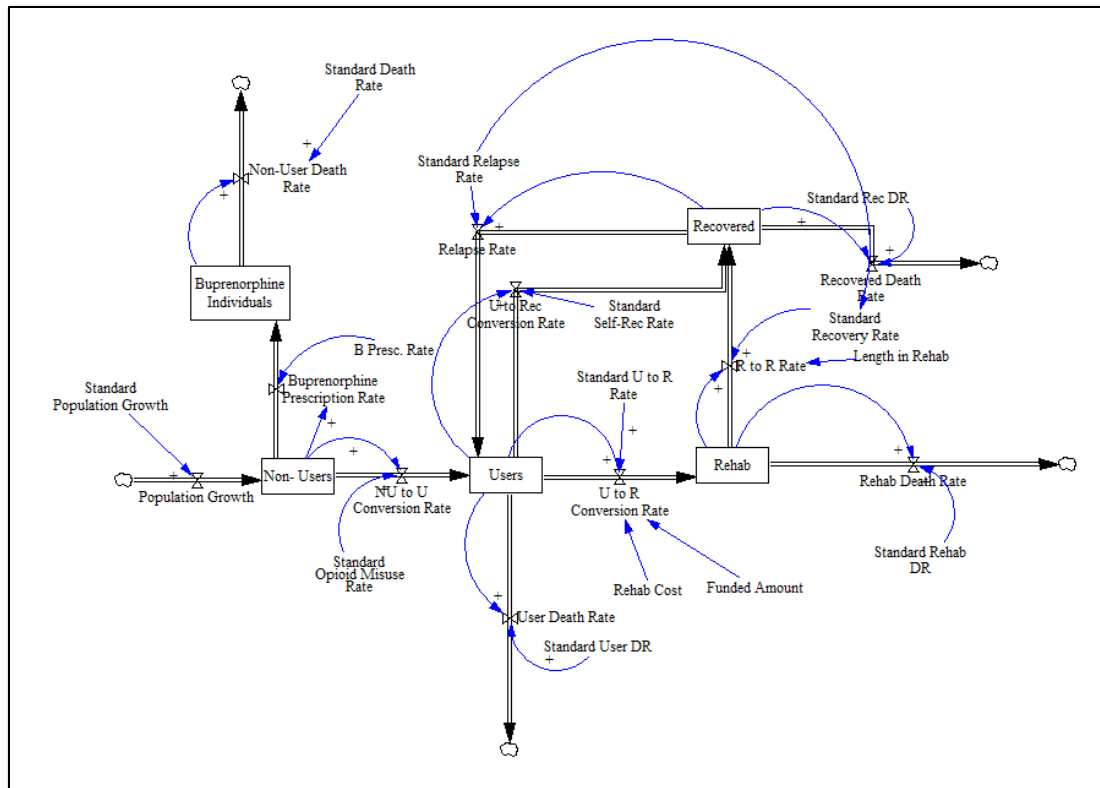2020 SISE Virtual Conference
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Figure 1. System Dynamics Model of Opioid Addiction

To validate the model, all variables were moved to their high and low extreme values to ensure the model behaved the way it was expected to. Once this occurred, the model was validated. After the model was created and validated, initial values and constants were established and a design of experiments (DOE) was conducted using a full-factorial design. Four factors were altered: buprenorphine prescription rate, rehab cost, funded amount, and length in rehab. The run order was randomized in order to reduce user variability. Next each trial was ran in order to evaluate which factors had the greatest impact on individuals recovered. Finally, the results were analyzed, and recommendations were made. With regards to the model simulation, four factors were changed: buprenorphine prescription rate, rehab cost, funded amount, and length in rehab. A high and a low was established for each factor based off the literature review. The high and lows for each factor are in Table 2. This chart clarifies the two options for each independent variable which changed based upon the trial number. The DOE was conducted with 16 trials to evaluate how changing the four factors would impact the synthetic population. The results can be seen in Table 3. At 12 months, the number of individuals recovered was between 26,000 and 70,000. At 24 months, 207,000 and 680,000 and finally at 36 months the recovered population ranged from about 100,000 to 361,000 individuals.

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Table 2. Independent factors

Factor	Low (-)	High (+)
A – Buprenorphine Prescription Rate	11%	60%
B – Rehabilitation Cost	$6,000	$60,000
C – Funded Amount	$2 M	$10 M
D – Length in Rehab	1 month	3 months

Table 3. DOE Results

StdOrder	RunOrder	Buprenorphine Rate	Rehab Cost	Funded Amount	Length in Rehab		12 months	24 months	36 months
2	1	60%	$6,000	$2 M	1 month		27284.8	64693.8	101955
3	2	11%	$60,000	$2 M	1 month		65668.4	206446	360056
8	3	60%	$60,000	$10 M	1 month		26971.2	64374.4	101636
1	4	11%	$6,000	$2 M	1 month		66233.2	207020	360631
4	5	60%	$60,000	$2 M	1 month		26720	64119	101381
10	6	60%	$6,000	$2 M	3 month		27257.5	64686.5	101948
5	7	11%	$6,000	$10 M	1 month		68731.9	209575	363184
16	8	60%	$60,000	$10 M	3 month		26957.9	64370.8	101633
12	9	60%	$60,000	$2 M	3 month		26717.4	64118.3	101380
15	10	11%	$60,000	$10 M	3 month		65906.3	206698	360308
7	11	11%	$60,000	$10 M	1 month		65919.6	206701	360312
6	12	60%	$6,000	$10 M	1 month		29781.6	67248.5	104508
11	13	11%	$60,000	$2 M	3 month		65665.8	206445	360056
9	14	11%	$6,000	$2 M	3 month		66206.1	207013	360624
13	15	11%	$6,000	$10 M	3 month		68583.7	209539	363150
14	16	60%	$6,000	$10 M	3 month		29631.6	67211.9	104474

3. Discussion

On table 3, it is noticeable that buprenorphine prescription rate had the most impact on the recovered population. When buprenorphine prescription rate was at its low level (11%), the number of recovered individuals was in the upper 60,000s (at 12 months) and when the prescription rate was at its high level (60%) the number of recovered individuals was in the upper 20,000s (at 12 months). This same trend followed for both the 24 and 36 months recovered populations as well.

While it may appear that a higher buprenorphine prescription rate lowers the individuals recovered, this occurred because there is an inverse relationship between the buprenorphine prescription rate and the number of individuals recovered from opioid addiction. Since buprenorphine has low addiction qualities, the portion of the population being prescribed this drug is not even entering the user category because they are not becoming addicted to opioids in the first place. Therefore, a higher buprenorphine rate is reducing the number of individuals needing drug rehabilitation thus making total number of recovered appear less.

4. Conclusions and Recommendations

Overall, the rate at which buprenorphine is prescribed has a drastic impact on the recovered population. The other factors: rehabilitation cost, funding amounts, and length in rehab did not appear to have a significant impact. By physicians prescribing this drug more compared to methadone, the number of individuals who become addicted to prescription opioids in the first place decreases thus decreasing the overall recovered population. This is a positive finding because that means less people are needing to attend drug rehabilitation. Also, by increasing the prescription rate of buprenorphine and decreasing other medications such as methadone, overdose deaths will decrease, as seen with France's study.

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For future studies, it is recommended to gain permission to view patient statistics of rehabilitation centers. This would allow for factors, such as relapse rate, cost, funding, etc. to be more accurate and specific. It would also potentially provide the differences between rehabs and why one may have a better success rate than others. Another recommendation for this study is to expand it beyond the prescription opioid crisis and evaluate within the fentanyl and heroine epidemic as well as other addictive substances.

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