PREVIEW PAPER: ABOVE AVERAGE

The quality of this paper differs from most papers, but it has some common traits shared by a large number of entries. First, the summary is relatively good. It has an overview of the problem and offers some insight into the questions. The team offers a good overview of their approach which is not common. Like many papers they do not offer many specific results for all of the questions, but this summary does include specific results for the third question.

With respect to the first question the paper includes a model that is problematic. The percentage of people vaping is approximated using a logarithmic function. The problems associated with the model are explicitly acknowledged, but the explanation justifying the choice is not convincing.

For the second question the paper includes a number of different factors. The details associated with the different factors is not as clearly laid out as they could be, and the sources for the summary statistics are not clearly defined. To predict what will happen to a class of 300 students the averages are multiplied by 300 rather than making use of specific demographics associated with a high school population.

For the third question the paper provides a simple estimate of the costs to society of the different drugs. The paper includes few details, and the response to the third question is incomplete. The approach to the third question is in terms of consistent units, though, and the use of monetary impacts was considered a better way to address this question than what was seen in many other papers.

MathWorks Math Modeling (M3) Challenge

One is too many and a thousand not enough: *Substance Use and Abuse*

1 Executive Summary

Drugs have been used for millennia, but the issue of drug use has become problematic in the past century and particularly in the past several decades. While nicotine was once believed to have fallen out of favor among the newest generations of Americans, it has seen its resurgence among adolescents and young adults in the form of e-cigarettes, as a product once intended to serve as a less deadly form of smoking has been marketed to hook a new generation of users. Given this new trend, the first part of this paper’s body sought to analyze the use of nicotine through vaping, project its growth over the next 10 years, and compare its growth to that of cigarettes.

The use of e-cigarettes is most prevalent among those under the age of 18 (E-Cigarettes: Facts, Stats and Regulations). For this reason, as we were investigating the rise in use of e-cigarettes, we decided to focus on the use of middle and high school students. Information from 2011 to 2017 was available for this population through the National Youth Tobacco Survey, providing insights into the rate of growth of the use of e-cigarettes and regular combustible cigarettes. To model the percentage of middle and high school students who use e-cigarettes, we settled on a logarithmic model to demonstrate a growth rate that would decrease over time. This showed that the rate of growth of e-cigarette contrasted the overall decrease in the use of traditional cigarettes.

Drug use - and the associated consequences - do not target all communities in America equally, as some communities are hit harder by drug use than others, and people of certain demographic and socioeconomic groups face an elevated risk of falling into drug abuse. The second part of this paper’s body intends to determine what factors affect the likelihood of a person of certain demographics using or abusing nicotine, alcohol, marijuana, or non-prescription opioids. Furthermore, the second part of this paper’s body takes a characteristically diverse 300 student senior high school class and calculates the predicted amount of students using each drug. This data is achieved by assuming the high school is equal in characteristic distribution to the 17-18 year old population of the United States and using the overall probability that any student of this age is dependent on or abusive towards any of the four studied drugs.

Drug use harms both the willing (or addicted) users and the unwilling society-at-large (through negative externalities). Both financial impacts - such as lost productivity - and non-financial impacts - such as lost utility for the friends and family of victims - arise when drugs are used or abused. The third part of this paper’s body seeks to quantify the effects of drug usage and determine which drugs harm our society the most. We concluded that based off the the annual number of deaths associated with each drug and the societal cost of human life, the substances ranked from greatest to least impact is: nicotine, alcohol, opioids, and marijuana. By multiplying the average annual number of deaths associated with each drug and the cost of human life, the product gave us an estimate of the economic and social burden that society holds due to deaths correlated with the aforementioned drugs. The societal cost of human life was calculated using the U.S. Department of Transportation’s methodology.

2 Part 1: Darth Vapor

2.1 Restatement of the Problem

The problem asks us to:

- Build a mathematical model that predicts the spread of nicotine use due to vaping over the next 10 years.
- Analyze how the growth of this new form of nicotine use compares to that of cigarettes.

2.2 Definitions

- E-cigarette user
  - One who used an e-cigarette at least once in the past 30 days.

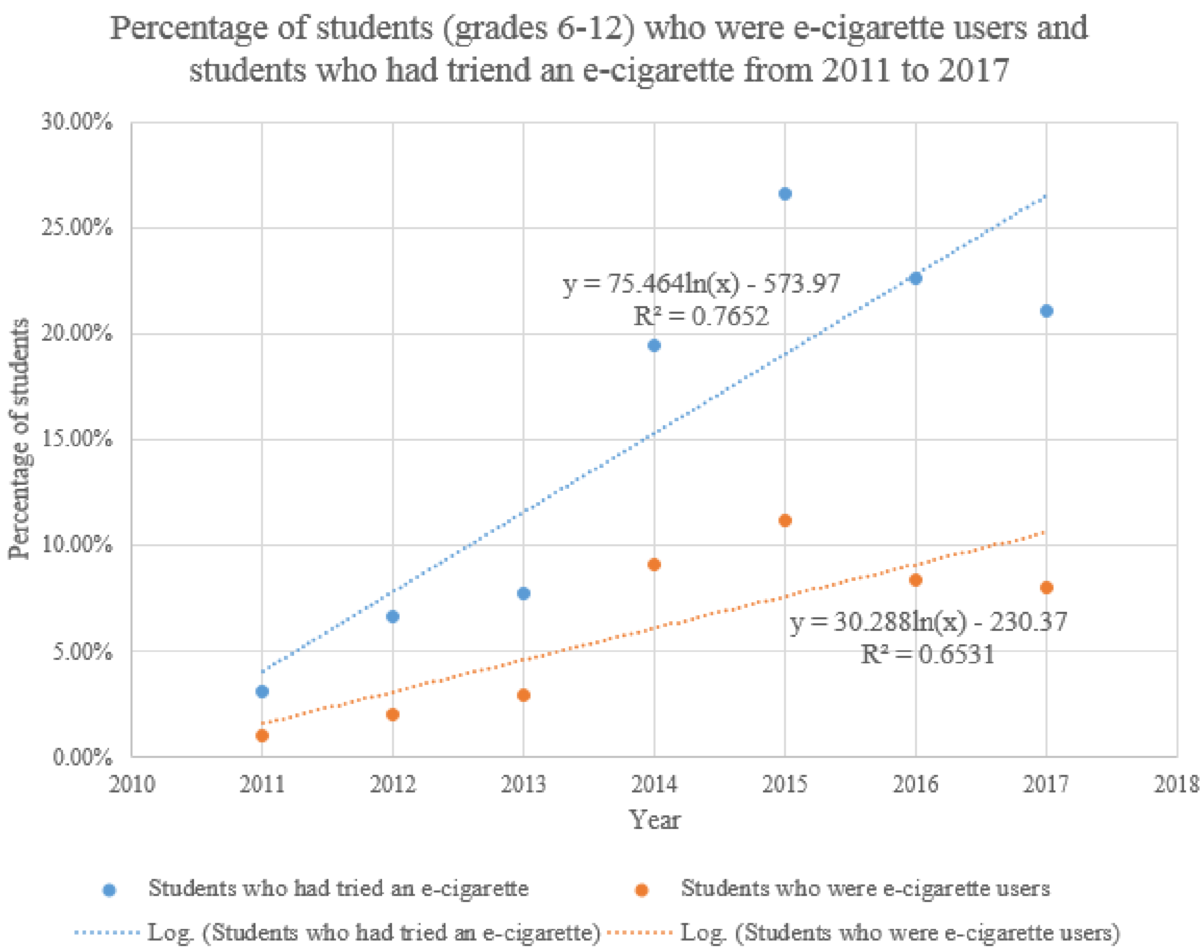
2.3 Assumptions

- E-cigarette use and vaping are synonymous.
- Those under the age of 18 are more likely to use e-cigarettes than those above the age of 18.
  - As of 2016, 4.7% of 18-24 year olds currently use e-cigarettes, with older age groups using e-cigarettes at lower and lower rates. However, in the same year, 8.4% of those in high school reported e-cigarette use, greater than any other age group (E-Cigarettes: Facts, Stats and Regulations).
- There will be no major legislative or public campaign developments in the next ten years that would impede the rate of growth of the percentage of middle school and high school students who use e-cigarettes.

2.4 Developing the Model

The e-cigarette industry takes many approaches to promoting their products, spending the most money on print, TV, and radio advertising (Murthy). This advertising often uses similar strategies to those of cigarette companies, glamorizing their products with sexual content and celebrities, with the added appeal of a variety of flavors (Murthy). The Internet is also used to advertise and sell e-cigarettes, with 40% of youth in a 2015 survey having seen e-cigarette advertisements online (Murthy). We also discovered that those under 18 were more likely to use e-cigarettes, and there was consistent yearly data on the use of e-cigarettes of middle school and high school students from 2011 to 2017 available through the National Youth Tobacco Survey (NYTS) (E-Cigarettes: Facts, Stats and Regulations).

For these reasons, we decided to focus our model on the e-cigarette use of middle school and high school students. Using data from the NYTS, we looked at the percentage of participants who reported having tried e-cigarettes, the percentage who were e-cigarette users, and the percent who were cigarette users.



When selecting a curve of best fit for the 2011-2017 NYTS data, we settled on using a logarithmic function instead of linear or polynomial function. Although a logarithmic model is problematic in that it would suggest there is no upper bound to the percentage of students using or trying e-cigarettes, it results in a growth rate that will decrease over time. This seems logical taking into account steep jumps in use from 2013-2015, followed by some relatively minor decline in 2016 and 2017.

Our model for the percentage of students who tried e-cigarettes is modeled by the equation:

$$y = 75.464 \ln(x) - 573.97$$

In this equation, y is the percentage of students in that particular year, x, who reported having tried an e-cigarette. The coefficient of the natural log of x, which controls the rate of growth, is 75.464.

Our model for the percentage of students who are e-cigarette users is modeled by the equation:

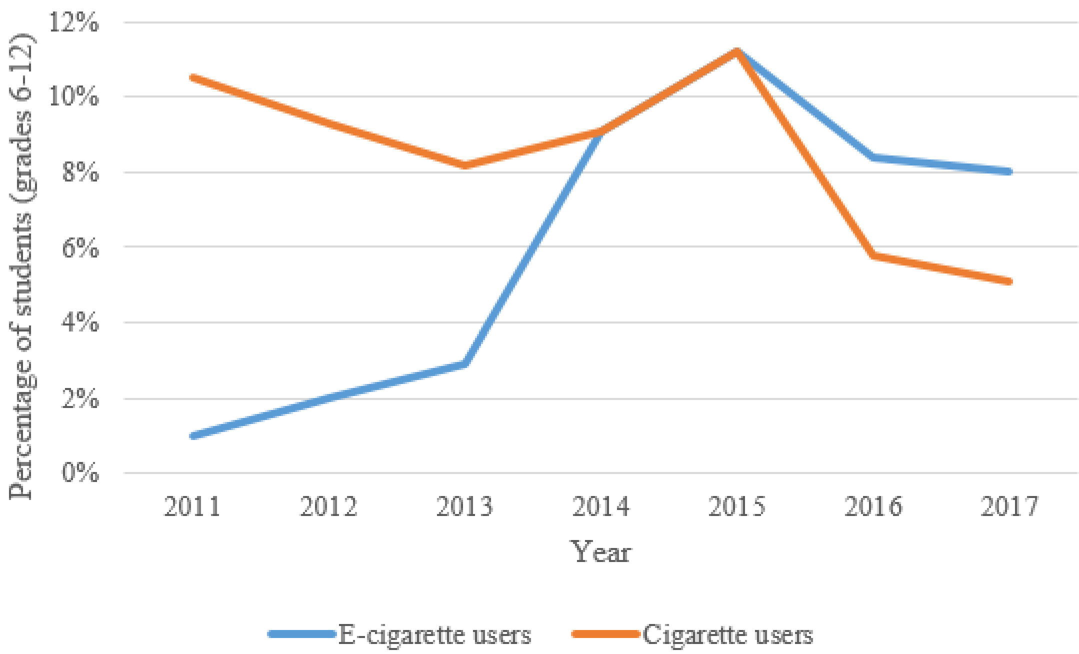
$$y = 30.288 \ln(x) - 230.37$$

In this equation, the percentage of students in that particular year, x, who reported using an e-cigarette at least once in the previous 30 days. The coefficient of the natural log of x, which controls the rate of growth, is 30.288.

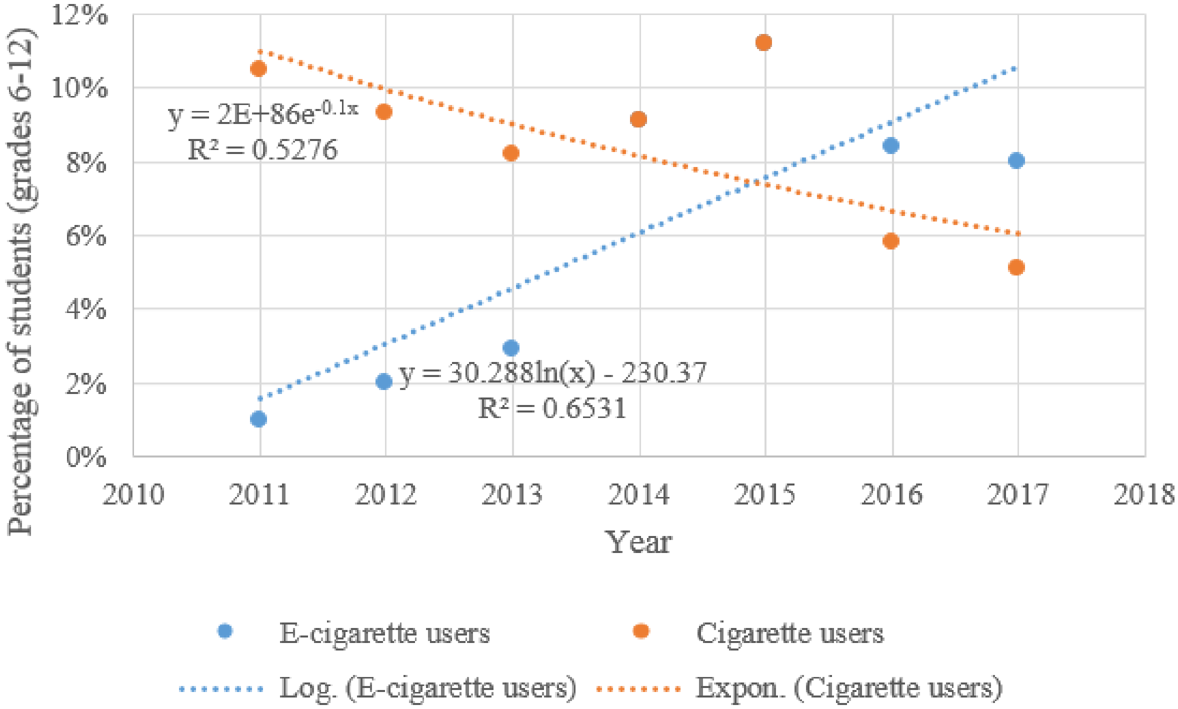
The coefficient of the natural log of x is smaller for the percentage of e-cigarette users, indicating that the percentage of students who have tried e-cigarettes is increasing at a faster rate than the percentage of students who had used an e-cigarette in the previous 30 days.

By this logarithmic model, ten years from now, in the year 2029 approximately 28.2% of all middle school and high school students will be e-cigarette users.

While the percentage of e-cigarette users among middle school and high school students has overall undergone a significant increase from 2011 to 2016, the percentage of regular combustible cigarette users among the same population has, on average, decreased over that time period, as shown in the graph below.



When modeling the percentage of cigarette users, we found using an exponential decay model yielded a reasonable r-squared value, better than that of a linear fit. The equation is displayed in the graph below, with the x value indicating the year and the y value indicating the percentage of students in grades 6-12 who had used a cigarette at least once in the previous 30 days.



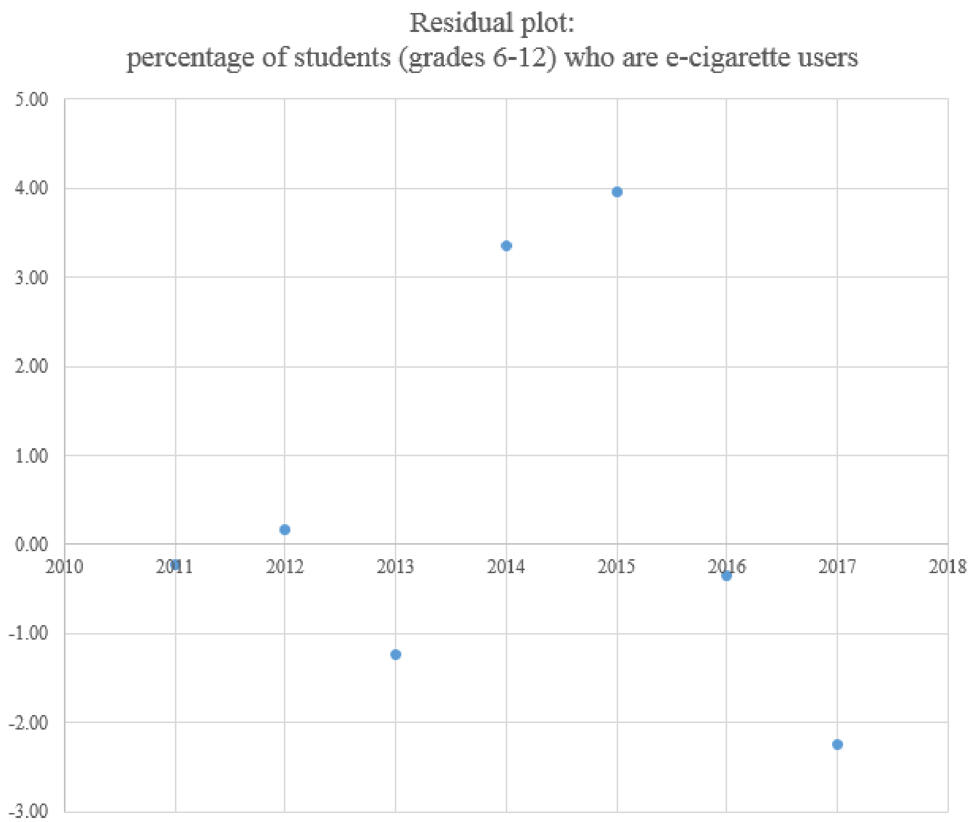
This model suggests that cigarette use will continue to decrease among middle school and high school students over time. Using this model, in 2029, approximately 5.43% of students in grades 6-12 will be cigarette users.

Together, these models project that by 2029, there will be more than five times as many teenagers who use e-cigarettes than teenagers who use combustible cigarettes.

2.5 Validation of the Model

For our model of the percentage of students grades 6-12 who are cigarette users, we used a logarithmic model to show a decreasing rate of growth. This model lended an r-squared value of 0.6531, a reasonably good fit.

When we look at the residual plot below of our model for the percentage of students in grades 6-12 who are cigarette users, there is no clearly defined line and there appears to be a roughly random distribution of points about the line $y = 0$.



2.6 Strengths & Weaknesses

- NYTS data
  - The data compiled in the NYTS survey could contribute to accuracy of our model. Our model focuses on students in grades 6-12, but each year in the NYTS survey there is a small percentage of students ranging from 0.1% to 0.2% of respondents who weren't assigned a grade or were in a grade not included in that range. These students, though small in number, could cause a lack of accuracy due to their lack of inclusion in our population.
- The logarithmic model
  - The logarithmic value has a decreasing growth rate, which implies more realistic results than a constant linear function. However, logarithmic functions have no value at which they level off, which is still unrealistic. Eventually, a logarithmic model would go over 100%, as would a linear one.
- Future developments
  - Our model does not include any potential future legislative developments regarding the issue of e-cigarettes. It does not take into account any public campaigns against the use of e-cigarettes or any future laws that would help curb the use of e-cigarettes among middle school and high school students.

3 Part 2: Above or Under the Influence?

3.1 Restatement of the Problem

The problem asks us to:

- Create a model that simulates the likelihood that a given individual will use a given substance.
- Take into account social influence and characteristic traits such as social circles, genetics, health issues, income level, and/or any relevant factors, as well as characteristics of the drug itself.
- Demonstrate how our model works by predicting how many students among a class of 300 high school seniors with varying characteristics will use the following substances: nicotine, marijuana, alcohol, and un-prescribed opioids.

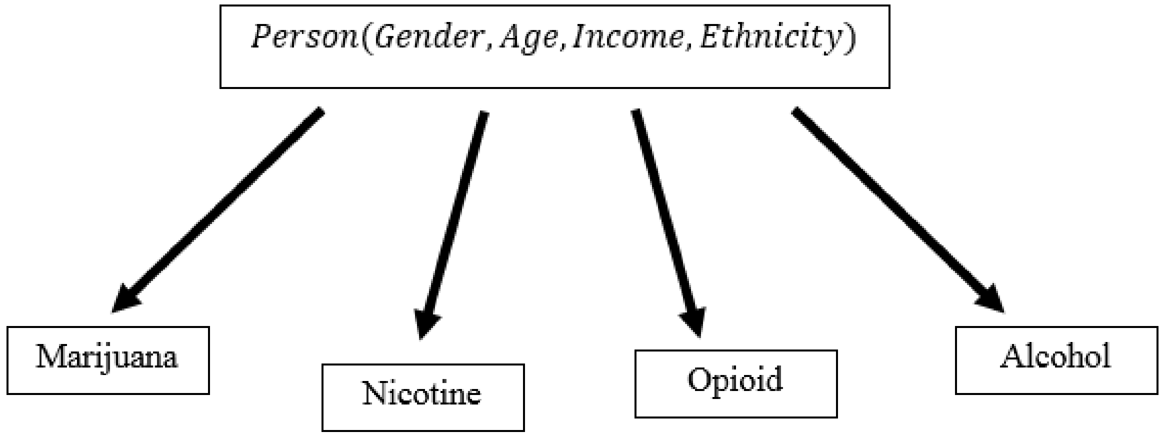
3.2 Assumptions

- Age, gender, race, and income level have equal impact on an individual’s drug usage patterns.
- A typical high school senior’s behavior can best be modeled by averaging the behaviors of the 12-17 age group and the 18-25 age group.
    - Because the Substance Abuse & Mental Health Data Archive does not report data by education level or graduating class, age is the best way of determining who fits the “high school senior” stratum. High school seniors are typically 17 or 18 years of age, hence the age groups selected.
- The percent distribution of one of the four categories we are taking into account (gender, age, income, and ethnicity) of the overall United States population is assumed to be evenly distributed within each other independent category used.
    - For example, the distribution of men and women over the entire population is 48.5% and 51.5%, respectively. Therefore, we are assuming every ethnicity group shares this distribution of gender.
- Gender, age, income, and ethnicity are the only factors that impact drug use and drug use is correlated to each of these factors.
- The probability of being addicted to each drug is independent of the probability of being addicted to any other drug.

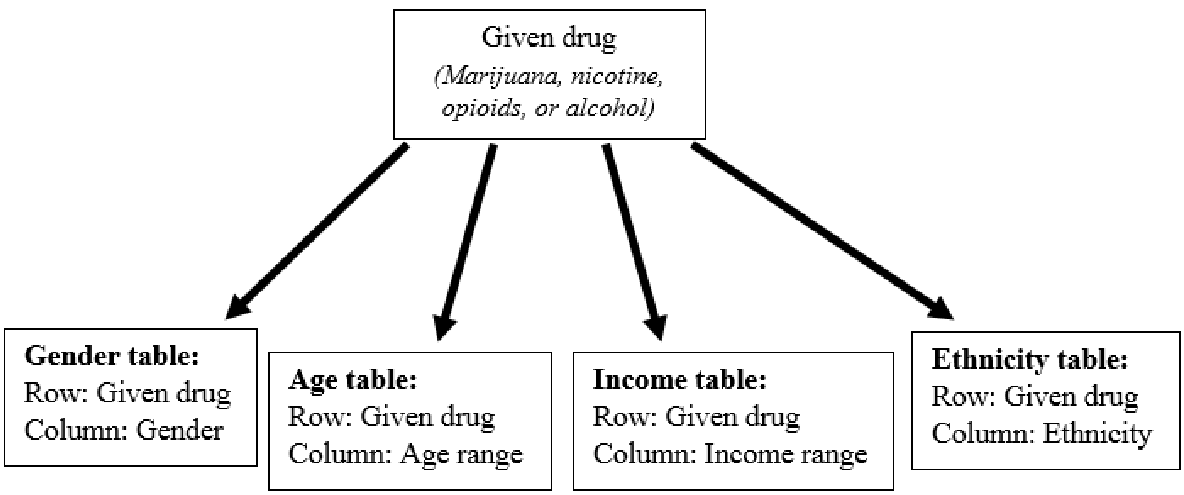
3.3 Developing the Model

To model the probability that a given individual will be dependent or abusive of a particular drug (marijuana, nicotine, opioids, or alcohol), we created a system of flow charts connecting data tables. This way, we are more effectively able to take into account an individual's socioeconomic attributes.

For each individual, we considered the factors of gender, age, income, and ethnicity.



First, we need those parameters of each individual. Next, we choose the drug for which we will calculate the probability that they are dependent on or abusive of.



We have charts for the probability of dependence or abuse based on gender, age, income, and ethnicity (respectively, with rows for each drug). For the given drug, as shown in the diagram above, in each table one will reference the cell defined by the row of the drug and the column that corresponds with the correct categorization of the attribute of the individual.

Below are the charts for probability of use based on our defined categories: age, gender, ethnicity, and income.

Age

	12 to 17	18 to 25	26 to 34	35+
Marijuana	0.0105	0.0148	0.0052	0.002
Opioids	0.0044	0.0127	0.0142	0.0059
Nicotine	0.009	0.0954	0.1298	0.1072
Alcohol	0.0184	0.0981	0.0869	0.0417

Gender

	Male	Female
Marijuana	0.0066	0.0032
Opioids	0.0096	0.0062
Nicotine	0.1122	0.0885
Alcohol	0.0692	0.0383

Ethnicity

	White	Black	Native American	Native HI/Pacific Islander	Asian	Multiracial	Hispanic
Marijuana	0.0039	0.0068	0.0106	0	0.0029	0.0118	0.0067
Opioids	0.0095	0.0064	0.0188	0.0114	0.0032	0.0099	0.0035
Nicotine	0.1154	0.1043	0.2061	0.1128	0.0294	0.1417	0.0547
Alcohol	0.0577	0.0441	0.0906	0.0378	0.0305	0.0727	0.0482

Income

	Less than $20,000	$20,000-$49,999	$50,000-$74,999	$75,000 and Over
Marijuana	0.0076	0.0055	0.0046	0.0033
Opioids	0.0131	0.0089	0.0086	0.0045
Nicotine	0.181	0.1266	0.0819	0.0539
Alcohol	0.0601	0.0512	0.0482	0.0541

Note: each non-hispanic ethnicity listed is implied to have no members of hispanic ethnicity in the populations.

Once you have located the probability in the prescribed cell in each of the four tables, average the four probability values in each appropriate cell to find the overall probability.

The values in each table represent the probability that a person of one of the specific categorizations as listed in the column titles will use each specific drug as listed in that particular row. The probability that they will not use each specific drug can be calculated by the difference of one and the value in the indicated cell (1 - cell value).

3.4 Demonstrating the Model: an Individual

For example, say one wants to find the probability that a 25-year-old multiracial woman who makes $60,000 a year is dependent on or abusive of nicotine. One would find the appropriate columns in each table (age: 18-25, gender: female, ethnicity: multiracial, income: $50,000-$74,999) and, finding the row associated with nicotine, average the probabilities of their nicotine dependence or abuse.

$$Average(0.0954, 0.0885, 0.1417, 0.0819) = 0.1019$$

Therefore, we can conclude that this person has about a 10.2% chance of being dependent on or abusive of nicotine.

3.5 Demonstrating the Model: a Class of 300 High School Seniors

In finding the number of students in a class of 300 high school seniors that will use a particular drug (marijuana, nicotine, opioids, and alcohol), many of the nuances of predictions for individuals are not necessary to know about the class as the whole. In this example, we will assume that the proportions of characteristics are representative of the overall United States population of the same age range.

For this reason, we only need the probabilities of dependency or abuse for each drug for two age ranges: 12-17 and 18-25. High school seniors are generally 17 or 18 years old, so we will average the probabilities of drug dependence or abuse of these two age ranges for each specific drug.

To find the approximate number of students who would be dependent on or abusive of marijuana, we can look at the probabilities referenced in the age table, in the row labeled marijuana and the columns labeled 12-17 and 18-25, respectively. We will then take the average of these probabilities and multiply by the size of the class, 300 students, to find the expected value of the number of students who are dependent on or abusive of marijuana. This yields the equation below:

$$Average(0.0105, 0.0148) * 300 = 3.795$$

Therefore, we can estimate that there are approximately 4 students in the senior class of 300 who are dependent on or abusive of marijuana.

To find the approximate number of students who would be dependent on or abusive of opioids, we can look at the probabilities referenced in the age table, in the row labeled opioids and the columns labeled 12-17 and 18-25, respectively. We will then take the average of these probabilities and multiply by the size of the class, 300 students, to find the expected value of the number of students who are dependent on or abusive of opioids. This yields the equation below:

$$Average(0.0044, 0.0127) * 300 = 2.565$$

Therefore, we can estimate that there are approximately 3 students in the senior class of 300 who are dependent on or abusive of opioids.

To find the approximate number of students who would be dependent on or abusive of nicotine, we can look at the probabilities referenced in the age table, in the row labeled nicotine and the columns labeled 12-17 and 18-25, respectively. We will then take the average of these probabilities and multiply by the size of the class, 300 students, to find the expected value of the number of students who are dependent on or abusive of nicotine. This yields the equation below:

$$Average(0.009, 0.0954) * 300 = 15.66$$

Therefore, we can estimate that there are approximately 16 students in the senior class of 300 who are dependent on or abusive of nicotine.

To find the approximate number of students who would be dependent on or abusive of alcohol, we can look at the probabilities referenced in the age table, in the row labeled alcohol and the columns labeled 12-17 and 18-25, respectively. We will then take the average of these probabilities and multiply by the size of the class, 300 students, to find the expected value of the number of students who are dependent on or abusive of alcohol. This yields the equation below:

$$Average(0.0184, 0.0981) * 300 = 17.475$$

Therefore, we can estimate that there are approximately 17 students in the senior class of 300 who are dependent on or abusive of alcohol.

This means that in total, our model projects that a typical senior class of 300 students will contain 17 students who are dependent on or abusive of alcohol, 16 students who are dependent on or abusive of nicotine, 4 students who are dependent on or abusive of marijuana, and 3 students who are dependent on or abusive of opioids. Our model does not specify whether any of the students are dependent on or abusive of multiple drugs. There may be overlap within the numbers.

3.6 Validation of the Model

We will attempt to validate our model by comparing it to statistics from other sources regarding the drug use of high school seniors.

As of 2017, 2.7% of high school seniors reported misusing prescription opioid Oxycontin.

To find the approximate percentage of students according to our model who would be dependent on or abusive of opioids, we can look at the probabilities referenced in the age table, in the row labeled opioids and the columns labeled 12-17 and 18-25, respectively. We will then take the average of these probabilities and multiply by 100 to find the percent of high school seniors who are dependent on or abusive of opioids. This yields the equation below:

$$Average(0.0044, 0.0127) * 100 = 0.855\%$$

This is not consistent with the 2.7% of high school seniors reported misusing prescription opioid Oxycontin. However, our data specifically describes those who are dependent on or abusive of the substance, rather than simply the percentage of all people who use the substance. In this way, it makes sense that the percentage from our model is smaller than that given in the source.

3.7 Strengths & Weaknesses

- Assuming Impact
  - To calculate the probability of drug dependence or abuse based on our defined characteristics, we had to assume that each characterization, in some way, impacted the probability of substance dependence or abuse. This may not always be the case.
- National Survey on Drug Use and Health, 2017
  - As this survey is the source of our data for all of our tables, weaknesses of the survey, such as nonresponse or people who incorrectly reported their drug use, contribute to weaknesses in our model.
- Combination of probabilities
  - When we combine the probabilities by averaging them, we have to operate under the assumption that all four factors have equal influence on the probability of a person to be dependent on or abusive of a particular drug. It is entirely possible that this is not the case.
- Specificity
  - One strength of this model is the specificity it allows, with individual values by drug type for each category of each attribute we decided to take into consideration.
- Independence
  - Uses of different drugs may not be independent of one another. Use of one drug may increase the probability that a given individual uses other drugs.

4 Part 3: Ripples

4.1 Restatement of the Problem

The problem asks us to:

- Develop a way of quantifying the societal cost of drug usage
- Include both financial and non-financial factors in our cost analysis
- Use our quantitative metric to rank the societal cost of alcohol, nicotine, marijuana, and opioid consumption

4.2 Assumptions

- The societal cost of one human life is $10.4 million.
  - In 2016, the U.S. Department of Transportation set the Value of a Statistical Life (VSL) at $9.6 million and explained a method of adjusting the VSL for each year. The formula used was:
    - $VSL_T = VSL_0 * (P_T/P_0) * (I_T/I_0)^{\varepsilon}$, where
      - 0 represents the base year
      - T represents the current year
      - P represents the Consumer Price Index (CPI) for a given year
      - I represents real incomes for a given year
      - Ɛ represents the income elasticity of the Value of a Statistical Life
  - The most recent CPI, for January 2019, was 251.712 relative to a CPI of 236.916 for January 2016.
  - According to the Brookings Institution, real incomes have remained stagnant recently, so we will assume $(I_T/I_0)^{\varepsilon} = 1$.
  - Therefore, $VSL_T = VSL_0 * (P_T/P_0) * (I_T/I_0)^{\varepsilon}$ can be written as $VSL_T = VSL_0 * (P_T/P_0)$ and, with terms substituted in: $VSL_T = 9.6 * (257.712/236.916)$ million.
  - This simplifies and rounds to a VSL of $10.4 million.
- We equated all nicotine-related deaths to tobacco-related deaths because there is not sufficient data supporting the hypothesis that e-cigarettes have caused fatalities.

4.3 Developing the Model

We began by using the U.S. Department of Transportation's methodologies to determine the cost of a human life. Because we are estimating the cost of a priceless contributor to society, these calculations were placed under the "Assumptions" subsection. The DOT calculated the cost of a human life by quantifying both the average earnings potential lost from a fatality and the lost utility a victim would've provided to his/her friends and family. This quantified value of a human life can be standardized from year-to-year using a model developed by the DOT to adjust for inflation and changes in real income. We worked through this process above to arrive at our estimated societal cost of $10.4 million per fatality.

After calculating the societal cost of human life, we found the average annual deaths associated with the use of each noted drug (nicotine, alcohol, opioids, and marijuana). From this non-financial data, we were able to use the cost of human life and multiply that to each value to find the total societal cost from lives lost. The consequences of drug-related deaths tragically affect loved ones. The lost utility of these persons also negatively affects the nation's economy as a whole.

Through our research, we noted that there were no average annual deaths associated with marijuana. A study done by the Drug Abuse Warning Network showed 0 average annual deaths caused by cannabis consumption. Another study by the National Drug and Alcohol Research Centre of Australia concluded that there was insufficient evidence to find a correlation between cannabis consumption and an increased risk of death. There have not been a substantial number of longitudinal studies to conduct a study between all-cause mortality rate and cannabis use.

We considered factoring in rehabilitation costs into our model but we quickly ran into some issues. Rehabilitation costs have many variables because most treatments are highly specialized to each patient. There are four general treatment types- Detox, Inpatient Rehabilitation, Outpatient Rehabilitation, and Medications. There are numerous treatment options within the general types and many different combinations of the four types depending on the patient. Considering these variables, the estimated cost for rehabilitation of each drug would likely be too broad of a range to be considered within our model. Also, the cost of rehabilitation generally depends on health insurance which can vary in coverage drastically between states, people, and different providers.

With all this considered, we found that for each drug the total societal costs can be modeled by the equation:

$$\$10{,}400{,}000 \times (Deaths\ associated\ with\ the\ drug) = Total\ societal\ cost\ per\ drug$$

Drug	Alcohol	Nicotine	Marijuana	Opioids
Societal Cost (in billions)	$915,200	$72,800,000	$0	$730,464

Showing all the costs per drug we can place these in an order of how much they cost to society from the most to least:

1. Nicotine
2. Alcohol
3. Opioids
4. Marijuana

4.4 Validation of the Model

In a study done to analyze the cost of the opioid crisis in 2016, Altarum researchers found that the estimated cost for the United States was about $95 billion. These numbers are purely economic based on factors such as lost productivity in the private sector and lost tax revenue. Our model is based on of the DOT's methodology which includes both economic and societal impacts as a result of fatalities.

A comparative risk assessment of alcohol, tobacco, cannabis, and other illicit drugs concluded that, in terms of a toxicological MOE (margin of exposure) approach, alcohol and tobacco were considered high risk and cannabis was considered low risk. These findings support our rankings in a different perspective that was not factored in our model.

4.5 Strengths & Weaknesses

Because this model uses the DOT's methodology to determine the VSL, we were able to consider the utility a victim of a drug fatality (for example, a drug overdose or drunk driving victim) can no longer provide to his/her friends and family as a result of his/her death. As a result, this model is able to consider both the economic and social impacts of drug-related fatalities as a part of the larger analysis of the societal costs of drug usage. Furthermore, our model agrees with findings in toxicological research as described in our validation.

One drawback to using the DOT's methodology to determine the VSL is that by considering more than just the economic impacts of drug use, our model overestimates the societal costs of drug use when the model is used in purely economic analyses, and therefore, our model cannot be applied universally to all studies on estimated costs of drug abuse.

5 Conclusion

In our first model, regarding the percentage of middle school and high school students who are e-cigarette users, our model could not take into account forthcoming legislations or initiatives to limit the use of e-cigarettes among youth. In this way, our model serves as a warning for what may happen if the use of e-cigarettes among youth continues with no further restrictions. A better model would include more data about teen's use of cigarettes. As the use of e-cigarettes is a relatively new issue, the NYTS only started asking questions about them in 2011. More data would provide a more accurate picture of their growth. In addition, the questions of the survey have not always been asked with consistent wording and could contribute to errors.

Due to the expansive nature of the second model, we had to make several assumptions on how demographics were spread between subdivisions of other demographics. A more precise model would be able to use more specific population data on variations of people based on their characteristics. In addition, a more precise model would get specific drug dependence and abuse data on a specifically 17-18 year old sample instead of averaging of the 12-17 and 18-25 probabilities to get an estimate on what the specific sample may look like. With this found data, and the ability to go in depth on characterizations specifically for high school students, the United States could make an effort to specify demographics with high probabilities of drug dependence or abuse. With the knowledge of which drugs are more commonly mishandled, a valiant effort could be made to prevent such demographics from suffering predicted ramifications.

The third model was limited within the parameters of deaths associated with each drug. To further our research and be able to extend it to future studies, non-fatal overdoses should be examined within the model. A better model would utilize non-fatal overdoses because the time spent recovering from the medical complications does increase lost wages and productivity. This would provide a more expansive look into how drug abuse affects the U.S. as a whole.

From a public policy perspective, the drugs that cost society the most - whether economically or privately within each family - should be targeted the most by legislation. Our third model indicated that marijuana is less costly to society than opioids, alcohol, and nicotine, despite the prevalent usage noted in our second model. Therefore, marijuana is most likely over-regulated compared to other drugs - especially the relatively unregulated drugs of alcohol and nicotine.

Alcohol isn't likely to face much more regulation as many Americans are wary of Prohibition-era restrictions on alcohol use. That said, nicotine presents a unique opportunity for new regulations in the face of new methods of nicotine consumption. As noted in our first model, nicotine consumption is expected to rise as e-cigarettes take over conventional cigarettes among teenagers and young adults, albeit at a slowing rate. By regulating the ability of e-cigarette companies to market flavored products to adolescents, legislation may be effective in combating the spread of this nation's most costly drug.

6 Bibliography

"2017-18 Annual Report." *Florida Department of Corrections*, Florida Department of Corrections, www.dc.state.fl.us/pub/annual/1718/FDC_AR2017-18.pdf.

"Alcohol Facts and Statistics." *National Institute on Alcohol Abuse and Alcoholism*, National Institutes of Health, www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/alcohol-facts-and-statistics.

"Annual Causes of Deaths in the US." *Common Sense for Drug Policy*, Common Sense for Drug Policy, www.csdp.org/publicservice/causes.pdf.

Bevilacqua, L., and D. Goldman. "Genes and Addictions." *PubMed Central*, National Institutes of Health, 27 July 2009, www.ncbi.nlm.nih.gov/pmc/articles/PMC2715956/.

Calabria, Bianca, et al. "Does Cannabis Use Increase the Risk of Death? Systematic Review of Epidemiological Evidence on Adverse Effects of Cannabis Use." *Drug and Alcohol Review*, vol. 29, no. 3, 2010, pp. 318–330., doi:10.1111/j.1465-3362.2009.00149.x.

Calabria, Bianca, et al. "Does Cannabis Use Increase the Risk of Death? Systematic Review of Epidemiological Evidence on Adverse Effects of Cannabis Use." *Drug and Alcohol Review*, vol. 29, no. 3, 2010, pp. 318–330., doi:10.1111/j.1465-3362.2009.00149.x.

Centers for Disease Control and Prevention. "Table 50. Use of Selected Substances in the Past Month among Persons Aged 12 and over, by Age, Sex, Race, and Hispanic Origin: United States, Selected Years 2002–2016." 2017.

Chaffee, Benjamin W., et al. "Electronic Cigarette Use and Progression From Experimentation to Established Smoking." *Pediatrics*, vol. 141, no. 4, 2018, doi:10.1542/peds.2017-3594.

"Chapter 2 Impact of Substance Abuse on Families." *National Center for Biotechnology Information*, U.S. National Library of Medicine, 2004, www.ncbi.nlm.nih.gov/books/NBK64258/.

"Consumer Price Index Historical Tables for U.S. City Average." *U.S. Bureau of Labor Statistics*, United States Department of Labor, stats.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm.

"E-Cigarettes: Facts, Stats and Regulations." *Truth Initiative*, Truth Initiative, 19 July 2018, truthinitiative.org/news/e-cigarettes-facts-stats-and-regulations.

"Fact Sheets - Alcohol Use and Your Health." *Centers for Disease Control and Prevention*, U.S. Department of Health & Human Services, www.cdc.gov/alcohol/fact-sheets/alcohol-use.htm.

"Fast Facts." *Centers for Disease Control and Prevention*, U.S. Department of Health & Human Services, www.cdc.gov/tobacco/data_statistics/fact_sheets/fast_facts/index.htm.

"Health Consequences of Drug Misuse." *National Institute on Drug Abuse*, National Institutes of Health, Mar. 2017, www.drugabuse.gov/related-topics/health-consequences-drug-misuse.

"Historical NYTS Data and Documentation." *Centers for Disease Control and Prevention*, U.S. Department of Health & Human Services, www.cdc.gov/tobacco/data_statistics/surveys/nyts/data/index.html.

"How Much Does Alcohol Rehab Cost?" *American Addiction Centers*, American Addiction Centers, americanaddictioncenters.org/alcohol-rehab/cost.

Karriker-Jaffe, Katherine J. "Neighborhood Socioeconomic Status and Substance Use by U.S. Adults." *Drug and Alcohol Dependence*, vol. 133, no. 1, 2013, pp. 212–221., doi:10.1016/j.drugalcdep.2013.04.033.

Lachenmeier, Dirk W., and Jürgen Rehm. "Comparative Risk Assessment of Alcohol, Tobacco, Cannabis and Other Illicit Drugs Using the Margin of Exposure Approach." *Nature*, Springer Nature Publishing AG, 30 Jan. 2015, www.nature.com/articles/srep08126?message-global=remove&wptouch_preview_theme=enabled.

Mccabe, Sean Esteban, et al. "Race/Ethnicity and Gender Differences in Drug Use and Abuse Among College Students." *Journal of Ethnicity in Substance Abuse*, vol. 6, no. 2, 2007, pp. 75–95., doi:10.1300/j233v06n02_06.

Moran, Molly J., and Carlos Monje. "Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses - 2016 Adjustment." *U.S. Department of Transportation*, U.S. Department of

Transportation, 8 Aug. 2016, cms.dot.gov/sites/dot.gov/files/docs/2016 Revised Value of a Statistical Life Guidance.pdf.

Murthy, Vivek H. “E-Cigarette Use Among Youth and Young Adults: A Report of the Surgeon General.” *Public Health Service*, U.S. Department of Health and Human Services, 2016, e-cigarettes.surgeongeneral.gov/documents/2016_SGR_Full_Report_508.pdf.

Newman, Katelyn. “NIH Survey: Students Vaping, Using Marijuana More in 2017.” *U.S. News & World Report*, U.S. News & World Report, 14 Dec. 2017, www.usnews.com/news/national-news/articles/2017-12-14/nih-survey-alcohol-marijuana-and-vaping-top-students-2017-drug-use.

Nunn, Ryan, and Jay Shambaugh. “If Real Wages Aren't Rising, How Is Household Income Going up?” *Brookings*, The Brookings Institution, 18 Oct. 2018, www.brookings.edu/blog/up-front/2018/10/04/if-real-wages-arent-rising-how-is-household-income-going-up/.

“Overdose Death Rates.” *National Institute on Drug Abuse*, National Institutes of Health, 29 Jan. 2019, www.drugabuse.gov/related-topics/trends-statistics/overdose-death-rates.

Patrick, Megan E., et al. “Socioeconomic Status and Substance Use Among Young Adults: A Comparison Across Constructs and Drugs.” *Journal of Studies on Alcohol and Drugs*, vol. 73, no. 5, 2012, pp. 772–782., doi:10.15288/jsad.2012.73.772.

“Public-Use Data Analysis System.” *Substance Abuse and Mental Health Data Archive*, Substance Abuse and Mental Health Services Administration, pdas.samhsa.gov/#/.

Sacks, J J, et al. “2010 National and State Costs of Excessive Alcohol Consumption.” *National Center for Biotechnology Information*, U.S. National Library of Medicine, Nov. 2015, www.ncbi.nlm.nih.gov/pubmed?cmd=search&term=26477807.

Shmulewitz, Dvora, et al. “Effects of State-Level Tobacco Environment on Cigarette Smoking Are Stronger Among Those With Individual-Level Risk Factors.”

Nicotine & Tobacco Research, vol. 18, no. 10, 2016, pp. 2020–2030., doi:10.1093/ntr/ntw114.

Substance Abuse and Mental Health Services Administration. “Key Substance Use and Mental Health Indicators in the United States: Results from the 2016 National Survey on Drug Use and Health.” *HHS Publication No. SMA 17-5044, NSDUH Series H-52*, www. samhsa.gov/data/. Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration.

“Understanding the Cost of Rehab.” *AddictionCenter*, Delphi Behavioral Health Group, www.addictioncenter.com/rehab-questions/cost-of-drug-and-alcohol-treatment/.

Zimmerman, Brian. “Opioid Epidemic Cost US $95B in 2016.” *Becker's Hospital Review*, Becker's Healthcare, 17 Nov. 2017, www.beckershospitalreview.com/opioids/opioid-epidemic-cost-us-95b-in-2016.html.