The Needle and the Damage Done:
An Exploratory Analysis of Wisconsin's Heroin Epidemic

Jon McHugh, Natalee Robson, Clare Trainor
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Objectives

Since the early 2000's, Wisconsin has experienced an explosive growth in the illicit use of heroin, leading to an epidemic of this highly addictive opioid. This project will attempt to identify hotspots of the use of heroin and other related opioids at the state's zip code level since the onset of the epidemic. We will further explore its association with income, age, and race by overlaying datasets of these additional variables with our zip code level data. With this information, we will create graphics that inform the general public in regards to where heroin and related narcotic use is present, what factors are correlated with its use, and what is being done to stop it.

By overlaying socioeconomic variables, we will be able to identify demographic and social factors associated with the abuse of these illicit drugs and compare different areas in Wisconsin. Once we have this information, the graphics we make will educate people about the various aspects of the heroin epidemic in Wisconsin. These graphics may also be beneficial for law enforcement, drug abuse prevention and rehabilitation programs.

Background

It has become impossible to ignore the heroin crisis that is happening within our state. This epidemic has become prevalent throughout the United States since the early 2000's, and Wisconsin was one of the hardest-hit states in the Midwest in 2013 according to the Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2013).

Heroin is a highly addictive analgesic (pain-relieving) drug that is derived from morphine and is often used illicitly as a narcotic to produce euphoria. Often, the terms "opiate" and "opioid" are used interchangeably with heroin. However, there is a subtle difference in the meaning of these words. Opiates are naturally derived from the opium poppy plant, while an opioid is a compound that binds opioid receptors in the brain and produces the pain-relieving effects characteristic of opiates. Opioids can be produced synthetically, but opiates cannot. For example, heroin and morphine are both opiates and opioids, but Demerol and Percocet are strictly opioids ("Opiates vs. Opioids", 2016).

The demographics and geographical distribution of heroin users has shifted greatly over the past fifty years. It has gone from being a primarily minority-centered urban problem to a very white, young suburbanite problem (Cicero, et al, 2014).

Heroin can be smoked, taken intravenously, or snorted, and no method is safer than any other. When heroin is pure, it is a fine white powder that looks similar to baking flour, but this is not the type of heroin that most people are using. Typically, it is cut with other additives like caffeine, quinine, or talcum powder that make it either light brown, grey, or even black (Di Justo, 2016). "Cut with" simply means that the ingredients are added to increase the weight (for purposes of sales) or to alter the experience of the drug user.

Many people whose lives have been gripped by heroin were first addicted to prescription opioids like Vicodin or OxyContin, but a crackdown on prescription pills has made it easier and much cheaper to access heroin ("Wisconsin's Heroin Epidemic", 4-6).

Although heroin acts similarly to the relatively safe prescription painkillers we are familiar with, street heroin is extremely dangerous because of the additives and unknown purity. No matter how experienced the user, each hit (or dose) comes with a risk that it will be their last, as no user knows exactly what the hit contains.

The effects of heroin on the body cannot be overstated. From the outside, a person who has used heroin looks drowsy, like someone who cannot stay awake; this is called "nodding'. Inside their head, it feels like a euphoric, worry-free rush. If you have ever taken melatonin or a sleeping medication, it feels similar to that time just before you fall asleep, when everything feels heavy and peaceful (but several orders of magnitude more intense).

However, the reality of what is happening in the body is quite sinister. Heroin is a sedative, so it is slowing down the body's functions – even the essential functions. The effects on the heart and lungs can lead to passing out or suffocation, which is often what kills someone who has overdosed. If the slowing of bodily functions does not kill an addict, the toxins from the additives can lead to liver and kidney disease. Further, sharing needles comes with a risk of HIV or hepatitis C (HCV).

Like most drugs, a tolerance to heroin gets built over time, which leads to more frequent heroin use and larger doses as the addiction escalates. Eventually, addicts may

require a large amount of heroin just to function normally. Rather than chasing a high, it becomes more about running away from withdrawal. Withdrawal is extremely painful, with bone and muscle pain as well as diarrhea and vomiting.

Heroin use has become a national issue, but as previously stated, Wisconsin's epidemic of heroin use is of the worst in the Midwest. Between 2009 and 2012, heroin-related arrests as well as the amount of heroin seized in Wisconsin increased steadily ("Wisconsin's Heroin Epidemic", 6). According to the Department of Justice's "Fly Effect" campaign, heroin cases rose in nearly every Wisconsin county over the last three years and the number of Wisconsin teens who have tried heroin has tripled since 1995. Chicago and Rockford are two primary sources for the state's heroin supply, but local cities like Madison, Milwaukee, and Fox River Valley are also becoming hubs ("The Fly Effect", 2015).

Heroin is primarily affecting young people in Wisconsin. A survey of residents who used injection drugs and who also have hepatitis C showed that heroin use began at an average age of twenty-one years. About 80% of those respondents began their heroin use within three years of prescription opioid abuse ("Wisconsin's Heroin Epidemic", 6). Further, acute Hepatitis C infection in young adults have increased, and in 2013, nearly 80% of people with new infections reported that they had injected drugs ("Wisconsin's Heroin Epidemic", 5).

Heroin also has an impact on society as a whole. Opiate abuse tends to be linked to greater crime and the use of weapons and violence; to pay for drugs, sometimes addicts are desperate and resort to crimes like theft ("Wisconsin's Heroin Epidemic", 6).

This increase in crime, the loss of economically young and vital people, the loss of education, as well as the health effects, mean that the cumulative effect of heroin use on society is dire. Thus, it is crucial to identify hotspots of heroin use, as well as its relationship to age, gender, education, and race.

Methodology

In our analysis, our goal was to identify hotspots of heroin use and its association with socioeconomic variables such as race, education, income, gender, and age.

In order to logically trace our steps in ArcMap and other software, we designed a conceptualization and implementation model to represent each step in solving our research question in ArcGIS software. The diagram below (Figure 1.1) is the visual representation of our conceptualization model, including key concepts, key variables, and operationalized variables.

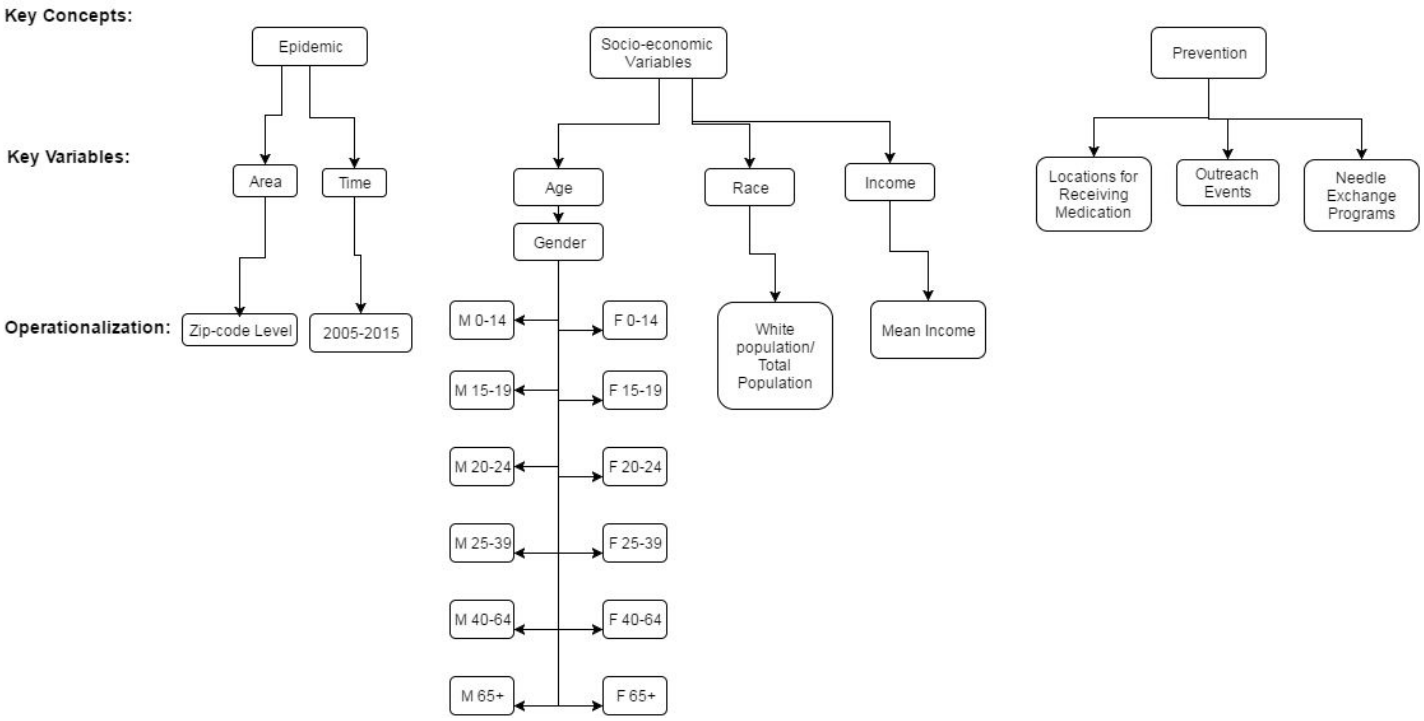


Figure 1.1- Conceptualization Model

We decided to analyze heroin incidence according to the most basic factors first: when and where heroin hospitalizations are occurring. This decision was made because of our desire to make a hotspot map and simply increase the general population's awareness of the basic problem. Because we knew we could not acquire individual addresses of heroin hospitalizations, our aim was to acquire zip code level data, which would be significantly more detailed than the county-level heroin maps that are easily found online.

We also chose to use data from the United States Census Bureau, as it provided the most accurate and fullest data sets for socioeconomic data that we could find. We chose to operationalize these variables according to the existing census brackets and cohorts, and

organize the data further as needed. Often, however, the brackets were given to use worked in our favor-- for example, as heroin use is more prevalent among teens and twenty-somethings, we expected more opioid-related hospitalizations for age cohorts of people in their late-teens and twenties.. We then merged outlying cohorts (for all children under 14 and adults over 65) in order to provide more distinct contrasts against youth and young adults, as we knew young adults were at higher risk for heroin use based off of research we had read.

For the race variable, we chose to simply identify the "whiteness" of a given zipcode area. This proved to be a beneficial way to measure racial diversity, as our initial attempts to measure specific amounts of other races in counties resulted in such small numbers; unsurprising, as Wisconsin is primarily white. By narrowing our scope to the percentage of whiteness, we were able to measure heroin hospitalizations' correlation to generally more racially diverse zip code areas.

For our census data focusing on income, we chose to analyze heroin incidents according to mean income. We chose this measure because it gave us a strong indication for heroin's incidence for a given area.

After we conceptualized our plan for analysis, the next step was to identify and acquire the necessary data for our analysis. Below is the visual representation of our implementation model (Figure 1.2).

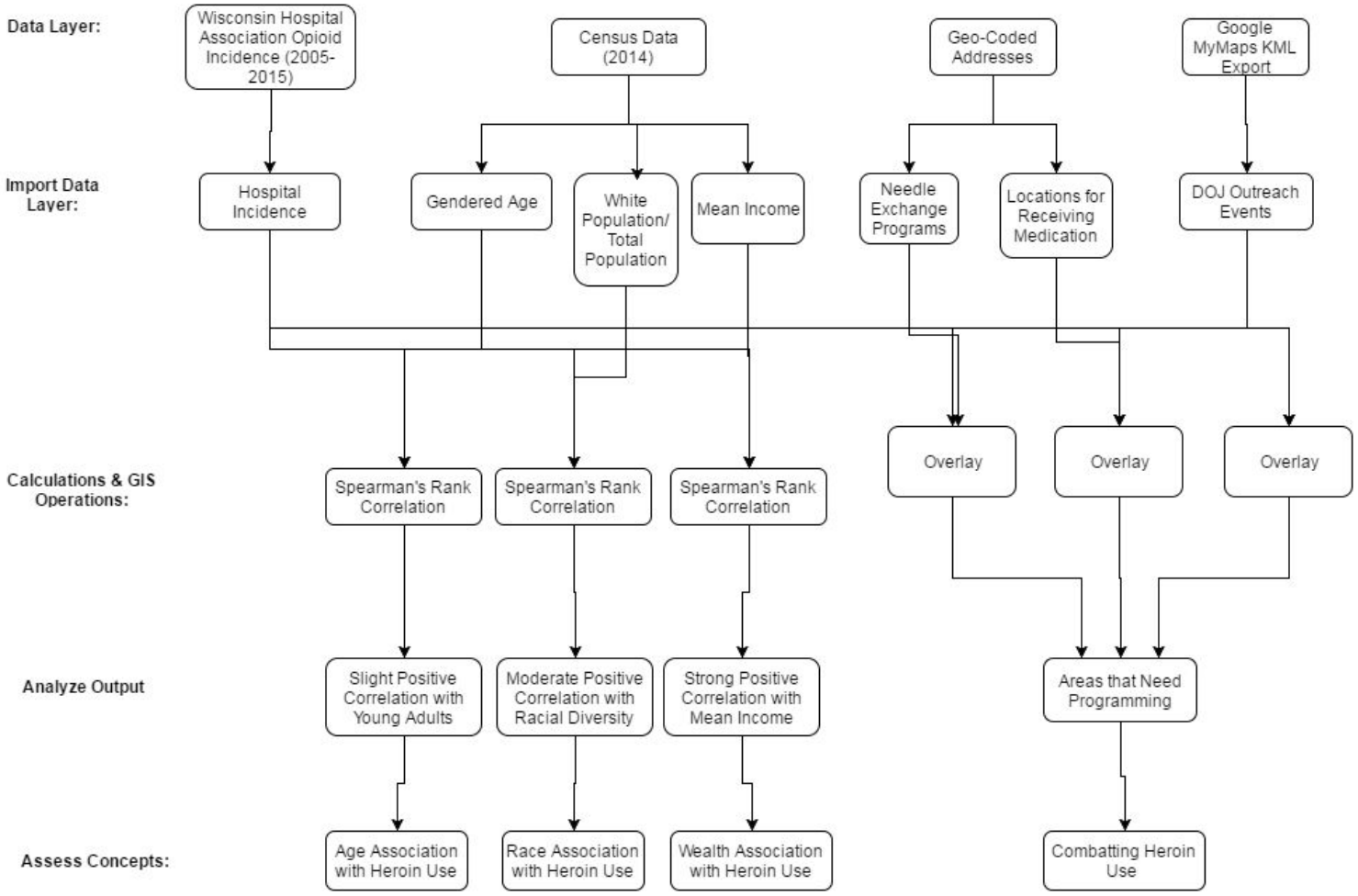


Figure 1.2 - Implementation Model

We were able to acquire our heroin-use data from the Wisconsin Hospital Association, who gave us data indicating hospitalizations of Poisoning by Opium, Poisoning by Heroin, Poisoning by Methadone, and Poisoning by Opiates and Related Narcotics per zip code (compiled, not discriminated) from January 2005 to September 2015. It is important to note that although we are particularly interested in the heroin epidemic in Wisconsin, the data we received also included these related narcotics; therefore, throughout the rest of the project, when we refer to incidents and the use of heroin, we are also including a broader set of related opioids as well. Furthermore, because our data was not complete for 2015, much of our analysis was conducted with data from 2014, our latest full year of data.

One of the limitations of our research dealt with the confidential nature of our topic, particularly since there are legal implications for people identified as heroin users, as well as HIPAA regulations protecting the privacy of patients.. Considering this, our data is masked for zip codes with less than five "counts" (or hospitalization incidents) *and* less than 1,000 people in a zip code (which was much nicer than having one *or* the other masked for our purposes). Furthermore, any zipcode that had above 1,000 people and less than 5 counts was simply marked as an "*", meaning it could have any number between 0-4 hospitalizations. One further note of significance for our research is that the zip code location represents the personal address-area of the person hospitalized, not the hospital itself.

Recognizing these conditions, we suspect that our methodologies only partly overcome the skew towards an emphasis on urban illicit use of heroin, since those zip codes tend to have higher populations. While we can see that many rural zip codes have fewer incidents, we cannot assume that the masked values did not have high incidences of opioid hospitalizations, especially since we have observed from the data given us that there has been a significant movement towards heroin use in rural areas as well. Our supplemental data came from the U.S. Census Bureau for our socioeconomic factors, from the Wisconsin Department of Justice website for our outreach program assessment, from the North American Syringe Exchange Network for syringe exchange locations, and the Wisconsin Department of Health Services for treatment locations in Wisconsin..

Our original layer was made from all of our prevention data. We used Texas A&M's geocoder (Figure 1.3) in order to convert addresses for needle exchange programs and locations for receiving medication into shapefiles with point data. We had to plug in the locations of the Department of Justice's outreach events into Google MyMaps (Figure 1.4) and then export the map as a .KML in order to get that point-data into ArcMap.

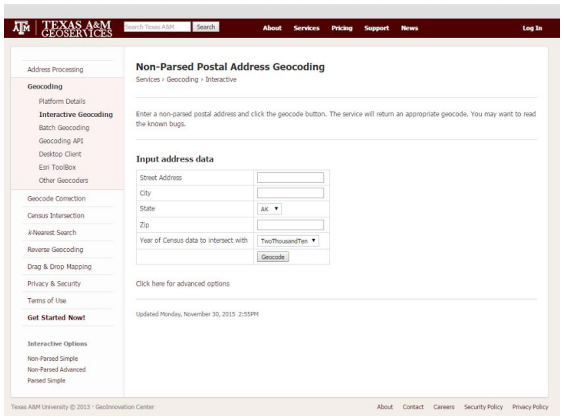


Figure 1.3

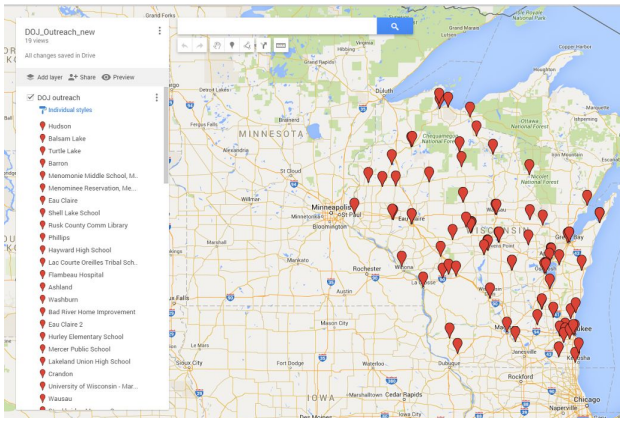


Figure 1.4

Due to the nature of our data, we used Spearman's rank correlation in order to overcome the aggregation of our data. Since our data was aggregated by space and time, regression analysis was not appropriate for our data.. Spearman's rank correlation (or Spearman's rho), however, is particularly useful because of the aggregated nature of our data, as well as the way in which it prevents outliers from skewing the results. This is because Spearman's ranks the data points according to a sequential number scale (x+1). This statistic was useful because rather than conducting a geographic analysis with our demographic and socio-economic variables, we decided to simply search for a basic correlation across the whole state.

In order to conduct this analysis between the WHA data and a socio-economic variable, we created multiple tables accordingly and then entered them into a Spearman's rho tool found online at Vassarstats ("Vassarstats", 2016). We found the r-value, which indicates a strong/weak strong/negative correlation between the two variables, as well as the p-value, which indicates the confidence-level we have about a given r-value.

The other statistic we conducted was an emerging hot spot analysis based on the space time cube. The space time cube is a model built in ArcGIS that takes into account time, location, and our specific data of interest. We chose to use this tool because it helped us base an analysis based on all ten years of our data, rather than just one year of opioid-use data. In order for the tool to work, the cube needs a set of point features that it can aggregate into space-time bins. Thus, we had to find the centroids of all of the zip codes. With each zip code centroid there is a count and timestamp associated with it. In addition, we are using

centroids because our goal was not to identify someone's personal address, but rather to look at all of the cases in that zip code.

When computing the output for these hotspots it was important to use smaller uniform bins. Using larger bin sizes meant that some bins would aggregate more zip codes centroids. For locations with several small zip codes within an area, large bin sizes would aggregate more zip code centroids, which would lead to those bins as having a larger count. Therefore, we made the bins small enough so that each bin did not have multiple clustered centroids.

Once we had calculated and produced maps for our emerging hotspot analysis, we were able to overlay our prevention point-data with our timeline of hospitalizations from heroin usage in order to see whether the prevention point-data represented an appropriate spot to areas that were being particularly ridden with heroin or opioid incidence.

These two major methodologies, then, led us to calculations that indicated correlations between opioid use and different socioeconomic variables, as well as hotspots of opioid use over the past 10 years overlaid with point-data representing prevention and outreach. We discuss the results in the next section further.

Results and Discussion

The hospitalization trend line (Figure 2.1) illustrates the steady climb of hospitalizations, which is what we expected given the onset of the heroin epidemic in Wisconsin since the early 2000's.

Figure 2.1: Hospitalization Trend Line, 2005-2014

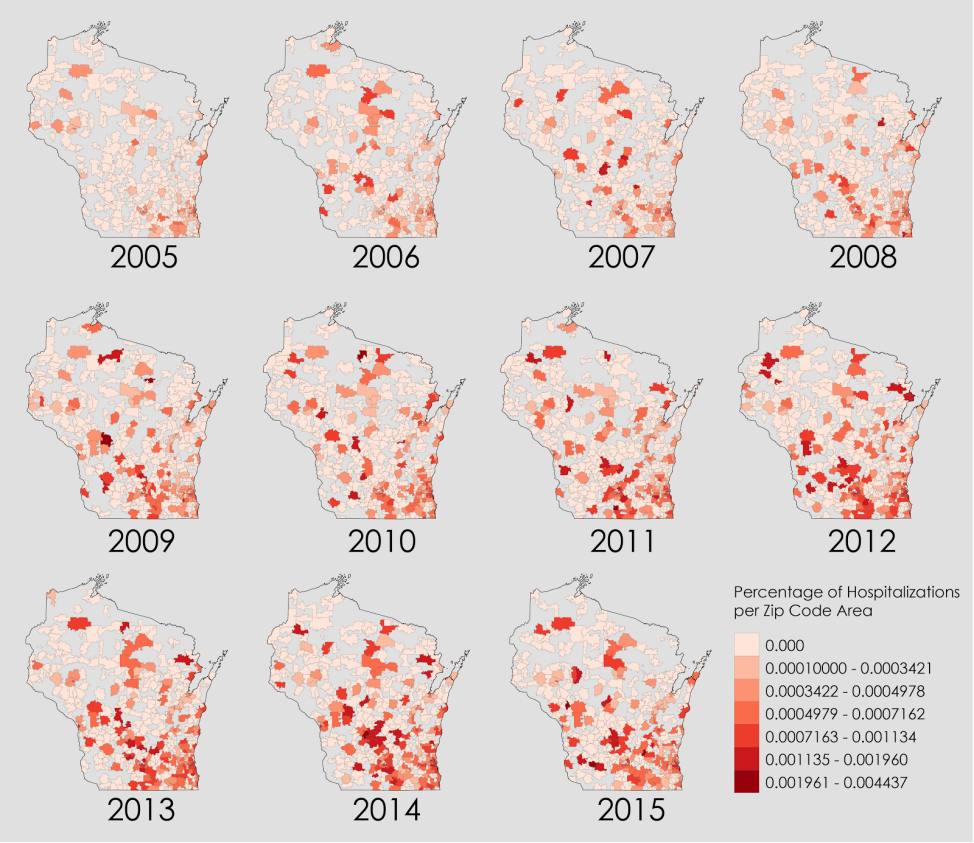
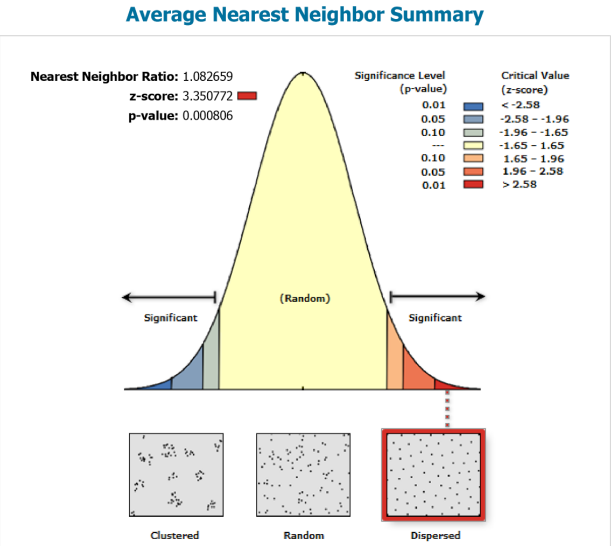


Figure 2.2: Heroin Hospitalization Time Series

In order to visually track the increase in opioid hospitalization increase, we normalized the data by population in each zip code and came up with a percentage of hospitalizations per population per zip code area. Then, using the same classification for each year, we made a time-sequence series of maps from 2005 - 2015 in order to illustrate where heroin and other opioid use was most severe (Figure 2.2, above). With this graphic a user can see where percentage of hospitalizations have rose substantially and where it has improved. However, we can see that the overall trend from 2005-2015 is that hospitalization from heroin use is climbing throughout the state.

To determine if there were clusters of people who had been hospitalized from heroin, we completed an average nearest neighbor statistic with our 2014 data. As a result, our z-score was 3.350772 with a p-value of .000806 (see Figure 2.3). From this statistic we can see that our zip code polygon level data has a significantly high dispersion level. While we can

see hotspots from our timeline, this statistic does not recognize the clustering of these high heroin usage areas. We might assume that because we lacked complete data for Wisconsin, the nearest neighbor statistic did not recognize any clustering.



Average Nearest Neighbor Summary

Observed Mean Distance:	10851.5542 Meters
Expected Mean Distance:	10023.0571 Meters
Nearest Neighbor Ratio:	1.082659
z-score:	3.350772
p-value:	0.000806

Figure 2.3 - Average Nearest Neighbor Summary

We also analyzed heroin hospitalization with the space time cube and the emerging hot spot analysis tools. The goal of these tools is to find areas within Wisconsin that have had people with high levels of heroin use from 2005-2015. Once we ran our data to make it the space time cube, we could analyze our results with the emerging hot spot analysis tool. This identifies the trends clustering of our point features over time and produces a raster map of areas that have hot spots over the years (Figure 2.4). As a result we can see that there are significant hot spot near the Madison (lower middle location), Milwaukee (lower right location), and some significant hot spot near Appleton/Green Bay Area (northeast corner)

(Figure 2.5). Based on the heroin hospitalization time series (Figure 2.2, above2.2), it is logical that those specific areas are highlighted because they have had consistent hospitalizations from 2005-2015.

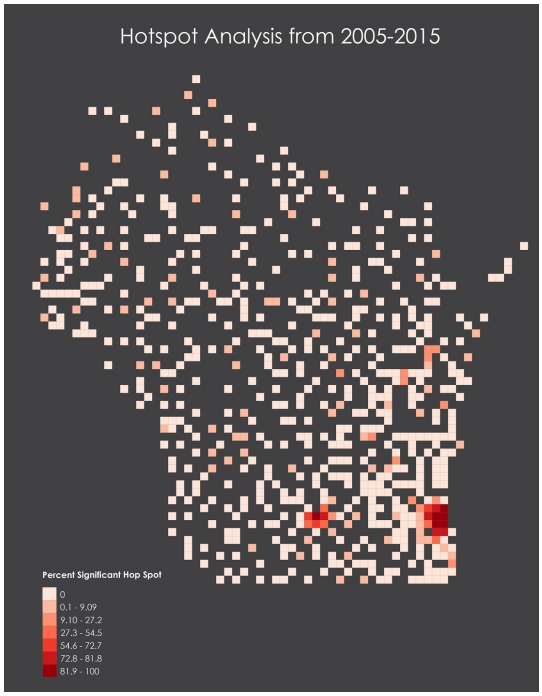


Figure 2.4 - Hot Spot Analysis

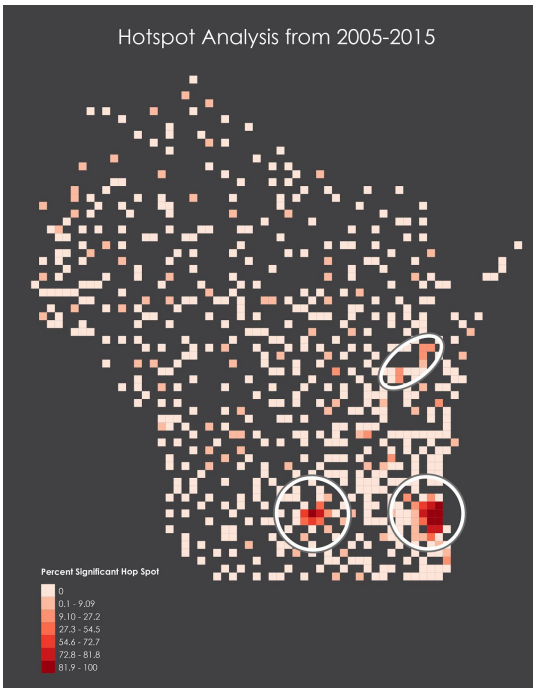


Figure 2.5 - Hot Spot Clusters

We also generated three maps to observe where our prevention locations overlapped with high areas of hospitalizations. Our first map looked at where opioid users can get medication as treatment throughout Wisconsin. When used properly, medications can help users manage addiction. Some of these medications can only be dispensed at licensed treatment centers, while others can be prescribed by doctors who have special approval. We created a shapefile from the addresses on their website and provided excel files. Our map (Figure 2.6) indicates that these locations are dispersed throughout Wisconsin. Currently these locations target more populated areas, and it would be beneficial to add additional treatment locations in the highly clustered hospitalization areas, especially north of Madison,

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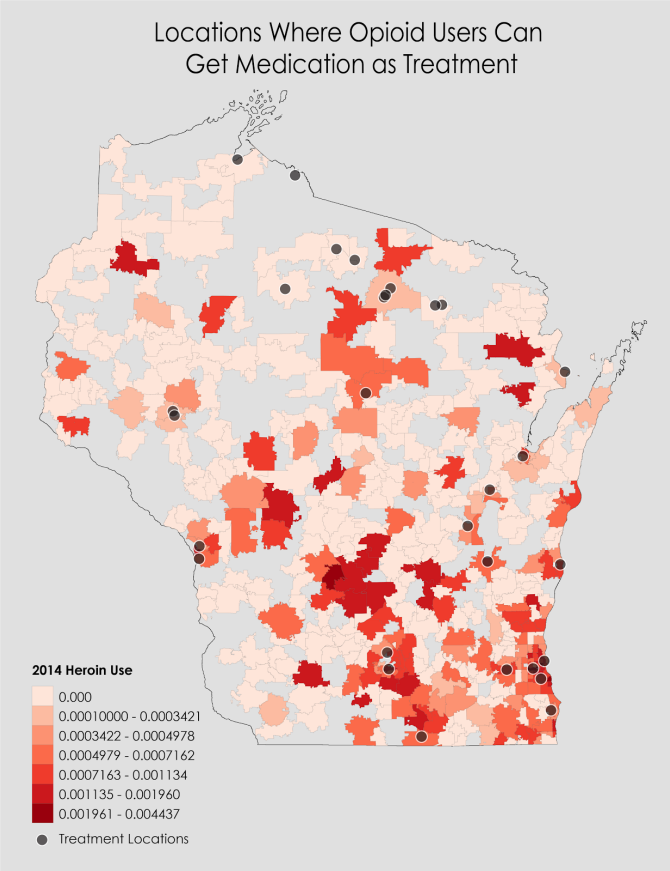

Figure 2.6 - Locations Where Opioid Users Can Get Medication

The second prevention shapefile layer contains places where the Department of Justice or the Division of Criminal Investigation have participated in community outreach events. These outreach events were in response to the launch of The Fly Effect prevention campaign that began in September of 2013. From this overlay (Figure 2.7) we can see that the Department of Justice has accomplished its goal of holding these events where there has been high rates of hospitalizations from heroin use. In addition, it looks as if they are targeting areas that have started to have increased use. Therefore, this is a good indicator that the Wisconsin Department of Justice is trying to educate about heroin use and effects before it starts getting even worse.

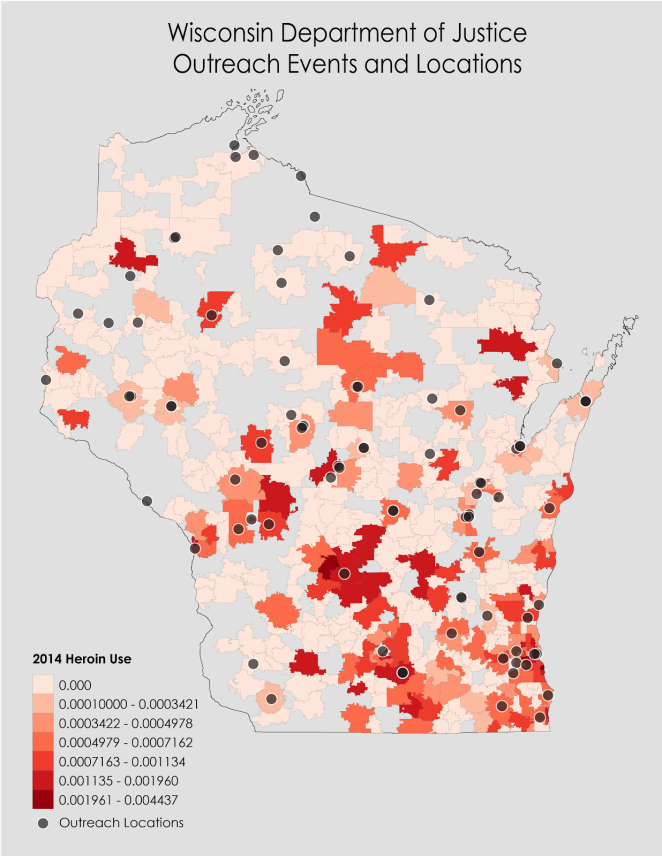

Figure 2.7 - Wisconsin Department of Justice Outreach Events and Locations

Lastly, we also looked at where Wisconsin Syringe Exchange Programs correlated geographically with heroin hospitalizations and found that they were mostly located in populated areas (Figure 2.8). We would suggest that Wisconsin consider expanding this program into more rural locations, but assume that there might not be the resources and funding to build these necessary programs.

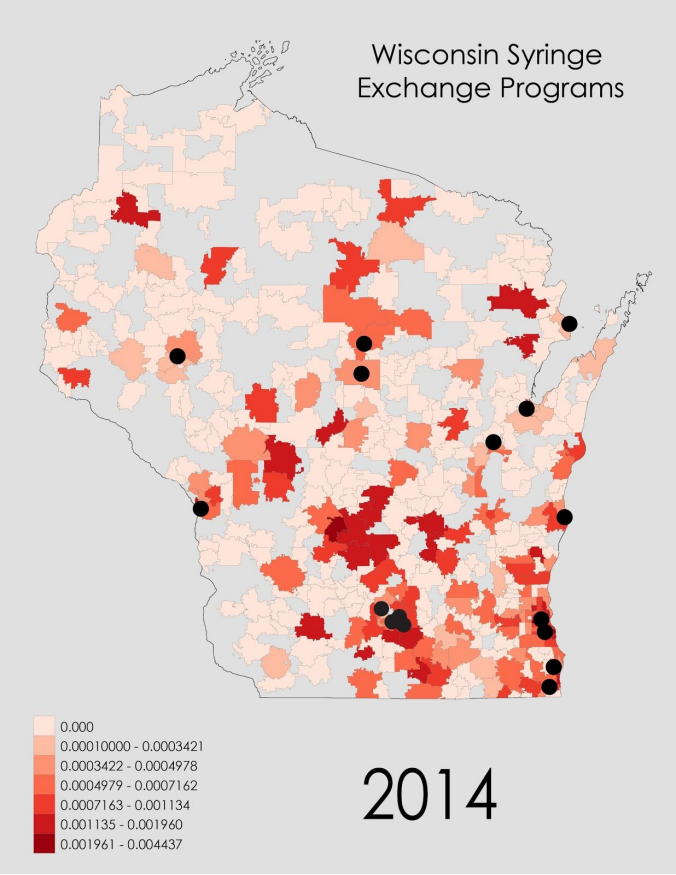

Figure 2.8 - Wisconsin Syringe Exchange Programs

Based off of Spearman's rank correlation, we explored the basic correlation between heroin and opioid hospitalizations and socioeconomic variables. Since the heroin epidemic is often said to have become a whiter, more suburban issue, we expected to see more of a correlation between whiter zip codes and opiate-related hospitalizations. However, we found that the opposite was true. Instead, we found a Spearman's rho of -0.44 at a significant p-value of <.0000005, which indicates that there is an inverse relationship between whiteness and opiate-related hospitalizations. There were clusters of high rates of opiate-related hospitalizations in less white areas, as well as high numbers in low incidents in more white areas, as shown in ranks (Figure 2.9).

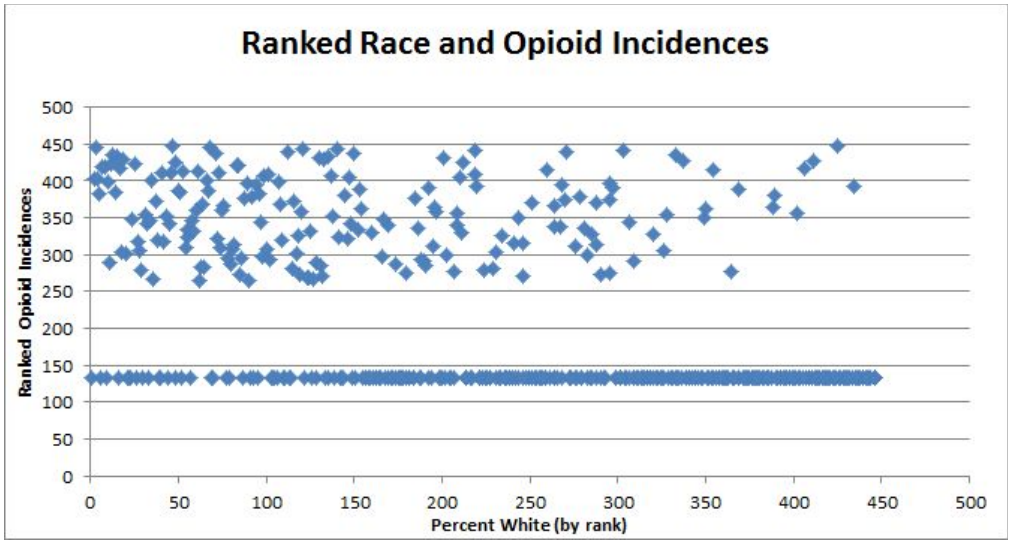

Figure 2.9 - Ranked Race and Ranked Opioid Hospitalizations

This might have been one of our most interesting findings, as it goes against what we anticipated and against the common narrative that heroin is impacts white people the most. It is worth considering whether the greater media coverage of heroin is because white people are more affected than ever before, while ignoring that minority populations are still impacted by it. Furthermore, this graph raises the question of why there would be more cases with high case-numbers for more diverse areas, but much more areas with high numbers of low counts.

For income, we found a Spearman's rho of 0.6878 with a significant p-value of <.000001, meaning that zip codes with higher income were correlated with zip codes of higher opioid-related hospitalizations. Our education analysis, however, yielded insignificant results with a Spearman's rho of <-.0473 and a highly insignificant p-value of 0.31785. Thus, we cannot make any conclusions based on our education analysis.

Overall, we had some results that we expected, such as higher income and ages 24-39 having a positive correlation with heroin other opioid hospitalization, but we also had some results we did not expect, such as heroin being associated with less white zip code areas.

Conclusion

When beginning this project, we knew that there was a rise in heroin use and we had an inkling of what its relationship might be with variables such as race, education, income, gender, and age. Based on our initial research, we expected to find that there had been an increase in opioid-related hospitalizations, that the hospitalizations are positively correlated with whiter, more educated, and more wealthy areas, as well as positively correlated with zip code areas with greater-than-average populations in their late teens and twenties. Our results, however, only confirmed some of these expectations; heroin hospitalization's positive correlation with income was confirmed, but while we expected it to also be positively correlated with whiter areas, we found instead a strong positive correlation with zip code areas with higher racial diversity. As expected, we did see a steady climb in opioid-related hospitalizations in the time period between 2005 and the first 9 months of 2015, as well as a positive correlation between the age cohorts of late teens/twenty-somethings.

Future Research

Some of our findings raise interesting questions that could be explored further. For instance, is the positive correlation of heroin hospitalizations with income a result of higher-income areas being more likely to seek hospitalization in the first place? Is the greater number of high-count cases associated with racial diversity and the greater number of low-count cases associated with "whiter" areas only indicative whiter areas generally being rural, and therefore with lower counts? If we were to continue research on this topic, we would explore these questions in greater depth.

In addition, we could do a more thorough analysis of the relationship of these heroin hospitalization clusters to urban and rural areas. We could do this in several ways. First of all, if our data were more complete, we would be able to conduct an analysis that had less of a skew towards heroin and opioid use in urban areas. We also could have looked at urban areas in other states that lie near rural areas of Wisconsin, such as Minneapolis and Chicago.

It would also be beneficial to find more a more detailed dataset for heroin hospitalizations in Wisconsin. Because of confidentiality, we only received counts of hospitalizations in each zip code area with a lot of masking. If it were possible, it would be

beneficial to have information about each patient who was hospitalized in order to do more regression statistics and see if there are correlations between heroin hospitalizations and specific demographic and socioeconomic variables.

Citations

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