Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 2, 2024
A Regional Conference of the Society for Industrial and Systems Engineering

Analyzing Health Care Market Capacity Using Spatiotemporal Analysis and Weighted Population Demographics

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Author Notes: The members of this team are all Cadets at the United States Military Academy at West Point pursuing their Bachelor of Science degrees from the Systems Engineering Department of USMA. This paper is the culmination of a yearlong project focused on utilizing the Systems Engineering Decision Process to tackle a real-world problem. After graduation on May 25, 2024, the members of this team will commission as Lieutenants in the Army and serve in their respective branches. The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: This article proposes a new methodology for analyzing patient populations and geographic marketability in healthcare sales. By leveraging the Analytical Hierarchy Process (AHP) and modern technology, it introduces the concept of the Patient Demographic Cadet Score to assess the need for medical products across segmented regions. This methodology, developed through a systematic process of data collection, cleaning, and analysis, provides sales forces with actionable insights to allocate resources effectively. Utilizing ArcGIS, a geographic information system used for cartography, this article demonstrates how geographical mapping enhances decision-making for sales and marketing teams. The approach addresses the current opportunities in pharmaceutical distribution, mainly focusing on anticoagulant medications. With its potential for broader applications beyond medical sales, this innovative framework offers a promising avenue for businesses to optimize sales strategies and enhance market penetration, fostering the future of healthcare sales.

Keywords: Analytic Hierarchy Process, Anticoagulant Medication, Spatiotemporal Analysis, Healthcare sales and marketing

1. Introduction

Medical sales encompass a broad spectrum of products, including medical equipment, medications, and devices. Medical sales representatives engage with healthcare providers and physicians to discuss the supplies needed for their facilities and patients. This sales and marketing structure differs from selling recreational products, services, or foods directly to consumers due to physicians' pivotal role in deciding which medications or medical solutions to prescribe to patients. Medical sales representatives may work by following their employer's directions of who and where to sell, but often, they arrange their own field and find their leads. Within these discussions with current or potential physician clients, representatives may give persuasive presentations or empathetic conversations about the products they can supply or their needs and how they can help meet those. Representatives are tasked with understanding the unique requirements of each physician's clientele to tailor their sales pitches, considering the needs of the patients as well (Indeed, 2024).

Sales and marketing teams within the health industry will follow leads dependent on many factors, including prominent patient profiles that specific physicians may be serving in their proximate communities. Every medicinal solution, whether medication or service, accommodates a specified medical illness or injury. These illnesses and injuries are recognized by symptoms, also known as patient identifiers. For a sales and marketing team, understanding where the patients anticipating a need for their health product are located is a significant means to achieving new leads and sales. The location of potential patients and patient identifiers will provide knowledge of the economic demand for a specified health solution being sold. Ensuring sales and marketing teams are equipped with this knowledge, the prominence of patient identifiers relative to targeted physicians enables them to make data-driven decisions and optimize resources and efforts effectively.

Furthermore, leveraging modern technology, such as ArcGIS, will help visualize this understanding of patient populations and streamline the decision-making processes. This research paper proposes a proof of concept of integrating this

process into medication sales and marketing methodologies and how this may be done within the scope of medication sales and marketing methodologies.

The article, Top-Selling Prescription Drugs by Revenue (Pharmaceutical Technology, 2023), has identified a gap in anticoagulant pharmaceutical sales to physicians through discussion and analysis of the healthcare industry, including publications. This paper proposes a novel method to address and close this gap by implementing spatiotemporal analysis and geographical visualization of patient populations. The spatiotemporal analysis studies quantifiable variables with geographic locators and their relation to time (Columbia Ed. Team, n.d.). The authors (Meliker et al., 2011) reviewed the evolving field of spatiotemporal epidemiology, focusing on critical domains offering insights into dynamic maps. The Authors (Byun et al., 2021) utilized spatiotemporal analysis in public health by recognizing the need in their country, Korea, for small-area analysis and its relation to point data for preventing and controlling infectious and chronic diseases. (Shukla et al. 2023) Proposed a model leveraging cloud computing and parallel processing to identify complex patterns like patient migration and illness propagation, offering valuable insights for healthcare and policy and underscoring the need for continued exploration in this interdisciplinary field.

The authors of this paper propose a similar approach of analysis in small areas of the population in relation to point data to examine potential Cardiovascular Disease patients in the vicinity of relevant providers in specialties of interest. The end goal of this methodology is to provide sales and marketing teams with a tool that illustrates the spatial relationships between patients requiring anticoagulants and physicians. Importantly, it will enable sales and marketing teams to assess the marketability and access of their drug within specific regions based on patient population metrics. The paper outlines identifying patient identifiers, collecting relevant data, employing a multi-criteria approach to evaluate market spaces, visualizing patient populations geographically, and delivering a dashboard to sales and marketing teams.

2. Methodology

2.1 Patient Identifiers

To initiate this approach, one will utilize stakeholder analysis and research to determine which patient identifiers are relevant to their mission. Patients with conditions or characteristics predisposing them to blood clot formation are primarily prescribed anticoagulant drugs. Confined by readily available data, this paper exclusively utilizes the following ten patient identifiers to fulfill this proof of concept: years of age, diabetes, market share, coronary artery disease (CAD), obesity, African American population proportion, population density, and income. These patient identifiers cite the following research work for them (AHA, n.d.) (Levine, 2011) (Kim et al., 2021). To highlight the increasing need for anticoagulants among aging populations, the authors segmented the population statistics into age brackets: 30 to 49, 50 to 59, and older than 60.

The model construction involves gathering data for every zip code, region, district, or chosen territory size and statistics for each patient identifier relevant to the population in each location. Each dataset row represents a unique zip code or entity called a record. Each column represents a unique patient identifier, also known as a field.

2.2 Anticoagulant Patient

This model offers the user the choice of visualizing the prevalence of each patient identifier individually or utilizing the Analytic Hierarchy Process (AHP), which will help develop a globalized value that accounts for all patient identifiers within each zip code. The AHP enables decision-makers to evaluate regions on multiple criteria simultaneously in relation to physicians. This process produces the Anticoagulant Patient Demographic Cadet Score for each zip code, numerically assigning a marketability score for sales and marketing teams to determine where to sell their product (Saaty, 1994). This knowledge enables sales and marketing teams to identify high-demand areas for their medication. The score can also be used in conjunction with the locations of physicians to streamline the decision-making process of where physicians are to target and sell their medication.

The use of the AHP to develop the anticoagulant patient demographic cadet score for each zip code follows four steps. First, build an empty matrix where the rows and columns represent the value measures. Second, a pairwise comparison of the value measures is performed against each other to assess their relative importance. Third, normalize the relative comparison matrix. Lastly, estimate the value measures global weights.

The first step of building a value matrix begins by identifying value measures for a given system. A value measure is a quantitative or qualitative assessment of the system's importance or worth of different variables. The model's value measures were broken down into the following variables: age, diabetes rate, CAD rate, obesity rate, population density, African American population proportion, and income. Furthermore, the age was segmented into the following ranges: 30 to 49, 50 to 59, and

above 60 years of age, as a weighted value measure that carries different weights according to the research and stakeholder analysis.

The second step is to compare each variable against each other and determine their relative importance on a scale of 0 to 4 from the constructive scale, as presented in Table 1. For instance, during the analysis, the authors found that the variable "diabetes rate" significantly outweighed "market share" concerning marketability considerations, resulting in a score of 4 for "diabetes" versus "market share." Conversely, when comparing "market share" to "diabetes," the score was determined to be 0.25. These comparative rankings were established based on comprehensive research, stakeholder analysis, and extensive client discussions. The authors presented each variable on a case-by-case basis, in which the clients responded with how important that variable is to overall drug marketability. The resultant matrix is shown in Table 1 below. These scores are adjustable to the market and client needs.

Table 1. Pairwise Comparison Using AHP.

		AGE									
		Market Share	60+	30-49	50-59	Diabetes Rate	CAD Rate	Obesity	Population	Race (AA)	Income
	Market Share	1	0.25	1	2	0.25	0.5	1	1	3	1
	60+	4	1	0.333	0.5	0.25	0.25	0.333	0.333	1	0.333
AGE	30-49	1	3	1	2	0.25	0.5	1	1	3	1
	50-59	0.5	2	0.5	1	0.25	0.333	0.5	0.5	2	0.5
	Diabetes Rate	4	4	4	4	1	3	4	4	4	4
	CAD Rate	2	4	2	3	0.333	1	2	2	4	2
	Obesity	1	3	1	2	0.25	0.5	1	1	3	1
	Population	1	3	1	2	0.25	0.5	1	1	3	1
	Race (AA)	0.333	1	0.333	0.5	0.25	0.25	0.333	0.333	1	0.333
	Income	1	3	1	2	0.25	0.5	1	1	3	1
	SUM	15.833	24.25	12.167	19	3.333	7.333	12.167	12.167	27	12.167

Comparison Score	Importance To Marketability
0.25	50 + less
0.333	30 to 40 less
0.5	10 to 20 less
1	Same
2	10 to 20 more
3	30 to 40 more
4	50 + more
	Do Not Change

Subsequently, in step three, a normalization process was conducted by dividing each variable's individual comparison score by the sum of scores attributed to that variable. This normalization process turns the relative comparison matrix into an objective weight for that variable. The normalization process is applied to each variable within the matrix, the objective score for each variable is identified, and the sum will always be one. The resulting normalized values are illustrated in Table 2 below.

Table 2. Normalized Values per Variable for Anticoagulant Patient Populations.

		AGE								
	Market Share	60+	30-49	50-59	Diabetes Rate	CAD Rate	Obesity	Population	Race (AA)	Income	Global Weights Sum
Global Weights	0.0762	0.0576	0.0875	0.0526	0.2800	0.1491	0.0875	0.0875	0.0344	0.0875	1.000

Lastly, Using these normalized values of each variable, the authors in this paper developed a quantitative function to determine the Anticoagulant Patient Demographic Cadet Score for each zip code, as shown in Equation 2. This was derived from applying Equation 1, which shows the Additive Value Model.

(1)

$$\begin{aligned} Cadet\ Score = {} & 0.0762 * Market\ Share + 0.0576 * Ages\ Over\ 60 + 0.0875 * Ages\ 30\ to\ 49 + 0.0526 * \\ & Ages\ 50\ to\ 59 + 0.28 * Diabetes\ Rate + 0.1491 * CAD\ Rate + 0.0875 * Obesity\ Rate + 0.0875 * \\ & Population\ Density + 0.0344 * African\ American\ Population\ Proportion + 0.0875 * Income\ Level \end{aligned} \quad (2)$$

From Equation 2, a new data set was formed listing the Anticoagulant Patient Demographic Cadet Score for each zip code that translated each entity's anticoagulant marketability (Saaty et al., 1994).

2.3 Process Framework

The model framework can be understood in three steps: inputs, calculations, and outputs. Our model's inputs include zip code shape files, online zip code population data, and client-provided data sources. Client-provided data sources are used to analyze niche realms of the healthcare industry better and focus on specific fields. This data is manually cleaned and consolidated into a compiled dataset. The model then transitions from inputs to calculations. The compiled data set includes a list of 8 variables provided in Figure 1. Using the AHP explained in section 2.2, a score is generated. Combining the compiled dataset and the Cadet Demographic Score is inputted into the ArcGIS software, which links the data to each zip code. Combining the zip code shapefile, join feature, geocode address tool, and natural breaks statistical tool develops a map with the shape of states and zip codes with a gradient score displayed over the map, which is layered with provider types and their institution's location. The ArcGIS modeling process is designed in ArcGIS Pro. This visual map and feature layers are uploaded to ArcGIS Online for cloud sourcing and publishing. ArcGIS Online is then used to create a dashboard to import the already-developed feature layers and maps. The dashboard allows the user to manipulate the visual output by selecting fields and areas of interest. The dashboard will match the criteria and display automated data analytics for the user, such as pie charts, histograms, and top performers. These widgets, paired with the map visualization, provide the user with a holistic viewpoint in the pursuit of better spatiotemporal analysis.

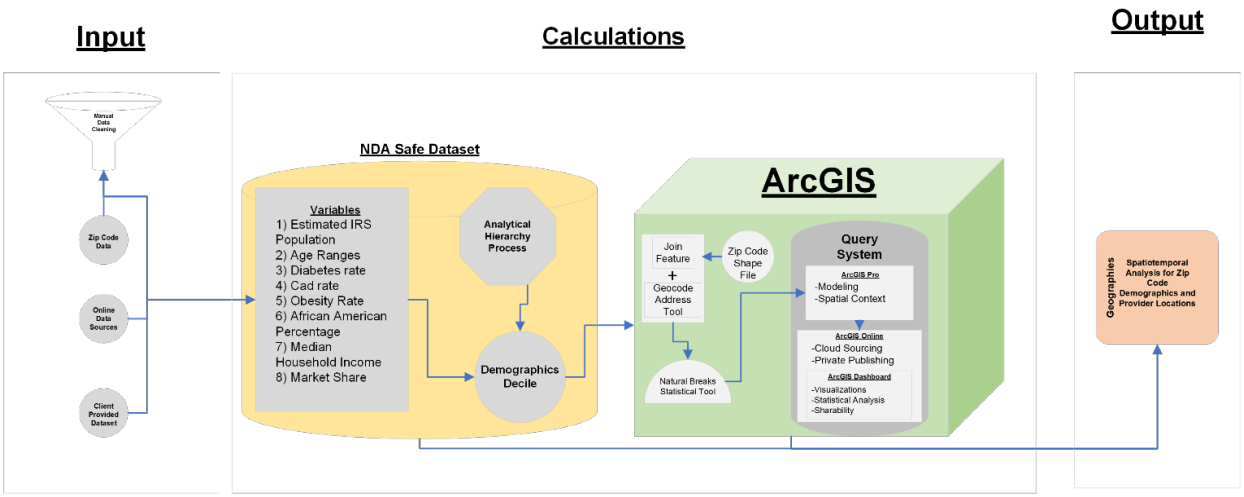

Figure 1. Proposed Process Framework Model.

3. Visualization

3.1 Demographic Cadet Score Visualization

ArcGIS is a visualization tool to aid in visualizing data by location. Developed by the Environmental Systems Research Institute, ArcGIS is a widely used software by governments, urban planners, environmental agencies, and industrial companies. The software has a plethora of capabilities, including data management, data analysis, and, most prominently, cartography. Utilizing its ability to develop interactive maps from imported data, decision-makers can visualize locational affiliations of prominent markets. For these capabilities, ArcGIS was chosen to exemplify this proof of concept.

To begin building the model in ArcGIS, one will input the final data set of each zip codes Anticoagulant Patient Demographic Cadet Score. Simultaneously, a shape file of all zip codes within the United States is uploaded from GIS Living Atlas public data ("ArcGIS Living Atlas of the World.", 2024). A shapefile, which stores geometric locations and attribute information of geographic features, is used to spatially describe the vector statistics of the Anticoagulant Patient Demographic Cadet Scores. These files are combined using a feature layer, which is a spatial dataset representing geographic features and associated attributes. A shape file provides an area, or conceptually, a 'shape' to store discrete data as points, lines, or polygons on a geographical landscape. It will be used to spatially describe each entity's vector or discrete data statistics for the Anticoagulant Patient Demographic Cadet Scores (Esri, n.d.). The feature layer effectively links the discrete Demographic

Statistics dataset, specifically the Cadet Score corresponding to each zip code, with the respective shape of those zip codes mapped across the United States. This can be seen in Figure 2 below, which shows an example of the Dallas, Texas area.

3.2 Outputs from ArcGIS

This visualization approach of the Cadet Scores calculated facilitates the identification of regions where there is both a demand for anticoagulant medication and a likelihood of a provider's prescriptions. It assists in targeted medication distribution and helps identify provider types requiring guidance in prescribing drugs. This model displays the development of the Patient Demographic Cadet Score using color-filled zip code boundaries, where each color represents the relative score of the zip code compared to others in the United States.

ArcGIS offers advanced tools enabling users to enhance their understanding of geographical statistics. As shown in Figure 2, this system employs a gradient to shade each zip code based on the associated numerical strength of the Cadet Scores. All null values were depicted as zero fill. The underlying map features the topography of the United States, including cities, roads, and buildings. One can plot the point locations of physicians to better equip sales and marketing team members with the necessary tools for lead generation. Since medical sales teams target physicians who prescribe the anticoagulation medication they aim to sell, the authors plotted the individual vector points of physicians.

Moreover, ArcGIS allows users to select one or more specialty types manually. The user may plot each specialty using a different shape, color, or pattern for deeper understanding and analysis. These adjustments are exemplified in Figure 2 below, where provider types have different plotted shapes. Finally, if the marketability of each physician is known, these vector points can be adjusted using a color scale to represent the numerical marketability values more clearly. Figure 2 breaks the marketability into 3 rating classes.

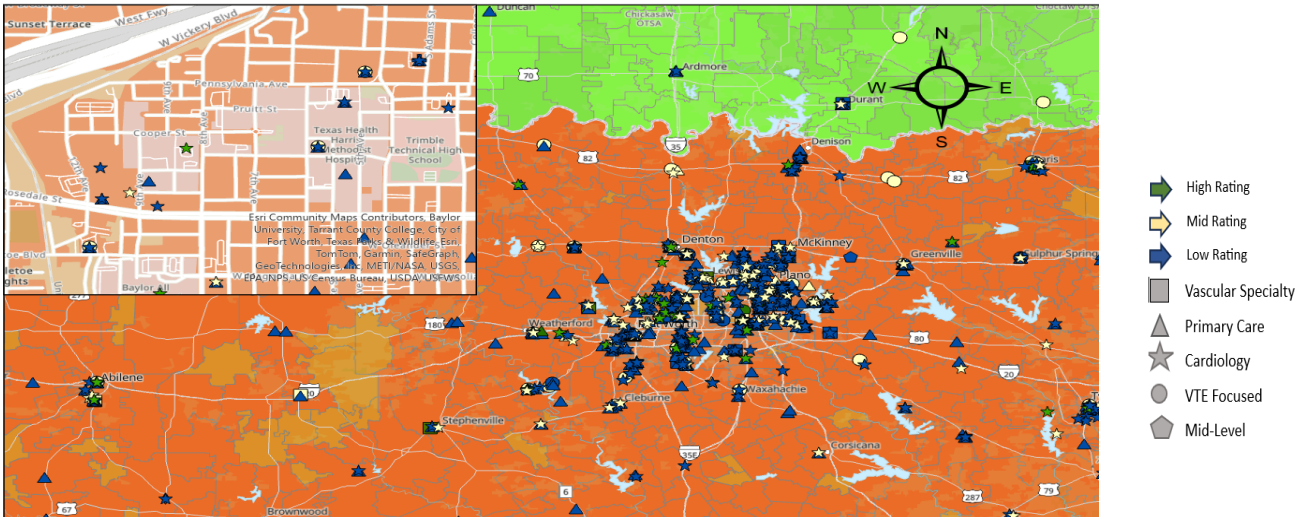

Figure 2. Vector Points Representing Providers Within Anticoagulant Market Space.

3.3 Implementation

A medical sales and marketing representative can employ these tools in several decision-making steps: first, identifying zip codes with high patient demographic scores for targeted focus; next, determining the relevant specialty fields of interest; and finally, analyzing the visual overlap between high-scoring zip codes and areas densely populated with providers in the selected specialty field with high ratings. The multi-criteria score will enable them to replace the prediction of where populations of interest may occur with an accurate depiction of the population's statistically found needs, considering multiple patient identifiers simultaneously in relation to accessible physicians and hospitals.

ISBN: 97819384962-4-0

4. Conclusion

In conclusion, this research underscores the pivotal role of medical sales representatives in bridging the gap between healthcare providers and patients needing medical supplies. Through understanding the needs of physicians and their clientele, sales and marketing teams can tailor their strategies to meet patient demands effectively. The proposed methodology offers a unique approach to optimizing sales efforts and addressing challenges in medical sales. By leveraging modern technology and a multi-criterion approach to decision-making, sales and marketing teams can be better equipped to navigate the healthcare industry and improve patient access to essential medications.

Nevertheless, incomplete data and missing values in the model's inputs limit this proof of concept. The data was formulated from a proxy client and publicly published online resources. To strengthen the model in future trials, holistic data sets provided for each patient identifier related to the focused medication is imperative.

Follow-up research and the use of this process may be expanded to fields outside of medical sales and into the broader sales industry to identify the prevalence of the client population. Additionally, small and large businesses continue to recognize ArcGIS as a crucial analytical tool for various purposes, including site selection, market analysis, and customer profiling. This integration proposes an opportunity to reduce uncertainty in decision-making and optimize geo-marketing strategies for identifying and capitalizing on market opportunities across all industry genres.

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