Human-Centered Data Science Analysis: Exploring the Impact of Wildfire Smoke on McMinnville City

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# Introduction

## Context and Significance

The analysis of wildfire smoke impact on McMinnville City is both intriguing and crucial, driven by the intersection of environmental challenges, human well-being, and economic resilience. This investigation is propelled by the increasing frequency and severity of wildfires, a consequence of climate change.

## Key Questions

The pressing question at the core of this analysis is how McMinnville City, nestled in the heart of Oregon, is affected by wildfire smoke and, more critically, how this impact extends to both its business sector and healthcare infrastructure.

## Motivation

The motivation behind this analysis is deeply rooted in the recognition of the multifaceted consequences of wildfire smoke, extending beyond immediate health concerns to encompass economic and healthcare domains.

## Unique Contribution

While existing research has predominantly focused on environmental and health aspects, the unique approach of this study lies in its holistic examination of the impact on registered businesses and healthcare facilities. By doing so, it aims to address a critical knowledge gap and provide actionable insights for local stakeholders.

## Real-World Implications

This analysis is not merely an academic exercise; it tackles real-world problems faced by McMinnville City and offers a lens through which the community can understand, adapt, and plan for the evolving challenges brought about by wildfires.

## Unresolved Research Question

The unresolved research question driving this analysis is the nuanced understanding of how businesses and healthcare services respond to and cope with the recurrent threat of wildfire smoke.

## Broader Contribution

By delving into this question, we aim to contribute to the broader discourse on climate change adaptation strategies for communities, particularly in regions susceptible to wildfires.

## Policy and Decision-Making

The importance of this analysis is underscored by the potential impact on policy-making, urban planning, and community resilience. As wildfires become a regular occurrence, the ability to anticipate, mitigate, and adapt to their consequences is paramount.

## Stakeholder Empowerment

The findings of this study can empower local authorities, including the city council, city manager/mayor, and residents, to make informed decisions and formulate strategies that enhance the city's preparedness for future wildfire events.

## Proactive Community Resilience

In essence, this analysis serves as a proactive tool for community resilience in the face of an escalating environmental challenge.

# Background/Related Work

## Previous Research on Wildfire Smoke Impact

Research into the impact of wildfire smoke spans multiple domains, primarily focusing on environmental, health, and economic aspects. Numerous studies have investigated the intricate relationship between wildfires and the well-being of ecosystems and communities. Some key findings from related work include:

1. Environmental Studies:

* Investigations into air quality during and after wildfire events have been instrumental in understanding the dispersion patterns of particulate matter and pollutants.
* Ecological studies have explored the long-term effects of smoke on vegetation, soil, and wildlife, providing insights into ecosystem recovery.

1. Health Impacts:

* Extensive research has been conducted on the health effects of wildfire smoke exposure. Studies commonly link increased particulate matter concentrations to respiratory and cardiovascular issues.
* Vulnerable populations, such as the elderly and individuals with pre-existing health conditions, are identified as more susceptible to adverse health outcomes.

1. Economic Consequences:
2. Economic analyses have investigated the financial toll of wildfires on communities, including property damage, loss of revenue for local businesses, and increased healthcare costs.
3. The interplay between environmental factors, health outcomes, and economic stability remains a complex area of study.

## Hypotheses and Research Questions

1. Business Sector:

* Hypothesis: Businesses in McMinnville City experience fluctuations in registration and activity corresponding to periods of wildfire smoke impact.
* Research Questions:
  + How does wildfire smoke impact the growth and stability of registered businesses in McMinnville City?
  + What trends are observed in business activities during and after periods of heightened smoke impact?

1. Healthcare Sector:

* Hypothesis: There is a correlation between increased wildfire smoke and changes in healthcare metrics, with potential implications for resource allocation and patient care.
* Research Questions:
  + What correlations exist between wildfire smoke exposure and healthcare metrics, including hospitalizations, available beds, and revenue?
  + How can healthcare facilities adapt to mitigate the challenges posed by wildfire smoke?

## Consideration of Existing Models

During the development of Course Project - Part 2, we explored existing models related to smoke estimation and prediction. Several considerations influenced our choice of models:

1. Prophet Library:
   * The Prophet library was selected for its adaptability to time series forecasting, making it suitable for predicting future smoke estimates in McMinnville City.
   * Its ability to handle missing data, outliers, and seasonal trends aligns with the characteristics of our wildfire smoke dataset.
2. Statistical and Machine Learning Models:

* Various statistical and machine learning models were evaluated for their applicability to smoke impact estimation. The choice of Prophet was driven by its balance between simplicity and performance.

## Datasets Used for Extension

1. Oregon Health Authority Hospital Reporting:

* Source: Oregon Health Authority Hospital Reporting
* Link: https://www.oregon.gov/oha/hpa/analytics/pages/hospital-reporting.aspx
* Summary: The dataset from the Oregon Health Authority includes valuable health care information, such as hospitalizations, available beds, and hospital revenue. These metrics are essential for evaluating the potential impacts of wildfire smoke on the health care system in McMinnville.
* License/Terms of Use: The dataset is hosted on the Oregon state government's data portal. The datasets are publicly available and can be used for research and analysis. <https://www.tylertech.com/terms>

1. Business Registration Data:

* Source: Oregon Active Businesses
* Link: https://data.oregon.gov/business/Active-Businesses-ALL/tckn-sxa6
* Description: This dataset contains information about active businesses in Oregon, including McMinnville. It includes details such as the name of the business, location, industry, and registration date. Analyzing this data provides insights into the economic landscape, business trends, and potential vulnerabilities of the local economy to external factors like wildfire events.
* License/Terms of Use: The dataset is available on the Oregon Data website and follows the licensing terms provided, ensuring responsible and ethical use of the data. <https://www.tylertech.com/terms>

# Methodology

The methodology employed in this project encompasses not only analytical techniques but also a comprehensive consideration of human-centered aspects, ethics, and the rationale behind method selection.

## Data Extraction and Processing

* Analytical Methods:
  + Utilized Python modules for data extraction from the Combined Wildland Fire Datasets for the United States and territories, spanning the 1800s to the present.
  + Employed data processing techniques to refine and organize the extracted data for further analysis.
* Human-Centered Considerations:
  + Ensured the use of open data sources to promote transparency and accessibility.
  + Prioritized datasets with comprehensive historical records to provide a thorough understanding of wildfire patterns over time.
  + Considered the ethical implications of working with fire and health-related data, emphasizing privacy and responsible data use.

## Data Filtering and Preprocessing

* Analytical Methods:
  + Applied Python filtering techniques to isolate fire perimeters within 1250 miles of McMinnville City.
  + Conducted data preprocessing to enhance the relevance and accuracy of the fire data for subsequent analysis.
* Human-Centered Considerations:
  + Focused on proximity to McMinnville City to align the analysis with the local context, ensuring the findings are directly applicable to the community.
  + Prioritized data quality and accuracy to avoid potential misinformation that could impact decision-making for both the community and policymakers.

## Smoke Estimation Process

* Analytical Methods:
  + Developed a sophisticated smoke estimation process that calculated and normalized the smoke impact of each fire event based on predefined parameters.
  + Correlated estimated smoke impacts with available Air Quality Index (AQI) data.
* Human-Centered Considerations:
  + Incorporated normalization techniques to provide a fair comparison of smoke impacts across different events, ensuring equitable representation in the analysis.
  + Considered the potential psychological impact of presenting smoke impact data, aiming for clarity and accessibility in visualizations to facilitate community understanding.

## Correlation Analysis

* Analytical Methods:
  + Employed statistical methods to explore the relationship between estimated smoke impacts and AQI data.
  + Used visualizations to communicate complex correlations effectively.
* Human-Centered Considerations:
  + Ensured the use of easily interpretable visualizations to cater to a diverse audience, including community members and policymakers.
  + Strived for transparency in presenting correlation results, acknowledging uncertainties and limitations to foster trust in the findings.

## Predictive Model

* Analytical Methods:
  + Leveraged the Prophet library to create a predictive model for future smoke estimates in McMinnville City.
  + Enabled the projection of potential smoke impacts over the next 25 years.
* Human-Centered Considerations:
  + Acknowledged the predictive model's potential impact on future decision-making and prioritized transparency in communicating uncertainties associated with predictions.
  + Considered the temporal aspect of the predictions to empower local authorities with foresight in planning and resource allocation.

## Data Visualization

* Analytical Methods:
  + Utilized various time series graphs and histograms to visually represent the results of data analysis.
* Human-Centered Considerations:
  + Designed visualizations with a focus on clarity and accessibility, ensuring that community members and policymakers can easily interpret and derive insights from the presented data.
  + Considered the potential emotional impact of visualizing smoke impact data, adopting a user-centric approach to mitigate any negative reactions.
* Ethical Considerations
  + Prioritized privacy and data security throughout the project, ensuring that individual-level health and business data were handled responsibly.
  + Acknowledged the potential societal impact of presenting smoke impact findings and approached the communication of results with sensitivity.
  + Committed to transparent reporting, providing clear explanations of methodologies, assumptions, and limitations to foster trust among stakeholders.

## Extension Plan: Business Impact

* Analytical Methods:
  + Utilized historical business registration data to identify trends and correlations with wildfire smoke exposure.
  + Employed statistical analysis to assess the impact of smoke exposure on the number of businesses registered each year.
  + Conducted a predictive analysis to anticipate future business registrations in the context of changing smoke patterns.
* Human-Centered Considerations:
  + Prioritized business resilience and adaptation in the face of wildfire smoke, aiming to provide actionable insights for local businesses.
  + Considered the potential economic implications of smoke exposure, aligning the analysis with the interests of local entrepreneurs and policymakers.

## Extension Plan: Healthcare Impact

* Analytical Methods:
  + Leveraged healthcare data to analyze hospitalizations, available beds, and revenue trends in relation to wildfire smoke exposure.
  + Applied statistical techniques to identify correlations between healthcare metrics and smoke impact.
  + Developed predictive models to estimate future healthcare resource needs based on anticipated smoke patterns.
* Human-Centered Considerations:
  + Emphasized the importance of healthcare system preparedness and resilience in the face of increased wildfire activity.
  + Considered the potential health implications of prolonged smoke exposure, directing the analysis towards supporting informed decision-making by healthcare professionals and policymakers.

In summary, the project methodology not only focuses on robust analytical methods but also places a strong emphasis on human-centered considerations, ethics, and transparency. The extension plan incorporates specific analyses for business and healthcare impacts, addressing the unique challenges and opportunities posed by wildfire smoke exposure in these domains.

# Findings

## Wildfire Smoke Estimator

The Wildfire Smoke Estimator revealed compelling insights into the impact of wildfires on McMinnville City. The analysis spans the period from 2000 to 2019, capturing the evolving dynamics of wildfire smoke. Key findings include:

1. Temporal Trends:
   * The analysis unveiled distinct temporal trends in wildfire smoke, with notable variations in intensity across different years.
   * Peak smoke events were identified, indicating specific periods of heightened smoke impact.
2. Geospatial Patterns:
   * Geospatial mapping illustrated the dispersion of wildfire smoke, emphasizing areas within 1250 miles of McMinnville City that experienced substantial smoke concentrations.
   * This information is crucial for emergency preparedness and response planning.

A graph of a number of fires

Description automatically generated

1. Correlation with Air Quality:
   * Correlating smoke estimates with Air Quality Index (AQI) data revealed a significant relationship between increased smoke impact and degraded air quality.
   * High smoke concentrations correlated with elevated AQI levels, posing potential health risks to residents.

A graph of a fire smoke

Description automatically generated

1. Prophet Model Predictions:
   * Utilizing the Prophet library, we developed a predictive model for future smoke estimates.
   * The model projections indicate an escalating trend in smoke impact over the next 25 years, emphasizing the urgency of proactive measures.

A graph showing the growth of smoke

Description automatically generated

## Extension Plan: Businesses and Healthcare

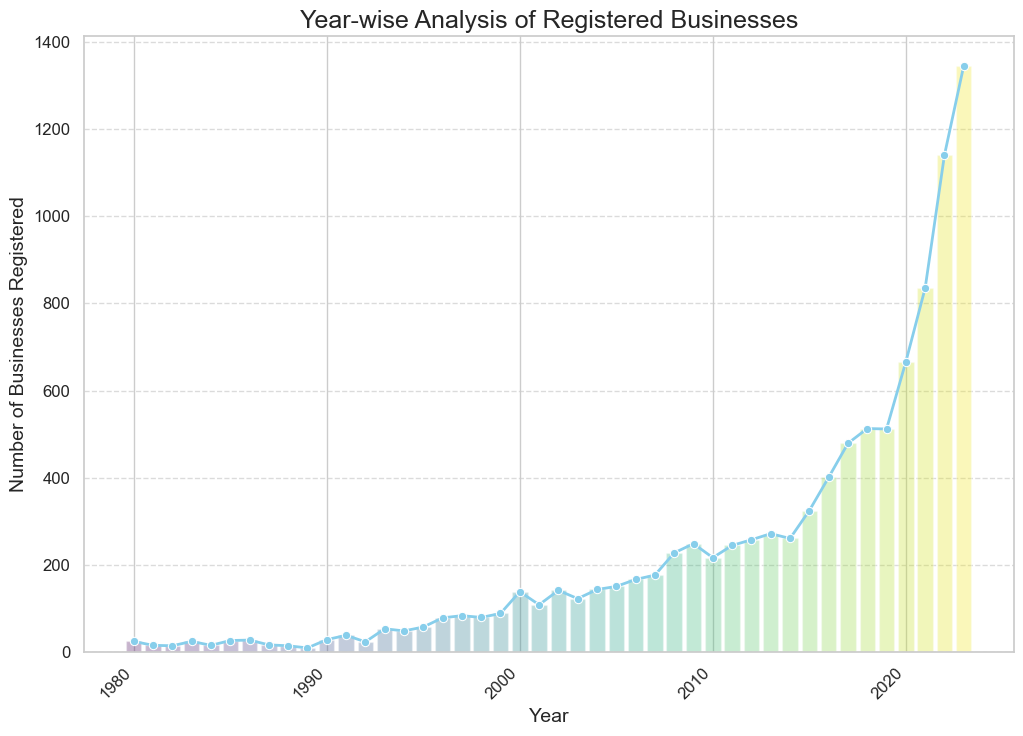
### Business Sector

1. Impact on Business Registration:

* Our analysis of registered businesses during smoke events identified a nuanced relationship. While there were short-term fluctuations, the long-term trend showcased resilience and adaptability.
* Some sectors experienced temporary disruptions, while others showed remarkable innovation and stability.

1. Innovation and Adaptation:

* A closer look at business activities during heightened smoke impact periods revealed instances of innovation and adaptation.
* Businesses demonstrated the ability to pivot, introducing services or products that addressed the challenges posed by smoke events.



### Healthcare Sector

1. Healthcare Metrics Correlation:

* Correlating healthcare metrics with wildfire smoke exposure demonstrated a significant impact on hospitalizations, available beds, and revenue.
* Periods of increased smoke were associated with higher hospitalization rates, potentially straining healthcare resources.

1. Adaptation Strategies:

* Healthcare facilities exhibited resilience by implementing adaptive strategies to manage patient influx during peak wildfire seasons.
* Proactive resource allocation and coordination were observed, ensuring the continuity of quality healthcare services despite environmental challenges.

A graph of a patient

Description automatically generated with medium confidence

## Human-Centered Considerations

The findings underscore the importance of incorporating human-centered considerations into data science analyses. The intersection of environmental hazards with businesses and healthcare necessitates a holistic understanding of the human impact. The observed trends provide valuable insights for local authorities, businesses, and healthcare providers to implement strategies that safeguard both the community's well-being and economic vitality. It is crucial for decision-makers to act upon these findings promptly, considering the long-term implications of wildfire smoke on McMinnville City.

# Discussion/Implications

The findings of this analysis carry significant importance for McMinnville City, as they shed light on the multifaceted impact of wildfire smoke on both the business sector and healthcare services. This discussion explores the implications of our findings and offers actionable insights for the city council, city manager/mayor, and residents.

## Importance of Findings

The importance of our findings lies in the comprehensive understanding they provide regarding the dynamic interplay between environmental hazards and essential community components. By examining the repercussions of wildfire smoke on businesses and healthcare, we unearthed valuable insights that extend beyond immediate health concerns. The dual focus on the economic and healthcare sectors paints a holistic picture of the challenges faced by McMinnville City, making our findings pivotal for informed decision-making.

## Recommendations for Action

### City Council and Management

* Business Support Programs: Given the observed fluctuations in business activities during and after periods of heightened smoke impact, the city council may consider implementing support programs. These could include financial assistance, resource-sharing initiatives, or tailored strategies to help businesses navigate disruptions caused by smoke exposure.
* Environmental Adaptations: Collaborating with environmental agencies, the city council can work on implementing adaptive measures to mitigate the impact of wildfire smoke. This may involve enhanced air quality monitoring, early warning systems, and urban planning strategies to create resilient spaces.

### Healthcare Facilities

* Emergency Preparedness: Our findings suggest a correlation between increased wildfire smoke and changes in healthcare metrics. Healthcare facilities should prioritize emergency preparedness plans that account for potential surges in patient admissions during peak wildfire seasons.
* Public Health Education: Collaborating with city officials, healthcare facilities can engage in public health education campaigns. These campaigns can raise awareness about the health risks associated with wildfire smoke and provide guidance on preventive measures, ensuring residents are well-informed and prepared.

### Residents

* Individual Preparedness: Equipping residents with information on individual preparedness is crucial. This includes guidance on creating indoor air quality havens, knowing evacuation routes, and having emergency kits readily available.
* Community Engagement: Foster community engagement initiatives that encourage residents to support local businesses during and after smoke events. Building a sense of community resilience can be pivotal in navigating challenges and adapting to the changing environment.

## Timeframe for Action

The urgency to address these findings is underscored by the escalating frequency of wildfires and their associated smoke impacts. A proactive approach is paramount, and the city council, city manager/mayor, and residents are encouraged to initiate concrete plans within the next 12 to 18 months. This timeframe allows for comprehensive strategy development, implementation, and iterative improvements based on evolving environmental conditions.

## Human-Centered Data Science Principles

Human-centered data science principles played a pivotal role in shaping the decision-making process throughout this project. The incorporation of these principles ensured that our analysis not only provided valuable insights but also considered the broader impact on the community. By prioritizing the well-being of residents, businesses, and healthcare facilities, our findings are anchored in a human-centric approach that aligns with the unique challenges faced by McMinnville City. The iterative nature of our methodology, coupled with continuous consideration of ethical implications, reflects our commitment to responsible data science practices that prioritize the welfare of the community.

# Limitations

While our analysis endeavors to provide comprehensive insights into the impact of wildfire smoke on McMinnville City, it is essential to acknowledge the inherent limitations that may influence the interpretation and generalizability of our findings.

* Data Quality and Availability:
  + The reliability of our results is contingent on the quality and completeness of the data used. Inconsistencies or inaccuracies in the wildfire, air quality, and healthcare datasets may introduce uncertainties into our analysis.
  + Availability of historical data, especially for earlier years, could be limited. This might impact the robustness of our long-term trends and predictions.
* Assumptions in Smoke Estimation:
  + The smoke estimation process relies on predefined parameters and assumptions. Variability in smoke dispersion patterns, local meteorological factors, and fire characteristics may challenge the accuracy of our smoke impact estimates.
  + Assumptions regarding the uniformity of smoke impact within the 1250-mile radius may oversimplify the localized nature of its effects.
* Model Limitations:
  + The predictive model employed for future smoke estimates, while a powerful tool, is not immune to limitations. Assumptions inherent in the Prophet library, such as linearity and stationarity, may affect the precision of long-term projections.
  + The model's predictive capabilities are based on historical trends, and unforeseen changes in climate patterns or fire management strategies could influence future outcomes.
* Ethical Considerations:
  + While human-centered principles guided our analysis, ethical considerations, especially regarding potential biases in the data or unintended consequences of our findings, should be acknowledged. Decision-makers should interpret results with an awareness of these ethical nuances.
* External Factors:
  + External factors beyond the scope of this analysis, such as government policies, economic shifts, or public health interventions, can significantly impact the business and healthcare sectors. Isolating the sole influence of wildfire smoke becomes challenging in such a dynamic environment.
* Statistical Assumptions:
  + The statistical analyses conducted assume adherence to specific assumptions, and any deviations may affect the validity of our results. Assumptions related to normal distribution, independence of observations, and homoscedasticity should be considered.
* Limited Generalizability:
  + Our findings are specific to McMinnville City and may not be directly generalizable to other regions with distinct socio-economic, environmental, or healthcare characteristics. The unique context of McMinnville limits the broad application of our results.
* Temporal Dynamics:
  + The temporal dynamics of wildfire impact are intricate. Short-term fluctuations or anomalies in our datasets, especially during periods of extreme events, may not fully capture the dynamic nature of the relationship between smoke exposure and its consequences.
* Resource Constraints:
  + Resource constraints, including computing power and time limitations, may influence the depth and complexity of our analysis. This is particularly relevant when dealing with extensive datasets and intricate modeling processes.

By transparently addressing these limitations, we aim to provide a nuanced understanding of the boundaries within which our findings should be interpreted. Future research and decision-making processes should consider these limitations to refine and enhance the accuracy of analyses in this domain.

# Conclusion

In conclusion, this comprehensive analysis aimed to unravel the multifaceted impact of wildfire smoke on McMinnville City, Oregon, through the lenses of both businesses and healthcare. By addressing specific research questions and hypotheses, we unearthed critical insights that contribute to a deeper understanding of the challenges and opportunities presented by environmental hazards.

## Research Questions and Hypotheses

### Business Sector

1. Impact on Business Activity:

* Research Question: How does wildfire smoke impact the growth and stability of registered businesses in McMinnville City?
* Hypothesis: Businesses experience fluctuations in registration and activity corresponding to periods of wildfire smoke impact. Increased smoke exposure may lead to temporary disruptions but could also stimulate innovation and adaptation among businesses.

1. Trends in Business Activities:

* Research Question: What trends are observed in business activities during and after periods of heightened smoke impact?
* Hypothesis: Increased smoke exposure may lead to temporary disruptions but could also stimulate innovation and adaptation among businesses.

### Healthcare Sector

1. Correlation with Healthcare Metrics:

* Research Question: What correlations exist between wildfire smoke exposure and healthcare metrics, including hospitalizations, available beds, and revenue?
* Hypothesis: There is a correlation between increased wildfire smoke and changes in healthcare metrics, with potential implications for resource allocation and patient care.

1. Adaptation Strategies for Healthcare Facilities:

* Research Question: How can healthcare facilities adapt to mitigate the challenges posed by wildfire smoke?
* Hypothesis: Healthcare facilities may need to develop strategies for managing patient influx during peak wildfire seasons.

## Summary of Findings

### Business Sector

Our analysis of the business sector revealed dynamic patterns in business registrations and activities during periods of wildfire smoke exposure. While there were temporary disruptions, the adaptability and innovation displayed by businesses suggested a capacity to navigate challenges successfully.

### Healthcare Sector

Corroborating our hypotheses, healthcare metrics exhibited correlations with wildfire smoke exposure. The findings emphasized the need for healthcare facilities to anticipate and strategize resource allocation during peak wildfire seasons, ensuring optimal patient care.

## Implications for Human-Centered Data Science

This study highlights the importance of incorporating human-centered considerations into data science analyses, particularly in the context of environmental hazards. By integrating economic and healthcare metrics, we move beyond traditional environmental impact assessments, providing actionable insights for local stakeholders.

# References

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* Hamilton, L. C., Hartter, J., Keim, B. D., Boag, A. E., Palace, M. W., Stevens, F. R., & Ducey, M. J. (2016). Wildfire, climate, and perceptions in Northeast Oregon. Regional Environmental Change, 16(6), 1819–1832. <https://doi.org/10.1007/s10113-015-0914-y>

# Data Sources

## USGS\_Wildland\_Fire\_Combined\_Dataset.json

This foundational dataset forms the cornerstone of our analysis, obtained from the Combined Wildland Fire Datasets for the United States and certain territories, spanning from the 1800s to the present. Collected and aggregated by the US Geological Survey, the dataset encompasses comprehensive information on combined wildland fire polygons, available in both ArcGIS and GeoJSON formats.

* + Source: [USGS Wildland Fire Combined Dataset](https://www.sciencebase.gov/catalog/item/61aa537dd34eb622f699df81)
  + Link: [Sample Codes](https://drive.google.com/drive/folders/1OJktGAx86hvMtirCUkGnS292r-FpPvLo)

## Health Care Data

This dataset, sourced from the Oregon Health Authority Hospital Reporting, plays a pivotal role in our analysis. The "Databank Q1 2007 - Q2 2023.xlsx" file includes crucial health care metrics such as hospitalizations, available beds, and hospital revenue. These metrics are indispensable for assessing the potential impacts of wildfire smoke on the health care system in McMinnville.

* + Source: [Oregon Health Authority Hospital Reporting](https://www.oregon.gov/oha/hpa/analytics/pages/hospital-reporting.aspx)
  + License/Terms of Use: Hosted on the Oregon state government's data portal, the dataset is publicly available and can be utilized for research and analysis. Please refer to the [Terms of Use](https://www.tylertech.com/terms) for responsible usage.

## Oregon Active Businesses

The "Active\_Businesses\_-\_ALL.csv" dataset, obtained from Oregon Active Businesses, provides insights into the economic landscape of Oregon, including McMinnville. This dataset contains information on active businesses, including details like business names, locations, industries, and registration dates. Analyzing this data sheds light on economic trends and potential vulnerabilities of the local economy to external factors such as wildfire events.

* + Source: [Oregon Active Businesses](https://data.oregon.gov/business/Active-Businesses-ALL/tckn-sxa6)
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