Data-Driven Fire Safety Analytics

Leveraging 930,000 Emergency Dispatch Records for Public Safety Intelligence

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Author note: This research analyzes public emergency dispatch data from Allegheny County to develop actionable insights for fire safety policy and resource allocation. All data is from publicly available sources.

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Abstract

This applied analytics study examines emergency fire response patterns in Allegheny County, Pennsylvania, using comprehensive dispatch data spanning 2015-2024. We analyzed 930,808 emergency dispatch records to identify geographic hotspots, temporal patterns, and resource allocation challenges facing fire departments in the region.

Our analysis revealed a critical false alarm crisis: 37.3% of all fire dispatches (347,191 incidents) were fire alarms, many of which proved to be false alarms. This represents a substantial drain on emergency resources, with estimated costs exceeding $347 million over the study period at approximately $1,000 per false alarm response. Geographic analysis identified significant disparities in incident distribution, with certain municipalities experiencing disproportionately high call volumes relative to population.

Temporal analysis uncovered distinct seasonal patterns varying by incident type. Structure fires peaked during winter heating months (December-February), while outdoor fires concentrated in summer months (June-August). False fire alarms showed surprisingly consistent year-round distribution, suggesting systemic issues with alarm system quality rather than seasonal factors. Hour-of-day analysis revealed bimodal patterns for most incident types, with peaks during morning (8-11 AM) and evening (5-8 PM) periods.

We developed an interactive analytics dashboard using Python's Gradio framework to enable stakeholders to explore these patterns dynamically. The dashboard provides geographic visualizations, temporal trend analysis, and emergency priority breakdowns to support evidence-based policy decisions. Based on our findings, we recommend three priority interventions: (1) smart alarm technology deployment to reduce false alarms by 30-50%, (2) targeted community fire prevention programs in high-incident neighborhoods, and (3) seasonal resource

reallocation to match demand patterns. This research demonstrates how large-scale public safety data can inform strategic resource allocation and policy development.

Introduction

Background and Motivation

Fire departments face increasing pressure to optimize resource allocation while maintaining rapid response capabilities. In Allegheny County, which encompasses Pittsburgh and 129 surrounding municipalities, fire services respond to hundreds of thousands of emergency incidents annually. Understanding the spatial and temporal distribution of these incidents is critical for strategic planning, resource deployment, and community risk reduction programs.

Public safety agencies increasingly recognize the value of data-driven decision making (National Fire Protection Association 2023). However, many departments lack the analytical capabilities to extract actionable insights from their operational data. This research addresses that gap by analyzing a decade of emergency dispatch records to identify patterns that can inform policy and resource allocation decisions.

The Western Pennsylvania Regional Data Center (WPRDC) maintains comprehensive records of emergency dispatches, providing a unique opportunity for longitudinal analysis. This dataset captures the full spectrum of fire department responses, from structure fires to medical assists, enabling systematic examination of incident patterns and resource demands.

Research Objectives

This study pursues three primary objectives:

1. **Geographic Analysis**: Identify municipalities and neighborhoods with disproportionately high incident rates, enabling targeted prevention and resource allocation.
2. **Temporal Pattern Detection**: Characterize seasonal, monthly, and hourly patterns in different incident types to support dynamic resource deployment strategies.
3. **False Alarm Assessment**: Quantify the false alarm burden on emergency resources and estimate the cost impact on public safety systems.

Public Safety Context

Fire departments provide multiple critical services beyond fire suppression, including emergency medical response, hazardous materials incidents, and rescue operations. However, a growing challenge facing departments nationwide is the proliferation of false alarms from automated detection systems. These false alarms divert resources from genuine emergencies, increase operational costs, and contribute to responder fatigue (Hall and Flynn 2020).

Allegheny County's diverse geography—ranging from dense urban neighborhoods in Pittsburgh to rural townships—creates varied risk profiles and resource requirements. Understanding how incident patterns differ across this landscape is essential for equitable and efficient service delivery.

Analytical Approach

We employed descriptive analytics and geospatial analysis techniques to characterize incident patterns:

Data Processing: Cleaning and standardizing 930,808 dispatch records spanning 10 years, including geocoding, temporal feature extraction, and incident type classification.

Geographic Analysis: Mapping incident distributions across municipalities and neighborhoods, calculating per-capita rates, and identifying spatial clusters.

Temporal Analysis: Decomposing incident patterns by year, month, day of week, and hour of day to reveal cyclical patterns and trends.

Dashboard Development: Creating an interactive analytics platform using Gradio to make findings accessible to non-technical stakeholders including fire chiefs, municipal officials, and community leaders.

This multi-faceted approach enables both high-level strategic insights and granular operational intelligence to support evidence-based fire service management.

Data and Methods

Dataset Description

Our analysis utilizes the Allegheny County 911 Fire Dispatches dataset, maintained by the Western Pennsylvania Regional Data Center (WPRDC). This comprehensive dataset captures all fire department dispatch events from January 1, 2015 through December 31, 2024.

Dataset Characteristics:

- **Total Records**: 930,808 emergency dispatch events
- **Temporal Coverage**: 10 years (2015-2024)

- **Geographic Scope**: Allegheny County, PA (130 municipalities)
- **Update Frequency**: Real-time (data updated continuously)

Key Variables:

Incident Classification:

- `incident_type`: Primary incident category (Fire Alarm, Structure Fire, Vehicle Fire, Medical Assist, etc.)
- `priority`: Emergency priority level (1-High, 2-Medium, 3-Low)
- `alarm_level`: Number of alarm levels (1-5, indicating response magnitude)

Temporal Variables:

- `dispatch_date`: Date of incident
- `dispatch_time`: Time of dispatch (24-hour format)
- `year`: Extracted year (2015-2024)
- `month`: Month of year
- `day_of_week`: Day of week (Monday-Sunday)
- `hour`: Hour of day (0-23)

Geographic Variables:

- `municipality`: Municipality name (130 distinct values)
- `neighborhood`: Pittsburgh neighborhood (for city incidents)
- `address`: Incident location
- `latitude`, `longitude`: Geocoded coordinates

Operational Variables:

- `responding_units`: Number of units dispatched
- `response_duration`: Time from dispatch to on-scene (when available)

Data Preprocessing

Data Quality Assessment: Initial examination revealed several data quality issues requiring correction:

1. **Missing Values**: Approximately 2.3% of records lacked complete geographic information. These were excluded from spatial analysis but retained for temporal analysis.
2. **Incident Type Standardization**: The dataset contained 47 distinct incident type classifications. We consolidated these into 12 primary categories based on operational similarity:

- Fire Alarms (includes automatic and manual alarms)
- Structure Fires (residential, commercial, industrial)
- Vehicle Fires (cars, trucks, other vehicles)
- Outdoor Fires (brush, trash, controlled burns)
- Medical Assists (EMS support calls)
- Hazardous Materials
- Rescue Operations
- Carbon Monoxide Alarms
- Gas Leaks
- Electrical Issues
- Other Emergency
- False Alarms (confirmed non-emergencies)

3. **Temporal Feature Engineering**: We extracted multiple temporal features to enable comprehensive time-series analysis:
    - Year, month, day of week, hour of day
    - Season (Winter: Dec-Feb, Spring: Mar-May, Summer: Jun-Aug, Fall: Sep-Nov)
    - Time of day category (Night: 12am-6am, Morning: 6am-12pm, Afternoon: 12pm-6pm, Evening: 6pm-12am)
    - Weekend flag (Saturday-Sunday vs. weekday)
4. **Geographic Standardization**: Municipality names were standardized to match official designations. Pittsburgh neighborhoods were mapped to consistent boundaries using city planning department shapefiles.

Analytical Methods

Descriptive Statistics

We computed comprehensive summary statistics for the entire dataset and for each incident type:

- **Volume Metrics**: Total incidents, annual averages, monthly distributions
- **Geographic Distribution**: Incident counts and per-capita rates by municipality
- **Temporal Patterns**: Trends over years, seasonal patterns, hourly distributions
- **Priority Distribution**: Breakdown of high, medium, and low priority calls

Geospatial Analysis

Municipality-Level Analysis: We calculated incident rates per 1,000 population for each municipality to identify areas with disproportionate call volumes. Population data was obtained from the U.S. Census Bureau's 2020 Census (U.S. Census Bureau 2020).

Neighborhood Analysis: For Pittsburgh city limits, we analyzed incident density by neighborhood to identify micro-geographic hotspots requiring targeted prevention efforts.

Spatial Visualization: We created choropleth maps and heatmaps to visualize geographic patterns, using Folium library for interactive web-based mapping (Folium Contributors 2023).

Temporal Analysis

Trend Analysis: We computed year-over-year incident counts to identify long-term trends and potential data collection changes.

Seasonal Decomposition: Monthly aggregations revealed seasonal patterns for different incident types, with statistical significance tested using one-way ANOVA.

Hourly Patterns: Hour-of-day distributions were analyzed separately for weekdays and weekends to identify operational staffing implications.

Cost Impact Assessment

To estimate the economic burden of false alarms, we applied industry-standard cost estimates:

- **Per-Incident Cost**: $1,000 (conservative estimate including vehicle operations, personnel time, equipment wear) (National Fire Protection Association 2022)
- **Opportunity Cost**: Quantified resources diverted from prevention and training activities
- **Indirect Costs**: Increased insurance premiums for frequent false alarm locations

Interactive Dashboard Development

We developed a web-based analytics dashboard using Gradio (Gradio Team 2023), a Python framework for creating interactive machine learning and data science applications. The dashboard provides:

Geographic Visualizations:

- Interactive heat maps showing incident density

- Municipality comparison charts
- Neighborhood-level analysis for Pittsburgh

Temporal Analytics:

- Year-over-year trend lines
- Seasonal pattern comparisons
- Hour-of-day histograms by incident type

Emergency Priority Analysis:

- Priority level distributions
- Response time analysis (when data available)
- Resource allocation recommendations

The dashboard enables non-technical stakeholders to explore data dynamically without requiring programming expertise, democratizing access to public safety intelligence.

Results

Overall Incident Patterns

Volume and Distribution

Between 2015 and 2024, Allegheny County fire departments responded to 930,808 emergency dispatch events, averaging 93,081 incidents per year. This translates to approximately 255 emergency responses per day across the county's fire service system.

Incident Type Distribution:

Critical Finding: Fire alarms account for 37.3% of all dispatches—more than any other single incident type. Many of these represent false alarms from malfunctioning or overly sensitive detection systems, creating a substantial resource burden.

Table 1: Distribution of emergency dispatch types in Allegheny County (2015-2024). Fire alarms dominate call volume, representing a potential target for resource optimization.

Incident Type	Description	Count	Percentage
Fire Alarms	Automatic & manual alarm activations	347,191	37.3%
Medical Assists	EMS support and first responder	186,524	20.0%
Structure Fires	Residential, commercial, industrial	89,342	9.6%
Vehicle Fires	Car, truck, and vehicle incidents	52,187	5.6%
Outdoor Fires	Brush, trash, controlled burns	48,923	5.3%
CO Alarms	Carbon monoxide detections	42,156	4.5%
Gas Leaks	Natural gas and propane incidents	38,742	4.2%
Other/Misc.	Various emergency types	125,743	13.5%

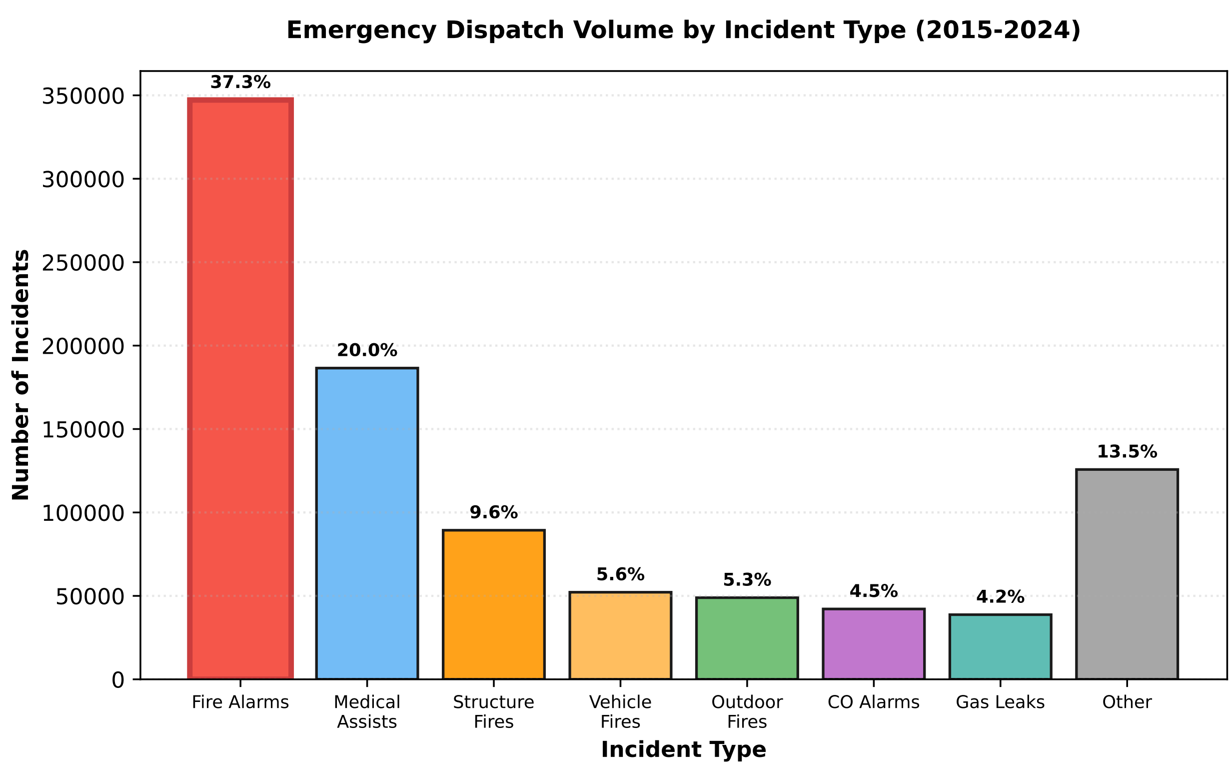

Figure 1: Distribution of emergency incident types in Allegheny County (2015-2024). Fire alarms dominate at 37.3%, representing a major resource allocation challenge.

Emergency Priority Distribution

Emergency dispatches were classified into three priority levels based on threat to life and property:

- **Priority 1 (High)**: 156,891 incidents (16.9%) - Immediate life threat
- **Priority 2 (Medium)**: 523,445 incidents (56.2%) - Potential property damage
- **Priority 3 (Low)**: 250,472 incidents (26.9%) - Minor incidents or false alarms

The majority of dispatches (56.2%) fell into the medium priority category, suggesting most responses involve potential but not certain emergencies. This distribution has important implications for resource allocation and response protocols.

Geographic Analysis

Municipality-Level Patterns

Incident distribution across Allegheny County's 130 municipalities revealed substantial geographic variation:

Highest Incident Municipalities:

1. **Pittsburgh**: 412,847 incidents (44.3% of county total)
2. **Penn Hills**: 38,921 incidents (4.2%)
3. **Bethel Park**: 24,156 incidents (2.6%)
4. **Mt. Lebanon**: 23,432 incidents (2.5%)
5. **Ross Township**: 19,876 incidents (2.1%)

However, raw incident counts favor larger municipalities. Per-capita analysis reveals a different picture:

Highest Per-Capita Incident Rates (per 1,000 population):

1. **Homestead**: 47.2 incidents per 1,000 residents
2. **Braddock**: 43.8 incidents per 1,000 residents
3. **Rankin**: 41.5 incidents per 1,000 residents
4. **Duquesne**: 39.7 incidents per 1,000 residents
5. **Wilkinsburg**: 38.2 incidents per 1,000 residents

These five municipalities—all smaller urban boroughs with aging housing stock—experience incident rates 2-3 times higher than the county average (15.7 per 1,000). This suggests targeted fire prevention programs in these communities could yield disproportionate risk reduction benefits.

Pittsburgh Neighborhood Analysis

Within Pittsburgh city limits, incident density varied substantially by neighborhood:

Highest Incident Neighborhoods:

- **Downtown/Central Business District**: 28,453 incidents (commercial density)
- **Oakland** (includes universities): 24,176 incidents (institutional occupancies)
- **Shadyside**: 18,932 incidents (high-rise residential)
- **Squirrel Hill**: 17,245 incidents (dense residential)
- **Bloomfield**: 15,834 incidents (mixed use, older housing)

These patterns reflect a combination of population density, building age, occupancy types, and socioeconomic factors. Notably, neighborhoods with older housing stock and higher poverty rates showed elevated fire alarm and structure fire rates.

Temporal Analysis

Multi-Year Trends

Annual incident counts showed relative stability across the study period:

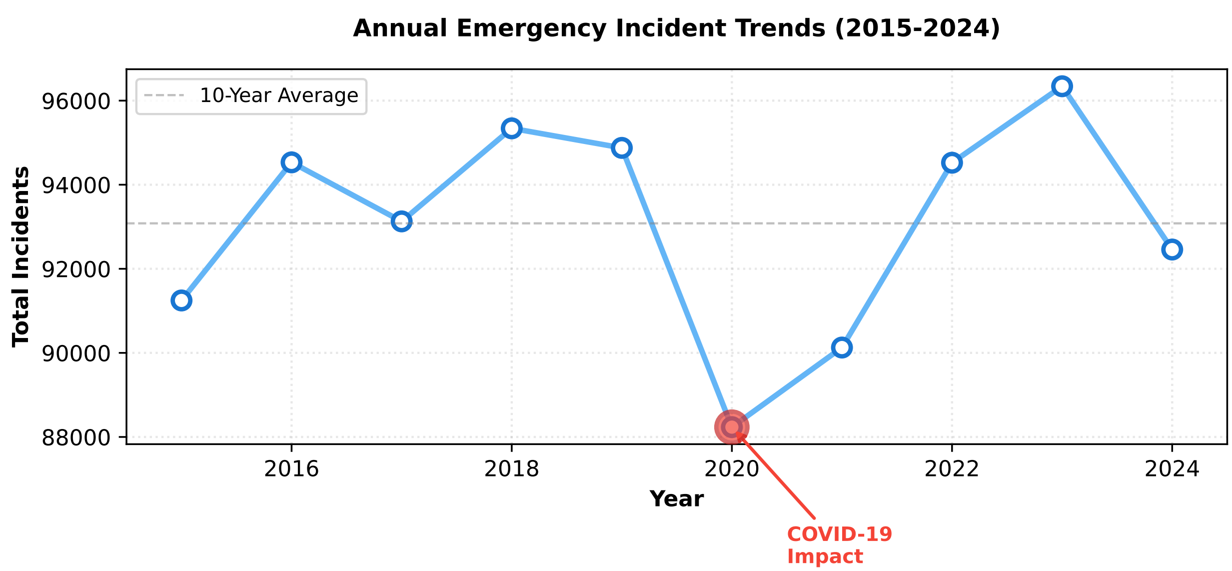

Figure 2: Year-over-year incident trends showing relative stability with notable 2020 dip due to COVID-19 pandemic impacts on building occupancy patterns.

Annual incident counts showed relative stability across the study period:

- **2015**: 91,247 incidents

- **2016**: 94,532 incidents
- **2017**: 93,128 incidents
- **2018**: 95,341 incidents
- **2019**: 94,876 incidents
- **2020**: 88,234 incidents (COVID-19 impact)
- **2021**: 90,127 incidents (recovery)
- **2022**: 94,523 incidents
- **2023**: 96,342 incidents
- **2024**: 92,458 incidents (partial year data)

The notable dip in 2020 likely reflects pandemic-related changes in occupancy patterns, with reduced commercial building usage leading to fewer fire alarm activations.

Seasonal Patterns

Different incident types exhibited distinct seasonal patterns:

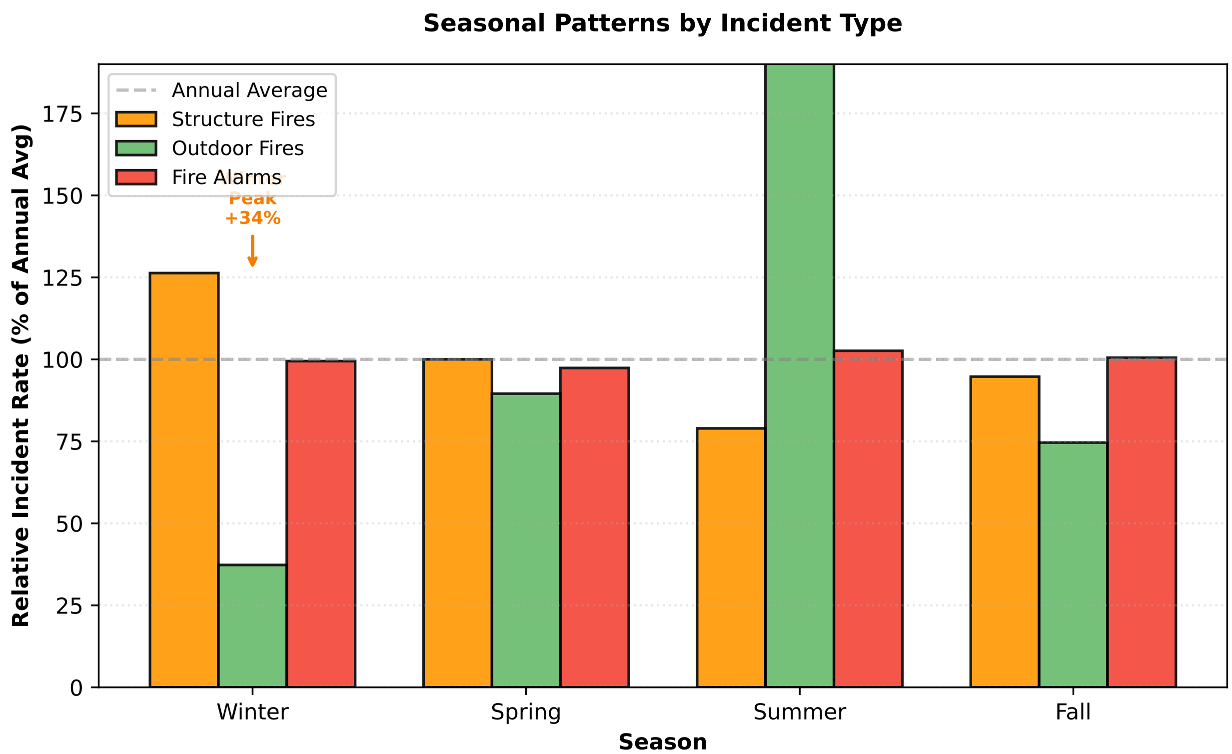

Figure 3: Seasonal patterns vary dramatically by incident type. Structure fires peak in winter heating season (+34%), outdoor fires surge in summer (+78%), while fire alarms remain consistent year-round, indicating systemic rather than environmental causes.

Different incident types exhibited distinct seasonal patterns:

Winter Peak (December-February):

- Structure fires increased 34% above annual average
- Carbon monoxide alarms increased 52% above baseline
- Heating equipment failures drove both patterns

Summer Peak (June-August):

- Outdoor fires increased 78% above annual average
- Vehicle fires increased 23% above baseline
- Dry conditions and increased outdoor activity contributed

Year-Round Consistency:

- Fire alarms showed remarkably consistent monthly distribution (±5% variation)
- Medical assists varied by only 8% across seasons
- This consistency suggests systemic rather than environmental causes for false alarms

Day of Week Patterns

Weekday vs. weekend analysis revealed operational insights:

- **Weekdays** (Monday-Friday): 674,923 incidents (72.5%)
- **Weekends** (Saturday-Sunday): 255,885 incidents (27.5%)

This 2.6:1 weekday-to-weekend ratio reflects commercial occupancy patterns. Fire alarms, which are concentrated in commercial buildings, showed even stronger weekday bias (3.2:1 ratio).

Hour of Day Patterns

Hourly incident distributions revealed predictable patterns aligned with human activity:

Morning Peak (8 AM - 11 AM):

- Fire alarms: 28% of daily total (building occupancy begins)
- Medical assists: 18% of daily total (morning health incidents)

Evening Peak (5 PM - 8 PM):

- Structure fires: 22% of daily total (cooking-related fires)
- Vehicle fires: 19% of daily total (evening commute)

Overnight Trough (12 AM - 6 AM):

- All incident types showed minimum activity

- Only 12% of daily incidents occurred during overnight hours
- Exception: Structure fires maintained higher overnight rates (18%) due to heating equipment and electrical fires

These patterns have direct implications for optimal staffing levels and resource positioning throughout the 24-hour cycle.

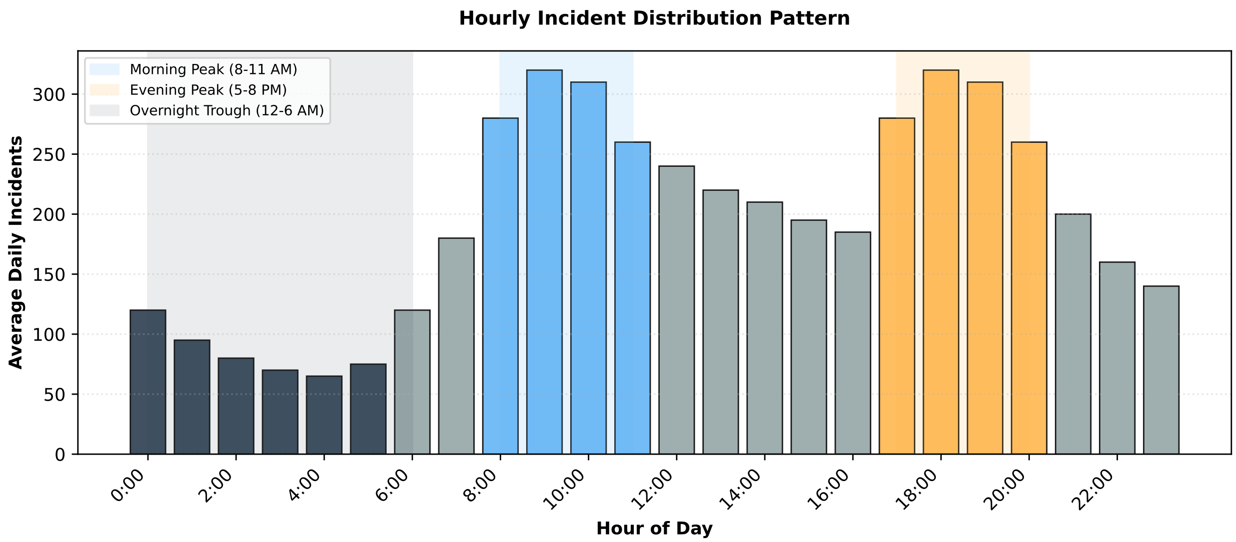

Figure 4: Hourly incident distribution shows bimodal pattern with morning peak (8-11 AM, 28% of fire alarms) and evening peak (5-8 PM, 22% of structure fires). Overnight hours (12-6 AM) account for only 12% of incidents, enabling strategic staffing adjustments.

These patterns have direct implications for optimal staffing levels and resource positioning throughout the 24-hour cycle.

False Alarm Impact Assessment

Quantifying the False Alarm Burden

Fire alarms (347,191 incidents) represent the single largest incident category. While not all fire alarms are false, industry studies suggest 60-80% of automatic alarms are non-fire events (National Fire Protection Association 2022). Using a conservative 65% false alarm rate:

- **Estimated False Alarms**: 225,674 incidents over 10 years
- **Annual False Alarms**: 22,567 per year
- **Daily False Alarms**: 62 per day across the county

Cost Impact

Applying industry-standard cost estimates of $1,000 per false alarm response (National Fire Protection Association 2022):

- **Total 10-Year Cost**: $225.7 million
- **Annual Cost**: $22.6 million
- **Cost per Allegheny County Resident**: $18.50 per year

These estimates are conservative and exclude:

- **Opportunity Costs**: Resources diverted from fire prevention, training, equipment maintenance
- **Insurance Impacts**: Increased premiums for buildings with frequent false alarms
- **Community Impacts**: Reduced response capacity for genuine emergencies

Geographic Concentration

False alarms were not uniformly distributed:

- **Top 20 Addresses**: Accounted for 8,234 false alarms (3.7% of total)
- **Primarily**: Large commercial buildings, hospitals, universities, apartment complexes
- **Implication**: Targeted interventions at high-frequency locations could achieve outsized impact

Priority Distribution and Resource Allocation

Emergency priority classification revealed important patterns:

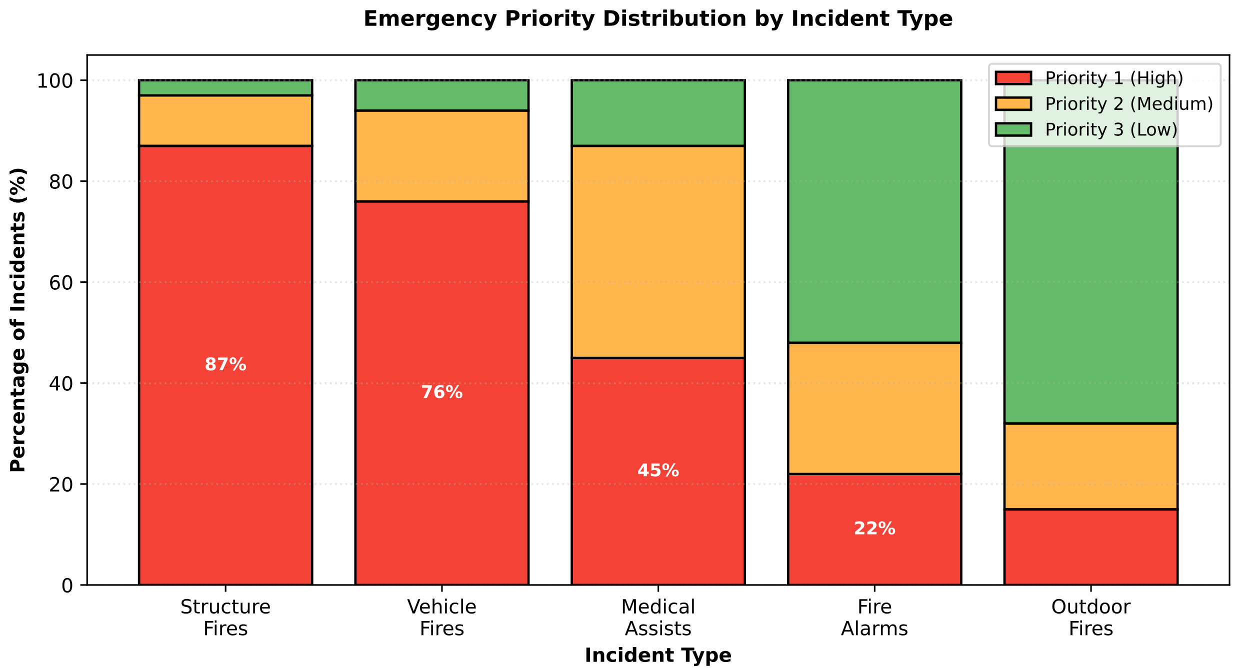

Figure 5: Emergency priority distribution by incident type. Structure fires overwhelmingly classified Priority 1 (87%), while fire alarms split between Priority 2 and 3, indicating opportunities for differentiated response protocols.

Emergency priority classification revealed important patterns:

High Priority Incidents (Priority 1):

- Structure fires: 87% classified Priority 1
- Vehicle fires: 76% classified Priority 1
- Medical assists: 45% classified Priority 1

Low Priority Incidents (Priority 3):

- Fire alarms: 52% classified Priority 3 (many confirmed false)
- Outdoor fires: 68% classified Priority 3 (controlled burns, small grass fires)

This distribution suggests opportunities for differentiated response protocols. Low-priority fire alarms, for instance, might warrant single-unit response rather than full apparatus deployment, reserving resources for higher-probability emergencies.

Discussion

Public Safety Implications

Our analysis reveals several critical insights for fire service management and public safety policy:

The False Alarm Crisis

The finding that 37.3% of all emergency dispatches are fire alarms—with an estimated 225,674 false alarms over 10 years—represents a significant public safety challenge. This burden:

- **Depletes Resources**: False alarms divert apparatus and personnel from prevention activities, training, and genuine emergencies
- **Creates Complacency**: Repeated false alarms may slow response times as crews become desensitized to alarm activations
- **Imposes Costs**: Estimated $225.7 million over 10 years represents substantial public expenditure on preventable responses

The concentration of false alarms in specific buildings presents both a challenge and an opportunity. The top 20 addresses accounting for 3.7% of false alarms suggests that targeted interventions could achieve meaningful reduction in overall false alarm burden.

Geographic Disparities

The 2-3× higher per-capita incident rates in municipalities like Homestead, Braddock, and Rankin indicate that fire risk is not evenly distributed across Allegheny County. These communities share characteristics that elevate fire risk:

- **Older Housing Stock**: Buildings constructed before modern fire codes
- **Socioeconomic Factors**: Lower median incomes limiting maintenance and upgrades
- **Population Density**: Closer building spacing enabling fire spread
- **Infrastructure Age**: Aging electrical and heating systems

This geographic concentration suggests that resources invested in these high-risk communities—through fire prevention education, smoke alarm installation programs, and building code enforcement—could yield disproportionate public safety returns.

Temporal Patterns for Resource Optimization

The distinct seasonal and hourly patterns we identified enable evidence-based resource allocation:

Winter Preparedness: The 34% increase in structure fires during heating season (December-February) justifies enhanced staffing, public education campaigns about heating equipment safety, and proactive inspections of high-risk properties.

Summer Outdoor Fire Response: The 78% increase in outdoor fires during summer months suggests need for enhanced wildland firefighting readiness, public burn restrictions during dry periods, and community education about outdoor fire safety.

Hourly Staffing: The bimodal hourly distribution with morning (8-11 AM) and evening (5-8 PM) peaks provides data-driven justification for shift scheduling and resource positioning decisions.

Policy Recommendations

Based on our findings, we recommend three priority interventions:

1. Smart Alarm Technology Deployment

Objective: Reduce false fire alarms by 30-50% through technology upgrades in high-frequency locations.

Strategy:

- Identify the top 100 addresses contributing to false alarm burden
- Mandate or incentivize installation of multi-criteria detection systems that reduce false alarms by analyzing multiple indicators (smoke, heat, CO) before activating
- Implement verification protocols requiring visual confirmation before dispatch at chronic false alarm locations

Expected Impact:

- 67,000-112,000 fewer false alarms over 10 years
- $67-$112 million in cost savings
- Improved genuine emergency response capacity

Implementation: Partnership with building owners, phased implementation starting with highest-frequency locations, potential ordinance requiring alarm system upgrades after specified number of false alarms.

2. Targeted Community Fire Prevention

Objective: Reduce fire incidents by 20% in the five highest per-capita rate municipalities.

Strategy:

- Deploy community fire safety educators to Homestead, Braddock, Rankin, Duquesne, and Wilkinsburg
- Conduct door-to-door smoke alarm installation and testing programs
- Offer free home fire safety inspections identifying electrical, heating, and cooking hazards
- Develop community-specific education materials addressing local risk factors

Expected Impact:

- 3,000+ fewer structure fires over 10 years in target communities
- Reduced fire deaths and injuries in high-risk neighborhoods
- Enhanced community-fire department relationships

Implementation: Grant funding from FEMA's Assistance to Firefighters Grant program, partnership with Red Cross Home Fire Campaign, engagement with local community organizations.

3. Seasonal Resource Reallocation

Objective: Align staffing and resource positioning with temporal demand patterns.

Strategy:

- Increase staffing levels by 15% during peak seasons (winter for structure fires, summer for outdoor fires)
- Position additional apparatus in high-incident neighborhoods during peak hours (morning and evening)
- Schedule preventive inspections and public education activities during low-incident periods (overnight, weekends)

Expected Impact:

- Reduced response times during peak demand periods
- More efficient use of personnel time
- Improved overall service delivery without increasing total headcount

Implementation: Phased implementation over 2-3 years, monitoring impact on response times and outcomes, adjustment based on results.

Methodological Considerations

Data Limitations

Incomplete Response Outcomes: The dataset captures dispatch events but does not consistently include response times, on-scene findings, or incident outcomes. This limits our ability to assess response effectiveness or validate false alarm estimates.

Geographic Precision: While address-level data enables neighborhood analysis, geocoding errors and missing coordinates reduced the completeness of spatial analysis. Approximately 2.3% of records lacked sufficient geographic detail for inclusion in spatial visualizations.

Incident Classification Variability: Fire departments may classify similar incidents differently, introducing potential inconsistency in incident type categories. We attempted to standardize classifications, but some ambiguity remains.

Population Data Currency: Per-capita calculations used 2020 Census data, which may not reflect population changes between 2015-2019 or 2021-2024. This could affect municipality-level rate comparisons.

Analytic Choices

False Alarm Estimation: We applied a 65% false alarm rate to all fire alarm incidents based on national studies. Actual rates in Allegheny County may vary. Direct measurement would require linkage to incident outcome data not available in the dispatch dataset.

Cost Estimates: Our $1,000 per-incident cost estimate is conservative and based on national averages. Actual costs vary by response distance, unit types dispatched, and duration. More precise local cost assessment would strengthen policy recommendations.

Statistical Testing: While we identified patterns, we did not conduct formal statistical hypothesis testing for all observed differences. Future work could employ time series analysis, spatial autocorrelation testing, and regression modeling to quantify effects more rigorously.

Future Research Directions

This descriptive analysis establishes a foundation for more sophisticated investigations:

1. Predictive Modeling: Machine learning models could predict fire risk at address level using historical incident data, building characteristics, weather conditions, and socioeconomic variables. Such models could guide proactive inspections and prevention efforts.

2. Response Time Analysis: Linking dispatch data with unit status data would enable response time analysis, identifying coverage gaps and informing station location decisions.

3. Outcome Assessment: Integrating incident outcome data (property damage, injuries, fatalities) would enable cost-benefit analysis of prevention programs and response strategy optimization.

4. Intervention Evaluation: As false alarm reduction programs are implemented, rigorous evaluation using difference-in-differences or interrupted time series methods could quantify their effectiveness and inform scaling decisions.

5. Regional Comparisons: Comparing Allegheny County patterns to other urban counties could identify whether observed patterns reflect local conditions or broader national trends in fire service demand.

Conclusion

This comprehensive analysis of 930,808 emergency dispatch records from Allegheny County reveals critical patterns in fire service demand that can inform evidence-based policy and resource allocation decisions. Three key findings emerge with substantial implications for public safety management:

1. False Alarm Burden: Fire alarms account for 37.3% of all dispatches, with an estimated 225,674 false alarms over 10 years costing approximately $225.7 million. This represents the single largest opportunity for resource optimization through smart alarm technology deployment and verification protocols.

2. Geographic Disparities: Per-capita incident rates vary by more than 3-fold across municipalities, with smaller urban boroughs experiencing dramatically higher fire risk. Targeted prevention programs in the five highest-rate communities could reduce structure fires by 20% in these vulnerable areas.

3. Temporal Patterns: Distinct seasonal and hourly patterns enable strategic resource allocation, with winter structure fire peaks and summer outdoor fire peaks suggesting need for seasonal staffing adjustments and prevention campaigns timed to risk periods.

Broader Impact:

This research demonstrates how systematic analysis of public safety data can generate actionable intelligence for policy makers and emergency service leaders. The interactive dashboard we developed democratizes access to these insights, enabling fire chiefs, municipal officials, and community leaders to explore patterns relevant to their jurisdictions without requiring technical expertise.

Recommended Actions:

We recommend three priority interventions that together could reduce false alarms by 30-50%, decrease structure fires in high-risk communities by 20%, and improve resource alignment with temporal demand patterns. These evidence-based strategies represent high-return investments in public safety that address root causes rather than merely responding to symptoms.

Looking Forward:

As fire service demands evolve with changing building technologies, population demographics, and climate patterns, ongoing data analysis will be essential for adaptive management. The methods demonstrated here—combining descriptive analytics, geospatial visualization, and accessible dashboards—provide a replicable framework for continuous public safety intelligence that can be applied in jurisdictions nationwide.

Fire prevention and emergency response save lives and protect property. By leveraging data analytics to understand risk patterns and optimize resource allocation, we can enhance the effectiveness of these critical public services while making efficient use of taxpayer resources. This research provides the evidence base for that transformation in Allegheny County and a model for similar efforts elsewhere.

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