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VAST Challenge 2022

Patterns of Life in Engagement, Ohio
Data Visualization

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Challenge Overview

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The Problem

Challenge Overview

Urban Planning Challenge

- City of Engagement, Ohio
- Limited understanding of resident behavior
- Traffic congestion issues
- Need data-driven insights

Our Mission

- Analyze patterns of daily life
- Identify city characteristics
- Support infrastructure planning
- Improve quality of life

Challenge Scope

- Map of urban area
- 15 months of data
- Multiple building types
- Diverse activity patterns

Deliverables

- Visual analytics platform
- Interactive dashboards
- Evidence-based recommendations

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The Dataset

Challenge Overview

Massive Urban Activity Data

- **Duration:** 15 months (March 2022 - May 2023)
- **Participants:** 1,000 volunteer residents
- **Data Volume:** 18GB of location and activity logs
- **Sampling Rate:** Every 5 minutes, 24/7

Data Sources

- **Participant Status:** Location, activity mode, joviality
- **Buildings:** Venue types, locations, polygons
- **Travel Journal:** Trip origins, destinations, purposes
- **Demographics:** Age, education, household, interests

Challenge: Transform raw data into actionable urban insights

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Research Questions

Challenge Overview

1. **Question 1:** What are the distinct areas of the city?
2. **Question 2:** Where are the traffic bottlenecks?
3. **Question 3:** How do individual daily routines differ?
4. **Question 4:** How do patterns change over time?

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Our Solution

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Visual Analytics Platform

Our Solution

Technology Stack

Frontend

- React + TypeScript + Vite
- D3.js for interactive visualizations
- Shadcn UI component library
- Responsive design

Backend

- Node.js + Express
- PostgreSQL with PostGIS extension
- Spatial indexing for performance

Deployment

- Docker containerization for all services

Key Features

- Interactive spatial heatmaps
- Temporal activity streamgraphs
- Participant activity calendars
- Building polygon overlays
- Participant comparison tools
- Real-time filtering and aggregation

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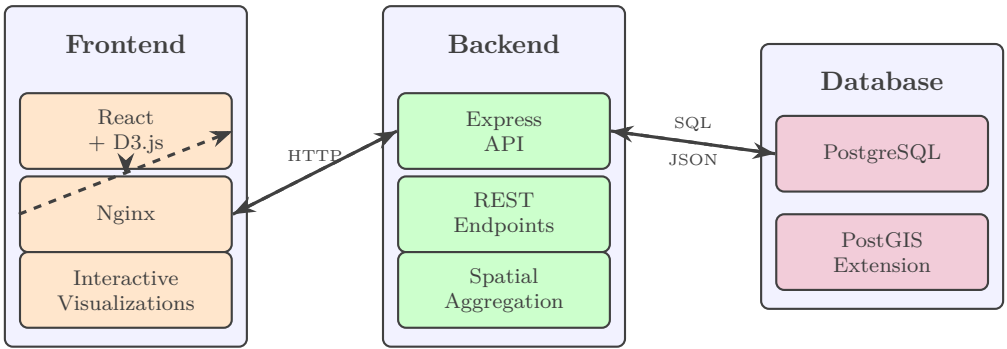
Architecture Overview

Our Solution



Dockerized deployment with Nginx reverse proxy for API routing

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Visualization Techniques

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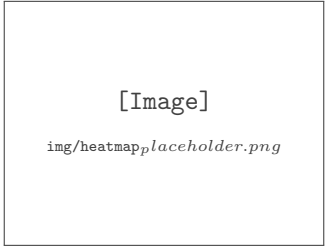
Visualization 1: Spatial Heatmap

Visualization Techniques



Spatial activity heatmap visualization

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Spatial Heatmap - Details

Visualization Techniques

Purpose

- Visualize activity density across the city
- Identify busy areas and hotspots
- Track temporal patterns

Key Features

- Grid-based aggregation
- Time slider (hourly/daily/weekly)
- Activity mode filtering
- Building polygon overlay
- Interactive zoom and pan

Technology

- D3.js for rendering
- PostgreSQL spatial queries with PostGIS

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Spatial Heatmap - Strengths

Visualization Techniques

Pros

- Intuitive geographic representation
- Reveals spatial patterns at a glance
- Flexible temporal exploration
- Supports multiple aggregation levels
- Combines well with building overlays
- Effective for identifying hotspots

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Spatial Heatmap - Limitations

Visualization Techniques

Cons

- Grid resolution affects interpretation
- Can obscure individual movements
- Performance challenges with high granularity
- Requires spatial context to interpret
- May hide temporal variations within aggregates

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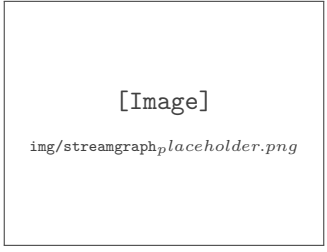
Visualization 2: Activity Streamgraph

Visualization Techniques



Activity composition streamgraph over time

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Activity Streamgraph - Details

Visualization Techniques

Purpose

- Show activity composition over time
- Reveal behavioral shifts
- Track participation trends

Key Features

- Stacked area chart with smooth interpolation
- Multiple activity types (work, social, dining, etc.)
- Temporal filtering capabilities
- Color-coded activity categories

Key Insights Revealed

- Work dominates weekdays
- Social activity peaks on weekends
- Meal times visible as distinct peaks

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Activity Streamgraph - Strengths

Visualization Techniques

Pros

- Shows composition and trends simultaneously
- Aesthetically appealing and engaging
- Reveals both macro and micro patterns
- Effective for time-series comparison
- Handles multiple categories elegantly

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Activity Streamgraph - Limitations

Visualization Techniques

Cons

- Difficult to read precise values
- Middle layers harder to interpret
- Can be overwhelming with too many categories
- Requires color differentiation
- Temporal aggregation may hide short-term spikes

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Visualization 3: Activity Calendar

Visualization Techniques

Participant activity calendar (days × hours matrix)

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Activity Calendar - Details

Visualization Techniques

Purpose

- Analyze individual daily routines
- Identify patterns and variations
- Compare participants side-by-side

Design

- Days × Hours matrix
- Color-coded by activity type
- One month visible at a glance
- Scrollable timeline for full 15-month period

Use Cases

- Find contrasting lifestyles
- Detect routine consistency
- Identify work schedules and patterns

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Activity Calendar - Strengths

Visualization Techniques

Pros

- Compact representation of long periods
- Patterns emerge naturally (work hours, weekends)
- Easy to spot anomalies and changes
- Effective for individual analysis
- Supports direct comparison
- Intuitive time-of-day interpretation

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Activity Calendar - Limitations

Visualization Techniques

Cons

- Limited to individual or small groups
- Requires significant screen space
- Can be cluttered with too many activity types
- Doesn't show spatial information
- Difficult to see population-level trends

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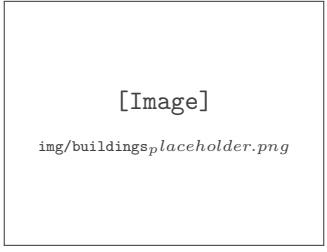
Visualization 4: Building Polygons Overlay

Visualization Techniques



Building polygons overlaid on activity heatmap

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Building Polygons - Details

Visualization Techniques

Purpose

- Provide spatial context for activity patterns
- Link activities to physical infrastructure
- Identify functional zones

Key Features

- Filter by building type (residential, commercial, schools, etc.)
- Integrated with heatmap for layered context
- Color-coded by function
- Interactive toggle on/off

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Building Polygons - Strengths

Visualization Techniques

Pros

- Connects activity to infrastructure
- Helps explain spatial patterns
- Supports urban planning decisions
- Reveals functional zoning
- Combines well with other visualizations

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Building Polygons - Limitations

Visualization Techniques

Cons

- Can clutter the map
- Requires accurate building data
- May obscure underlying heatmap
- Static representation of dynamic spaces

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Visualization 5: Participant Comparison

Visualization Techniques

Side-by-side participant comparison dashboard

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Participant Comparison - Details

Visualization Techniques

Purpose

- Compare individual behavioral patterns
- Identify contrasting lifestyles
- Support hypothesis about proximity and well-being

Key Metrics

- Daily travel distance
- Average joviality score
- Social activity percentage
- Work patterns
- Demographics

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Participant Comparison - Strengths

Visualization Techniques

Pros

- Direct quantitative comparison
- Reveals individual differences
- Supports finding extreme cases
- Evidence-based storytelling
- Helps answer ”why” questions

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Participant Comparison - Limitations

Visualization Techniques

Cons

- Limited to 2-3 participants at once
- Doesn't show population distribution
- Risk of cherry-picking examples
- Requires manual selection
- No temporal dimension visible

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Data Aggregation Strategy

Visualization Techniques

Spatial Aggregation

- Grid-based binning (configurable cell size)
- `GROUP BY FLOOR(lat/cell_size), FLOOR(lng/cell_size)`
- Enables density calculation and hotspot identification

Temporal Aggregation

- Hourly: Daily patterns and rush hours
- Daily/Weekly: Routine identification
- Monthly: Long-term trends

Activity Mode Filtering

- Work, Home, Restaurant, Pub, Recreation, School, Shopping
- Supports focused analysis by activity type
- Reveals functional zones in the city

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Key Findings

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Question 1: City Areas - Overview

Key Findings

Three Distinct Urban Zones Identified

1. **Downtown Commercial Core**
   - Zones: B2, C2, C3
   - High concentration of employers, restaurants, pubs

2. **Residential Zones**
   - Zones: A1-2, B3-4, D2, D4
   - Dominated by apartment buildings

3. **Mixed Suburban Areas**
   - Zones: Northwest, Southeast
   - Gradient from commercial to residential

Analysis Method: Building type distribution, temporal activity patterns, movement flows

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Area 1: Downtown Commercial Core

Key Findings

Characteristics

- High employer density
- Restaurants and pubs
- Peak activity: 9 AM - 6 PM
- Lower evening/night activity

[Image]

img/q1_commercial_placeholder.png

Commercial building distribution

Evidence

- Building type concentration
- Business hours heatmap
- Commuter influx patterns
- Lunch hour spikes

[Image]

img/q1_business_hours_placeholder.png

Area 2 & 3: Residential and Mixed Zones

Key Findings

Residential Zones

- High apartment concentration
- Peak: Evening/night
- Low daytime presence
- Social activity localized

[Image]

img/q1_residential_placeholder.png

Residential building clusters

Mixed Suburban

- Commercial facing downtown
- Residential at periphery
- Limited connectivity (NW)
- Transitional character

[Image]

img/q1_evening_placeholder.png

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Question 2: Traffic Bottlenecks - Overview

Key Findings

Three Critical Bottlenecks Identified

1. **Northwest Connector**
   - MOST CRITICAL: Single route, no alternatives
   - Severe rush hour congestion

2. **Downtown Corridors**
   - Persistent through-traffic
   - Multiple intersection points

3. **Southern Connector**
   - Bidirectional bottleneck
   - Residential convergence point

Rush Hour Patterns: 7-9 AM (inbound) and 5-7 PM (outbound)

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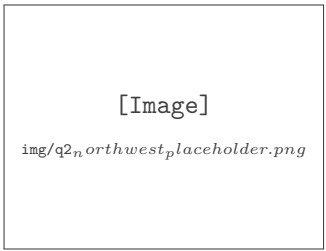
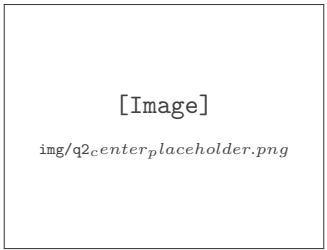
Bottleneck Locations

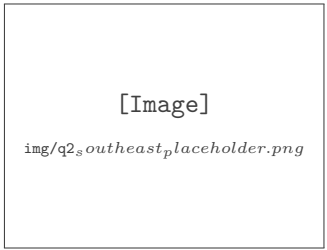
Key Findings



Northwest bottleneck
Single-point failure



Downtown congestion
Intersection clusters



Southern connector
Residential convergence

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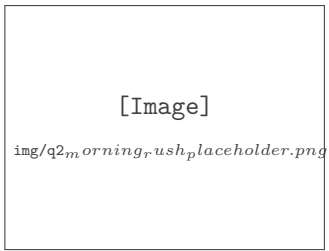
Temporal Traffic Patterns

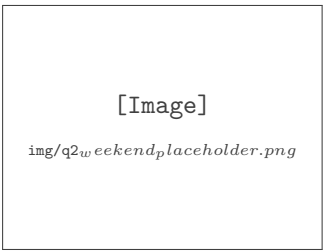
Key Findings

Morning Rush (7-9 AM)



Residential → Commercial flow

Weekend Pattern



Uniform distribution, social clusters

Key Insight: Weekday bottlenecks disappear on weekends

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Question 3: Contrasting Lifestyles

Key Findings

Selection Criteria

- Used participant comparison tool
- Filtered by travel distance and joviality
- Found extreme opposites

Participant 266
The Social Local

Age:	32 years
Travel:	5 units/day
Joviality:	**97.3%**
Social:	18.3%

Participant 845
The Long Commuter

Age:	40 years
Travel:	32.2 units/day
Joviality:	**Below avg**
Social:	5.2%

6× difference in daily travel distance!

Participant 266: The Social Local

Key Findings

Profile

- Lives and works in city center
- Walking distance to work
- Avoids major bottlenecks
- Regular 9-5 schedule

Lifestyle

- Frequent evening socializing
- Multiple social venues nearby
- Weekend social activities
- High quality of life

Regular work (orange), active social life (green)

Impact

- Very high joviality (97.3%)

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Participant 845: The Long Commuter

Key Findings

Profile

- Home in south
- Work in east
- 2-hour daily commute
- Crosses multiple bottlenecks

Lifestyle

- Leaves home at 7 AM
- Returns after 5 PM
- Limited evening time
- Minimal social activity

Long commutes (red), limited social time

Impact

- Below-average joviality

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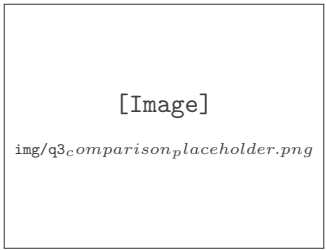
Key Insight: Proximity Matters

Key Findings



Geographic proximity between home, work, and amenities profoundly impacts quality of life and well-being

Urban planning should prioritize reducing commute distances

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Question 4: Temporal Changes (1/2)

Key Findings

Major Trends Over 15 Months

1. **Initial Adjustment Period** (Days 1-60)
   - Elevated activity in first weeks → normalization
2. **Early Social Surge**
   - High social engagement weeks 1-4
   - Transition to sustainable routines
3. **Activity Composition Stability**
   - Despite participant dropout, proportions stable
   - Work dominates weekdays, social on weekends
4. **Weekend vs Weekday Transformation**
   - Weekday: Employment travel
   - Weekend: Social/dining journeys
5. **Individual Persistence**

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Question 4: Temporal Changes (2/2)

Key Findings

6. **Spatial Clustering Evolution**
   - Dispersion → concentration over time
   - Participants find preferred venues

7. **Venue Popularity Cycles**
   - "Flash popularity": 2-4 week surges
   - Some permanent, some temporary hotspots

8. **Multi-Activity Evenings**
   - 18:00-21:00: 5-6 activity types simultaneously
   - Mornings: Work dominates

9. **Interest Group Homogeneity**
   - Minimal demographic divergence
   - Spatial constraints override demographics

10. **Cyclical Variations**
    - Seasonal/circumstantial influences

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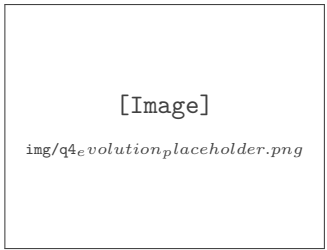
Temporal Evolution Evidence

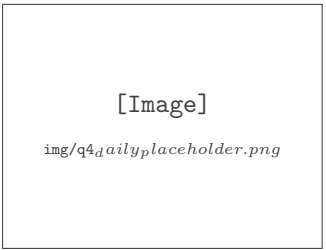
Key Findings

15-Month Overview



Participant dropout, stable activity proportions

Daily Patterns



Work, social, eating rhythms

Observation: Macro-level changes coexist with micro-level stability

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Recommendations

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Key Insights Summary

Recommendations

1. **Spatial:** Clear functional zones, northwest vulnerable
2. **Traffic:** Predictable rush hour bottlenecks
3. **Behavioral:** Proximity correlates with well-being
4. **Temporal:** Individual stability, population dynamics

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Urban Planning Recommendations

Recommendations

Priority 1: Infrastructure

- Create alternative route to northwest zone
- Expand downtown corridor capacity
- Implement traffic management systems

Priority 2: Development

- Promote mixed-use development
- Reduce residential-workplace distances
- Support local social venues

Priority 3: Quality of Life

- Design for walkability
- Plan around behavioral patterns, not just demographics
- Enable 15-minute neighborhoods

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Reflection

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Strengths & Limitations

Reflection

Strengths

- Interactive exploration
- Multi-scale analysis
- Evidence-based insights
- Scalable architecture
- Accessible visualizations

Future Enhancements

- Flow diagrams
- Speed heatmaps
- Predictive modeling
- Real-time integration

Limitations

- Sample representativeness
- No causal analysis
- Performance constraints
- Learning curve

Applicability

- Urban planning
- Transportation analysis
- Behavioral studies
- Decision support

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Key Takeaways

Reflection

1. **PostGIS essential** for spatial data
2. **Iterative design** reveals insights
3. **Performance matters** for 18GB datasets
4. **Context drives interpretation**
5. **Visual analytics** enables discovery

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Conclusion

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Summary: Challenge Accomplished

Conclusion

Answered All Four Questions

1. **City Areas:** 3 distinct zones identified
2. **Bottlenecks:** 3 critical congestion points
3. **Routines:** 6× difference in commute impacts life
4. **Changes:** 10 temporal patterns documented

Delivered actionable urban planning insights through interactive visual analytics

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Thank You!

Questions?

Alberto Finardi Tommaso Crippa Tom Gave

Temporary page!

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been added to receive it.
If you rerun the document (without altering it) this surplus page will go away,
because LaTeX now knows how many pages to expect for this document.