Pulse of Engagement

Visual Analytics for Economic Health in Engagement, OH

VAST Challenge 2022 – Challenge 3

Thomas Gantz Michal Sterzel Jan Marxen

December 2025

uni.lu
UNIVERSITY OF
LUXEMBOURG

Introduction

VAST Challenge 2022 – Challenge 3

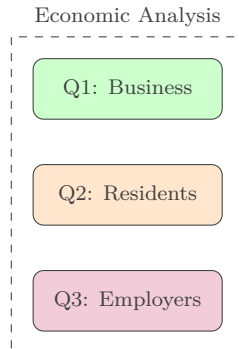
Introduction

The Challenge

- Analyze economic health of a fictional city
- Dataset: ∼120 million data points
- 15 months of 5-minute granularity data

Three Questions

1. Business Prosperity
2. Resident Financial Health
3. Employer Health & Turnover

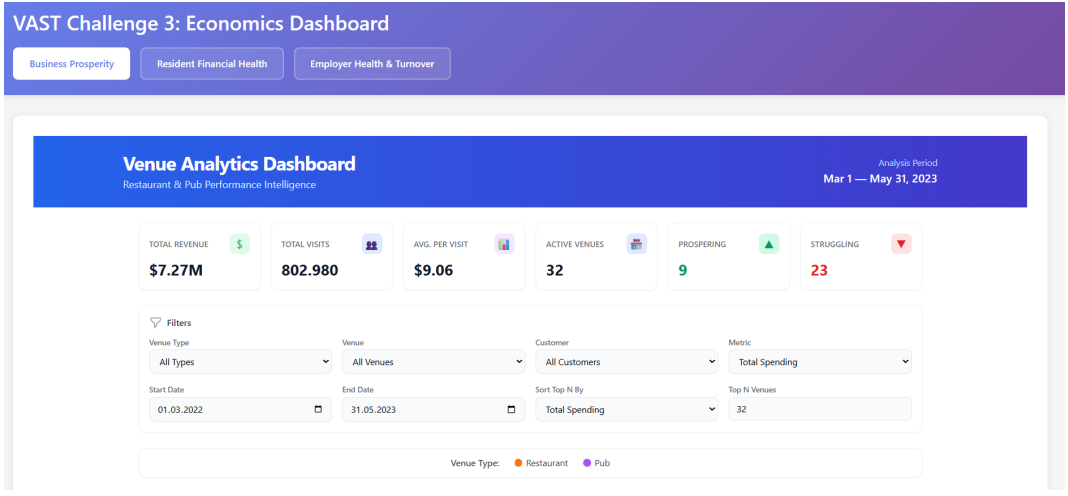


Question 1: Business Prosperity

UNIVERSITY OF LUXEMBOURG

Dashboard Overview

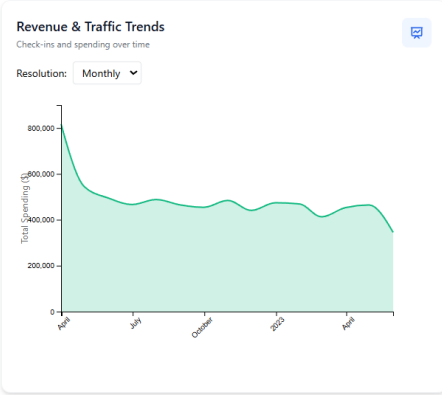
Question 1: Business Prosperity

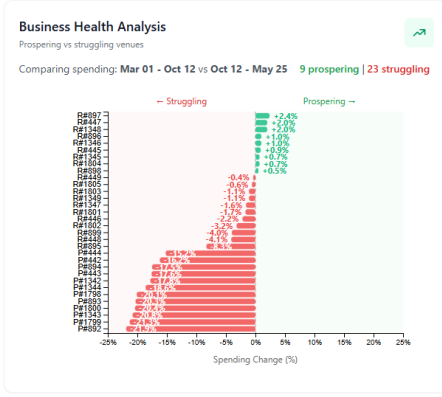


UNIVERSITY OF LUXEMBOURG

Growth Analysis

Question 1: Business Prosperity

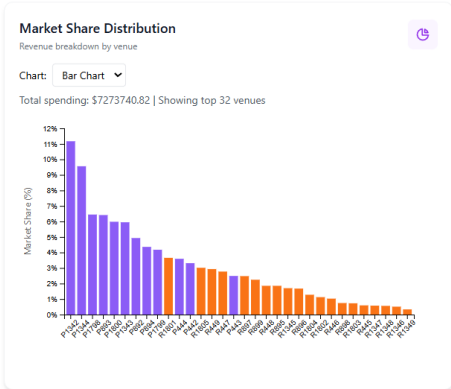


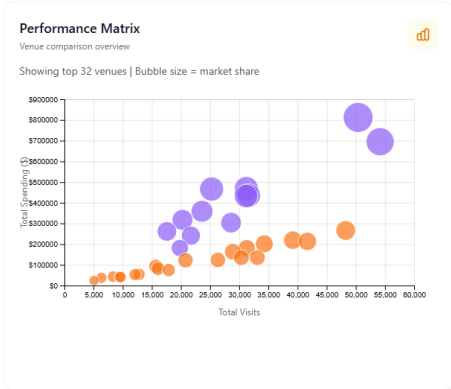


Key Insight: Revenue drops in April · Business health is heterogeneous:
~1/3 growth ↑ ~1/3 slight decline ↓ ~1/3 significant decline ↓

Market Concentration

Question 1: Business Prosperity



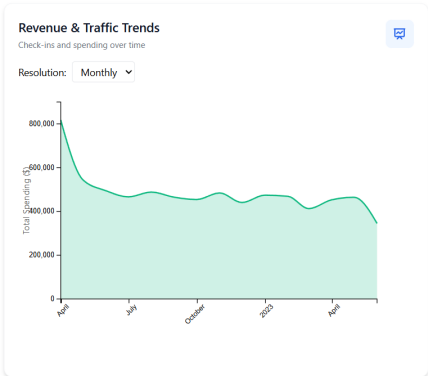


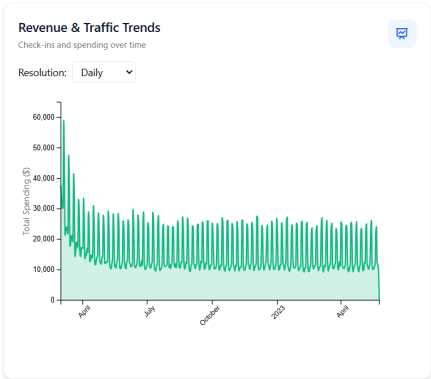
Key Insight: Two pubs capture 20% of total spending · Pubs dominate restaurants

UNIVERSITY OF LUXEMBOURG

Temporal Trends

Question 1: Business Prosperity



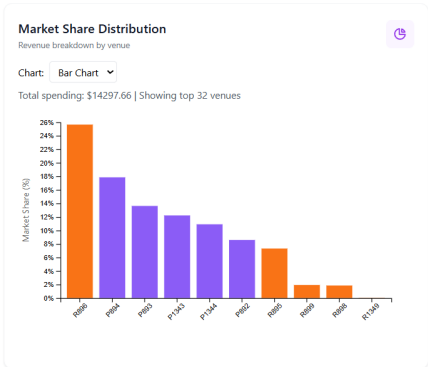


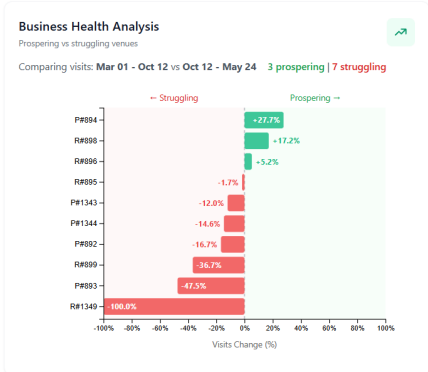
Key Insight: Weekend oscillation distinguishes cyclical from structural decline

UNIVERSITY OF LUXEMBOURG

Individual Customer Patterns

Question 1: Business Prosperity





Micro-level signals: ♥ R#896: 26% share · P#894: +27.7% growth · R#1349: abandoned

UNIVERSITY OF LUXEMBOURG

Key Findings

Question 1: Business Prosperity

Prosperous

- ✔ Pubs outperform restaurants
- ✔ P#1342, P#1344 dominate market

Struggling

- ✖ Top performers decline in H2
- ✖ ∼1/3 show substantial drops

⚠ **Overall:** Aggregate spending declining over 15 months

UNIVERSITY OF LUXEMBOURG

Design Rationale

Question 1: Business Prosperity

Visualization Progression

- **Overview** → establish baseline context
- **Temporal filtering** → identify patterns over time
- **Individual detail** → surface micro-level signals

Key Design Decisions

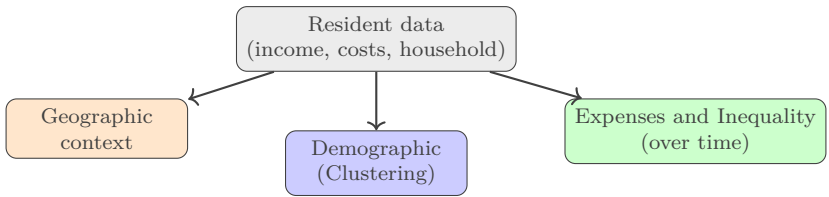
- **Coordinated views:** hover-linking for cross-chart exploration
- **Split-period comparison:** quantifies growth directly
- **Global filters:** all-to-all, one-to-all, one-to-one analysis
- **Dual metrics:** visits and spending reveal correlation

UNIVERSITY OF LUXEMBOURG

Question 2: Resident Financial Health

Q2: Analysis Approach

Question 2: Resident Financial Health



- Building heatmap
- Savings by location
- Identify red zones

- Demographic, expense and salary features
- K-Means clustering
- Personas & drivers

- Expense dynamics over time
- Inequality trends (Gini)
- Income vs. expenses

Geographic Financial Health

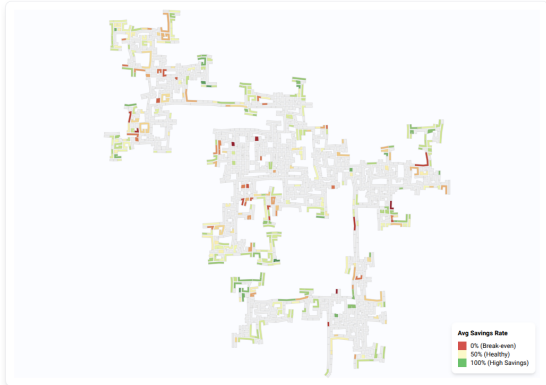
Question 2: Resident Financial Health

Building-Level Heatmap

- Colors by average savings rate
- Red: break-even or negative
- Yellow: moderate savings
- Green: high savings

Insights

- “Red pockets” persist over time
- Chronic, not worsening, conditions
- Mini-clusters suggest local stressors



Clustering Summary (k = 3)

Question 2: Resident Financial Health

Model Choice

- Elbow plot used to balance fit vs. complexity
- Smallest stable solution selected: $k = 3$ **clusters**
- Used all participant data (+ financial journal)

How It's Used in the Dashboard

- **Cluster** filter applied to the PCP
- Same filter applied to the **Living Gap scatterplot**
- Global time slider

Affluent Achievers
High income, strong buffer

Stretched Households
Kids & tight budgets

Lean Savers
Moderate income, lower costs

Resident Profile: Affluent Achievers

Question 2: Resident Financial Health

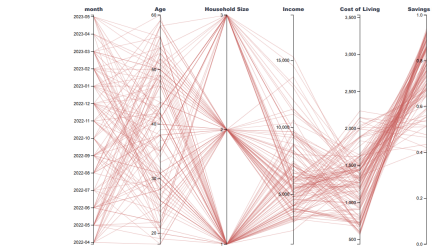
Affluent Achievers

Main Characteristics

- High income levels
- Predominantly graduate education
- Significant financial buffer

Median Statistics (Apr 2022)

- **Income:** $5,756
- **Cost:** $1,419
- **Savings:** 76.6%



Resident Profile: Stretched Households

Question 2: Resident Financial Health

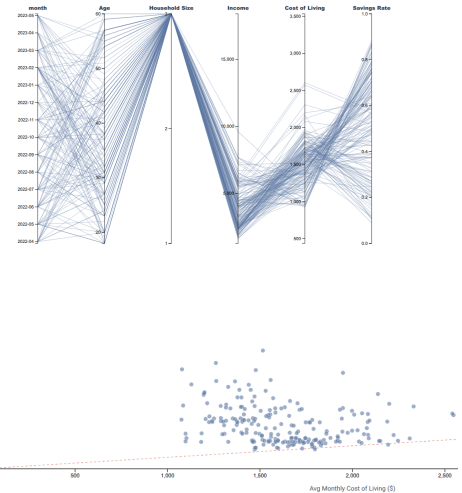
Stretched Households

Main Characteristics

- Larger households, often with children
- Tightest budget constraints
- ”Living Gap” pressure is highest here

Median Statistics (Apr 2022)

- **Income:** $2,869
- **Cost:** $1,405
- **Savings:** 51.0%



Resident Profile: Lean Savers

Question 2: Resident Financial Health

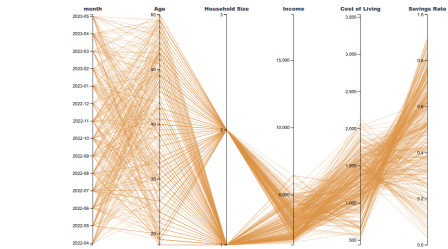
Lean Savers

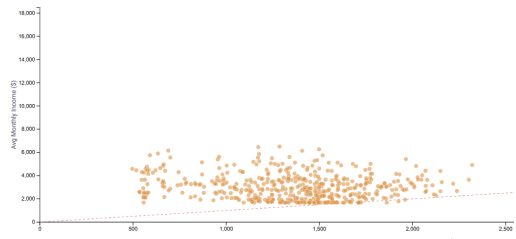
Main Characteristics

- Smaller households
- Typically without children
- Moderate income, but lower costs than families

Median Statistics (Apr 2022)

- **Income:** $3,352
- **Cost:** $1,586
- **Savings:** 54.5%





What Drives Savings?

Question 2: Resident Financial Health

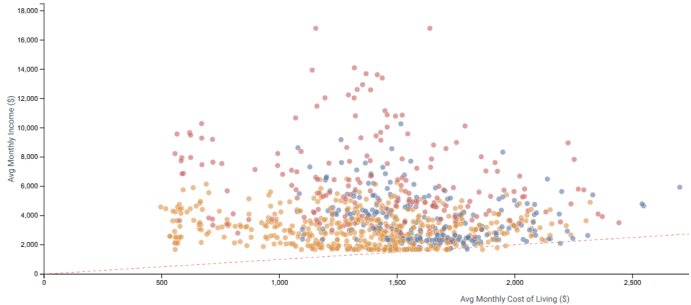
Demographic Drivers

Savings rate predictors (ΔR^2)

- Cost of living (0.828)
- Income (0.408)
- Household size (0.376)
- Has kids (0.127)

Cluster separators (η^2)

- Has kids (83.1%)
- Graduate education (72.0%)
- Household size (61.9%)
- Income (38.0%)



Inequalities Over Time

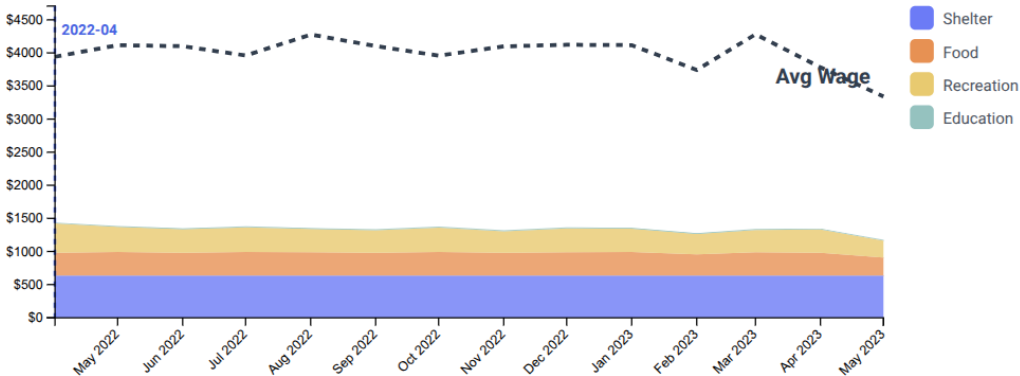
Question 2: Resident Financial Health

Inequality Trends

- Gini coefficient tracks disparity
- Income inequality stable over time
- Savings inequality slightly higher

Expense Dynamics Over Time

Question 2: Resident Financial Health



UNIVERSITY OF LUXEMBOURG

Question 3: Employer Health

Employer Health: Methodology & Approach

Question 3: Employer Health

Workforce Dynamics

- Turnover, hires, quits, net change
- Identifies extreme churn and instability
- Focus on employer-level change intensity

Stability & Retention

- Turnover vs. average tenure
- Headcount as contextual factor
- Distinguishes stable vs. high-risk employers

Mobility & Context

- Job-to-job flows between employers
- Geographic concentration of churn
- City-level employment and economic scale

Employer Turnover Ranking

Question 3: Employer Health

Ranking Methodology

- Ranks employers by turnover, hires, quits, or net change
- Focuses on upper tail of workforce churn
- Highlights extreme instability cases

Key Observation

- Some employers exceed 100% turnover
- Driven by small average headcounts
- Indicates intense, concentrated churn

Turnover vs. Workforce Tenure

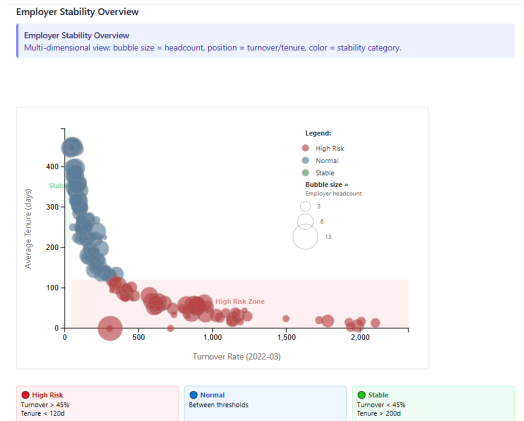
Question 3: Employer Health

Inverse Relationship

- Clear separation into two regimes
- **Stability Zone**: low turnover, high tenure
- **Instability Zone**: high turnover, low tenure

Bubble Size

- Encodes employer headcount
- Size alone does not guarantee stability
- High-risk large employers amplify impact



Worker Mobility Between Employers

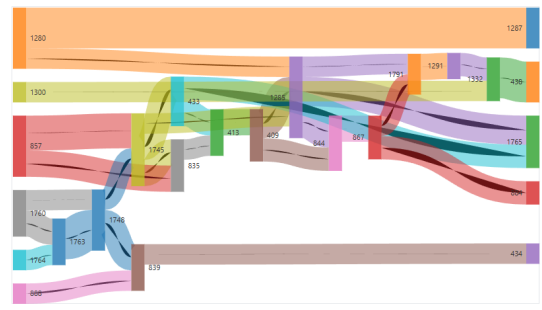
Question 3: Employer Health

Job-to-Job Flows

- Directional worker movement
- Some employers act as labor sources
- Others function as recipients

Network Effects

- Worker movement links employers
- Instability propagates through network
- Asymmetry reveals labor market structure

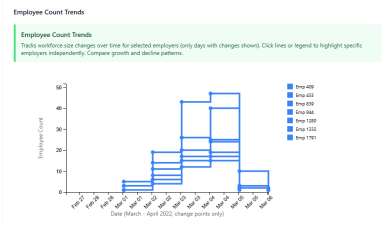


Short-Term Workforce Growth & Decline

Question 3: Employer Health

Non-highlighted View

Highlighted View



- Step-line chart: only days with changes
- Abrupt spikes and drops
- Reflects short-term, episodic workforce adjustments within the observed period

Geographic Concentration of Employer Instability

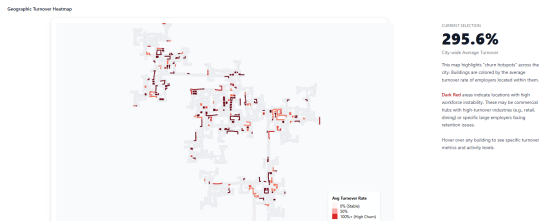
Question 3: Employer Health

Building-Level Aggregation

- Turnover aggregated to building level
- Clear spatial hotspots visible
- Identifies localized instability clusters

Implications

- Workforce instability concentrates spatially
- Not uniformly distributed across city
- Suggests local economic stressors



Design Decisions

UNIVERSITY OF LUXEMBOURG

Tech Stack

Design Decisions

Frontend

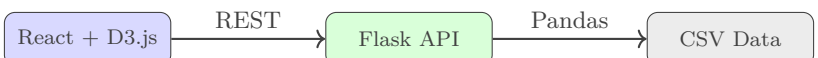
- **React 18:** Component architecture
- **D3.js v7:** Visualization rendering
- **TailwindCSS:** Styling
- **Axios:** API communication

Infrastructure

- **Docker Compose:** Orchestration
- **Nginx:** Reverse proxy

Backend

- **Python 3.11:** Core language
- **Flask:** REST API
- **Pandas/NumPy:** Data processing
- **Scikit-learn:** K-Means clustering
- **Pytest:** Testing



Team Organization

UNIVERSITY OF LUXEMBOURG

Work Organization

Team Organization

Division of Work

- One question per team member
- Shared infrastructure setup
- Code reviews via Git

Thomas	Q1: Business Prosperity
Jan	Q2: Resident Financial Health
Michal	Q3: Employer Health

Shared Components

- Docker infrastructure
- API structure
- Test framework

Communication

- Regular syncs and feedback
- Clear API contracts

Lessons Learned

UNIVERSITY OF LUXEMBOURG

Lessons Learned

Lessons Learned

What Worked Well

- Docker for reproducibility
- Clear question separation
- Caching for large datasets
- Test-driven development

Challenges

- Large dataset with uneven distributions
- Balancing detail vs. overview
- Pre-processing for real-time usage

Would Do Differently

- More upfront data profiling

UNIVERSITY OF LUXEMBOURG

Thank You!

Questions?

Thomas Gantz — Q1: Business

Jan Marxen — Q2: Residents

Michal Sterzel — Q3: Employers

github.com/janmarxen/VAST-challenge

Data Visualization – EUMaster4HPC – December 2025

Temporary page!

LaTeX was unable to guess the total number of pages correctly. As there was so
unprocessed data that should have been added to the final page this extra page
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.