

Geospatial Intelligence for Healthcare Operations: Interactive Mapping for Multi-Facility Network Analytics

Ameer Fahad Ali Khan

Oracle Corporation

ameerfahadali@gmail.com

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Abstract

Healthcare networks spanning multiple facilities face unique operational challenges that are inherently geographic: patient flow between hospitals, regional capacity constraints, and resource allocation across territories. Traditional tabular dashboards fail to capture these spatial relationships. This paper presents an implementation of geospatial intelligence for healthcare operations, deployed as part of an AI-powered analytics platform for a Southeast Asian hospital network with 15+ facilities. Using Leaflet.js for interactive mapping integrated with real-time operational data, we enable healthcare executives to visualize bed utilization, patient volumes, and performance metrics across their geographic footprint. The implementation demonstrates how location-aware analytics provide insights impossible to derive from traditional reports, including regional clustering patterns, optimal patient transfer routes, and geographic gaps in service coverage.

1. Introduction

Healthcare delivery is fundamentally geographic. Patients choose hospitals based on proximity. Ambulance routing depends on traffic and distance. Capacity planning must account for population density. Yet most healthcare analytics platforms present data in tables and charts that strip away this geographic context [1].

For healthcare networks operating multiple facilities across a region, this limitation is particularly acute. Executives reviewing tabular reports cannot easily answer questions like: "Which facilities are geographically positioned to absorb overflow from our busiest hospital?" or "Are there underserved areas where we should consider expansion?"

This paper presents an implementation of geospatial intelligence for healthcare operations, deployed as part of a broader AI analytics platform [2]. We detail the technical implementation using Leaflet.js, the integration with operational databases, and the unique insights enabled by location-aware visualization.

1.1 The Geographic Dimension of Healthcare

Healthcare operations have inherent geographic characteristics:

- **Catchment areas:** Each facility serves a geographic population
- **Transfer patterns:** Patients move between facilities based on specialty and capacity
- **Regional variations:** Disease prevalence and demographics vary by location
- **Competitive landscape:** Other providers' locations affect market dynamics

1.2 Contributions

1. **Technical implementation** of Leaflet.js for healthcare facility mapping

2. **Integration patterns** connecting maps to real-time operational data
3. **Use cases demonstrating** unique insights from geospatial healthcare analytics
4. **Performance optimization** for responsive map interactions

2. Technical Implementation

2.1 Technology Selection

We evaluated several mapping libraries before selecting Leaflet.js:

Library	Pros	Cons	Decision
Leaflet.js	Lightweight, React-friendly, free	Less 3D support	✓ Selected
Google Maps	Familiar UX, rich features	Per-load pricing, API limits	Rejected
Mapbox GL	Beautiful styling, 3D	Commercial license cost	Rejected

Table 1: Mapping Library Evaluation

2.2 React-Leaflet Integration

```
// HospitalMap.jsx
import { MapContainer, TileLayer, Marker, Popup } from 'react-leaflet';
import 'leaflet/dist/leaflet.css';

function HospitalMap({ hospitals, onHospitalSelect }) {
  // Center map on network's geographic center
  const center = calculateCentroid(hospitals);

  return (
    <MapContainer
      center={center}
      zoom={7} // Country-level view
      style={{ height: '500px', width: '100%' }}
    >
      <TileLayer
        url="https://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png"
        attribution="© OpenStreetMap"
      />
    </MapContainer>
  );
}
```

```
{hospitals.map(hospital => (  
  <HospitalMarker  
    key={hospital.id}  
    hospital={hospital}  
    onClick={() => onHospitalSelect(hospital)}  
  />  
))}  
</MapContainer>  
);  
}
```

3. Data Integration

3.1 Hospital Data Model

```
// Hospital data structure
{
  id: 'HOSP001',
  name: 'Regional Medical Center',
  coordinates: { lat: 3.1390, lng: 101.6869 },

  // Real-time operational metrics
  metrics: {
    bedUtilization: 0.82,      // 82% beds occupied
    admissionsToday: 47,
    dischargesToday: 38,
    avgLengthOfStay: 4.2     // days
  },

  // Static facility info
  facility: {
    totalBeds: 350,
    specialties: ['Cardiology', 'Oncology', 'Pediatrics'],
    tier: 'Tertiary'
  }
}
```

3.2 Color-Coded Markers

Markers are dynamically colored based on operational status:

Color	Bed Utilization	Operational Meaning
Green	< 70%	Capacity available; can accept transfers
Yellow	70-85%	Moderate load; monitor closely
Orange	85-95%	High load; prepare contingency
Red	> 95%	Critical; divert admissions

Table 2: Marker Color Coding by Utilization

4. Operational Use Cases

4.1 Regional Capacity Planning

Executives can visualize capacity across regions at a glance. A cluster of red markers in one area immediately signals regional strain, while nearby green markers indicate potential overflow destinations.

4.2 Patient Transfer Optimization

When a facility reaches capacity, the map shows which nearby hospitals have available beds. Click-through to facility details reveals whether the destination has appropriate specialty coverage.

4.3 Service Gap Analysis

By overlaying population density data with facility locations, executives can identify underserved geographic areas—informing expansion planning and mobile clinic deployment.

4.4 Executive Dashboard Integration

The map serves as a navigation hub. Clicking any facility marker opens a detailed drilldown panel showing that hospital's KPIs, trending metrics, and AI-powered insights [2].

5. Performance Optimization

5.1 Rendering Performance

Metric	Target	Achieved
Initial map render	<2s	1.2s
Marker click response	<100ms	45ms
Pan/zoom smoothness	60 fps	60 fps
Data refresh interval	5 min	5 min

Table 3: Map Performance Metrics

5.2 Optimization Techniques

- **Marker clustering:** Group nearby markers when zoomed out
- **Lazy popup loading:** Fetch detailed data only on marker click
- **Tile caching:** Browser caches map tiles for faster pan/zoom
- **React memoization:** Prevent re-renders when data unchanged

6. Conclusion

This paper presented an implementation of geospatial intelligence for healthcare operations.

Key findings:

- **Geographic visualization reveals insights** impossible to derive from tabular reports
- **Leaflet.js provides excellent performance** for healthcare facility mapping
- **Color-coded markers** enable instant capacity assessment across regions
- **Integration with AI analytics** creates a powerful operational command center

For healthcare networks operating multiple facilities, geospatial intelligence should be considered an essential component of operational analytics platforms.

References

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