



# Redefining Surgical Efficiency: How the Surgical Spatial Layout Impacts Total Operative Time



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## Introduction/Background

- **Critical Metric & Systemic Impact:** Total operative times are a key indicator of OR performance; accurate tracking improves scheduling, resource allocation, and cost analysis
- **Enhanced Care:** Optimizing operative efficiency enhances surgical workflows and patient safety, while reducing staff fatigue and improving overall staff satisfaction
- **Existing Knowledge:** Prior research has extensively examined organizational factors, including team size, team composition, and scheduling interruptions
- **Research Gap:** Limited research on how OR spatial configuration, and its integration into the broader physical environment, impacts operative time
- **Spatial Risks:** The spatial configuration can drive surgical errors, communication breakdowns, and reduced staff performance
- **Flow Disruptions:** Layout-related issues constitute >50% of observed flow disruptions within the OR
- **Travel Time:** Spatial layout impacts efficiency by influencing the travel time of clinical and support staff between different zones or regions within the surgical space

## Research Questions and Hypotheses

- **Research Question 1 (Local Accessibility):** Does the Harmonic Mean Depth (HMD), which captures the accessibility of spaces in their neighborhood, significantly impact total operative times?
  - **Hypothesis 1 (H1):** There is a positive and significant relationship between a surgical suite's HMD score and total operative times. Higher depth = longer times
- **Research Question 2 (Global Centrality):** Does the Betweenness (BETW), which measures the extent to which spaces are on the shortest paths between other space-pairs, significantly impact total operative times?
  - **Hypothesis 2 (H2):** There is a negative and significant relationship between a surgical suite's BETW score and total operative times. Greater global centrality = shorter times
  - **Comparative Question:** Which spatial property, local accessibility (HMD) or global centrality (BETW), is a stronger predictor of surgical efficiency?

## Materials and Methods

- **Setting:** A 100-bed Level II trauma center located in Germany
- **Context:** Largest American military hospital outside the continental U.S.; staffed by Army, Air Force, and civilian personnel
- **Sample:** 14,515 surgical procedures across 14 surgical specialties
- **Database selection:** Surgical case data from an enterprise-wide, web-based, automated surgical scheduling system

## Materials and Methods

### Research Design & Theoretical Approach

- **Design:** Retrospective, cross-sectional study utilizing network analysis and linear regressions
- **Network Approach:** Buildings and constituent spaces treated as micro-level geographies, as complex as urban environments
- **Topological Analysis:** Utilization of a spatial network approach to understand the impact of configurational properties (e.g., accessibility, connectivity) on outcomes
- **Local vs. Global:** Distinction between local network aspects (i.e., access to space) and global aspects (i.e., critical flows across the system)
- **Inclusion Criteria:** We examined four years of surgical cases from 14 specialties regardless of classification, type, or level of complexity

### Measures

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|--|--|
| <b>Dependent Variable</b>                      | Log-transformed Total Operative Time (LogTotOp), measured from "wheels-in" to "wheels-out"   |
| <b>Independent Variables (Spatial Network)</b> | <b>Harmonic Mean Depth (HMD):</b> "Space Syntax" measure of local accessibility; gives more weight to shorter paths<br><b>Betweenness (BETW):</b> Global connectivity measure; quantifies frequency of space on shortest paths |
| <b>Control Variables</b>                       | Surgical complexity (wRVU), Case order (CASE), Surgical specialty (SURG), and Suite Identifier (ORID)  |

### Statistical Analysis

- **Network Analysis:** Electronic floor plans were first processed into convex spatial graphs using CAD. The resulting graph was analyzed with specialized software to compute measures: Harmonic Mean Depth (HMD) via depthmapX, and Betweenness (BETW) via Pajek/NetDraw
- **Regression Modeling:** Estimated using Ordinary Least Squares (OLS) Regression

## Key Findings/Results in Plain English

- **Easy Access Saves Time:** Surgeries finish faster when the operating room is easy to get to from the rooms immediately surrounding it (like scrub rooms and supply areas)
- **"Buried" Rooms Cause Delays:** Operating rooms that are tucked away deeper in the floor plan, making them harder to reach, are linked to longer surgery times
- **Main Hallways Don't Help:** Being located on a busy, central corridor of the hospital floor does not speed up surgeries
- **Neighborhood Matters Most:** The layout surrounding the operating room affects speed over two times more than the general floor plan
- **Standard Factors Still Apply:** As expected, more complicated surgeries and cases scheduled later in the day take longer, but the room's layout remains a critical hidden factor

## Results

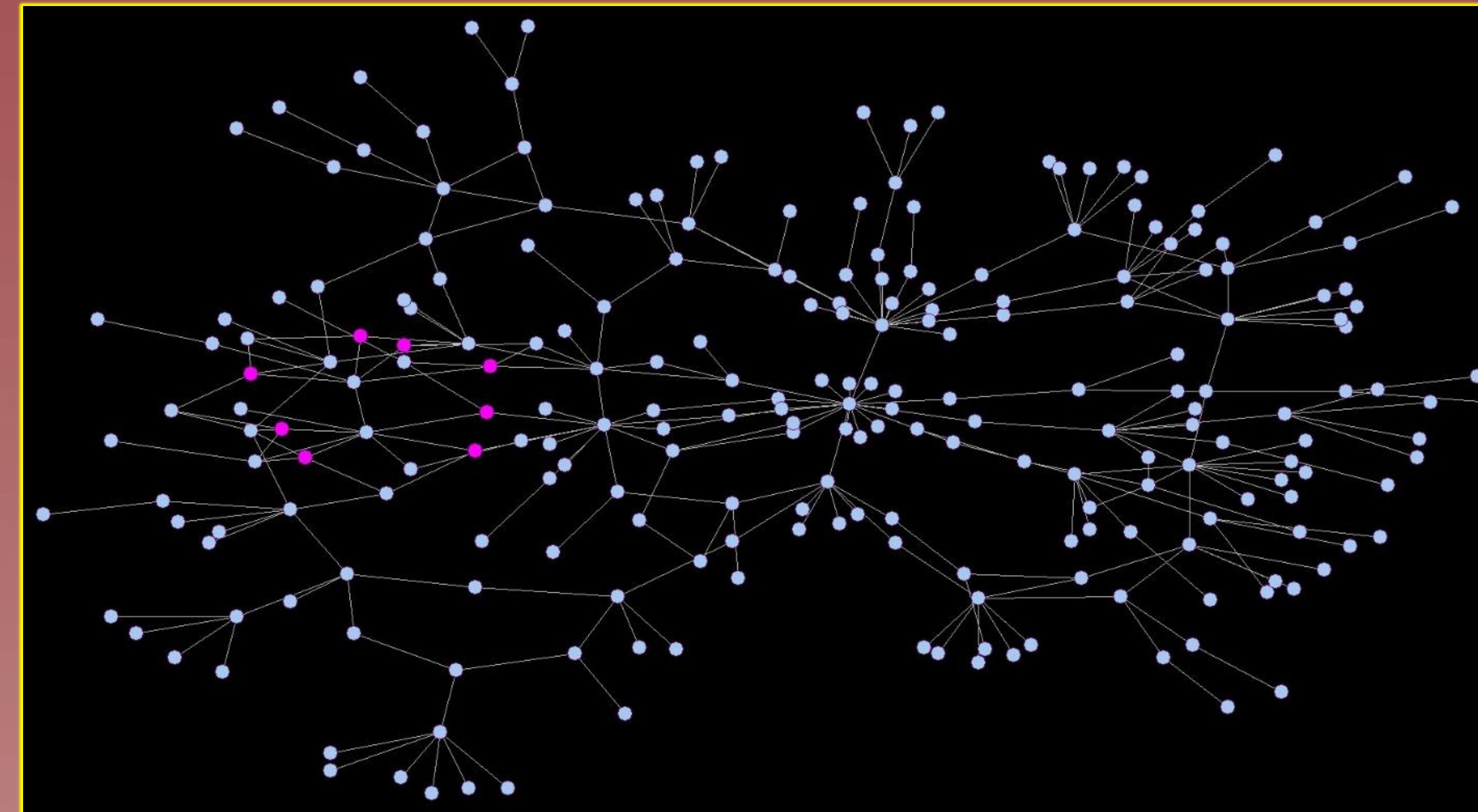


Figure 1. Spatial network of the hospital's third floor, including the OR. The 8 surgical suites are colored pink to distinguish them from the other spaces on the floor

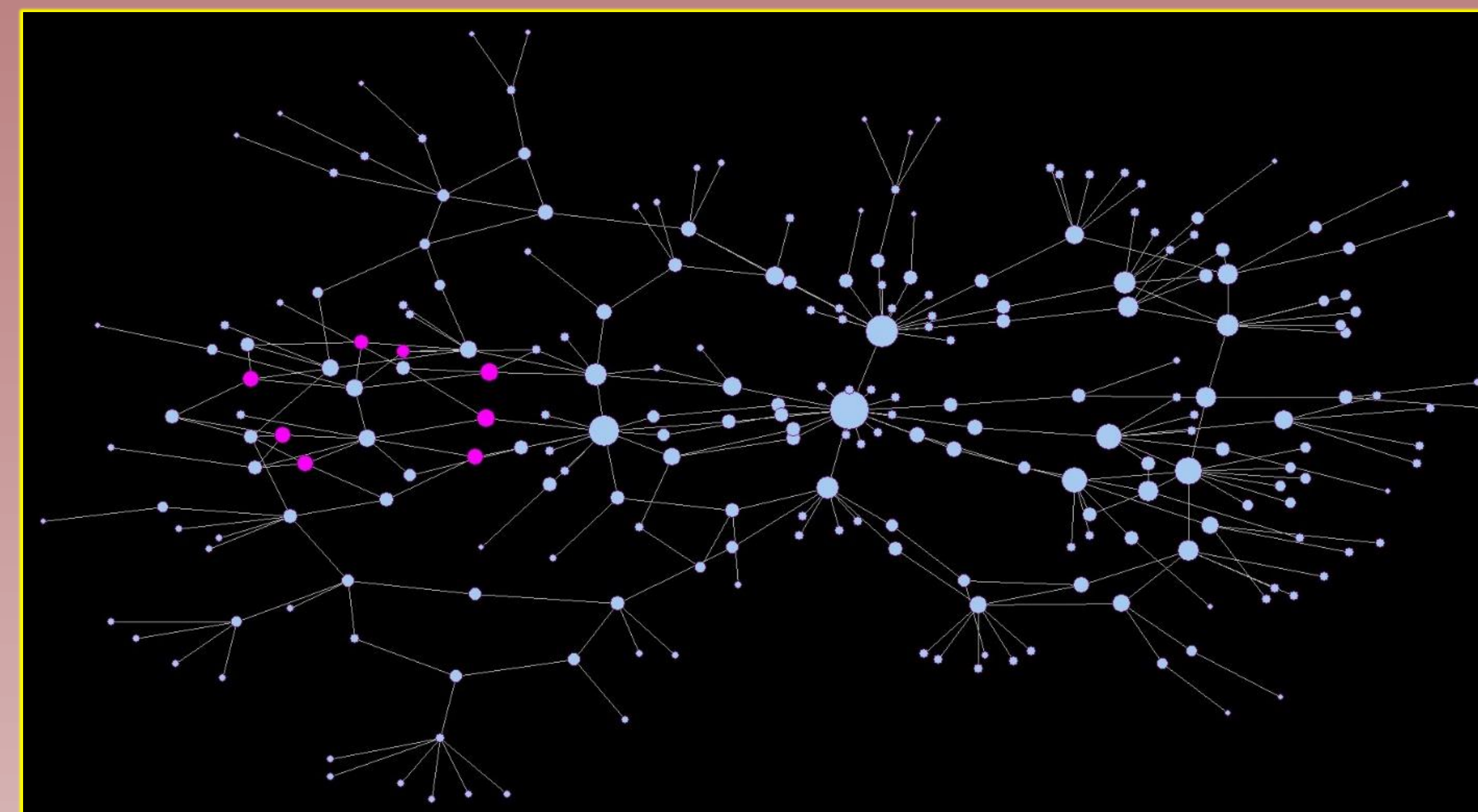


Figure 2. Third floor spatial network with the nodes or spaces resized by their HMD values (the larger the HMD value, the bigger the node)

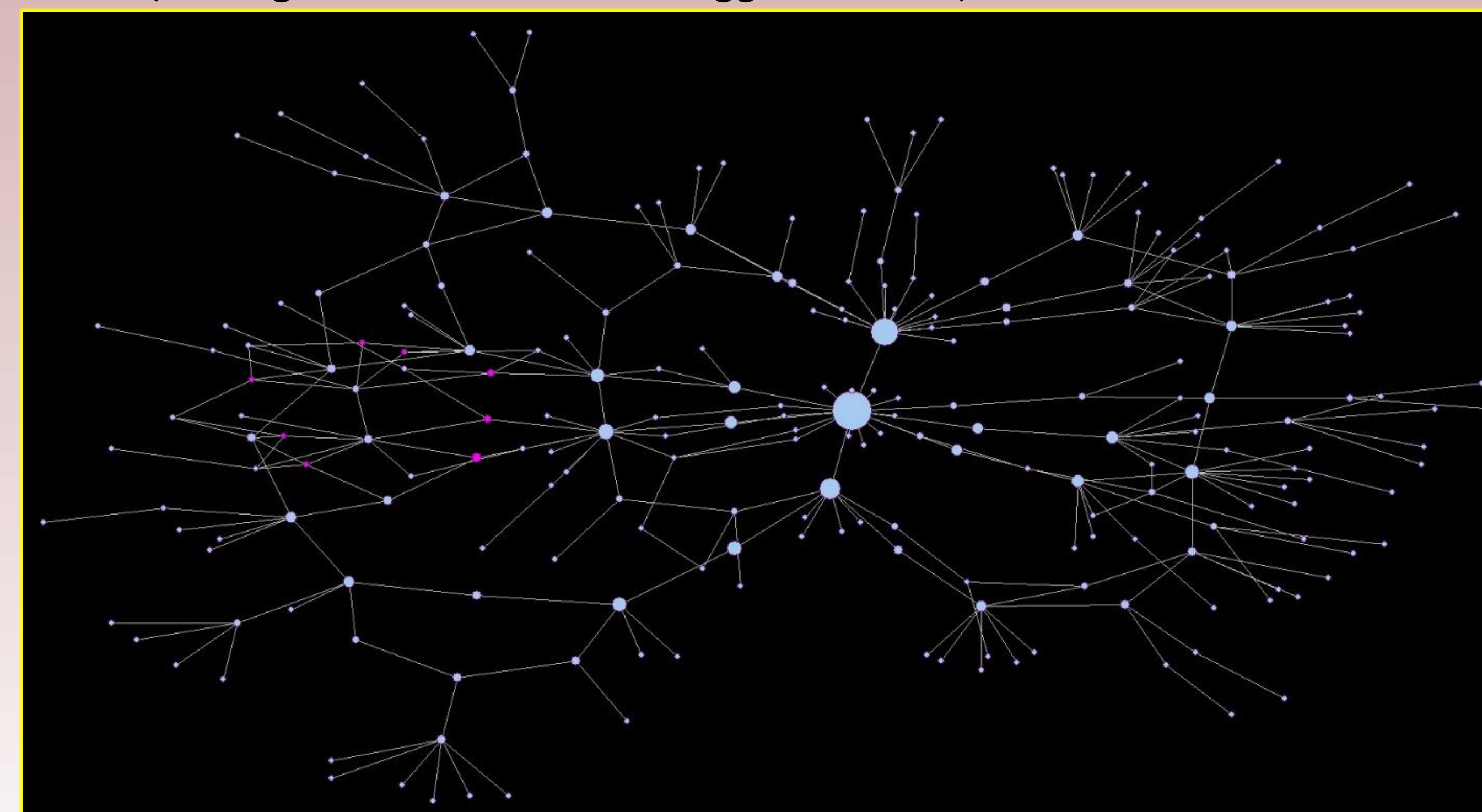


Figure 3. Third floor spatial network with the nodes or spaces resized by their BETW values (the larger the BETW value, the bigger the node)

## Results

### Network Topology

- **The ORs are Local Hubs:** Surgical suites have high local accessibility (Mean HMD = 13.88), scoring 36.9% higher than the floor average, indicating strong connectivity to immediate adjacencies
- **The ORs are Not Throughways:** Suites have low global centrality (Mean BETW = 514.39), scoring 15.7% lower than the floor average, meaning they do not serve as major corridors

### Hypothesis Testing

#### H1: Local Accessibility Impacts Time = SUPPORTED

- **Finding:** Higher depth (lower accessibility) is significantly associated with longer total operative times ( $p < 0.001$ )
- **Impact:** The more "buried" or less locally accessible an OR suite is, the longer the surgical procedure takes

#### H2 Global Centrality Impacts Time = NOT SUPPORTED

- **Finding:** Being on a "main road" (high Betweenness) had no significant effect on operative time ( $p = 0.504$ )
- **Impact:** Global location within the hospital floor is less critical than local configuration

### Comparative Influence

- **Local > Global:** The local layout factor (HMD) is 2.63 times more influential on operative time than the global layout factor (BETW)

### Control Factors

- Higher surgical complexity (wRVU) and later case orders were both significantly associated with increased operative times

## Implications

- Prioritize interventions targeting the local OR layout (immediate neighborhood), offering a higher return on investment than global reconfiguration
- Focus redesign on optimizing circulation paths and decluttering areas immediately surrounding suites to reduce flow disruptions
- Implement point-of-use storage for instruments/medications to minimize staff travel time during procedures
- Distraction Management: Position surgical assets away from high-traffic global connectors to reduce ambient noise and foster a focused environment

## Limitations

- Single Site: Data from a single military medical center; may limit generalizability to other populations/multi-center settings
- Use of Work Relative Value Units (wRVU) for complexity; requires periodic refinement to reflect evolving technologies

### References available upon request

**This Study is under review in Results in Engineering (RINENG)**  
Kabo F.W., Stucky C.H., De Jong M.J., House S.L. (2025). Local vs Global Effects of the OR's Spatial Network on Total Operative Times at a Military Medical Center

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