Observing, Analyzing, and Modeling Design Team Problem Decompositions in Facility Design

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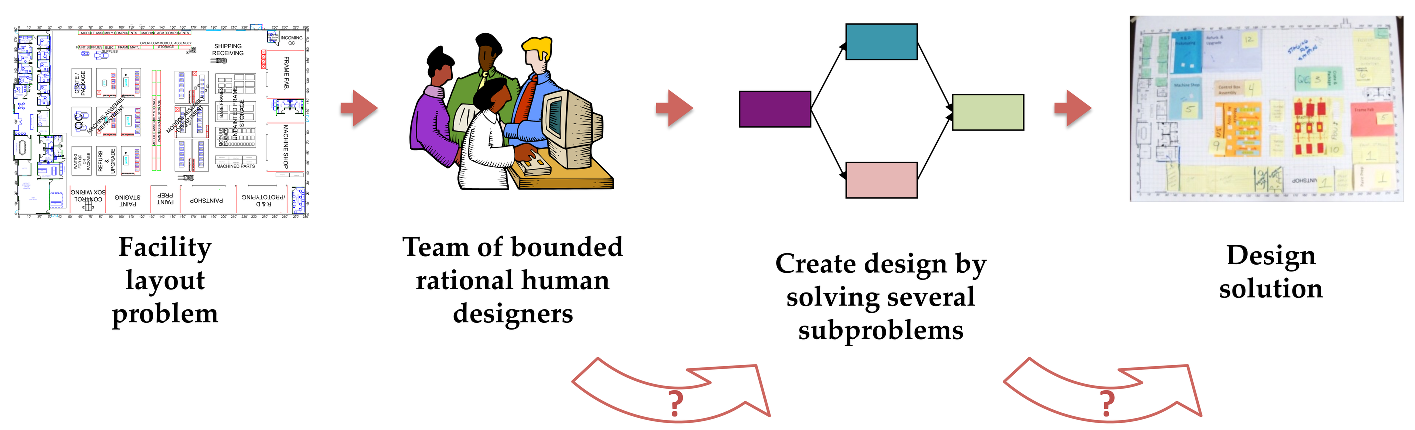
MOTIVATION

When faced with the problem of designing a complex system, a design team must make many decisions. Because many design problems are too difficult to solve all at once, the design problem is decomposed into more manageable subproblems. The decomposition is governed by the design process, which may be a formal process imposed by an organization or an informal set of activities organically determined by a team of designers.

The way in which a problem is decomposed may affect the quality of the solution that can be constructed, especially when time and resources are limited. Investigating how teams decompose problems and the impact of decomposition on design solution quality will support the design of better design processes.



RESEARCH QUESTIONS

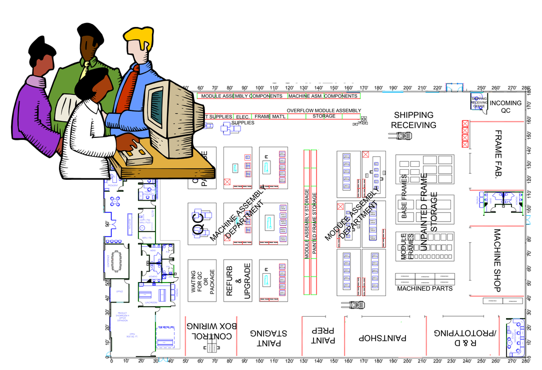
How do design teams decompose a complex design problem into related subproblems?

What subproblems do they solve, and in what order?

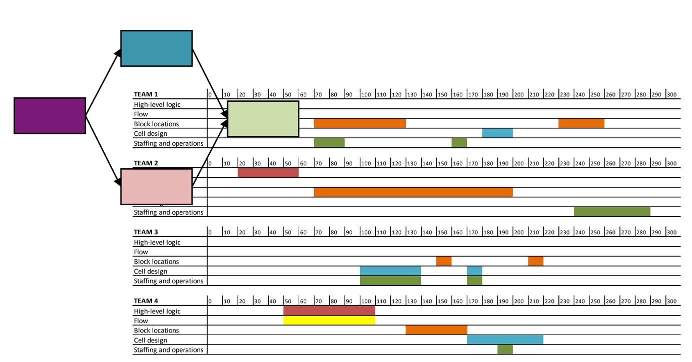
How does the choice of decomposition impact the character and quality of the resulting design solution?

APPROACH

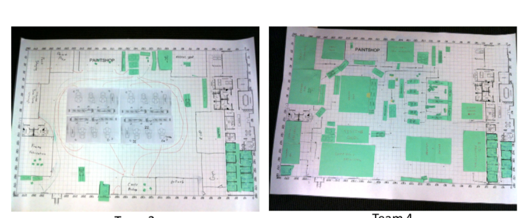
1. Design teams solve a factory redesign problem. Researchers record their activities.



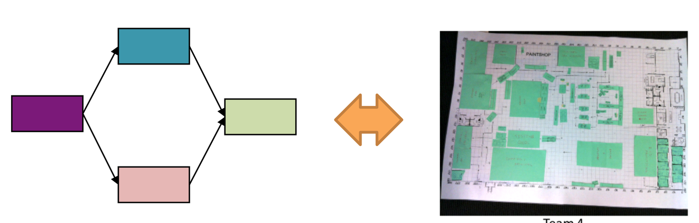
2. Design team activities analyzed to describe the subproblems they solved as they made their designs.



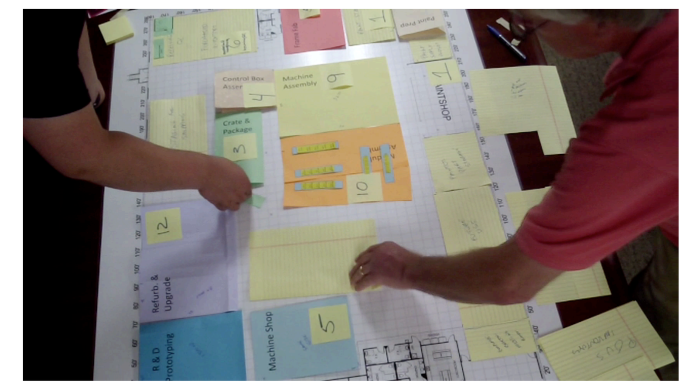
3. Quality of design solutions evaluated quantitatively and qualitatively by an expert.

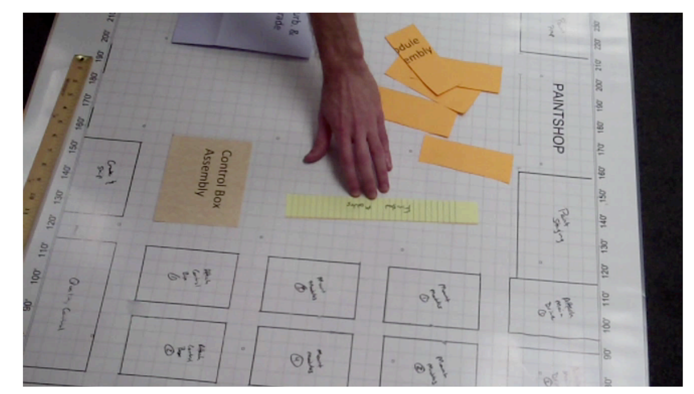


4. Researchers analyzed the decompositions of the teams alongside their solutions.



DATA COLLECTION AND EXERCISE DESIGN





Data Collection: Teams of 3 to 6 participants design a facility during a 2 to 4 hour exercise. Activities are video- and audio-recorded.

Data collected to date:

- 10 teams for factory redesign study (manufacturing professionals)
- 4 teams for POD study (students); 6 teams planned (public health professionals)

Factory Redesign Problem: Teams redesign a factory by rearranging manufacturing operations to enable more efficient production and material movement.

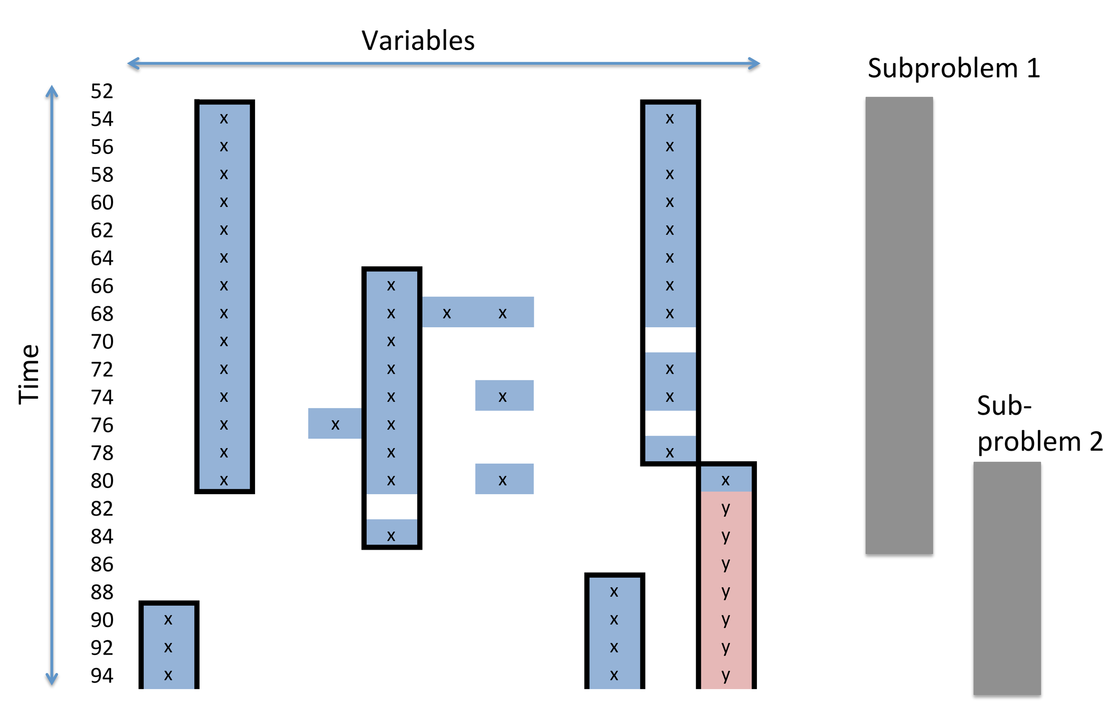
POD Design Problem: Teams design a Point of Dispensing (POD) for distribution of antibiotics to the public after a suspected anthrax attack. Teams must determine the locations of critical stations, the number of staff at each station, and parking and pedestrian flow arrangements.

DATA ANALYSIS

Identifying Subproblems: We identified the subproblems that each team solved and when they considered those subproblems. To do this, we used both qualitative and quantitative analysis techniques.

1. We first used qualitative analysis techniques to inductively develop variable definitions. For each 2-minute segment of video, we then identified the variables they discussed.

2. We divided the coded timelines into longer segments in which teams worked on the same set of variables. We used association rules (a data mining technique) to identify groups of variables that tended to occur in the same segments. Beginning with these groups, we used qualitative methods (constant comparison with data) to distill a set of subproblems.



Evaluating Design Solutions: For each design layout, we evaluated its quality in two ways: a set of quantitative measures and a qualitative expert review.

1. Quantitative measures:
   - Total distance traveled from receiving to shipping
   - Adjacency score that measures the proximity of areas that should be near each other
2. A manufacturing facility design expert evaluated each layout based on four criteria: overall impression, assembly operations, facility material flow, area location and design.

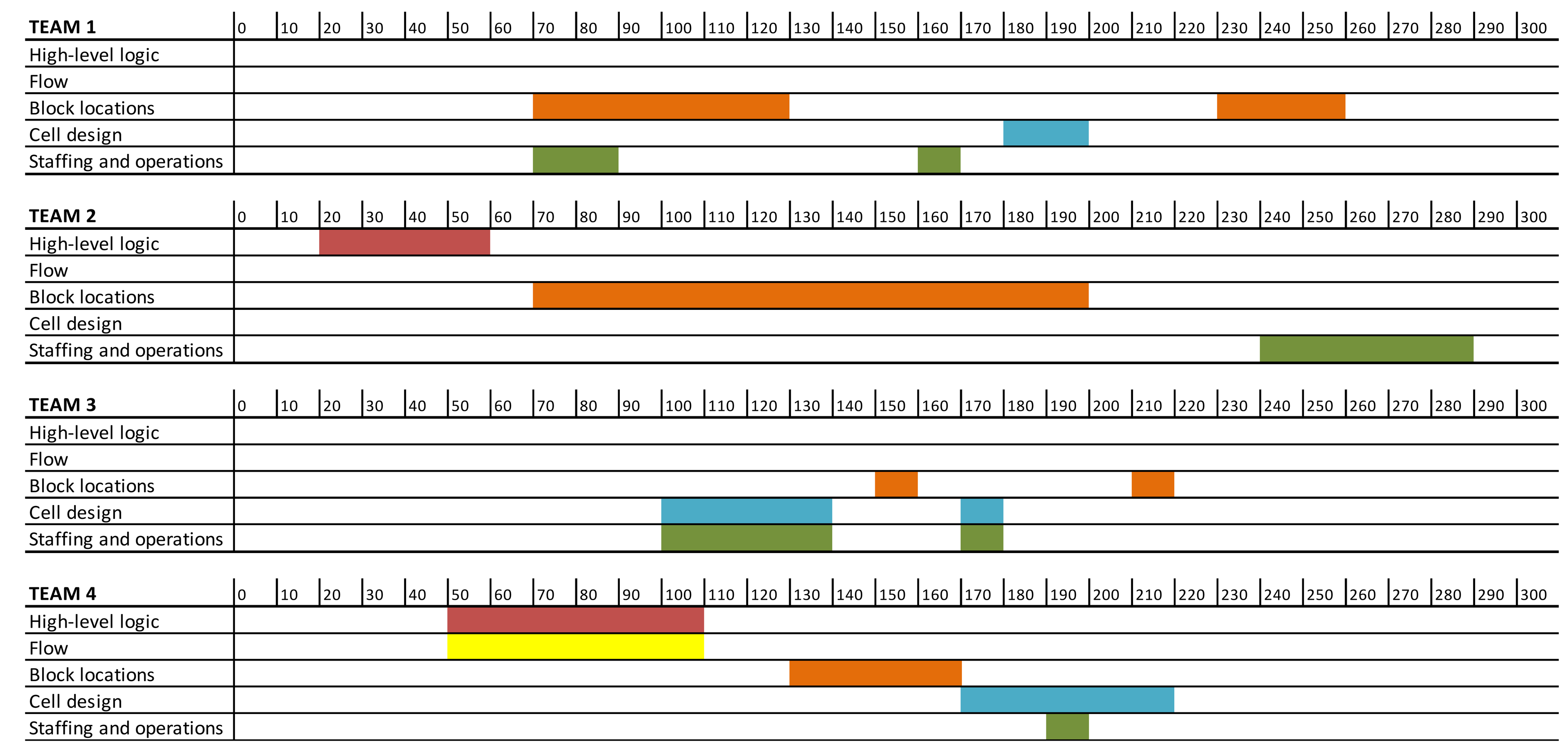
PRELIMINARY RESULTS AND CONCLUSIONS

Data: Based on the results from four teams with 20 participants: eight engineers, three production and facility managers, six executives, two sales personnel, and one technician. Average experience in industry = 14 years (min = 2 years, max = 38 years).

Results: Identified five major subproblems.

The timelines show the 10-minute intervals when each team worked on each subproblem.

Subproblem	Description	Variables included
High-level logic	Logic of flow through facility, including order of steps, grouping of operations into cells (independent of geography)	High-level flow logic, Assignment of products to cells, Assignment of operations to cells
Flow	Direction and shape of flow through facility (spatially)	Spatial flow pattern
Block locations	Location of blocks representing functional areas or groups of operations, such as machine shop or assembly cells	Location of [all blocks], Storage
Cell design	Design of assembly cells or lines that group a series of operations. Includes shape, layout of operations, determination of operations and products to include in cells.	Layout of cell, Shape of cell, Assignment of products to cells, Assignment of operations to cells
Staffing and operations	Sequencing and balancing of operations, including takt times, staffing and tasks.	Staffing in cell, Staffing in functional area, Operation sequencing and balancing



Analysis: Teams 2 and 4 worked "top-down" from a high-level view. Teams 1 and 3 worked "bottom-up," beginning with details.

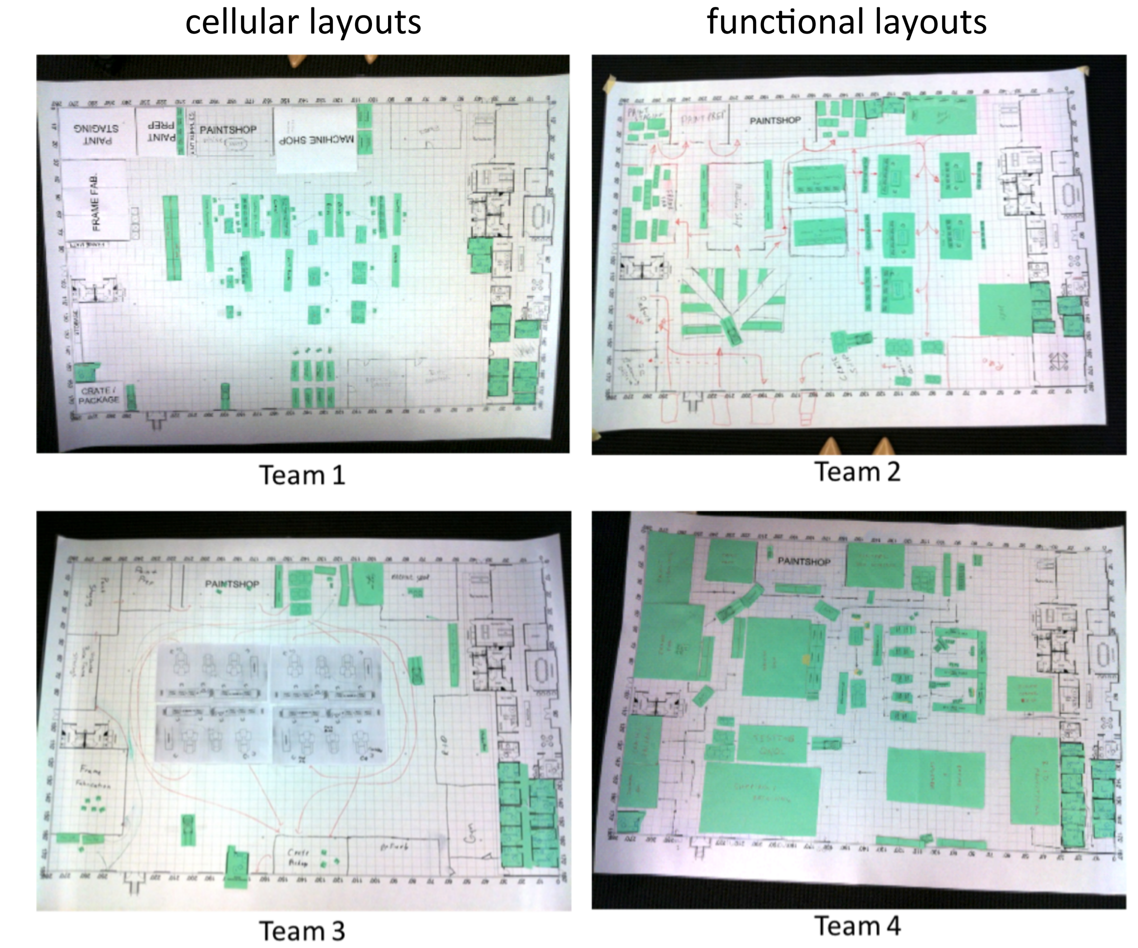
Conclusions: Problem decomposition appears to influence the character and quality of design solutions:

- Bottom-up decompositions led to better cellular layouts.
- Top-down decompositions led to poorer functional layouts.

The design solutions differed in character and quality:

Teams 1 and 3 developed cellular layouts

Teams 2 and 4 developed functional layouts



PUBLICATIONS AND SUPPORT

This project is supported by National Science Foundation grants CMMI-1435074 and CMMI-1435449.

Publications

- Gralla, Erica L., and Jeffrey W. Herrmann, Design Team Decision Processes in Facility Design, ISERC 2014 Proceedings, Y. Guan and H. Liao, eds., Montreal, Canada, June 1-3, 2014.
- Tobias, Connor, Jeffrey W. Herrmann, and Erica L. Gralla, Exploring Problem Decomposition in Design Team Discussions, ICED 2015, Milan, Italy, July 27-30, 2015.

For more information, please see:

http://www.isr.umd.edu/~jwh2/projects/teams.html