Project Title: System Analysis and Optimization in Design for Digital Manufacturing  
Research Team: Guiping Hu (IMSE), Randy Boeckenstedt (Institute for Transportation)

**Thrust Area: Design Optimization**

### Need and Industrial Relevance
- Expect cost of heavy-duty trucking to rise substantially relative to rail ...
- Roadway financing underpriced … long-term financing proposals focus on “market-driven” pricing … fully loaded semi pays about $0.06/mile in fuel taxes … generates ~25,000 times more roadway deterioration than passenger car getting 25 mpg and paying $0.02/mile ...
- In other words, trucks “consume” ~ 5000 times more roadway per dollar paid ... expect some form of reconciliation
- e-Design concepts should be conceptualized to bypass as much roadway dependency as possible.

### Approach and Methods

1. IMSE will supervise data development and formulate decision and optimization strategies.
2. Introns will assemble data, search literature, and assist in strategy formulation.
3. Data will center on: the Commodity Flow Survey, Industry and Geographic Area Reports, BEA Input-Output Accounts, and related industry and employment reports.
4. Predictive model will be developed from origin and destination data that will be copied into a common data base and indexed to longitude and latitude coordinates.
5. Supply side data (i.e., origin) data will be indexed at the county level.
6. Demand side data (i.e., retail) will be indexed at the “place” level (i.e., cities and towns).
7. The model will predict cumulative freight flows (i.e., ton-miles by rail or truck) from reported origin and destination data.
8. Results will be tested against aggregated totals reported in the Commodity Flow Survey. The model will later be used to generate input data for optimization and other decision modeling.
9. Supply side data will track originating base materials (e.g., mining output) through sequential processing and distribution stages. Allocations from one stage to the next will be based on Input X Accounts, and related industry and employment reports.
10. Population density will serve as a proxy for consumer demands. Tonnage estimates will be calibrated to location-specific retail data adjusted to state-level pull factor averages.

The predictive model will be capable of estimating cumulative freight flow characteristics specific to the roughly 25,000 cities, towns, and rural populations identified throughout the country. This can then be used to selectively develop aggregate decision and optimization protocols by key criteria, such as population density, region, shipping level or input material.

### Outcome/Deliverables

1. Tangible deliverables include an annual report with quarterly updates to industry partners and others (TBD).
2. Reports will discuss progress, along with the rationales for selecting key performance metrics, decision frameworks, analysis, and optimization methods.
3. Peer reviewed journal publications (TBD) will be pursued.

### Objectives

1. Define a predictive model to calculate “benchmark” freight flow dependencies of key structural base materials generated by traditional manufacturing and distribution systems relative to specific consumer markets served.
2. Use the predictive model to formulate relevant performance metrics, analyses, and optimization methods that can be used to site, scale, and position e-Design receiving facilities (i.e., 3-D printing sites) around rail freight and bulk shipping volumes.

### Project Goals

1. Initiate interdisciplinary study of freight flows between IMSE and InTrans with emerging e-Design, 3-D printing and on-demand manufacturing concepts in mind.
2. Position e-design as an alternative to fuel and freight flow instead of as generator of it (i.e., prevent the unintended consequences that JIT generated).
3. Define, formulate, and calibrate new methods to link aggregate, lifecycle truck and rail freight dependencies to consumer (i.e., end user) markets.
4. Promote development of optimization methods for minimizing freight flow dependency at both the macro and enterprise levels.

### Impact

Is it better to formulate e-design concepts around centralized facilities, which distribute finished products broadly by truck (25 ton cargo loads), or is it better to re-position to localized facilities that receive bulk materials by rail (100 tons/rail car)? What are the key transition criteria? What are the key transportation issues?

How does population density affect operating scale? How can these issues be conveniently measured, understood, and accepted by a broad constituency?

### Project Duration

12 Months

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### Proposed Budget

$65,000

- **Boeckenstedt (P&S, includes fringe)** $30,000
- **IMSE Grad Student** $33,000
- **Travel** $2,000

**Total** $65,000