Center for Engineering Logistics and Distribution (CELDi)

A National Science Foundation sponsored Industry/University Cooperative Research Center (I/UCRC)
The promise of an I/UCRC is based on synergy and leveraging.
CELDi Academic Partners

University of Oklahoma

University of Arkansas

University of Missouri

Texas Tech

Lehigh University

Clemson University

Virginia Tech

Arizona State University
| ABF Freight System, Inc.                      | Medline Industries                      |
| Aerospace Inc                                | Michelin North America, Inc.            |
| Air Force Research Lab                        | Northrop Grumman                        |
| Air Liquide                                   | Oklahoma City Air Logistics Center      |
| Arizona Department of Transportation          | Oklahoma Department of Transportation   |
| Arkansas Electric Cooperative                 | Port of Guaymas / State of Sonora       |
| BWXT/Pantex                                   | Queensland Dept of Mines and Energy     |
| Cook Technologies                             | Red River Army Depot                    |
| Crane Div., Naval Surface Warfare Center     | Sam’s Club                               |
| Emcien                                        | Science Applications International Corp.|
| Factory Physics, Inc.                         | SPAWAR                                  |
| F.L. Smith, Inc.                              | U. S. Army Defense Ammunition Center    |
| Federal Aviation Admin. Logistics Center      | United Parcel Service                   |
| Fragrance Manufacturing Inc.                  | Wal-Mart Stores, Inc.                   |
| GE Energy                                     | MU Member – Legget & Platt              |
| Halliburton Energy Services                   | MU Member – AmerenUE                    |
| Innovative Scheduling                         | MU Member – Hallmark Cards              |
| Invistics Corporation                         | MU Member – Boeing                      |
| Lockheed Martin Logistics Services            | MU Member – Freight Pipeline Company    |
• Company specific project that exceeds $50K for one year buys a 1 year membership in CELDi
  – Involves a faculty member and at least 1 graduate & 1 undergraduate student
  – Single project or sequence of projects in phases
• NSF Role
  – Provides $50K per year for center administration
  – NSF requires each university to cost share => no overhead
• Members agree to share the "fundamental research" component of the projects with the other members
  – Confidential remains confidential
  – Companies review all documents before they are released and the university works to develop a version that is acceptable to both the company and CELDi
CELDi Membership Benefits

• Member company specified project with specific deliverables

• Shared fundamental research results provides tremendous *leveraging* of each industrial members research dollars
  – Each member has a nonexclusive, royalty free license to use all project results (access to over $5M in research!)
  – Dissemination
    • Two CELDi Research Conferences per year where results are presented
    • Written reports are accessible from CELDi web page to all members

• Receive CELDi Center Designated Project products
  – Software
  – White papers and Seminars
  – Industry benchmarking

• Membership in the CELDi Industrial Advisory Board (IAB)
  – access to logistics trained students
  – provide direction to CELDi Center Designated Project products
IAB selects the top 10% of the company-designated projects and then are leveraged to all Center members via generalized work products.
Logistics Network Design for Less-than-Truckload Consolidation
Research Team: W Jang (PI), J Noble, Z Yu, P Wutthisirisart

Sponsor: CELDi – Center Designated Project 2009-2010

Problem in context: Many manufacturing and retail companies operate large but sparse domestic distribution networks consisting of highly dispersed origins and destinations and varying levels of shipment volumes. The problem is to evaluate the existing LTL transportation network for possible shipment consolidation strategies, and optimize it to get the maximum transportation cost savings.

Technical Approach
• Develop and solve a mathematical model for the uncapacitated hub network design problem
• Develop software to automatically evaluate and design optimal shipment consolidation strategies
• Test the software using industrial partner data

Important Results
• A Excel-based logistics network design software that evaluates different modes of transportation
• A logistics network design software that develops an optimal shipment consolidation strategy to maximize the overall transportation cost savings
The MU team:
- 8 industrial engineering faculty
- 5 transportation systems engineering faculty
- 2 management logistics faculty
- 1 health management faculty
- 2 agricultural economics faculty

Research Focus:
“An integrated approach to both facility and large scale logistics system challenges through modeling, analysis, and intelligent systems technologies.”
CELDi Focus Areas

- Logistics Systems Analysis and Design
- Supply Chain Modeling
- Material Flow Design & Improvement
- Intelligent Systems
Logistics Systems Analysis and Design

Logistics Strategy
Logistics Network Design
Vehicle Routing
Facility Location
**An Inventory Replenishment Strategy Using International Shipment Consolidation**

Research Team: Wooseung Jang (PI), James Noble, Na Deng

**Sponsor:** Legget and Platt, Inc.

**Problem in context:** Each branch of Legget & Platt places orders to China independently. They have low order frequencies and high inventory. Coordinated inventory replenishment strategy will reduce inventory a lot. The project is to minimize the total cost by consolidating small international shipments when the coordinated inventory policy is taken.

**Important/Expected Results**
- Coordinated inventory replenishment and shipment policy for international logistics network
  - Shipment assignment
  - Inland transportation mode selection
  - Reduced inventory levels
  - Reduced cycle time
  - Increased flexibility

**Technical Approach**
- Analyze purchase order history data of each branch
- Improve current logistics network
- Formulate a mathematical model
- Solution algorithms
- Test various scenarios
- Develop feasible implementation practices

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**Logistics Systems Analysis and Design**

University of Missouri
Integrated Winter Road Maintenance Logistics
Sponsor: Midwest Transportation Consortium / MoDOT
Research Team: W. Jang, J.S. Noble, C.M. Klein

Research Objectives:

- Develop an integrated systems, optimization based approach to winter road maintenance planning decisions

Approach:

1) Develop a protocol for determining the desired level of service and the required constraints.
2) Develop an integrated model and efficient algorithms for large scale applications.
3) Validate the model/algorithms and apply results to the state of Missouri.

Broader Impact:

An integrated model that can be applied to a wide range of DOT operations (e.g. snow removal, pavement striping, herbicide application).

Significant Results:

Able to maintain current high level of service with fewer resources (20-30% savings)
Integrated Rail Capacity Analysis
Sponsor: Missouri Department of Transportation
Research Team: J. Noble and C. Nemmers

**Research Objectives:**

Improve on-time passenger service and reduce freight delays on the Union Pacific line from St. Louis to Kansas City.

**Approach:**

1. **Assess Kansas City – St. Louis Union Pacific rail line constraints / variability associated with passenger / freight flow.**
2. **Develop TOC and simulation models.**
3. **Generate set of rail enhancements that improve overall rail performance.**
4. **Conduct alternative analysis with respect to performance and economic criteria**

**Broader Impact:**

An analysis rail flow analysis model that can be utilized to improve inter-modal traffic flow.

**Significant Results:**

Developed alternatives that provide an overall reduction in train delay of up to 23% for passenger service and up to 27% for freight. Recommended $4M project that would result in a 16% delay reduction for passenger and a 6% reduction for freight service.

![Diagram showing rail line with various enhancements and sidings recommended.]
## Research Objectives:

Investigate the cost savings associated with changing strategic and tactical transportation and distribution strategies

## Approach:

- Model outbound tire distribution for DC
- Partition orders by demand type
- Design dedicated routes and pool points
- Use a greedy random search followed by local search to find consolidated routes

## Broader Impact:

- Problem has interesting generic features: minimum cost transportation strategies with constraints like hours of service, delivery time windows and conflicting objectives between truckload carriers and vendors
- Heuristic is efficient and runs on Excel

## Significant Results:

- Consolidation of loads (even non-optimally) provides significant savings in distribution.
- Quality solutions are generated in less than 1 minute on consumer level hardware under all real life distribution constraints.

![Diagram showing distribution network]
Supply Chain Configuration
Supply Chain Management
Inventory Analysis
Demand Forecasting
Supply Chain Design for Energy Conservation
Research Team: James Noble (PI), Wooseung Jang, Kara Staub-Bono, Kelsey Kotur, Adam Rubemeyer

Sponsor: The Boeing Company

Problem in context: Overall supply chain performance is impacted by energy cost which has significantly increased in the past 10 years. Supply chain decisions such as supplier and mode selection, routing, inventory profile and load consolidation, can all be impacted by energy cost. This study aims to lay the groundwork for addressing this crucial issue.

Important/Expected Results
• Identification of key supply chain trade-offs with respect to energy issues
• Development of supply chain reconfiguration approaches as energy cost changes
• Reduce overall supply chain cost
• Design of more robust supply chains from an energy consumption perspective

Technical Approach
• Supply chain and transportation data collection
• Supply chain evaluation model development
• Formulation of energy based supply chain optimization models
• Solution algorithm development
• Model sensitivity analysis
• Supply chain reconfiguration strategies
Demand Forecasting Models for Dynamic Material Requirements
Research Team: Wooseung Jang (PI), James Noble, Matt Roman, Na Deng

Sponsor: Ameren UE
Thrust Area: Inventory

Problem in context: Thousands of transformers across several different storerooms are used by Ameren every year. These transformers consist of hundreds of different types with widely varying individual demands.

Important/Expected Results
• Production of accurate forward looking forecast results
• Creation of a forecast that can be easily applied when scheduling production slots from vendors
• Increase in customer satisfaction by limiting monthly stock outs over a 1 year planning horizon

Technical Approach
• Examine existing problem
• Gather relevant data
• Analysis of historic usage data
• Aggregate similar groups of transformers and choose individuals to forecast
• Review different forecasting techniques used on similar demand
• Create forecasting algorithm
• Evaluate forecast accuracy

Total Usage Seasonality

<table>
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<th>Month</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
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- Graph showing total usage seasonality from 2003 to 2007.
# Improving Inventory Record Accuracy in Retail Store Operations

**Sponsor:** Walmart  
M. D. Rossetti (PI), N. Buyurgan (co-PI), J. English (co-PI)

<table>
<thead>
<tr>
<th>Research Objectives:</th>
<th>Significant Results:</th>
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| To quantify the costs of inventory record inaccuracy and misplaced SKU’s at the store and system level  
To develop process improvement recommendations for the store and distribution centers to improve in-store inventory record accuracy |  
• Set of departments and items that impact the inventory accuracy was found.  
• Correcting the problematic SKUs via PIRS provides approximately 10% accuracy, 30% discrepancy improvements.  
• Utilizing PIRS generates approximately $500,000 in savings (carrying excess inventory, additional transportation and labor cost, inappropriate replenishment decisions, stock-out). |

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<thead>
<tr>
<th>Approach</th>
<th>Broader Impact:</th>
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| • Gathering data to perform a statistical analysis to identify problem SKUs.  
• Applying cycle counting in order to correct these items.  
• Models/methods to quantify the costs and benefits related to these issues are developed. |  
Data mining sampling techniques for large-scale inventory systems  
Statistical process control techniques developed to maintain inventory record accuracy |

Supply Chain Modeling  
University of Arkansas
Material Flow Design & Improvement

Facility Layout
Material Handling System Design
Storage Systems
Material Scheduling and Control
Warehouse Floor Layout Optimization
Research Team: Jim Noble (PI), Alec Chang, Almas Ospanov, Sam Trevino, Sarah Harper, Nichole Hillstrom

Sponsor: Hallmark Cards.
Thrust Area: Distribution

Problem in context: Hallmark Cards operates a very large distribution center (> 80k SKU and 220M items/year). The project objective is to develop a user-friendly warehouse floor layout tool that addresses the trade-offs between picking, stocking, shipping and retail stocking costs in order to reduce overall operating cost.

Important/Expected Results
• Effective and efficient methodology for optimal filling floor layout.
• Significant cost savings through explicit analysis of cost trade-offs between picking/stocking/shipping.
• Effective implementation strategy for filling floor relayout timing.

Technical Approach
• Analyze current Hallmark warehouse picking and stocking practices and supporting data.
• Analyze current filling floor layout practices and develop performance metrics.
• Formulate and analyze an integrated warehouse layout model.
• Develop a user-friendly warehouse floor layout tools and provide database integration support.

Material Flow Design & Improvement
University of Missouri
## Space and Resource Constrained Outage Scheduling

**Sponsor:** Ameren  
**Research Team:** J. Noble and C. Klein

### Research Objectives:

Development of an optimization-based approach for resource constrained outage laydown planning and scheduling for both nuclear and coal-fired power plants.

### Approach:

- Document outage laydown activities/issues based on Refuel VII and Refuel VIII
- Collect data from Callaway Plant
- Formulate problem to incorporate a detailed representation of laydown activities and resources
- Develop solution procedure
- Perform outage laydown analysis

### Significant Result:

Considers all relevant factors that influence the laydown process during outage scheduling enabling a further 10 - 20% reduction in outage duration.

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### Material Flow Design & Improvement

**Objective**

Mimize

- Outage Time
- MH Distance

**Constraints**

- Space Constraints
- Substitution of Resources
- Splittable Jobs
- Predecessor Relations
- MHE Constraints

**Variables**

- Job Completion

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*University of Missouri*
# Staging Needs in a Cross-docking Environment

**Research Team:** J. Noble and D. Taylor

## Research Objectives:

Develop new staging strategies to minimize space requirements while maximizing crossdock throughput and trailer cube utilization.

## Significant Results:

A Zoned Strategy with simultaneous loading results in a 20% decrease compared with current staging practices.

## Approach:

Development of an integrated analytic and simulation model:
- Analyze a range of environments where staging space = f(material flow pattern, flow pattern stochasticity, dock door availability, dock door assignment policy)
- Evaluate performance with respect to: staging requirements, flow time, cost of operations

## Broader Impact:

This research addresses a key distribution issue as less-than-truckload (LTL) carriers seek to improve their operating efficiency.

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[Diagram of cross-docking environment]

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**Material Flow Design & Improvement**  
University of Missouri / Virginia Tech
Project: Development of a Resource Planning Algorithm  
Sponsor: BWXT/Pantex  
Research Team: Timothy I. Matis, Ph.D.

Research Objectives:
The primary objective for this project is to develop a resource planning algorithm that will improve the existing production and inventory control models used by BWXT/Pantex.

Significant Results:
An algorithm used for production planning that is sensitive to multiple variables that affect daily production rates (used for resource planning (personnel, equipment, facilities) to make real-time adjustments to perturbations in production operations).

Approach:
The approach that will be used to achieve these objectives includes:

1) Evaluate the current production scheduling and work assignment methods.
2) Develop appropriate production scheduling models for BWXT/Pantex
3) Develop capacity planning models to more accurately measure throughput capacities

Broader Impact:
This research effort will have immediate beneficial impact to the Pantex facility. Other member companies have the potential to benefit from the deliverables of this project by modifying and adapting the model to fit their constraints.

Adaptation of program Bottle, originally developed by W. Applegate and D. Cook
Intelligent Systems

RFID

2-D Bar-Code

UID

Database and Information Systems
Multi-Item Load Building Tool for Containers
Research Team: C. Altan (PI), B. M. Pulat, Z. Siddique

**Sponsor:** TSM/US Army DAC  
**Thrust Area:** Intelligent Systems

**Problem in context:**
Develop a web-based tool to help DOD ammunition transporters transport various load configurations with minimum number of containers.

**Technical Approach**
- Review existing process
- Research and capture all requirements
- Develop packing algorithms
- Develop web-based interactive tool
- Test and implement

**Important/Expected Results**
- Web tool that can be used from remote locations
- Heuristic that can handle a given load with minimum containers
- Ability to change loads and see the impact

**What can other members use?**
- Capability developed can be used by others for similar transport needs
- Other needs can be addressed with modifications
## Research Objectives:

- To investigate technical, data management and economic issues of implementing Automatic Identification (Auto-ID) Technologies (including RFID, Wi-Fi, 2-D barcodes) in depot and ramp operations, and assess their impact on business processes of Tinker AFB

## Significant Results:

- New model to predict the read-rate probabilities of backscatter RFID systems
- New POMDP approach to use RFID to search and locate misplaced items
- Framework for economic analysis of AIT systems in warehouse/depot operations by the use of advanced value stream mapping (VSM) tools
- Survey and documentation of industry best practices to address various technological and economic issues

## Approach:

- Survey of alternative Auto-ID (AITs) and Automatic Monitoring Technologies (AMTs)
- Economic analysis of the insertion of certain candidate AMTs for various asset management applications in Tinker ramp operations including the operations within and beyond the supply chain using value stream mapping tools

## Broader Impact:

- The presented research approach seems to be of interest to a few manufacturing and small businesses located in Oklahoma
Next Steps

First,
• Develop project proposal – objective, tasks, schedule, and deliverables
• Sign CELDi Membership Participation Agreement

Second,
• Commence company research project
• Attend the biannual CELDi Research Conference and IAB meeting
• Participate in Center-designated project selection

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