A REVIEW OF INFRASTRUCTURE MODELLING FOR GREEN LOGISTICS (GL)

Irina Harris
Prof. Mohamed Naim
Dr. Christine Mumford
Cardiff University

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1 Cardiff School of Computer Science
2 Cardiff University Innovative Manufacturing Research Centre
Infrastructure Modelling for GL

- Introduction
- Performance Measures
- Infrastructure Modelling for GL
- Multi-Objective Optimization (MOO) methods
- Conclusion
Objectives

○ critically examine current techniques for multi-objective infrastructure modelling

○ the models that consider both economic (gold) and environmental (green) criteria simultaneously
Methodology

- **Keywords**
  - supply chain
  - network, logistics
  - supply chain design
  - performance measure
  - environment and green
  - green logistics
  - multi-objective

- Scopus, ABI/Inform, Business Source Premier
- Google
- Follow on references
What is Infrastructure Modelling for GL?

- Infrastructure modelling
  - the optimum number, location, allocation of the facilities

- Green Logistics:
  - “an environmentally friendly and efficient transport distribution system” (Rodrigue et al. 2001)
Infrastructure Modelling for GL

- Aronsson and Brodin (2006)

<table>
<thead>
<tr>
<th>Changes</th>
<th>FoodComp</th>
<th>FurniComp</th>
<th>PaperComp</th>
</tr>
</thead>
<tbody>
<tr>
<td>New distribution structure: fewer warehouses (nodes);</td>
<td>Consolidation of flows to Europe; Change of transport mode for bulk transport; Larger warehouses; Standardised vehicles; Product design for packaging; etc</td>
<td>Consolidation of flows; Changes of transport mode; Standardised load carriers; Fixed system always available capacity, bookings avoided;</td>
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<td>New information system-centralisation of planning; Dynamic storage,</td>
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<td>product specific routing; Pallet utilization; etc</td>
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<td>Effect/results</td>
<td>Reduced emissions; Cost reductions; Energy savings; Increased visibility; etc</td>
<td>Reduced emissions; Cost reductions; Fast transports; High delivery accuracy;</td>
<td>Cost reductions; Higher reliability in customers perceived lead-times; Reduction of emissions; etc</td>
</tr>
</tbody>
</table>
Factory Gate Pricing

- Le Blanc et al. (2006)
  - Dutch retail
- Potter et al. (2002)
  - UK grocery

- cost reduction
- reduced miles
Decentralised vs Centralized Network

- **Kohn (2005)**
  - case study ITT Flygt
  - increased tonne – km: 2,181,146 → 2,928,666
  - increased CO₂ per tonne-km: 0.042 kg → 0.045 kg
Performance Measures

- Traditional: min costs, higher customer service etc
- (Shepherd and Gunter 2006) - taxonomy
  - whether they are qualitative or quantitative
  - what they measure: cost and non-cost;
  - their strategic, operational or tactical focus
- Current et al. (1990)
  - cost minimization
  - demand oriented
  - profit maximization
  - environmental concerns
    - air quality
    - risk to surrounding population
    - quality of life
    - low-flow stream augmentation
Green Performance Measures

- Need to incorporate quantitative environmental measures (Bloemhof-Ruwaard et al. 1995), Beamon (1999)
- Taplin et al. (2006) - sustainable metal production system
  - efficient use of energy and raw materials
  - reducing CO2 emissions
  - scrap and waste
  - higher productivity
- Khoo et al. (2001)
  - low transport pollution
  - promotion of recycling of scrap metal
  - conservation of energy
Green Performance Measures

- Potter, Mason et al. (2002)
  - Emission rate per item: Using conversion factor applied to calculate the level of emissions.
  - Amount of payload used: Vehicle utilisation (e.g. trailer,) represents the efficiency of the transport operation. (weight or volume)
  - Energy use per item: Amount of energy used to move an item (litres of fuel used or joules of energy).
  - Rank: 1, 2, 3

- Beamon (1999), Aronsson and Brodin (2006)
  - Emissions
  - Total energy consumed
Infrastructure Modelling for GL

- Aronsson and Brodin (2006)
  - “there is an agreement among researches that strategic decisions should have a larger impact on emissions than operative decisions.”
  - “there is a disagreement on which particular decisions have the largest impact, and what effect of those decisions will have on environmental impact.”
Infrastructure Modelling for GL

- Khoo et al. (2001), metal SC

  - Low total market costs
  - Low transport pollution
  - Fast deliveries between plants
  - Promotion of recycling of scrap metal
  - Energy conservation
Infrastructure Modelling for GL

- Hugo and Pistikopoulos (2005)
  - generic MO MIP model, strategic, long range planning for bulk chemical network:
    - minimize the environmental impact
      - Eco-Indicator 99 method (Pré Consultants 2000)
        - human health
        - ecosystem quality
        - resource depletion
    - maximize the net present value (NPV) of the investment
Infrastructure Modelling for GL

Eco-Indicator 99 method (Pré Consultants 2000)
Infrastructure Modelling for GL

- CAST
  - CAST FE – optional CO₂ emissions module
MOO methods

- Combine all the objectives into a single scalar value
- Solve for the objectives in a hierarchical fashion
- Obtain a set of alternative, non-dominated solutions (Pareto sets)
Preference-based approach

MOO problem
Minimize $f_1$
Minimize $f_2$
......
Minimize $f_M$
subject to constraints

One optimum solution

Higher level information

Estimate a relative importance vector $(w_1w_2...w_M)$

Single-objective optimization problem
$F = w_1f_1 + w_2f_2 + ... + w_Mf_M$

or

a composite function

Classic $\epsilon$-constraint method:
Guillen et al. (2005), Sabri and Beamon (2000), Hugo and Pistikopoulos (2005)

Deb (2002)
MOO methods

- Min and Melachrinoudis (1999) - AHP

**Goal**: Relocation of a hybrid manufacturing/distribution facility

- **Site characteristics** (0.152)
  - Capacity (0.110)
  - Operating (0.455)

- **Cost** (0.181)
  - Start-up (0.545)
  - Operating (0.455)

- **Traffic access** (0.216)

- **Market opportunity** (0.164)

- **Quality of living** (0.122)

- **Local incentives** (0.164)
  - Union (0.313)
  - Tax Incentives (0.125)
Ideal MO approach

MOO problem
Minimize $f_1$
Minimize $f_2$
......
Minimize $f_M$
subject to constraints

IDEAL
Multi-objective optimizer

Multiple trade-off
solution found

Choose one solution

Higher level
information

Uses population of solutions in each iteration

Deb (2002)
MOO methods

- Altiparmak et al. (2006)
  - Genetic Algorithm
  - min total costs
  - max customer services
  - maximization of capacity utilization balance
General structure

chromosomes

1100101010
1011101110
0011011001
1100110001

crossover

110010 1010
101110 1110

mutation

00110 1 1001

00110 0 1001

evaluation

offspring

1100101110
1011101010
1100110110

decoding

solutions

fitness computation

selection

roulette wheel

new population

solutions
MOO methods

- Villegas et al. (2006) - UFLP, MCLP
  - Non-dominated Sorting Genetic Algorithm
  - Pareto Archive Evolution Strategy
  - Mathematical programming
  - min total costs
  - max coverage
MOO methods

- Villegas et al. (2006)

Approximate Pareto optimal frontier
Conclusion

- If environmental assessment is incorporated as part of infrastructure modelling then there is a possibility of achieving both economic and environmental savings.
- Classical MOO methods:
  - Hugo and Pistikopoulos (2005)
- Simulation:
  - Khoo et al. 2001
- Model environmental concerns as objectives
- Investigate MOO techniques for efficient infrastructure modelling for GL
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○ Any questions?

e-mail: Irina.Harris@cs.cf.ac.uk