A Multi-Objective Geographic Information System for Route Selection of Nuclear Waste Transport

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Outline

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- Methods
- Optimization
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Problem introduction

- How to transport nuclear material from a nuclear plant to harbor in order to make it as safe as efficient as possible?

Objective #1

- Minimization of travel time

$$\text{Min } z_1 = \sum_i \sum_j t_{ij} x_{ij}$$

  - t_{ij} = travel time
  - x_{ij} = decision variable (= 1 if link i-j is used, otherwise 0)
- Directly computed by the length of each link divided by travel time

Objective #2

- Minimization of transportation risk

$$\text{Min } z_2 = \sum_i \sum_j r_{ij} x_{ij}$$

  - r_{ij} = traffic volume

- More traffic => higher risk

Objective #3

- Minimization of exposure to the population

$$\text{Min } z_3 = \sum_i \sum_j p_{ij} x_{ij}$$

- More exposed population => more civil resistance
- Population x

Constraints

1) Any node not beginning/end have a corresponding pair of links for vehicles traveling in and out.
2) Any link connected to the origin point will have only one link with the value 1.
3) Any link connected to the destination point will have only one link with the value 1.

Methods

- Application of Geographic Information System (GIS)
- Coded using Avenue script in ArcView 3.

Optimization

- Weighting method in MCDM
- Global weight of each objective determined by the Analytical Hierarchy Process, 5 experts
  - INER, traffic control, medical doctor, transportation carrier, anti-nuclear advocate
- Each expert create pair-wise comparison among the objectives
- Averaged to form global weights
- Shortest distance found using Dijkstra's algorithm

Results

Objective\value	Compromised	Maximum	Minimum	Attainment
Travel time (z_1)	326.55 (min)	789.93 (min)	106.44 (min)	0.68
Transportation risk (z_2)	875.98 (veh/h)	1421.05 (veh/h)	720.00 (veh/h)	0.77
Exposed population (z_3)	16124 (people)	24036 (people)	12819 (people)	0.53

Table 1 Computed result

$$\text{Attainment}\ t_k = 1 - \frac{z_k - z_k^{\min}}{z_k^{\max} - z_k^{\min}}$$

Results

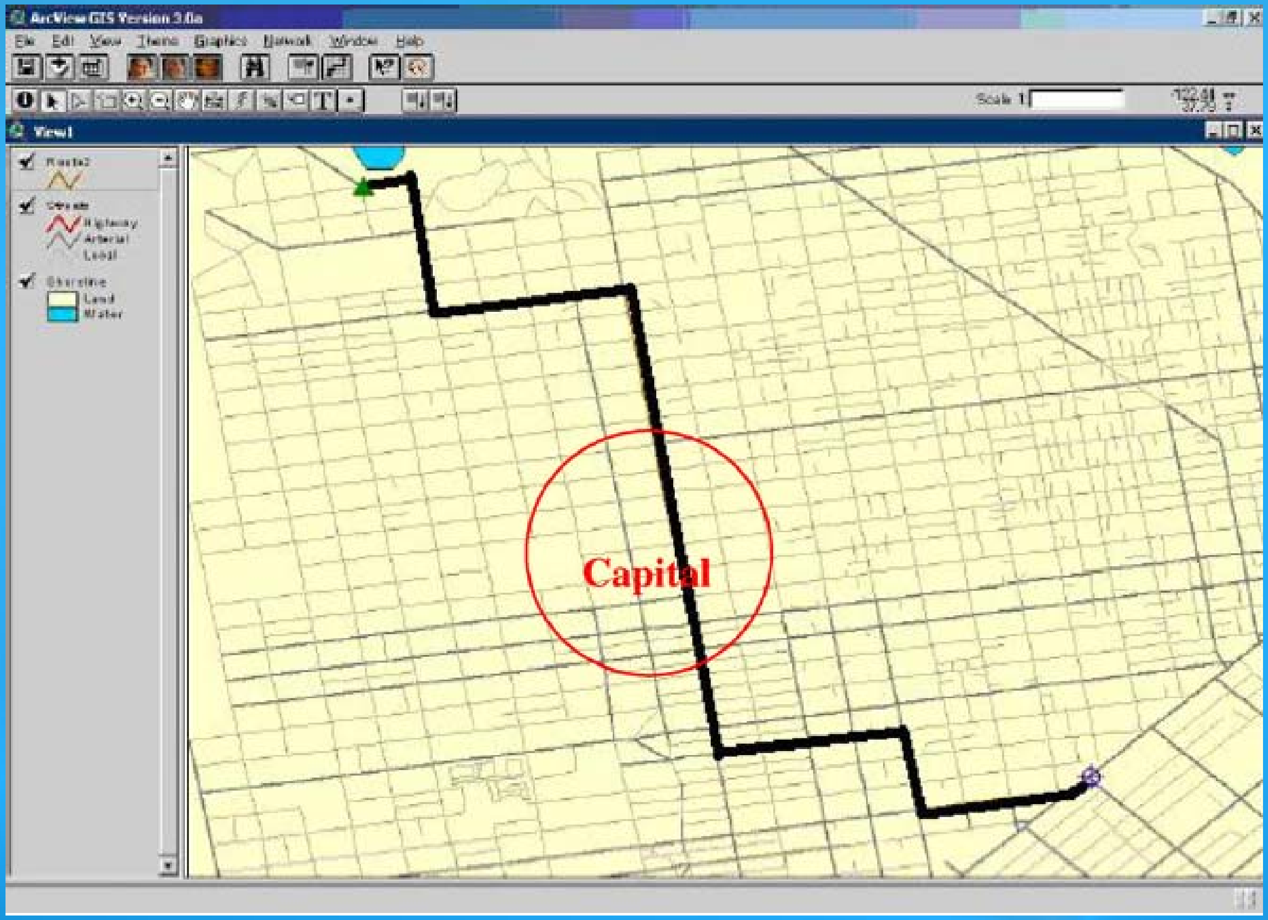

Figure 1 Optimal route with minimal travel time.
$z1 = 106.44$ (min).

Results

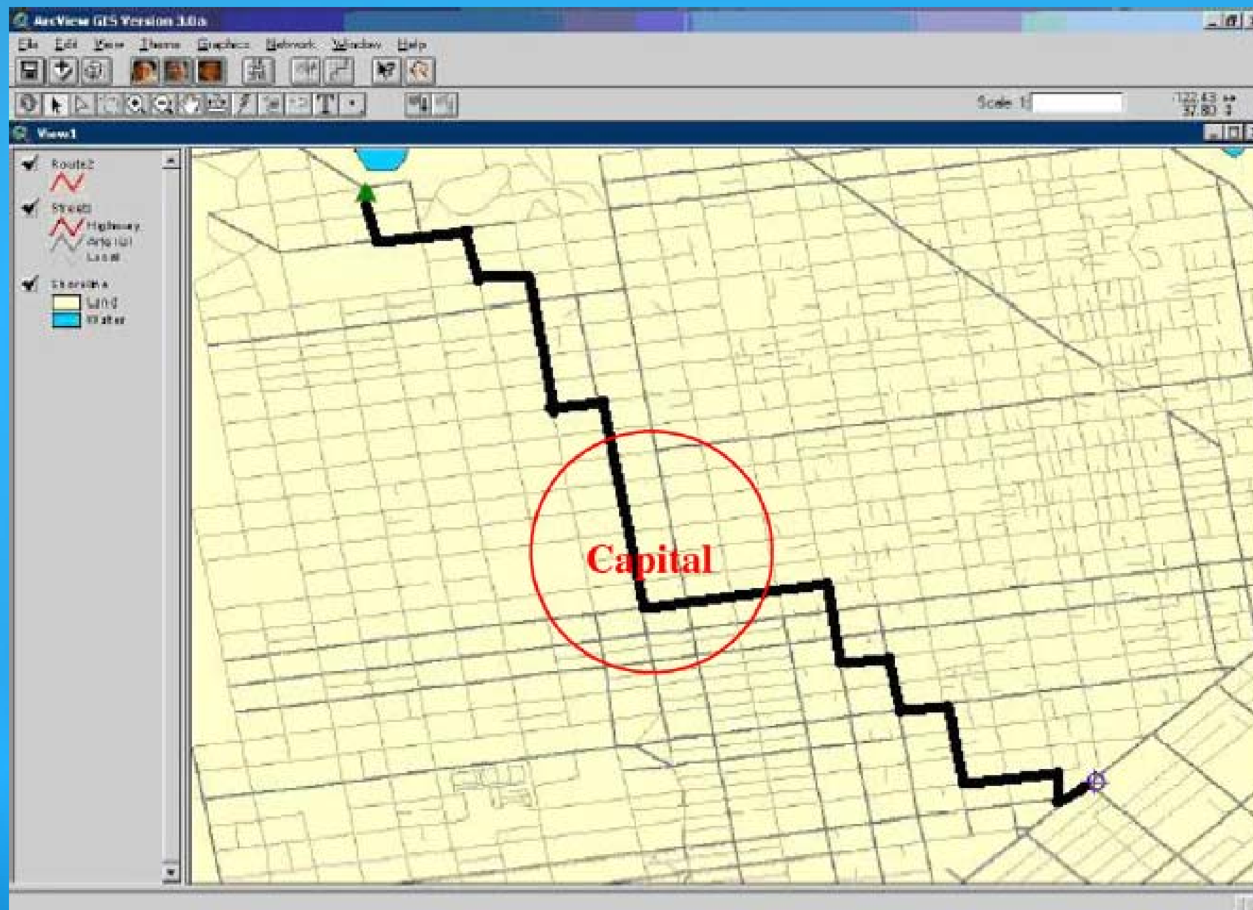

Figure 2 Optimal route with minimal transportation risk.
$z2$ = 720.00*(veh/h)*.

Results

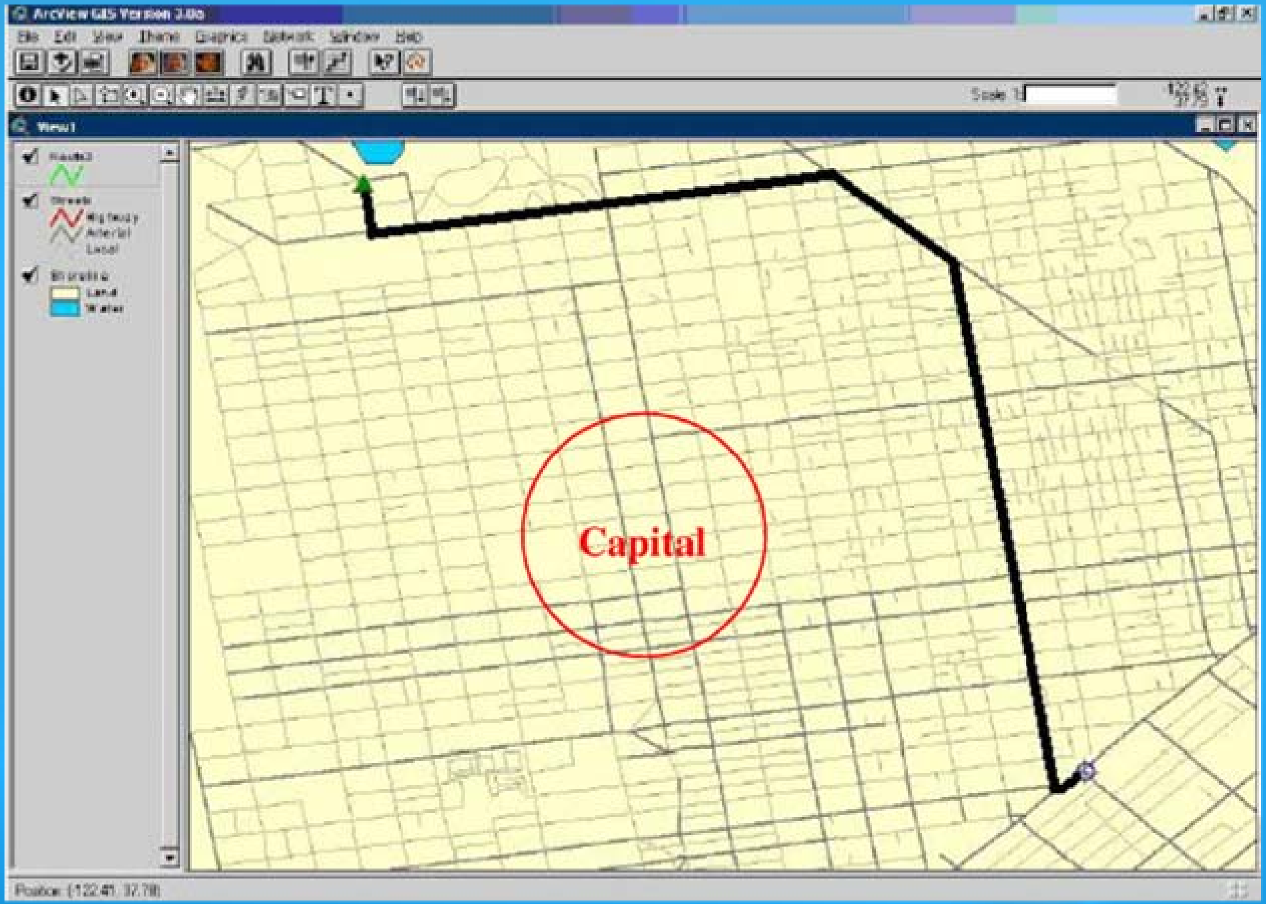

Figure 3 Optimal route with minimal exposed population.
$z3$ = 12819 *(*people*)*.

Results

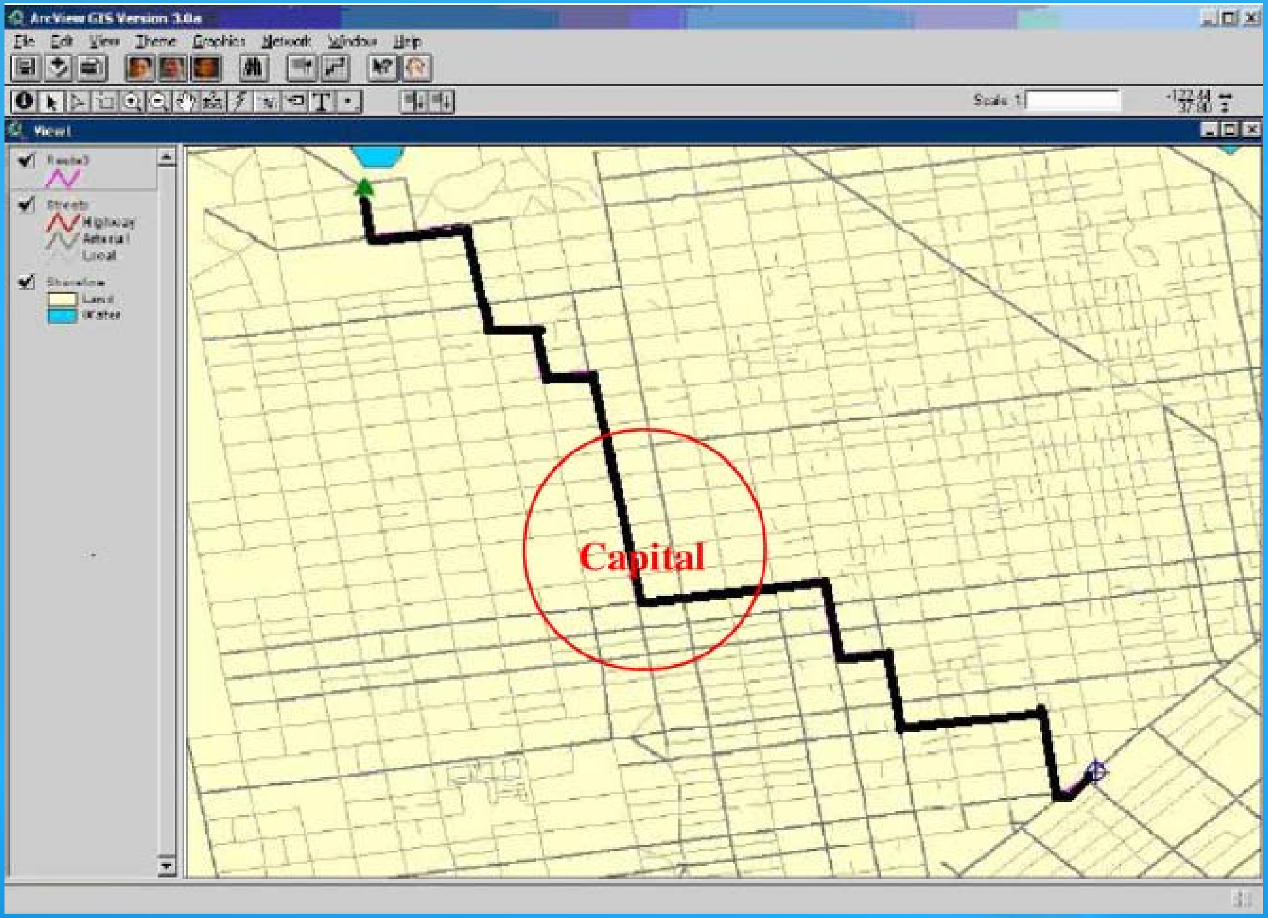

Figure 4 Compromised route with multi-objective optimization. *z*1 = 326.55 (min), *z*2 = 875.98 (veh/h), *z*3 = 16124 (people).

Thank you!