Incorporating Computational Geometry into Second-best Congestion Pricing Design Problem: Algorithm Development and Applications

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Highlights
- Develop model and algorithm for designing area/cordon-based pricing considering constraints of shape of charging boundary
- Generate realistic area/cordon-based charging boundary & propose index that represents unreality of boundary
- Consider multiple charging boundaries improving social welfare (SW)

Second-best Congestion Pricing Design Problem

Existing Method for Optimizing Charging Boundary

Branch-Tree Method

- Not optimizing center
- Not consider the shape of boundary
- Sometimes generates unrealistic boundary

Proposed Index for Presenting Unreality of Charging Boundary

Additional Operation

Shape Constraints

Fitness Expression

Convex Hull

Shape

Equilibrium

Equilibrium

Proposed Approach

Model: Bi-level Problem

\[
\min \sum_{i=1}^{n} \left( \sum_{j=1}^{m} c_{ij} x_{ij} \right) + \lambda \left( \sum_{i=1}^{n} \sum_{j=1}^{m} x_{ij} a_{ij} - 1 \right)
\]

\[
\text{Equilibrium (unrefined shape)}
\]

\[
\text{Equilibrium (refined shape)}
\]

\[
\text{Convex hull}
\]

Conclusion

- Develop model & algorithm for designing area/cordon-based pricing considering constraints of charging boundary
- Realistic charging boundary are generated while middle welfare improvement
- Multiple boundaries improves welfare
- Proposed an index that represents the unreality of charging boundary
- Extract the effect of boundary optimization

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References


SW151%UP

Toll level $1

Convex Cordon Toll

Convex Area Toll

With Convex-Boundary Constraint

Multiple Boundaries

Double Area Toll

Double Cordon Toll

Case Study in Real World Network (Utsunomiya, Japan)

Optimal Area Toll

Optimal Cordon Toll

SW156%UP

Toll level $1.2

Convex Area Toll

Convex Cordon Toll

SW123%UP

Toll level $2

Convex Area Toll

Convex Cordon Toll

SW151%UP

Toll level $1.2

Convex Area Toll

Convex Cordon Toll

SW178%UP

Toll level $2.5

Convex Area Toll

SW230%UP

Toll level $1

Convex Area Toll

Future Studies

Extracting Effect of Boundary Optimization

- Toll level is fixed: Area $2; Congestion $0
- Optimal convex boundary without/with optimalizing center location
- Size of area: Convex Area toll + Circle Cordon Toll

Conclusion