An Alternative Approach to Economic Analysis for Pre-evaluating Infrastructure Investments

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Rho, Jeong Hyun
Hanyang University

비용-편익 분석이란?

- 잠재적 파레토현상을 바탕으로 사회 전체의 복지수준 향상 여부를 평가하기 위한 기법
- 공공투자정책의 의사결정을 돕는 수단
- 편익(얻은 자의 얻은 가치)와 비용(잃은 자의 잃은 가치)를 일련의 합리적 과정을 통해 측정 및 비교 평가

공공투자정책의 기본 특징

- 사회전체를 대상
- 투자 후 최종 결과는 원상복구 불가능
- 비용은 초기에, 편익은 장기간에 걸쳐 서서히 발생
- 정책의 평가는 사회전체의 복지의 증감을 대상

비용-편익 분석의 특징

공공성 중시 → 사회 전체에서 발생하는 비용과 편익에 초점

- **비용항목** : 공공투자사업의 목적추구에 소요되는 투입 요소
- **편익항목** : 공공투자로 인한 기존체계의 변화로 발생하는 긍정적 효과

비용-편익 항목에 따라 분석 결과가 달라짐

비용-편익 분석의 한계 및 문제점

1. 사업 유형별 비용항목 및 산출방식의 차이

부문	사업비		운영비 (운영경비, 유지관리비, 대체투자비 등)	비 고
	건설비	차량 구입비		
도로	O	X	단위 거리(Km)당 원단위 적용	시설 연장만 반영
철도	O	O	$\alpha \cdot$ 연장$(km) + \beta \cdot$ 운송수입(원) $+\gamma \cdot$ 운행거리(차량$\cdot km$) $+\delta \cdot$ 역 개수(개)	-시설연장과 운행량을 반영 - 여객, 화물운송 별도 산출 (이중계산?)
항만	O	X	항만시설의 경제적 자산 가치에 대한 시설 별 운영비 비율 및 유지보수비 비율을 적용	- 시설의 자산 가치에 비례

비용-편익 분석의 한계 및 문제점

2. 편익항목 특성 및 반영의 한계

구 분	계량화	가치화	반 영	산 출
시장재 효과(Market Good Effect)	O	O	**필요**	**가능**
이전소득(Transfer Payment)	O	O	**불 필요**	**가능**
이중계산(Double Counting)	O	O	**필요**	**불 가능**
계량화 불능 효과(Intangible Effect)	X	O	**필요**	**불 가능**
가치화 불능 효과(Incommensurable Effect)	O	X	**필요**	**불 가능**

사례: 서해 뱃길 사업 : 개요

한강르네상스 사업의 일환으로
'경인 아라뱃길'을 활용한 서해 연결 선박도입 프로젝트

주운 기반시설조정	대형선박의 한강 내 운항이 가능하도록 주운 수로 및 양화대교 개조
서울항 건설	여의도 한강공원 둔치 및 수상에 대형 선박을 위한 항구 및 지원시설 건설
여객선 및 관광선 운항	국제여객선, 국제 크루즈, 서해 연결 유람선 운항

사례: 서해 뱃길 사업 : 비용항목

항 목	계량화	가치화	효과 구분
서울항(광역터미널) 건설 및 운영비	O	O	시장재
주운 수로 공사비	O	O	
양화대교 교량 공사비	O	O	
(구)행주대교 및 우물통 기초 철거비	O	O	
수질 악화	O	X	가치화 불능

사례: 서해 뱃길 사업 : 비용항목

항 목	계량화	가치화	효과 구분
외국인 방문객 증가로 인한 경제 활성화	O	O	시장재
서해연결 유람선 운항으로 국민의 여가 기회 향상	O	O	시장재(이전소득)
세관출입국 관리검역시간 절감(내국인)	O	O	시장재
서울항 중심의 지역개발 제고	O	O	시장재(이중계산)
건설에 따른 고용증가	O	O	시장재(이전소득)
도시의 국제적 이미지 부각	X	X	계량화 불능

Any Weak Points in the Traditional Economic Analysis ?

Benefits Obtained from Constructing a New Transportation Facility

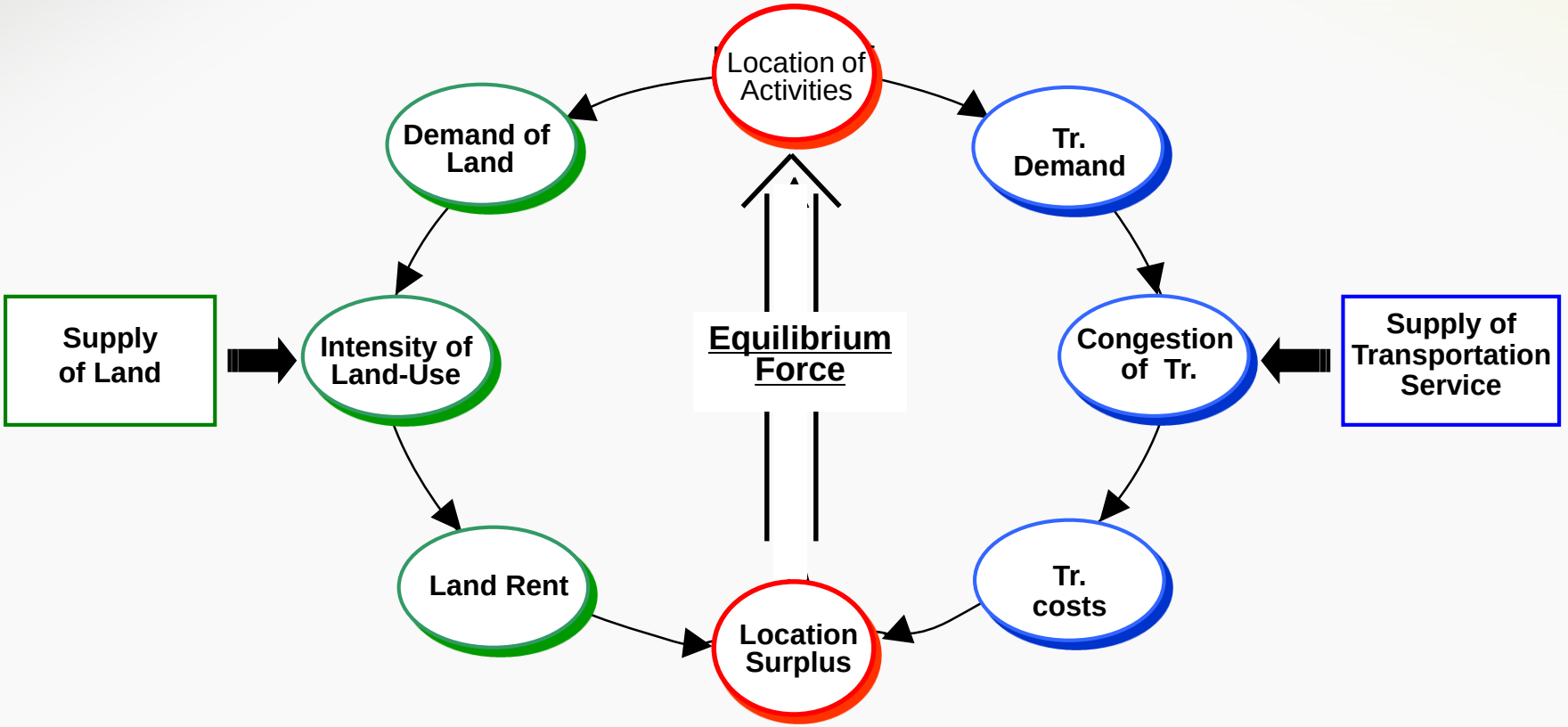
Direct Benefits	Under Construction	Increase of Employment
	After Completion	Transport Costs Savings (for Users)
Indirect Benefits	Under Construction	Production Effect & Income Effect
	After Completion	Increase of Land Values (for Non-user)

Costs Occurred

Direct Costs	Under Construction	Construction Costs Including Land Inputs
	After Completion	Operating & Maintenance Costs
Indirect Costs	Under Construction	Intermediate Inputs for Construction Materials
	After Completion	Inputs & Shipment Costs for the Increase of Regional Products

Any Way to Recover the Limitations ?

- **Location of Activity & Its Effect (in Land-Use & Transportation System)**



How to Measure the Location Surplus ?

Models of Land-Use, Production, & Transportation

- Transportation Demand Model

  - Minimize: Total Transportation Costs for Shipping Transportation Demand
  - Subject to: Sum of Inter-zonal Shipment $\leq$ Transportation Demand
    Dispersion of Inter-zonal Shipment $\geq$ Level of Dispersion

- Land-Use Model

  - Minimize: Total Land & Capital Inputs(Costs) for Producing Products
  - Subject to: Demand of Land $\leq$ Supply of Land

- Spatial Production Model (Commodity Flow Model)

  - Minimize: Total Production & Total Cost of Consumption
  - Subject to: Inflow + Production $\leq$ Outflow + Consumption + Final Demand

A Combined Land-Use, Production, & Transportation Model

A Combined Regional Activity Model

- Minimize Total Costs = Total Transportation Costs + Total Land & Capital Inputs + Total Intermediate Consumption Costs

- Subject to Inflow + Production $\leq$ Outflow + Consumption + Final Demand (by Sectors & Zones)

Dispersion of Inter-zonal Shipment $\geq$ Expected Value of Entropy (by Sectors)

Demand of Land $\leq$ Area of Developed Land (by Zones)

A Combined Land-Use, Production, & Transportation Model

Min.

$$\sum_i \sum_j \sum_r c_r^{ij} X_r^{ij} + \sum_i \sum_r \left(\sum_q a_{rq}^{ii} X_q^i\right) p_r^i$$
$$+ \sum_i \sum_r \left[L \exp(\alpha_{1r} s_r^i + \beta_{1r}) + R \exp(\alpha_{2r} s_r^i + \beta_{2r})\right] X_r^i$$

s.t.

$$\sum_{j \neq i} X_r^{ij} + X_r^i \geq \sum_{j \neq i} X_r^{ij} + \sum_q a_{rq}^{ii} X_q^i + F_r^i \qquad \text{for all } i, r$$

$$-\sum_i \sum_j X_r^{ij} \ln X_r^{ij} \geq S_r \qquad \text{for all } r$$

$$\sum_r \exp(\alpha_{1r} s_r^i + \beta_{1r}) X_r^i \leq l^i \qquad \text{for all } i$$

$$X_r^i, X_r^{ij} \geq 0 \qquad \text{for all } i, j, r, k$$

Where ,

- i, j - zones
- r, q - sectors
- X - production, consumption, shipment
- F - final demand
- c - transportation costs
- a - input-output coefficients
- s - intensity of land-use
- p - price of good
- L - rent of agricultural land
- R - rent of capital
- l - area of developed land
- S - entropy value of inter-zonal shipment
- α, β - parameters for land & capital inputs

Endogenous Variables (Outputs Obtained from the Model)

- **As Primal Variables**

  X_r^{ij} - Inter-zonal Shipment of r between i and j

  X_r^i - Production of r in i

  s_r^i - Intensity of Land-Use for r in i

- **As Dual Variables**

  λ^i - Land Rent in i

  γ_r^i - Location Surplus of r in i

What Location Surplus Means ?

Opportunity Cost of Resources

In the 1st constraint;

- If Export is RHS, the dual means Marginal Export Handling Cost of Product r in i.
- In Same ways, the Dual Variable means the Opportunity Cost of Production & Consumption as well as Trip Generation & Attraction.
- By Integration this means a Compound Surplus obtained when a unit of activities is located there.

Applications

- Production Effects by Regions ← X_r^i
- Employment Effects by Regions ← X_r^i
- Effects on the Balanced Development in a Nation ← γ_r^i

How to Solve this Model ?

- **From the Optimality Conditions,**

$$\sum_r \exp(\alpha_{1r} s_r^i + \beta_{1r}) X_r^i(\bar{\lambda}) - l^i + y^i = 0 \quad \text{for all } i$$

$$\lambda^i \cdot y^i = 0 \quad \text{for all } i$$

- **Using the Solution $(\bar{\lambda})$,**

$$s_r^i = \frac{\ln - \left[\frac{\alpha_{1r}(L+\lambda^i)}{\alpha_{2r} \cdot R}\right] - (\beta_{2r} - \beta_{1r})}{\alpha_{2r} - \alpha_{1r}} \quad \text{for all } i,r$$

$$\gamma_r^i = \sum_q \{[(L+\lambda^i)\exp(\alpha_{1r} s_r^i + \beta_{1r}) + R\exp(\alpha_{2r} s_r^i + \beta_{2r})] + \sum_q a_{qr}^{ii} p_q^i\} \cdot b_{qr} \quad \text{for all } i,r$$

$$X_r^{ij} = \exp\{-\mu_r(c_r^{ij} + \gamma_r^i - \gamma_r^j)\} \quad \text{for all } i,j,r$$

$$X_q^i = \sum_r b_{qr} \{\sum_{j \neq i} X_r^{ij} - \sum_{j \neq i} X_r^{ij} + F_r^i\} \quad \text{for all } i,q$$

How to Measure the Benefits ?

Change of Total Location Surplus

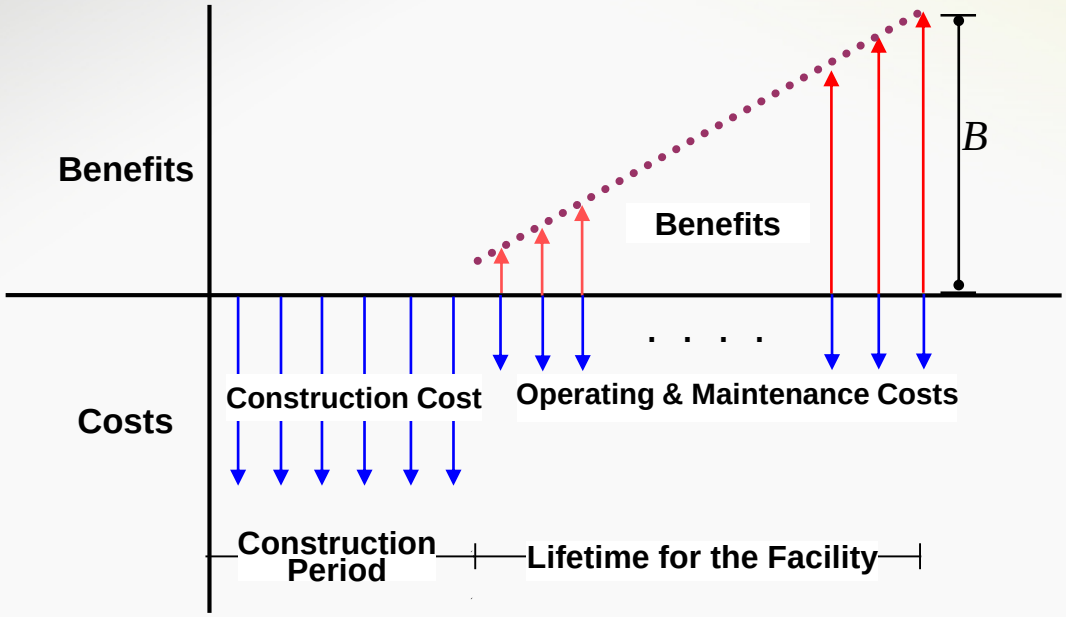
$$\sum_i \sum_r (\hat{\gamma}_r^i \cdot \hat{F}_r^i - \gamma_r^i \cdot F_r^i)$$

where
- γ_r^i : Location Surplus in Case of Do-nothing
- $\hat{\gamma}_r^i$: Location Surplus in Case of Do
- F_r^i : Final Demand in Case of Do-nothing
- $\hat{F}_r^i$: Final Demand in Case of Do

Total Benefits

= (Increase of Total Location Surplus) — (Increase of Production & Transportation Costs)

How to Calculate the Present Value of Benefits ?



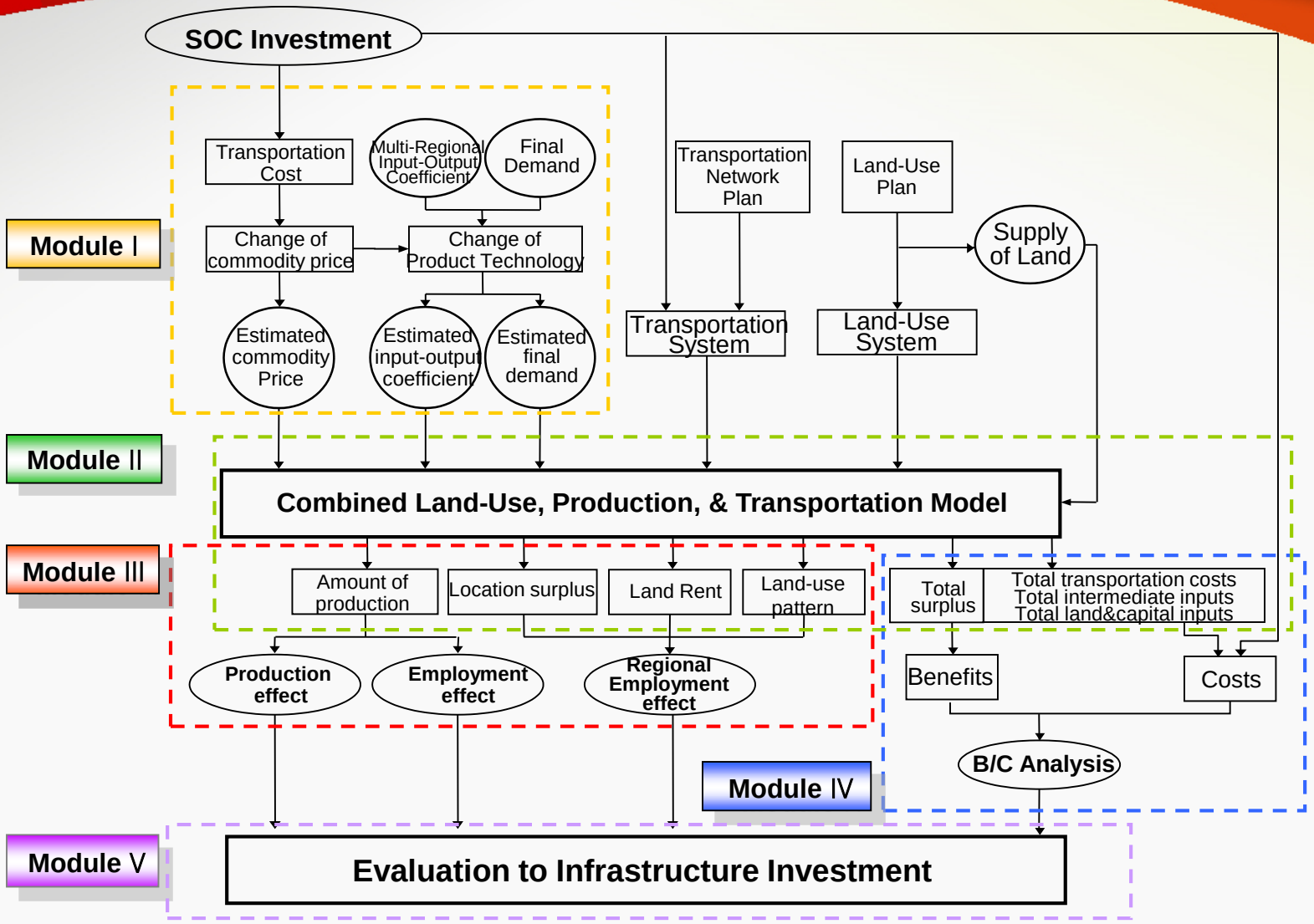
- **Present Value of Benefits**

$$= \sum_{n} \frac{n}{N(1+d)^{n}} B \qquad n = 1,2,3 \cdots N$$

where,

N : Lifetime for the Facility
B : Annual Benefits at Steady State
d : Social Discount Rate

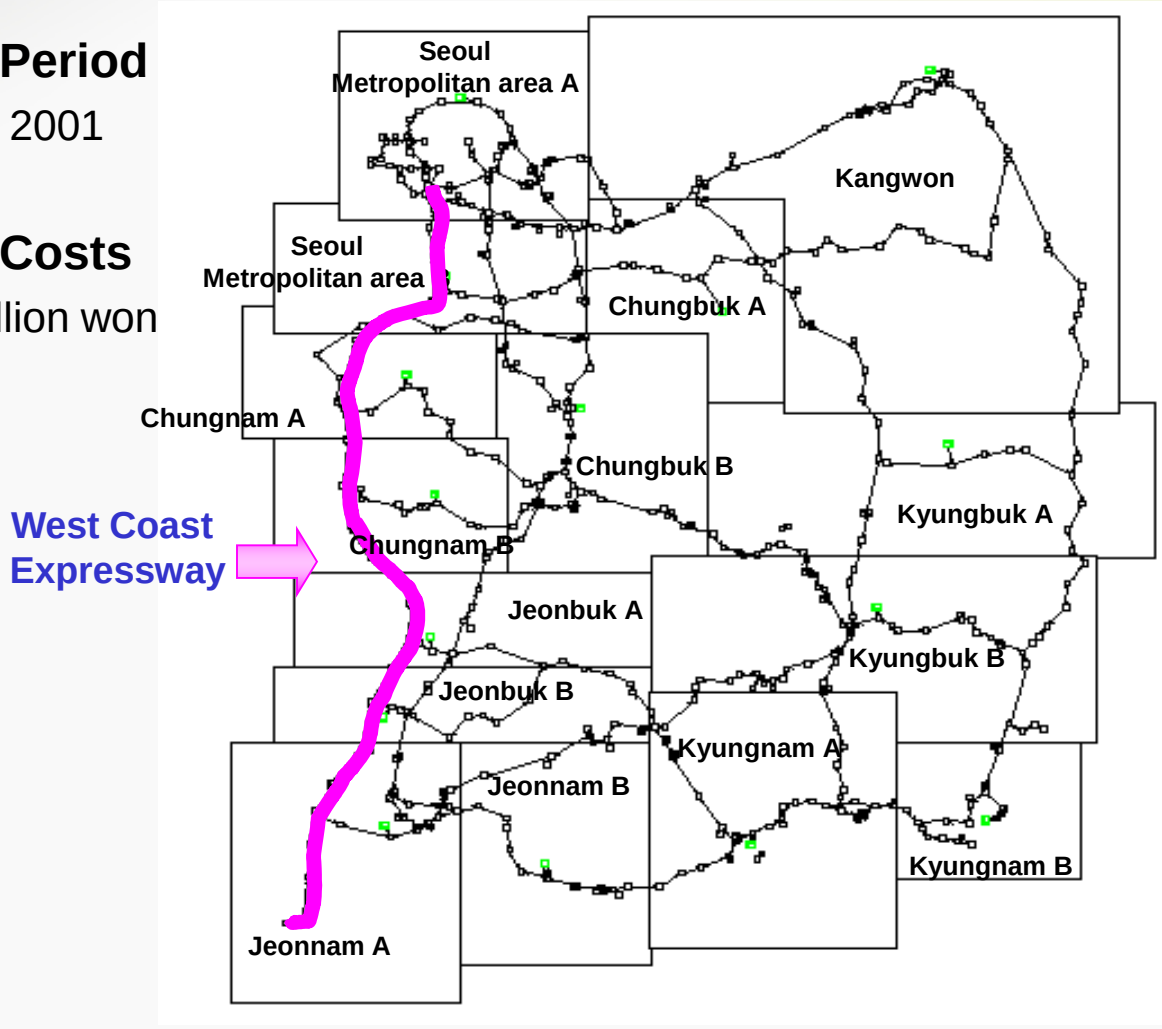
Structure of the Model for Evaluating Infrastructure Investment



Application & Implementation (The West Coast Expressway in Korea)

- **Construction Period**
  : From 1996 To 2001

- **Construction Costs**
  : 4, 775, 400 million won



Application & Implementation

Costs of Production & Transportation

Unit : 100 million won

	Intermediate Inputs	Land & Capital Inputs	Interregional Shipment Costs	Total Costs
Do Nothing (A)	4,729,238	1,895,614	1,744	6,626,597
Do (B)	4,770,972	1,935,164	1,706	6,707,843
(B)/(A)	1.01	1.02	0.98	1.01

Application & Implementation

Change of Total Location Surplus

$$\sum_i \sum_r (\hat{\gamma}_r^i \cdot \hat{F}_r^i - \gamma_r^i \cdot F_r^i)$$

Where, γ_r^i : Location Surplus in Case of Do-nothing

$\hat{\gamma}_r^i$: Location Surplus in Case of Do

F_r^i : Final Demand in Case of Do-nothing

$\hat{F}_r^i$: Final Demand in Case of Do

Total Benefits

= (Increase of Total Location Surplus) — (Increase of Production & Transportation Costs)

Application & Implementation

Result of Economic Analysis

Unit : 100 million won

Present Value of Benefits (B)		154,478
Present Value of Direct Costs (C)	Construction Costs	36,133
	Operating & Maintenance Costs	5,554
	Total	41,687
Net Present Value		112,791
B/C Ratio		3.71

Limitations

- **Much Detailed Data Required**
  - Input-output Coefficients by Regions
  - Land & Capital Inputs by Intensities
  - Transportation Networks
- **Not Evaluate the Effects in Micro-level**
- **Hard to Validate**
- **Long-run Equilibrium Steady State**

Future Studies

- **Dynamic Approach**
- **Policy Evaluations related to the National Comprehensive Plan**
- **Evaluation & Impact Assessment for the other type of Infrastructure Investment**

Thank You