The Economics of Transportation Systems: Module 1

Introduction to the Reference

Movement, Transport, & Location

Costs & Benefits of Transportation

August 21, 2012

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Webinar Overview

- **3 Modules** highlight key concepts and topics in reference manual ***The Economics of Transportation Systems.***

Module 1	Module 2	Module 3
• Introduction to the Reference • Land use & transportation interactions • Quantifying transportation costs & benefits • Benefit-cost analysis	• Project evaluation methods of analysis • Time value of money • Life cycle cost analysis • Multi-criteria analysis • Constrained optimization • Transportation pricing	• Economic impact analysis • Input-Output models • Statistical analysis methods for transportation data • ROW acquisition cost estimation case study

ECONOMICS AS A TOOL FOR TRANSPORTATION DECISION MAKING

Introduction

Source: tree_leaf_clover

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Table of Contents

"I am an engineer, so I never use economics – do I?"

- **It's all about the money!** Transportation investments involve some of the the most difficult & complex decisions for DOT staff.
- **Which project(s) should get the money?** Multiple projects compete for the same funding source.
- **Public demands answers.** Most transportation projects use public money; members of the public want to know their money is being used wisely.

"I am an engineer, so I never use economics – do I?"

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Speed Limits: An Economic Question?

- Should a **speed limit** be raised (to save travel time) or lowered (to decrease severe crashes)?
  - What are the projected traveler times savings from the speed limit increase?
  - What is the projected increased crash cost due to more severe injuries/fatalities at higher speeds?
  - In comparing these costs & benefits, how do we incorporate uncertainty?

Source: melissambwilkins

Transportation Funding

What is better for DOT budgets, the environment, & travelers?

Source: futureatlas.com

Gas Taxes?

Source: michaelrperry

VMT Fees?

Source: zol87

Variable Tolls?
(by time of day & location)

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Why is Economic Analysis Important?

- It allows decision makers to compare costs & benefits on an “apples to apples” basis (e.g., 2011$).
- Provides quantitative support for decisions that may otherwise be subjective.
- Federal agencies starting to mandate economic impact analysis & comprehensive quantification of transportation costs & benefits (e.g., EIS, TIGER grants).

Module 1. Topic Overview

- **Mobility** & **Accessibility**
- Relationship between Land Use & Transportation
- **Internal Costs**
- Vehicle Operating Costs, Travel Time Costs
- **External Costs**
- **Cost-Benefit Analysis**
- **Case Studies** for Austin, Texas

CHAPTER 4: Movement, Transportation, & Location

Source: mtaphotos

Mobility

- Refers to the efficiency of transportation infrastructure.
- Faster travel speeds & shorter driving distances both increase mobility.

Source: MSVG

Accessibility

- Level of **attractive destinations** one can get to within a given travel time or cost budget.
- Residents in highly accessible locations reach more desirable activity sites more easily.

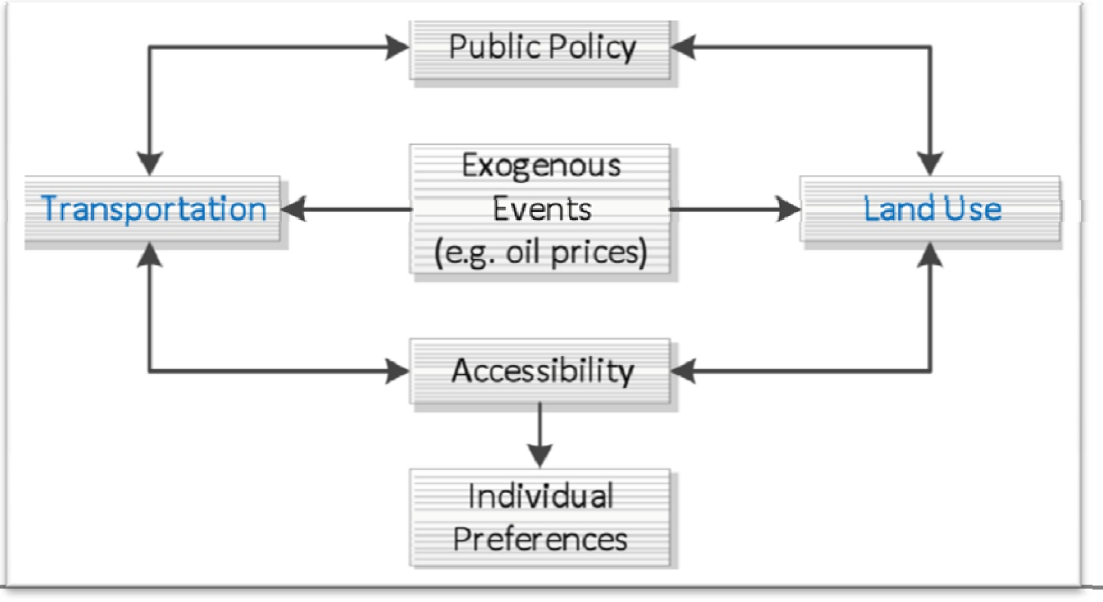
Source: cahighspeedrail.ca.gov

Mobility *versus* Accessibility

- Mobility relates to higher travel speeds.
- Increased mobility **does not** always lead to increased accessibility:
  - **Highest access** tends to emerge in **dense, urban centers.**
  - **Greatest movement** often associated with peripheral **freeways**, in lower-density settings**.**

Urban Planning & Transportation

- Chicken & Egg relationship: Good transportation infrastructure pulls in new business, which creates new travel demands.
  - Short Term: Land use patterns determine travel behavior & transportation investment.
  - Long Term: Travel access impacts land values & land use.

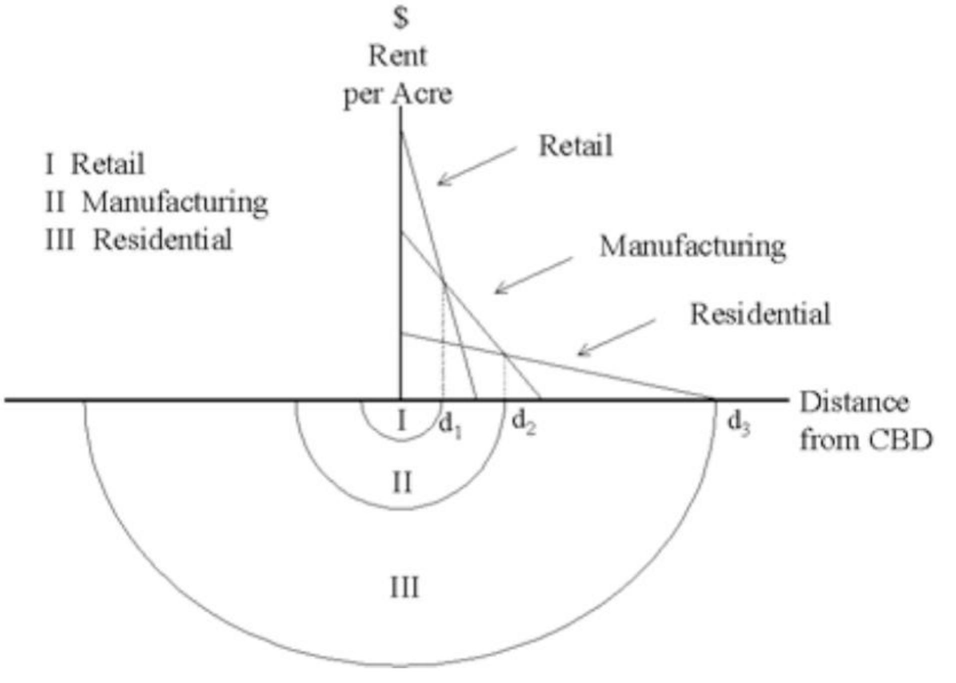


Urban Planning & Business Locations

- **Consumer Range**:
  - Distance that a consumer is willing to travel for a good or service.
  - Many business location choices reflect **consumer range.**
  - Lowered travel costs lead to longer range.
- Major factors in Business Location:
  - **Cost & availability** of improved/built space, Access to **labor**, & Access to **consumers**

Central Place Theory

- $D = f(P_h, P_t, P_g)$
- D = Housing demand
- P_h = Housing cost
- P_t = Travel cost
- P_g = Price of "all other goods"



Source: Alonso 1964

(Source: Campbell 2007)

Zoning & Policy Impacts

- Theories assume a **perfectly competitive** land market.
- **Zoning** & **infrastructure** provision also play key roles in shaping business & residential location choices.
- Zoning is linked to **tax revenues.**
  - Some policies are designed to generate tax revenue, not necessarily to benefit the surrounding area.
    - **Example:** Municipalities encourage development of high-volume, "big box" retailers, while low-income housing developments are often avoided.

Rail Transit & Land Values

- **Mixed results** on rail transit's effect on business & residential land value…
  - Atlanta & Miami: **No land value increase** around transit stations after rail lines installed (Nelson 1992, Gatzlaff & Smith 1993).
  - Parts of San Francisco & DC: **Increases in land value** within walking distance to transit stations (Cervero & Landis 1997).
- Land values rise when stations are positioned in areas already enjoying **economic growth.**
- Systems that have the **highest ridership rates** & link travelers to more locations experience the **greatest gain** in property values from rail-transit investment.

Highway Investment & Land Values

- Land immediately adjacent to highways **decrease in value** (Gamble et al. 1974, Haider & Miller 2000)
  - Caused by **construction effects, noise, & pollution**
  - Largest detrimental affects when highway is **elevated**, smallest when **depressed.** (Lewis et al. 1997)
- Land nearby new development but not abutting the new highway **increases in value.**
- Highway investments in **rural** areas have more pronounced impacts on land values than those in **urban** areas.

Transportation & Economic Development

- Efficient transportation & economic development are closely linked -- yet hard to quantify.
- Benefits, over time & space, according to Button (2010):
  - **Primary Economic Benefits**: Gains from construction itself, mostly in the form of **construction jobs** for local workers.
  - **Secondary**: Jobs created from **operation & maintenance** of the project once completed.
  - **Tertiary:** Economic **development drawn to the area** because of the new infrastructure.
  - **Perpetuity**: Long-term result of accumulation of transportation investments, creating a more vibrant economy for the entire area.

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Construction Impacts

- Construction activities can have **negative effects** on **land values and rents** (Buffington et al. 1997, Luskin & Chandrasekaran 2005)
  - Depressed freeways tended to be less productive for business, while elevated sections were less desirable for residents.
  - Traffic delay during construction can temporarily decrease market rent of offices (due to employees' commute time increases.

Source: sdot_photos

Access Management

- Modifying road access can have various economic & safety consequences:
  - High **driveway density** increases **crashes** while reducing driving speeds (e.g., Gluck 1999).
  - Adding a **median** improves traffic flow and reduces crashes (TRB 2000, TxDOT 2011).
    - Medians have little or no **net** affect on the economy of the area but do affect individual retailers differently.
    - Gas stations, motels, & convenience stores experience most negative effects since they rely on passerby traffic.
    - Site accessibility is less important to customers than service, product quality, & price.

In Summary…

- Access & Mobility are very important concepts, relating urban & regional planning & transportation.
- Land values & transportation have a push-pull relationship.
  - This relationship only grows more complex as new technologies (e.g., telecommuting, autonomous vehicles) emerge & urbanization continues.

Source: visualistimages

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CHAPTER 1: Costs & Benefits of Transportation

Source: brewbooks

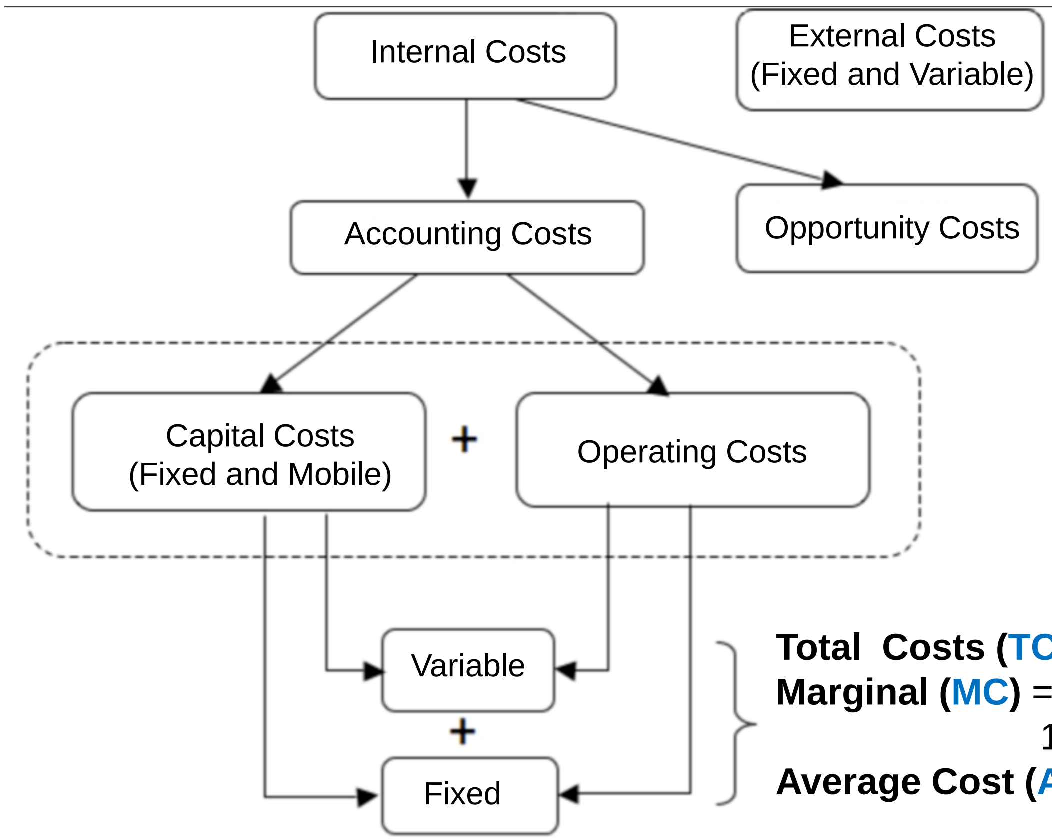
Project Costs

Potential Costs (and Benefits) of Transportation Projects and Policies	Description	Examples
Capital	**One-time** design and construction costs	Planning, preliminary engineering, project design, environmental impact analysis, right-of-way acquisition, construction, equipment purchases, etc.
Operating	**Recurring** operations, maintenance, and rehabilitation costs	Traffic management, accident- or weather-related repair and cleanup, equipment (vehicles, traffic signals, signs), utilities, resurfacing (but not reconstruction), etc.
Vehicle	**Vehicle ownership** and maintenance costs such as fuel, tire replacement, insurance, etc.	Pavement resurfacing improves road conditions and reduces vehicle wear and maintenance costs.

Project Costs (2)

Travel Time	**Lost time** and productivity	Implementation of signal timing coordination on an arterial street enables faster travel times and reduces delay.
Travel Time Reliability	Variance of schedule **uncertainty**	Dynamically priced high-occupancy/toll (HOT) lane keeps travel speeds close to free flow speed and reduces variability in travel time.
Safety	Number, severity, and cost of **crashes**	Addition of rumble strips reduces the number of crashes related to driver fatigue.
Emissions	**Health** and other costs of vehicle-produced pollution	Fleet conversion from diesel to compressed natural gas vehicles reduces emissions.
Noise	Discomfort and **property value** loss	Construction of a sound wall between a freeway facility and an adjacent neighborhood reduces traffic noise.
Ecological Impacts	Travel's impacts on wildlife habitat, water flow, and **water quality**	Planned roadway alignment runs through an endangered species habitat, impeding animal movements through the area.

Transportation Cost Relationships



Total Costs (TC) = Variable + Fixed Costs
Marginal (MC) = Change in TC per added 1 unit of Output = $\Delta TC/\Delta Q$
Average Cost (AC) = TC/Q

Internal Costs

- Costs that apply directly to those using & providing the services & products.
- These include materials, labor, fuel, maintenance, travel time, parking, & insurance payments -

… as opposed to external costs.

Source: metrolibraryarchive

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Capital Costs

- One-time costs associated with initial planning, design & construction of a new project.
- These include:
  - Planning (including environmental review)
  - Design
  - ROW acquisition
  - Construction materials & labor

Source: jamiejohn

Estimating Capital Costs

- **Bid Item Estimate**: Calculated from materials unit prices on similar projects.
  - **Examples:** Cost per ton of aggregate & Cost per manhole cover
- **Conceptual Cost Estimate**: Compute overall costs for a unit of production, not unit of material.
  - **Example:** Cost per mile of at-grade two-lane rural highway

ALABAMA DEPARTMENT OF TRANSPORTATION
LOW BID SHEET
LETTING DATE: August 28, 2009

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001 . STMAA-0001(553)
COUNTY: CHAMBERS LENGTH: 0.255

SAFETY IMPROVEMENTS
ON SR-1 (US-431) FROM 1 MILE SOUTH OF SR-147 (MP 148.466) TO MP 148.
721 NORTHWEST OF OAK BOWERY

1. EAST ALABAMA PAVING CO., INC. $ 189,550.84
   OLD COLUMBUS ROAD
   OPELIKA , AL 36804

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002 . STMAA-0022(510)
COUNTY: RANDOLPH LENGTH: 1.002 MILES

SAFETY IMPROVEMENTS
ON SR-22 FROM 1 MILE NORTH OF CR-17 NORTHEAST OF ROCK MILLS TO THE
GEORGIA STATE LINE

1. APAC MID-SOUTH, INC. $ 400,898.47
   500 RIVERHILLS PARK, SUITE 590
   BIRMINGHAM , AL 35242

2. MCCARTNEY CONSTRUCTION CO., INC. $ 451,985.30
   331 ALBERT RAINS BOULEVARD
   GADSDEN , AL 35901-0000

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003 . STMAA-0055(504)
COUNTY: COVINGTON LENGTH: 6.504 MILES

PLANING, RESURFACING AND TRAFFIC STRIPE
ON SR-55 FROM SR-12 (US-84) TO THE NORTH CITY LIMITS OF RED LEVEL

1. WIREGRASS CONSTRUCTION COMPANY, INC. $ 3,217,107.84
   170 EAST MAIN STREET
   DOTHAN , AL 36301

2. APAC-SOUTHEAST, INC. $ 3,562,582.00
   381 TWITCHELL ROAD
   DOTHAN , AL 36303

Estimating Capital Costs

- **Design** Costs
  - Estimate using a percentage of **capital costs.**
  - Different for every field: the more complex the project, the higher the **percentage.**
- **ROW** Acquisition
  - Estimate what needs to be acquired.
  - Apply cost per structure, per parcel square foot, etc.
  - More information can be found in **TxDOT's ROW Information System database .**

Operation & Maintenance Costs

- These continue after construction is complete:
  - Manual **toll collectors'** salaries
  - Subway station **security guards** & **HVAC**
- These can be based on…
  - Estimates of costs per mile or per station.
  - They should reflect daily labor costs & electricity use.

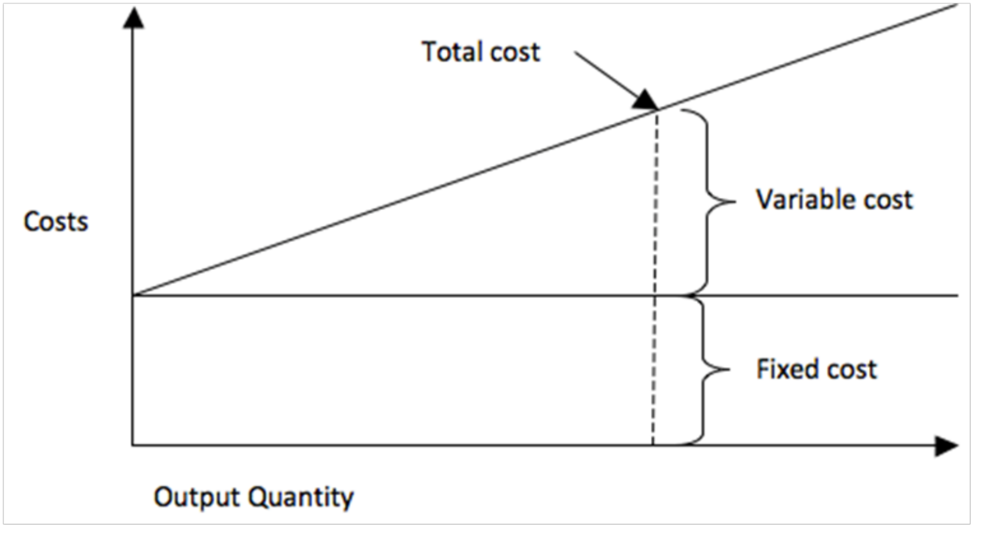
Source: jeremybrooks

Vehicle Operating Costs

- For only **gas & maintenance** (Polzin et al. 2008):
  - Standard Automobile: $0.173 per mile
  - Truck or SUV: $0.217 per mile
  - Commercial Truck: $0.49 per mile
- **Vehicle Depreciation:** Additional cost of around $.06 per mile (Barnes & Langworthy 2003).

Variable vs. Fixed Costs

- **Fixed** costs are one-time costs…
  - Do not change with level of output, &
  - Need to be paid before the system is usable.
  - **Example:** Capital Costs



- **Variable** Costs…
  - Do change with level of output.
  - **Example:** Operation & Maintenance Costs

Marginal vs. Average Cost

- **Marginal Cost (MC)**: The cost of adding on to an existing proposal per unit output.
  - How much extra would it cost to change a 4-lane design to a 6-lane design?
  - How much would it cost Amtrak to fill another seat on a train that is not yet full? How much would it cost Amtrak to fill a seat on a train that requires an additional car?
- **Average Cost (AC)**: The total cost divided by total units produced.
- Usually MC is lower than AC due to economies of scale.

Marginal vs. Average Cost

Costs	How to Calculate TC = Total Cost Q = Total Output	Example	Interpretation
Point Marginal Costs (**MC**)	MC = dTC/dQ (Derivative of TC with respect to Q)	TC=$200+4Q → MC=$4/unit	**MC** = Slope of the TC function, relative to output (Q)
Arc Marginal Cost (incremental)	Arc MC = $\frac{TC_2 - TC_1}{Q_2 - Q_1}$	Arc MC here also equals $4/unit	Normalized change in costs for a specific change in output
Average Cost (**AC**)	AC = TC/Q	If Q=100 → AC = $6/unit	Also called unit cost, AC is total cost divided by total output

EOS & RTS

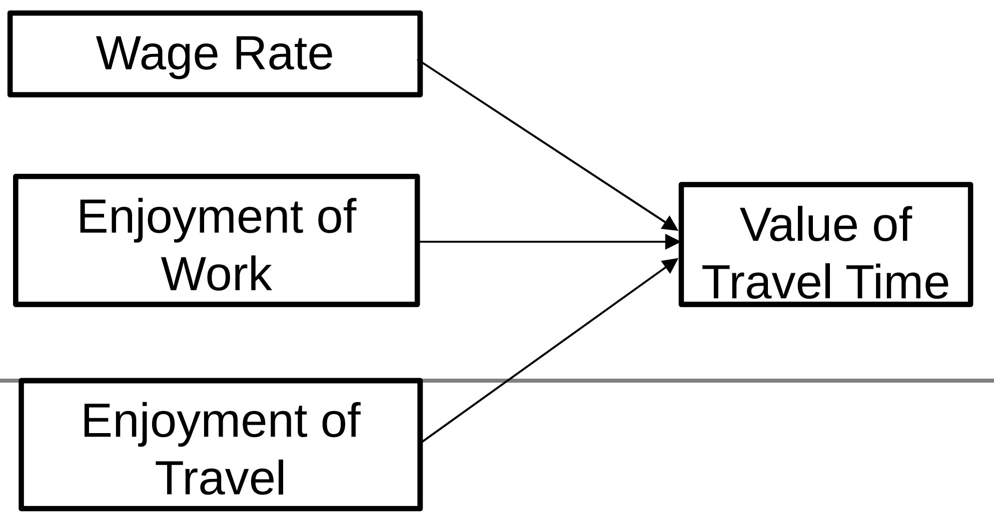
- **Economies of Scale (EOS)**: Unit (average) costs fall as production increases or project becomes larger.
  - **Example:** Cost of building 6-lane road is **less than** 3 times that of a 2-lane road.
- **Returns to Scale (RTS)**: The factor change in production in response to a factor increase in all inputs.
  - If all input (e.g., track miles for railroad industry) are increased 50%, will capacity (in ton-miles) rise by more than 50%?

EOS & RTS

Case	**EOS = $/unit** (Small 1992)	**RTS = Q/Inputs** (Samuelson & Nordhaus 2005)
Increasing EOS **or** **Increasing RTS**	**MC(Q) < AC(Q)** The **average cost (per unit) decreases** as output increases. *Example:* Average input costs per seat on Amtrak decrease as seat-miles increase.	Increasing all inputs by same proportion results in a **more-than-proportional increase** in the level of output. *Example:* Number of Amtrak seat-miles increases by 60% when all inputs increase by 40%.
No EOS **or** **Constant RTS**	**MC(Q) = AC(Q)** The **average cost (per unit) stays the same** as output increases. *Example:* Average input costs per seat stay the same as seat-miles increase.	Increasing all inputs by same proportion results in the **same proportional increase** in the level of output. *Example:* Number of seat-miles increases by 50% when all inputs increase by 50%.
Diseconomies of Scale **or** **Decreasing RTS**	**MC(Q) > AC(Q)** The **average cost (per unit) increases** as output increases. *Example:* Average input costs per seat increase as seat-miles increase.	Increasing all inputs by same proportion results in a **less-than-proportional increase** in the level of output. *Example:* Number of seat-miles increases by 10% when inputs increase by 20%.

Value of Travel Time (VOTT)

- Travel time is an implicit **opportunity cost.** (That time could be spent elsewhere.)
- VOTT is the amount of money a traveler is willing to spend to save time travelling.
- VOTT converts time to money (e.g., $10/person-hour).



Estimating VOTT

- Stated Preference Surveys
  - Ask travelers what they would most likely do to save money or time.
- Revealed Preference Surveys
  - Ask what travelers actually do when presented with options to trade money for reduced travel time.
- **Estimates of VOTT** around \$11–\$21 per person-hour for intra-city travel & \$15–\$21 for inter-city travel (USDOT 2003).
- Lower-income travelers tend to demonstrate a lower VOTT.

Source: nikoretro

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Reliability of Travel Times

- Having an average travel time of 25 minutes with possible range of 15 to 45 min. is not as desirable as an average of 30 min. with range of 25 to 35 min.
- Reliability costs quantify how important this reliability really is to travelers.
- Studies have found the costs to be anywhere from $10 – $32 per hour a user is late or early (Brownstone & Small 2005, Litman 2009).
  - Values are much higher for being late than for being early.
  - Can be very important for public transit systems.

Source: gringoart

Project Delay Costs

- Are a type of **opportunity cost**
- What is the cost of delaying a transportation project (either in planning/design stage or construction stage)?

Source: London Looks

  - **Vehicle Operating Costs**: Extra gas & maintenance on cars due to increased congestion or longer detour routes.
  - **User Delay Costs**: Extra time spent by the traveler that would have otherwise been saved if the project was complete.
  - **Crash Costs**: Extra cost of crashes due to the increased likelihood of an crash occurring at a construction site.

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External Costs

- External costs are not directly internalized by consumers or producers (i.e., system users or providers)
- External costs apply to those outside the system, & often to society as a whole:
  - **Noise**
  - **Pollution**
  - **Crash damages** (to third parties, including traffic delays)
  - **Water flow & water quality**
  - **Wildlife habitat, ecological impacts**

External Costs: Crash Costs

- Just 25% crash costs are paid by those involved (USDOT BTS 2003) → **Society pays for the other 75%**!
- Each U.S. crash causes around $3,000 to **$977,000 in total damages** (Blincoe et al. 2002).
  - These include lost productivity, first responders, medical services, travel delay, & property damage for all of society.

- Fatal crashes costs are valued at **$6 million** per crash.

External Costs: Air Quality

- Pollution harms humans, plants, animals, & buildings.
- Common pollutants from transport projects:
  - Carbon dioxide (**CO_2**), oxides of nitrogen (**NO_x**), **VOC**, fine particulate matter (**PM2.5** & **PM10**), carbon monoxide (**CO**)
- **Dollar values** depend on local human exposure (e.g., population density), wealth (willingness to pay), & meteorology.

Source: ESRI

Pollutant	Estimated Costs
HC	$2,900 to $5,800/ton
CO	$70 to $140/ton
NOx	$620 to $5,600/ton
SO2	$620 to $6,400/ton
PM2.5	$9,300 to $830,000/ton

Source: McCubbin and Delucchi 1996, Mailbach et al. 2008

External Costs: Noise

- Noise caused by transportation projects can reduce land value, increase stress, & cause hearing loss.
- Some vehicles contribute more to these costs than others.
  - Electric vehicles < Automobiles < Trucks < Motorcycles
- Studies have shown reduction in land values of around 0.5% for every decibel above 50 dB (OECD 1989).
- Automobile noise costs 1.3 cents per mile on urban roads & 0.7 cents per mile on rural roads, on average (Litman 2009).

Other External Costs

- New impervious surface can increase **rain runoff.**
  - Adds to heat pollution in streams, flash flooding, & other issues.
- Vehicles deposit rubber, oil, & other polluting particles on pavements. Rain washes these pollutants over impervious roadway surfaces into nearby areas.
- Hard to quantify such costs. They are usually analyzed on a case-by-case basis.

Source: wrh.noaa

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Estimated Transportation Costs Per Mile

(Small & Verhoef 2007)

Type of Cost	Private (Internal)	Social (Internal + External)	
	Average	Average	Marginal
Variable Costs			
Costs borne mainly by highway users			
(1) Operating & maintenance	$0.141/mile	0.141	0.141
(2) Vehicle capital	**0.17**	**0.17**	**0.17**
(3) Travel time	**0.303**	**0.303**	**0.388**
(4) Schedule delay & unreliability	0.093	0.093	**0.172**
Costs borne substantially by non-users			
(5) Crashes	0.117	0.14	**0.178**
(6) Government services	0.005	0.019	0.019
(7) Environmental externalities	0	0.016	0.016
Fixed Costs			
(8) Roadway	0.016	0.056	
(9) Parking	0.007	**0.281**	
Total Costs	**$0.852/mile**	**$1.219/mile**	

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In Summary…

- There are **many costs** involved in transportation projects.
  - Fixed **capital costs &** variable **operating costs.**
  - **External costs** also must be considered for a true comprehensive analysis.
- As the state of knowledge progresses, we quantify more & more costs that were once considered subjective.

Cost-Benefit Analysis (CBA)

- Method to measure & evaluate all relative direct economic impacts of public investment projects.
  - Used to **prioritize** & rank potential project alternatives.
- **Common process:**
  1. Identify project needs
  2. Identify project constraints
  3. Define the base case
  4. Identify alternatives
  5. Define a time period
  6. Define work scope
  7. Analyze alternative traffic effects
  8. Estimate benefits & costs
  9. Evaluate risk
  10. Conduct sensitivity analysis
  11. Find **benefit/cost ratio**
  12. Make **recommendations**

Some Costs & Benefits…

Agency Costs	• Design & Engineering • Land Acquisition • Construction • Reconstruction/Rehabilitation • Preservation/Routine Maintenance • Mitigation (e.g., noise barriers)
User Costs/Benefits Associated with Work Zones	• Delays • Crashes • Vehicle Operating Costs
User Costs/Benefits Associated with Facility Operations	• Travel Time & Delay • Crashes • Vehicle Operating Costs
Externalities (non-user impacts, if applicable)	• Emissions • Noise • Other Impacts

Simple CBA Example

A bridge linking two towns over a river is close to failing and will be decommissioned in 5 years if repairs are not made. TxDOT is calculating a B/C ratio to compare the benefits of travel time savings, reduced operating expenses, crashes, and pollution to construction and maintenance costs.

Removing the bridge will require some users to travel further out of their way to reach destinations across the river, resulting in increased VMT overall. Assuming a lifespan of 50 years for the rebuilt bridge, TxDOT projects VMT in the area to be as follows:

	Total VMT	Total VHT
No-build	1,400,500	40,800
Bridge rebuild	1,275,000	39,100

Simple CBA Example

Benefits

- Travel time savings: $250 million
- Reduced operating costs: $185 million
- Reduced crash costs: $65 million
- Emissions reductions: $45 million
- **Total benefit of bridge repair: $545 million**

Costs

- Bridge repair: $100 million
- Total operating and maintenance costs: $85 million
- **Total cost of bridge repair: $185 million**

$$\frac{B}{C} = \frac{\$545{,}000{,}000}{\$185{,}000{,}000} = 2.95$$

Project Evaluation Toolkit (PET)

- Computes B/C ratios, internal rates of return, emissions totals, toll revenues, and other indicators for transportation projects.
- Can compare new build roads, variable toll projects, capacity addition, speed harmonization, and other system changes against one another.
- Anticipates near- and long-term impacts: travel welfare, crash counts by severity, travel time reliability effects, and toll revenues.

Project Evaluation in Austin

- Using the **Project Evaluation Toolkit** (PET), projects can be simulated to predict impacts on traffic.
- PET uses a simplified network for the Austin transportation infrastructure.

Case Study 1: Upgrading US290

- Improving **5.2-mile stretch** from US 183 to SH 130.
- **Three alternatives** evaluated (vs. no-build base case):
  - Same number of lanes, but **grade separate** these.
  - Same number of lanes, grade separated, & **$1 toll** added.
  - Add an **additional lane in each direction**, keep **at grade.**

Case Study 1: US Route 290

	Base-Case: No Build	Alt. 1: Grade Sep. Freeway	Alt. 2: Grade Sep. Tollway	Alt. 3: Extra Lanes (Arterial)
Net Present Value	-$18 M	$134 M	$109 M	**$117 M**
Internal Rate of Return	N/A	26%	22%	**70%**
Benefit / Cost Ratio	N/A	3.86	3.24	**6.38**
Payback Period (yrs)	N/A	4.9	6.0	**1.6**

Economic Summary Measures of Case Study 1's Project Alternatives

			Design Year	
	Crash Reduction	**Total VMT Reduction**	**Traffic Volume (AADT)**	**Traffic Speed (mph)**
Base	0.0%	0.00%	25,600	20
Alternative 1	3.8%	0.66%	29,900	52
Alternative 2	3.5%	0.62%	27,600	52
Alternative 3	**1.2%**	**0.61%**	**27,800**	**26**

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Review of Presentation

- What is the difference between mobility & accessibility?
- What are some internal costs of transportation?
- What are some external costs of transportation?
- Give an example of a fixed cost.
- Give an example of a variable cost.
- Compared to MC, AC is usually higher or lower? Why?
- Which transportation cost is typically most dominant (on a per mile basis)?

Thank You!

Questions & Suggestions?

Source: Brisbane City Council

The Economics of Transportation Systems: Module 2

Methods for Analysis

Pricing of Transportation Services

August 23, 2012

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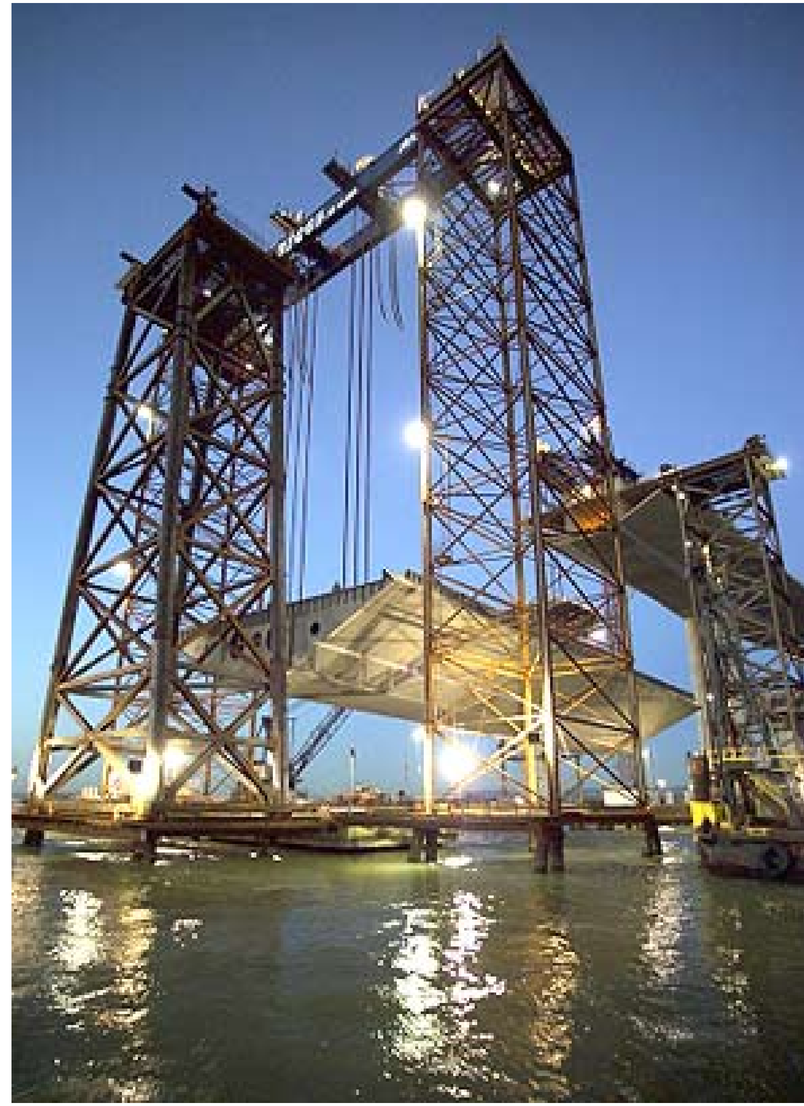
TRANSPORTATION ECONOMICS: METHODS FOR ANALYSIS



Source: mtc.ca.gov

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Topic Overview

- Discounting & **Interest Rates**
- Net **Present Valuation**
- Internal **Rate of Return**
- Incremental Rate of Return
- **Payback** Period
- **Life-Cycle** Cost Analysis
- **Multi-Criteria** Analysis
- Constrained **Optimization**
- **Sensitivity** Analysis

Introduction

- TxDOT must consider how potential projects & policies will impact the **well-being of an entire community.**
- This Chapter discusses how to assess various projects from an **economic** standpoint.
- Predicting future demands & scenarios is risky & uncertain. **Sensitivity analysis** can be used to analyze this risk.

Discounting & Interest Rates

- Discounting
  - *A dollar tomorrow is worth less than a dollar today.*
  - Why?
    - Risk
    - Opportunity
    - Inflation

- How to pick a **discount rate**?

Discounting & Interest Rates (2)

- Interest Rate
  - *Real* interest rate (excludes inflation)
  - *Nominal* interest rate (includes inflation)

- ***Real* interest** rate
  - ***Risk free?***
  - ***Risk premium***
  - ***Risk-adjusted discount*** rate
    - The summation of risk-free rate & risk premium.

Discounting & Interest Rates (3)

- *Nominal* interest rate
  - Rate inclusive of **inflation**
  - Used by most departments of TxDOT (besides Finance Division).
- **Example:**
  - $1000 invested in a CD that earns 4% interest per year.
    - Thus, the **nominal interest rate is 4%**.
  - At the end of the year, you will have $1040. But the annual inflation was 2% that year, so the ***real*** **interest rate is/was 2%.**

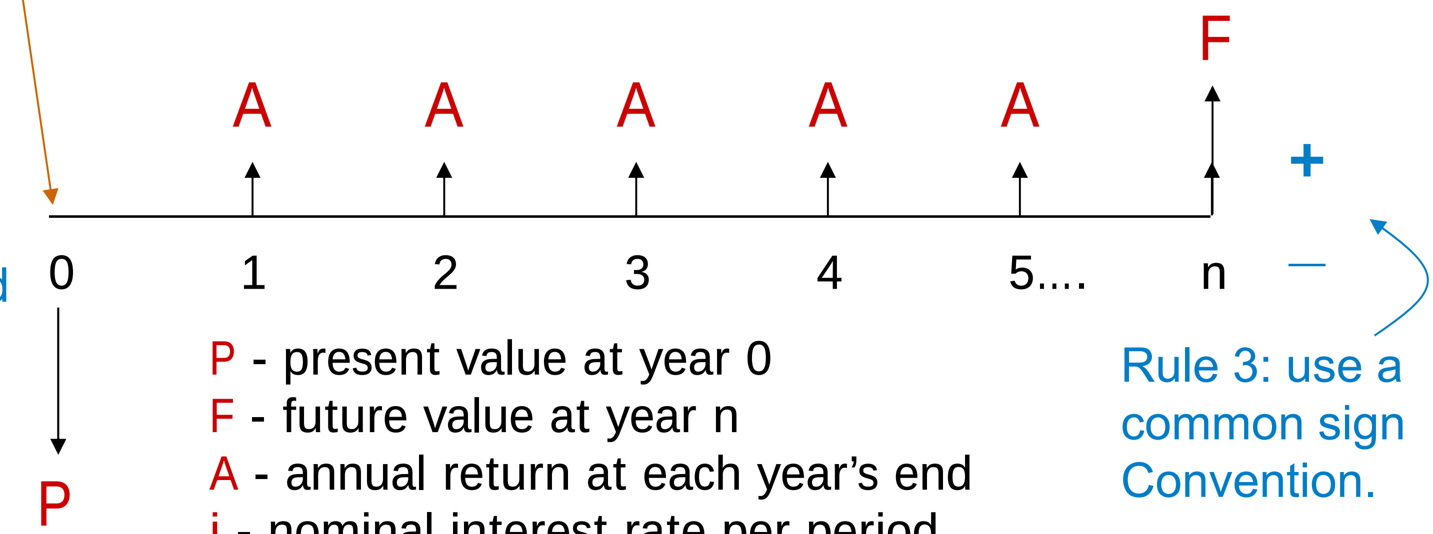
Net Present Value (NPV)

If...	It means...
NPV > 0	The investment would ***add value*** to the firm.
NPV < 0	The investment would ***subtract value*** from the firm.
NPV = 0	The investment would ***neither gain nor lose*** *value* for the firm.

Cash Flow Mapping

Rule 1: Always start at year 0!
(present time or start of study period)

Rule 2:
Ignore expenses before study period (sunk costs).



Rule 3: use a common sign Convention.

P - present value at year 0
F - future value at year n
A - annual return at each year's end
i - nominal interest rate per period
N - number of years/periods

If you can get the cash flow diagram straight, you have the problem mostly solved!

Discounting or NPV Formulas

Single Payment

$$What\ is\ P, if\ we're given\ F\ (P|F,i,N)?$$

$$P = F \times (1+i)^{-N}$$

Example:

If we have $100 today & invest it at 10% **simple annual compound** interest rate for two years, then:

Interest Earned in Year 1: $100 x %10 = $10

Interest Earned in Year 2: $110 x %10 = $11

Total Interest Earned in two years= $21

Present Value = $100

Future Value at the end of Year 2 = $121

Discounting or NPV Formulas (2)

Example:

A planned project is suddenly **delayed for 2 years**. Costs are expected to increase 2% annually, while unused funds could be **accruing** 1.75% interest.

- Current Construction Cost: $10,000,000

Present value of funds from interest:

- (1+0.0175)^2**$10,000,000* → F_i = **$10,353,063**

Present value of inflation costs:

- (1+0.02)^2*$10,000,000* → F_f = **$10,404,000**

- **2-year delay** would cost overall **$50,937.**

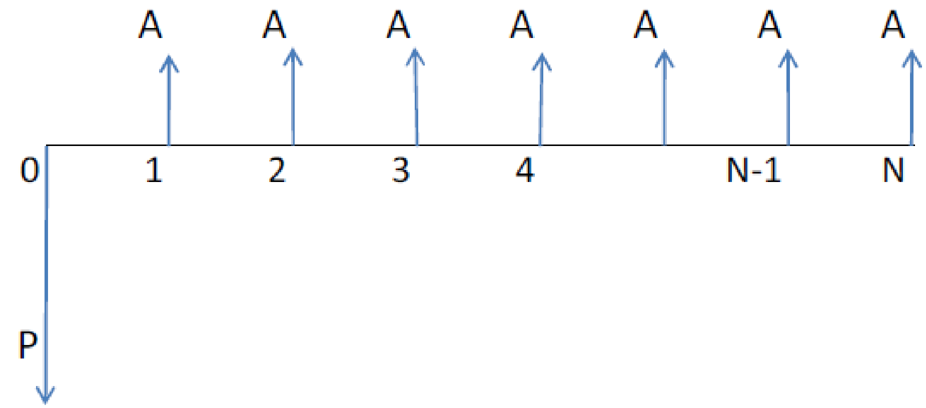
Discounting or NPV Formulas (3)

Equal Payment Series

To find P, given A (P|A, i, N):

$$P = \frac{A}{i}[1 - (1+i)^{-N}]$$

$$P = \frac{A}{i}\ (if\ N = \infty)$$



Example:

TxDOT considers a project with constant **revenue of $1,000,000 per year** for 20 years. What is the NPV of this project? Assume a **discount rate** of 5%.

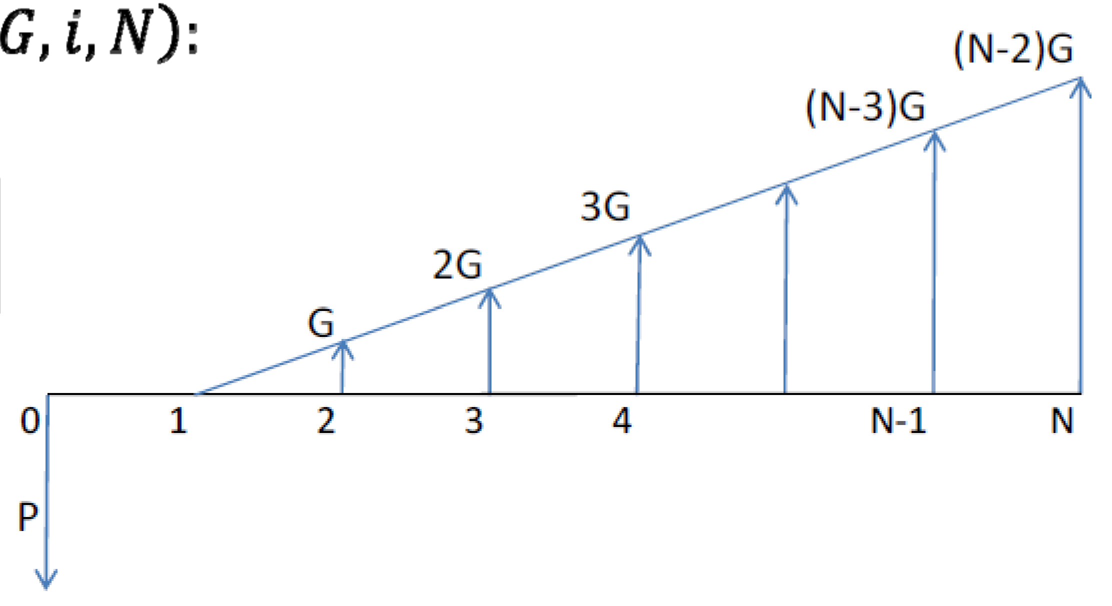
$$P = \frac{1{,}000{,}000}{0.05}[1 - 1.05^{20}] = \$33{,}065{,}954$$

Discounting or NPV Formulas (4)

<u>Linear Gradient Series</u>

$To\ find\ P, given\ G\ (P|G, i, N)$:

$$P = G\left[\frac{(1+i)^N - iN - 1}{i^2(1+i)^N}\right]$$



Discounting or NPV Formulas (5)

Linear Gradient Series

Example:

TxDOT considers the benefits of the project shown in the Table. Toll revenue is assumed to **increase $80,000 each year**. What will be the project's NPV? Assume a discount rate (i) of 10%.

Annual cash flow A = $1,000,000/period

Gradient cash flow G = $80,000/period

Year	End-of-year Payment
1	$1.00M
2	$1.08M
3	$1.16M
4	$1.24M
5	$1.32M

$$NPV = \frac{1{,}000{,}000}{0.10}\left[1 - 1.1^{-5}\right] + 80\left[\frac{(1+0.1)^5 - 0.1 \times 5 - 1}{0.1^2 \times (1+0.1)^5}\right]$$

$$= \$4{,}339{,}731$$

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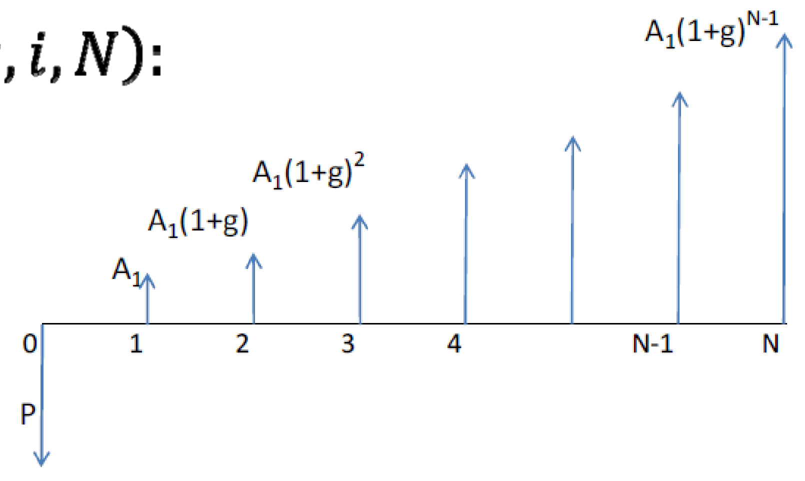
Discounting or NPV Formulas (6)

Geometric Gradient Series

$$To\ find\ P, given\ A_1\ and\ g:\ (P|A,g,i,N):$$



$$P = A_1\left[\frac{1-(1+g)^N(1+i)^{-N}}{i-g}\right]\ (if\ i \neq g)$$

$$P = A_1\left(\frac{N}{1+i}\right)\ (if\ i = g)$$

Discounting or NPV Formulas (7)

Geometric Gradient Series Example

Planners have determined that a **Continuous Flow Intersection (CFI)** alignment at a busy intersection will significantly reduce delay.

- Average no-build intersection delay: 425.0 sec/veh
- Average CFI delay: 40.0 sec/veh
- Current ADT: 36,000 vpd
- Traffic growth rate: 2.5% (exponential)

Assuming **a user value of travel time (VOTT) of $25 per vehicle-hour** & an **interest rate of 2%**, estimate the total cost savings benefit of the continuous flow intersection over 10 years.

Discounting or NPV Formulas (7)

Geometric Gradient Series Example

$$Delay\ Cost = VOTT \times Delay \times ADT \times Days \times \frac{1\ hr}{3600\ sec}$$

Year 1 delay savings from installing CFI:

$$\$25 \times (425 - 40) \times 36{,}000 \times 365 \times \frac{1}{3600} = \$35{,}131{,}250$$

Because traffic is increasing exponentially at 2.5% every year, a geometric gradient series can be used to determine present value of delay cost savings over 10 years.

$$P = \$35{,}131{,}250 \left[\frac{1 - (1 + 0.025)^{10}(1 + 0.02)^{-10}}{0.02 - 0.025}\right] = \$352{,}121{,}780$$

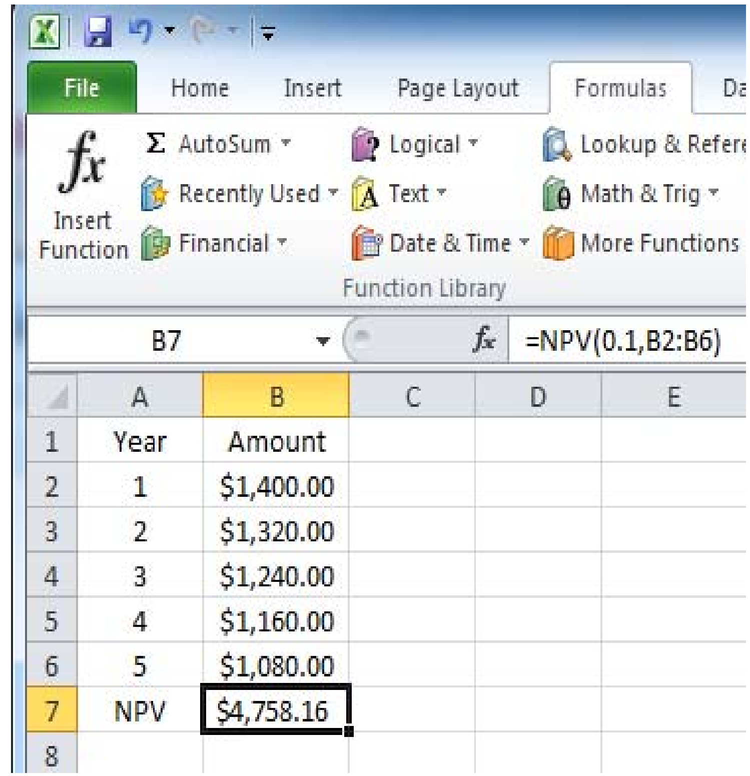
MS Excel NPV Function

NPV (*rate, value1, value 2,…*)

where…

- *rate* is **discount factor** for one period.
- *value1* is the cash flow input for the end of the **first period.**
- *value2* is the cash flow input for the end of the **second period.**
- & so on…

The returned NPV refers to the value at the end of the initial year.



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NPV

- NPV can be used to compare similar projects.
- BUT, NPV can fall short when comparing projects of different investment amounts, life cycles, etc.
- **Example:**
  - Suppose TxDOT considers building a new highway with alternatives A & B with respective NPVs of $2.0M & $3.5M.
  - The required investment for alternatives A & B are $10M, & $30M, respectively.
  - Although alternative B's NPV is greater than that of alternative A, alternative B requires significantly more investment.

Internal Rate of Return (IRR)

- IRR can only be used **when the project will generate income**.
- The Discount Rate at which the **NPV of costs** of the investment **equals** the **NPV of the benefits**.

$$C_i + \sum_{y=1}^{proj\ life} (C_y)(\frac{1}{1+IRR})^y - SV(\frac{1}{1+IRR})^{proj\ life} + IPC(\frac{1}{1+DR})^{year} = \sum_{y=1}^{proj\ life} (B_y)(\frac{1}{1+IRR})^y$$

where

- C_i is the initial project cost
- SV is the salvage value
- IPC is the interim project costs
- DR is the discount rate
- B_y denotes the benefits realized in year y
- C_y denotes costs realized in year y.
- In the transportation arena, typical project lifetimes (*proj life*) may be 20 years

IRR Example

TxDOT considers building a new toll road with the following cash flow for first five years. What is the IRR for this period?

Year	Cash Flow
0	-$10,000,000
1	$1,340,000
2	$2,010,000
3	$2,345,000
4	$2,680,000
5	$2,847,500

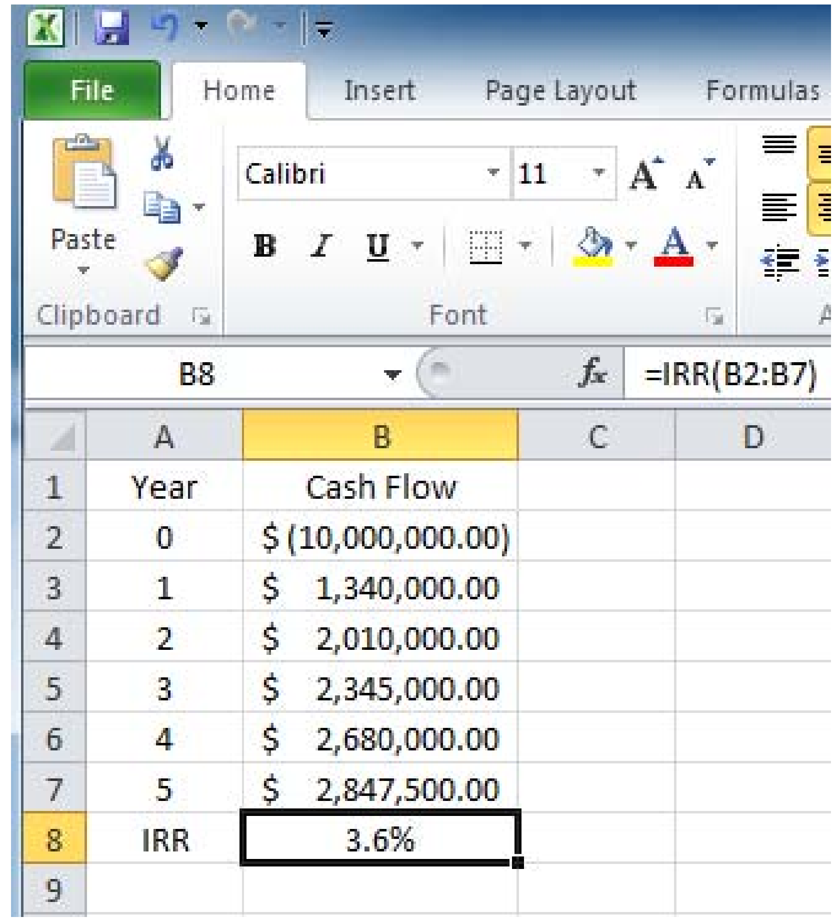
$$10{,}000{,}000 = \frac{1{,}340{,}000}{(1+IRR)} + \frac{2{,}010{,}000}{(1+IRR)^2} + \ldots + \frac{2{,}847{,}500}{(1+IRR)^6}$$

IRR = 3.6%

MS Excel IRR Function

IRR(*value*)

where *value* is a reference to cells which the user would like to calculate the IRR for.



	A	B
1	Year	Cash Flow
2	0	$ (10,000,000.00)
3	1	$ 1,340,000.00
4	2	$ 2,010,000.00
5	3	$ 2,345,000.00
6	4	$ 2,680,000.00
7	5	$ 2,847,500.00
8	IRR	3.6%

Life Cycle Cost Analysis (LCCA)

- Used to compare projects with different investments & durations.
- Considers all of the benefits & costs associated with different project alternatives over the project's lifetime.
- Converts costs to **EUAC**: equivalent uniform annual cost
- For projects with comparable benefits over the same lifetime, the alternative with the lowest LCC is usually preferred.

LCCA Example

- A TxDOT district is deciding between flexible & rigid pavement for a new roadway.
- Engineers expect required surface rehabilitation after 20 years for flexible pavement & 40 years for rigid pavement.
- Flexible pavement would cost $4 million initially & $2 million to rehabilitate 20 years later. Rigid pavement would cost $6 million for initial construction.
- Because rehabilitation costs are to occur 20 years in the future, they must be translated to present value before they can be compared with initial costs. Assume 2% annual interest rate.

LCCA Example (2)

- Present worth of flexible pavement rehabilitation costs in year 20:

$$P = \$2{,}000{,}000 \times \frac{1}{(1+0.02)^{20}} = \$1{,}345{,}943$$

	Rigid	Flexible
Initial Costs	\$6M	\$4M
Rehabilitation Costs	-	\$1.35M
Total Costs	\$6M	\$5.35M
Total Benefits	\$11M	\$10M
NPV	**\$5M**	**\$4.65M**

- The rigid pavement returns a higher NPV and would therefore serve as a better choice.

Multi-Criteria Analysis (MCA)

- CBA and LCCA assign monetary value to account for environmental & safety impacts (one dimension of measure).
- MCA allows alternatives analysis to be done across different types of criteria with various dimensions of benefits.
- MCA allows assessment of criteria on any quantitative or qualitative scale.
- MCA is more flexible than CBA, but weighting process is subjective and can heavily influence outcome.
- Benefits may be double-counted or under-counted due to overlap in criteria considered in MCA.

MCA Example:
Simple Additive Weighting (SAW)

- SAW converts a multi-criterion problem into a single dimension

$$Overall\ Score = \sum_{j=1}^{n} w_j Rating_{ij}$$

where:

i indexes alternative projects or policies

j indexes evaluation criterion

MCA Example: SAW

Consider 3 alignments for a new route based on the following criteria & weights:

1. Operations and safety considerations (0.35)
   - Congestion impacts (0.15)
   - Safety impacts (0.15)
   - Network connectivity impacts (0.05)
2. Environmental considerations (0.3)
   - Noise pollution impacts (0.1)
   - Air pollution impacts (0.1)
   - Landscape (e.g., parks & wildlife refuge) & historical site impacts (0.1)
3. Cost considerations (0.25)
   - Construction cost (0.2)
   - Efficiency of construction (0.05)
4. Political/community considerations (0.1)
   - Community preferences at a local level (0.05)
   - Political acceptability at a regional level (0.05)

MCA Example: SAW (2)

- **Alt. A**: No-build
- **Alt. B**: Lower construction cost, greater impacts to landscape & historical sites
- **Alt. C**: Higher construction cost, fewer impacts to landscape & historical sites, better received by local community

Criterion (Weight)	Alt. A	Alt. B	Alt. C
Congestion (0.15)	0	3	3
Safety (0.15)	1	2	2
Network connectivity (0.05)	0	3	3
Noise Pollution (0.1)	3	2	2
Air Pollution (0.1)	3	2	2
Landscape & Historical Sites (0.1)	3	2	1
Construction Cost (0.2)	3	1	2
Efficiency of Construction (0.05)	3	2	1
Community Preferences (0.05)	2	1	3
Political Acceptability (0.05)	0	3	3

MCA Example: SAW (3)

Criterion (Weight)	Alt. A	Alt. B	Alt. C
Congestion (0.15)	0 x 0.15 =0	3 x 0.15 = 0.45	3 x 0.15 = 0.45
Safety (0.15)	0.15	0.3	0.3
Network connectivity (0.05)	0	0.15	0.15
Noise Pollution (0.1)	0.3	0.2	0.2
Air Pollution (0.1)	0.3	0.2	0.2
Landscape & Historical Sites (0.1)	0.3	0.2	0.1
Construction Cost (0.2)	0.6	0.2	0.4
Efficiency of Construction (0.05)	0.15	0.1	0.05
Community Preferences (0.05)	0.1	0.05	0.15
Political Acceptability (0.05)	0	0.15	0.15
Overall Score	***1.9***	***2***	***2.15***

Sensitivity Analysis

- There is uncertainty in forecasting **model inputs**.
  - Some variables can vary greatly, while others have a very narrow range of values (e.g. highly volatile gas prices, relatively stable population growth)
- How to conduct single factor sensitivity analysis?
  - Develop a **base-case**
  - Change one value & holding other values constant.
  - The **slope of a line on a graph** = change in NPV per change in input.
    - The steeper the slope, the more sensitive the NPV is to change in a particular variable.

Single-Factor Sensitivity Analysis: Example

TxDOT is considering building a new highway with the following estimated parameters:

- Construction cost: $10 million
- Demand: 1,000 cars per day
- Maintenance: $500,000
- Toll: $3
- Interest Rate: 4%
- Study Period: 25 Years

Single-Factor Sensitivity Analysis can help determine **which parameter** has the most **influence on the NPV** of the project.

Single-Factor Sensitivity Analysis: Example (2)

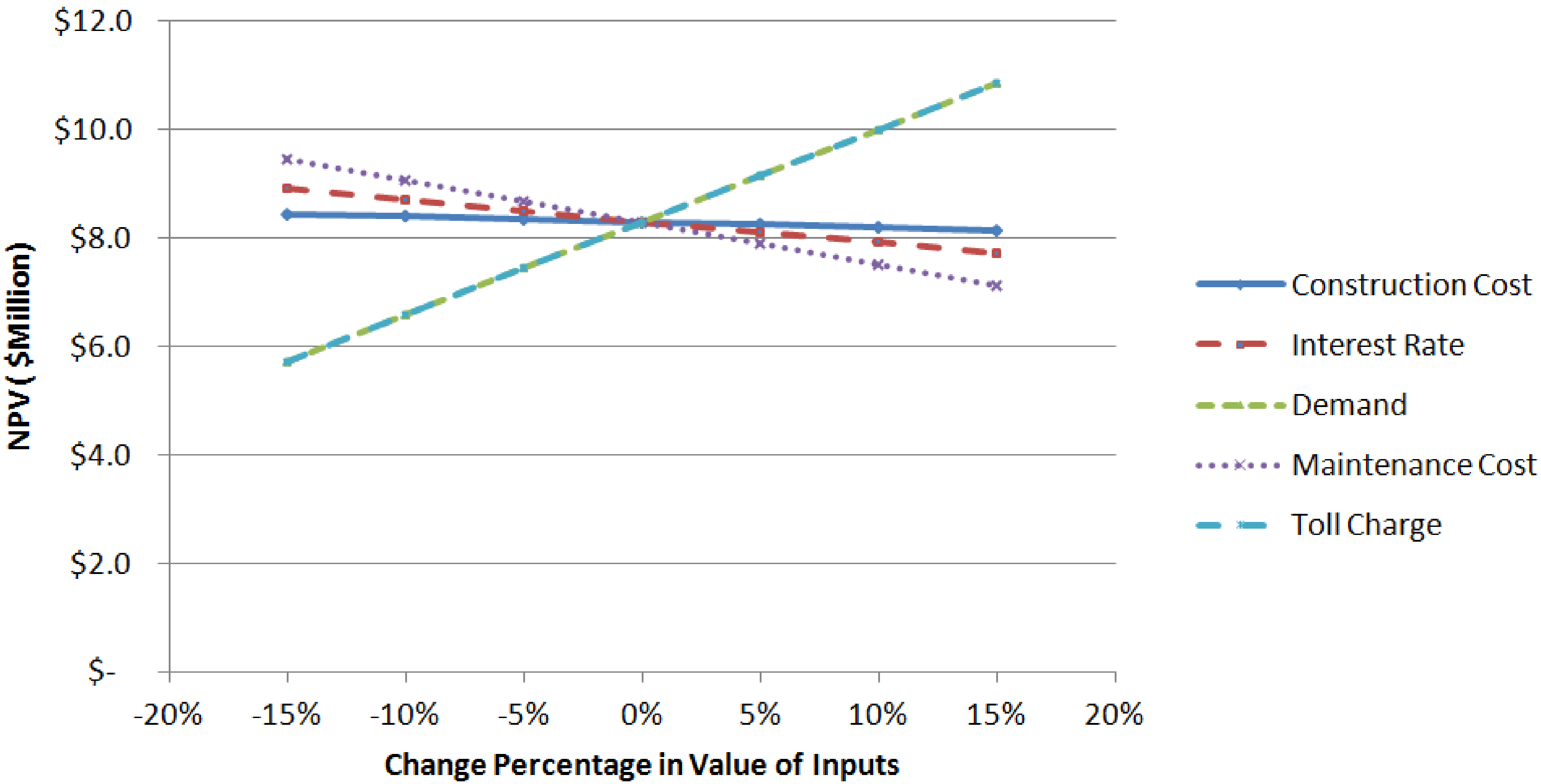
Step 1	**Demand**	Toll	Construction Cost	Maintenance Cost	Interest Rate
Step 2	Demand	**Toll**	Construction Cost	Maintenance Cost	Interest Rate
Step 3	Demand	Toll	**Construction Cost**	Maintenance Cost	Interest Rate
Step 4	Demand	Toll	Construction Cost	**Maintenance Cost**	Interest Rate
Step 5	Demand	Toll	Construction Cost	Maintenance Cost	**Interest Rate**

Legend

Fixed Variable

Changing Variable

Single-Factor Sensitivity Analysis: Example (3)



Multi-Factor Sensitivity Analysis

- Why Multi-factor sensitivity analysis?
  - Single sensitivity analysis does not explain **interactions among different variables.**
- How to conduct multiple factor sensitivity analysis?
  - All possible **combinations of different possible values** for each input are developed.
  - **NPV for all combinations** are calculated.
  - Combinations of inputs have the most influence on the final result can be seen.

Multi-Factor Example

- Estimates for **retrofitting a bridge** are as follows:
  - Construction cost = $9 M
  - Annual revenue = $1 M
  - Annual maintenance cost = $350,000
  - Discount rate = 4%
  - Study period = 25 years

- By conducting multiple factor sensitivity analysis, one can determine which **parameter combinations** have the most influence on the NPV of the project.

Picture Source: NCDOT

Multi-Factor Example (2)

Optimal, Most-Likely & Pessimistic Values for Inputs ($ million):

	Optimistic	Most-Likely	Pessimistic
Construction Cost	7.5	9	10.5
Revenue	1.35	1	0.75
Maintenance Cost	0.3	0.35	0.41

Multi-Factor Example (3)

NPV for All Combinations of Estimated Outcomes ($ million)

	Construction Cost								
	Optimistic			Most-Likely			Pessimistic		
	Maintenance Cost			Maintenance Cost			Maintenance Cost		
Annual Revenue	Optimistic	Most-Likely	Pessimistic	Optimistic	Most-Likely	Pessimistic	Optimistic	Most-Likely	Pessimistic
Optimistic	**8.9**	**8.1**	**7.2**	**7.4**	**6.6**	**5.7**	**5.9**	**5.1**	**4.2**
Most-Likely	**3.4**	**2.6**	**1.7**	**1.9**	**1.2**	**0.2**	**0.4**	**-0.3**	**-1.3**
Pessimistic	**-0.5**	**-1.2**	**-2.2**	**-2.0**	**-2.7**	**-3.7**	**-3.5**	**-4.3**	**-5.2**

A combination of **annual revenue** & **construction costs** has the most influence on the NPV of this project.

NPV for the most-likely condition = **$1.2 million**.

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Constrained Optimization

- Definition
  - A mathematical problem to *minimize or maximize* a function (f) subject to *certain constraints*(x).

maximize $$z(\mathbf{x}) = \sum_i b_i x_i$$

subject to $$\sum_i c_i x_i \leq B$$

$$x_i \in \{0, 1\}$$

- Useful Application
  - *Allocating monies* across a variety of competing projects.
- How to Solve
  - ***MS Excel's Solver***

Constrained Optimization Example

- CAMPO is considering 14 projects for fiscal years 2011-2014.
- These projects are a variety of roadway expansion & improvement types.
- The potential benefit & cost of each project are shown in the next slide's table.
- There are some **constraints** for allocating the budget to these projects.
  - No more than 2 projects can be implemented in each of the 4 locations (Austin, Georgetown, Cedar Park, & Other).
  - No more than 3 projects of the same type (New build, Widening, & Reconstruction) can be implemented simultaneously.
  - The total budget constraint is $556,780,000 (over 4 years).
- With constraints, construction of which projects would be the most feasible/beneficial?

Constrained Optimization Ex. (2)

Project	Location	Roadway	Project Description (basic project type in italics)	Cost (Initial in million $)	Benefit (NPV in million $)
1	Cedar Park	RM 1431	Widen a 4-lane divided arterial to a 6-lane divided arterial with wide outer lanes, raised median & sidewalk fronting public land	$26	$102
2	Other	FM 2001	Realign a 4-lane divided roadway	$4.9	$5.9
3	Austin	SH 71	Build an underpass, frontage roads & main lanes	$54	$464
4	Other	SH 195	Widen existing 2-lane roadway to 4-lane divided roadway	$46	$354
5	Austin	SH 130 & Cameron Rd	Build northbound & southbound entrance ramps & related toll integration equipment	$4.6	$36
6	Austin	FM 3177	Realign FM 3177	$5.0	$41
7	Other	IH 35	Build southbound frontage roads & convert frontage roads to one-way operation	$14	$110
8	Georgetown	IH 35	Build a 3-lane frontage road & ramps	$8.5	$67
9	Georgetown	IH 35	Build ramp & auxiliary lane & reconfigure ramps	$2.3	$17
10	Other	US 79	Widen roadway to a 4-lane divided arterial	$16	$137
11	Austin	US 290	Build 6 tolled main lanes & 6 continuous non-tolled frontage roads	$455	$3,128
12	Other	SH 71	Build an overpass at FM 20 & frontage roads	$16	$115
13	Other	FM 1626	Widen FM 1626 to a 4-lane divided roadway	$47	$402
14	Austin	Loop 1	Build northbound & southbound managed lanes	$253	$739

Constrained Optimization Ex. (3)

- The objective function is:
  maximize $z(\mathrm{x}) = p_1x_1 + p_2x_2 + \cdots + p_{14}x_{14}$

subject to $c_1x_1 + c_2x_2 + \cdots + c_{14}x_{14} \le B$

$$x_3 + x_5 + x_6 + x_{11} + x_{14} \le N_{l,max}$$
$$x_2 + x_4 + x_7 + x_{10} + x_{12} + x_{13} \le N_{l,max}$$
$$x_3 + x_5 + x_7 + x_8 + x_9 + x_{11} + x_{12} + x_{14} \le N_{t,max}$$
$$x_1 + x_4 + x_{10} + x_{13} \le N_{t,max}$$
$$x_1, x_2, \ldots, x_{14} \in \{0, 1\}$$

where $p_1 = \$102{,}146{,}400$, $p_2 = \$58{,}785{,}000$, …, $p_{14} = \$739{,}229{,}000$;
$c_1 = \$26{,}809{,}766$, $c_2 = \$4{,}899{,}000$, …, $c_{14} = \$253{,}162{,}143$; &
$B = \$556{,}780{,}000$.
$N_{l,max} = 2$; &
$N_{t,max} = 3$.

Constrained Optimization Ex. (5)

- Formulating the spreadsheet:
  - **Inputs**: Enter the various inputs such as cost, benefit, budget, maximum number of projects in each region & maximum number of projects in each type.
  - **Changing cells**: These values do not have to be the values shown. These are the cells where the decision variables are placed. Any values can be used initially. Solver will eventually find the optimal values.

Constrained Optimization Ex. (8)

- Stages for formulating the spreadsheet model are as follows:
  - Total cost & benefit: in cell F27 enter G4*I4+G5*I5+…+G17*I17
  - Cell F20 should be less than total budget, F22.
  - For total benefit, enter F4*I4+I5*F5+…+I17*F17
    - This cell is defined as an objective cell in the Solver dialog box

Constrained Optimization Ex. (10)

- Final Results
  - $x_3 = x_4 = x_{11} = 1$
  - $x_1 = x_2 = x_5 = x_6 = x_7 = x_8 = x_9 = x_{10} = x_{12} = x_{13} = x_{14} = 0$
  - Total cost is equal to $556,107,659
  - Total benefit is equal to $3,947,057,900

Pricing of Transportation Systems

ITS America

Texas Department of Transportation

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Optimal Price

- What is the **best price** to charge for a transportation service?
- Relies heavily on the **goal** of the pricing…
  - To keep traffic flowing at 60 mph?
  - To recover roadway maintenance & bridge replacement costs for the next 10 years?
  - To incentivize the purchase of hybrid & electric vehicles?
  - To reduce the number of high emissions vehicles in urban areas?
  - To generate revenue?

Consumer Surplus (CS)

- (The max price a consumer is **willing to pay**) – (The price they **actually pay**)
- The sum of all realized **net benefits** to society

Example:

Veh operating costs = $40 for a trip between Austin & San Antonio. Avg VOTT is $12/hour for the 1.5 hour trip. Then total cost per traveler for the Maximum Price (P_{max}) trip can be approximated as

$40 + $12*1.5 = $58/traveler

If the trip is worth $60 to the traveler, then the $2 difference is the **consumer's surplus** (per traveler).

Producer Surplus (PS)

- **Benefit that producers gain** by selling at a higher price than the lowest price they would be willing to sell for.

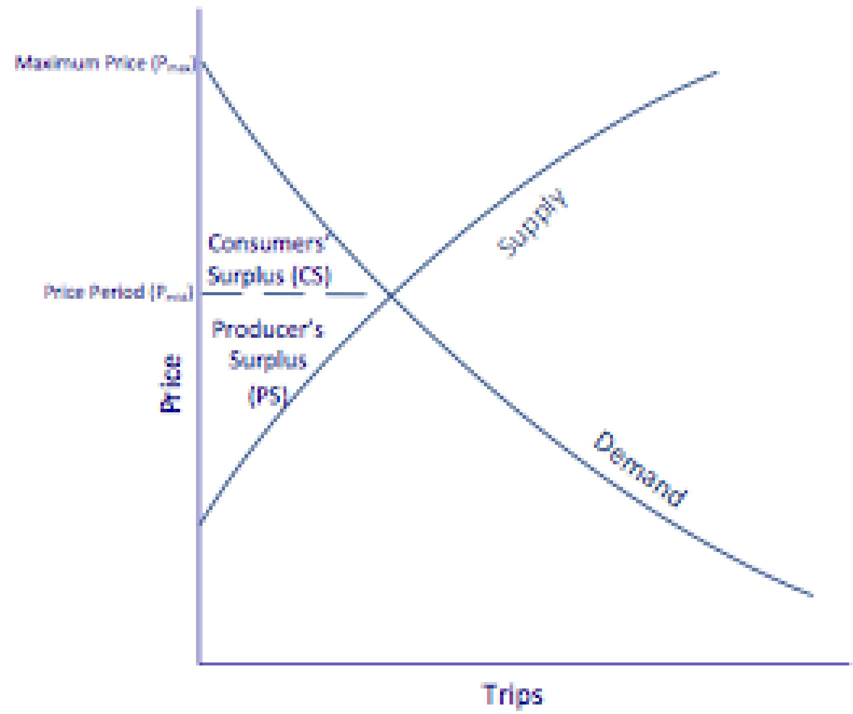
- **PS** is maximized when the **profit is maximized.**

- CS + PS = **Social Welfare (SW)**

- TB(Q) – TC(Q) = SW

- Setting price equal to marginal cost (MC) maximizes SW:

$$MC = \frac{\partial TC}{\partial Q}$$



Maximizing Social Benefits

$$SW = PS + CS = TR - TC + CS$$

- Where…
  - **SW** = Social Welfare
  - **PS** = Producer Surplus
  - **CS** = Consumer Surplus
- Maximized when **marginal social benefit (MSB) = marginal social cost (MSC)**
- Used by **transportation agencies**
  - Not just taking into account making money
  - Includes **net benefit** to society

Roadway Pricing: Total Cost

$TC = Q * AC_{User} + Q * T * VOTT + FC_{Gov} + VC_{Gov} + SC_{Crash} + SC_{Env}$

- Where…
  - $Q * AC_{User}$ = Veh ownership & **op costs** for all travelers (Q)
  - $Q * T * VOTT$ = **Travel time costs** as function of # of travelers (Q) & time per trip (T)
  - FC_{Gov} represents the **fixed costs** of roadway infrastructure
  - VC_{Gov} = **variable costs** of roadway infrastructure
  - SC_{Crash} = **social costs** borne by both users & non-users from **crash risk.**
  - SC_{Env} = **social costs** borne from **environmental impacts**.

Short-run Marginal Cost (SRMC) Pricing

SRMC = **MPC** + **MSC**

- **MPC** = Marginal **Private** Costs, including
  - User's **vehicle operating** costs
  - User's **travel time** costs
  - User's **schedule delay uncertainty** costs
- **MSC** = Marginal **Social** Costs, including
  - Congestion (**travel time delay**) costs the user imposes on others
  - **Crash** costs the user imposes on others
  - **Environmental** costs the user imposes on others
  - Marginal **government service** costs (law enforcement, crash response, etc)

Long-run Marginal Cost (LRMC) Pricing

- While SRMC pricing is very popular, it has certain **limitations**:
  - Does not account for **capital costs**
  - Can lead to minimal charges for road use that are ineffective in containing excess demand.
- **LRMC** Pricing
  - treats **capacity** either as a **continuous variable** or a discrete variable measurable in units such as lanes
  - ≈$0.056 per vehicle-mile (US Department of Commerce 2005) in addition to SRMC

Static vs. Dynamic Pricing

- **Static pricing** stays constant through a defined period
  - Typical systems that charge the same price every day during the peak hour
- **Dynamic pricing** adjust prices to maintain a flow rate just below capacity
  - This keeps the cars from **overloading the system** & causing a queue to form
  - Make the system much more **efficient** & **responsive**
  - Current systems implemented in San Diego, Los Angeles, & Minneapolis
  - New systems being built in Maryland & Chicago

First-Best Pricing

- Hypothetical pricing model that takes all variables into account to create an **optimal price**
- Would need **incredibly detailed** information:
  - Monitor the actual emissions, the place & time of driving, the driving style, the prevailing traffic conditions, etc.
  - Would require a "**Big Brother**" system that would be very politically charged
- **Not practical**; too difficult to implement
  - Now way to determine emissions, noise level, driving style, etc. without being very **invasive**
  - Drivers are **not aware of all alternatives** (e.g., all possible routes and real-time travel times)

Second-Best Pricing

- Next best pricing scheme
  - But many **problems** exist in this configuration
- **Examples:**
- **Case 1**: Not all links in the network are tolled
  - While one link is tolled, another non-tolled parallel route is available
  - Better for social welfare to toll both but too complex
- **Case 2**: Unable to differentiate price by user group
  - Low emission vehicles are overpriced while high emission vehicles are underpriced
  - No way to incentivize certain driving styles, car choices, etc.

VMT Fees

- Ideally these take into account vehicle **weight** & **emissions** along with VMT
  - Public service plus other external costs avg. around **$0.03-0.09** per mile (Litman 2011)
  - Current gas taxes only charge around **$0.01-0.02** per mile
- **Variable VMT-Pricing** Pilot program in Oregon had positive results
  - Reduction in VMT by **12%**
  - Reduction during congestion period by **22%** (increased VMT charges during peak hours)
  - Other states considering using VMT taxes include Alabama, California, Iowa, Indiana, Kentucky, Michigan, Minnesota, Utah, & Washington.

Review of Presentation

- What is discounting?
- How to calculate NPV?
- What is incremental rate of return (IRR)?
- Why should we use sensitivity analysis?
- What is consumer surplus & social welfare?
- What different costs need to be taken into account when pricing a toll road?
- What is a dynamic toll?

Questions? Thank You!

Source: Donna Chen

The Economics of Transportation Systems

Module 3

Economic Impact Analysis

& Statistical Methods

August 23, 2012

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ECONOMIC IMPACT ANALYSIS (EIA) OF TRANSPORTATION INVESTMENTS

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Topic Overview

- Why are EIAs conducted?
- Economic Indicators
- Economic Impacts
- Methods of Economic Analysis
- Input-Output Modeling
- Computable General Equilibrium (CGE) Models
- Critical Issues

Why are EIAs conducted?

- EIAs are conducted to:
  - **Evaluate changes in the economy** due to a past project or policy.
  - **Predict future changes in the economy** due to a change in transport investments in policies.

- Top Motivations
  - Regulatory Project Assessment (e.g. EIS)
  - Public Information & Planning
  - Research Studies

Economic Indicators

Typically, economic impact studies use indicators such as:

- **Spending** by households & businesses
- **Employment** (number of jobs, by industry sector)
- **Income** (wages & salaries of local populations)
- Value-added (**GDP**)
- Business **Sales**
- Exports & Imports
- Land prices

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Examples of Economic Indicators in Texas EIAs

Study	Economic Indicators
Economic Effects of **Highway Relief Routes** on Small- & Medium-Size Communities: An Econometric Analysis (Kockelman et al. 2001)	• Per capita **sales** • Numbers of **establishments** • Total sales for four highway-related sectors: retail, gasoline service stations, dining & drinking places & service industries.
Guide to the Economic Value of **Texas Ports** (Siegesmund et al. 2008)	• Total **employment** • Personal **income** • Business sales • Local, state & federal **tax revenues**
Estimated Economic Impact of Selected **Highway Widening** Projects in Texas (Buffington & Wildenthal, 1998)	• **Property values** • Sales tax revenue • Property tax revenue • Total employment • **Total output** (value of goods & services)

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Measuring Economic Indicators

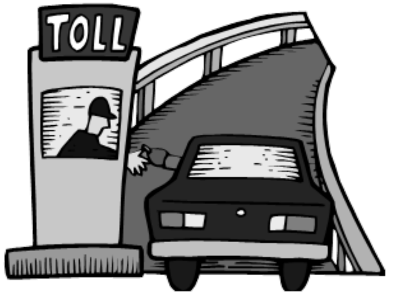
- Data sources:
  - The Texas Comptroller of Public Accounts
  - U.S. Department of Commerce Bureau of Economic Analysis (BEA)
  - U.S. Census Bureau
  - Private sources (e.g. CoStar real estate sales info and business sales data)

Caution: Double Counting

- Double-counting related economic indicators overstates net benefits.
- Changes in distinct indicators are often highly correlated: for instance, an increase in jobs may increase business sales. (Since these two are interdependent, adding them is **double counting** & needs to be avoided.)
- In general, only these impacts can be combined:
  - User impacts (travel time savings & reliability improvements)
  - Government fiscal impacts (public revenues & expenditures)
  - Societal benefits (environmental impacts)

Impact Measures

- **Transport costs**
  - Travel time savings
  - Gas savings
  - Crash savings
- **Transport linkages**
  - Addition or removal of rail service, airport or sea port.
- **Environmental quality**
  - Increase or decrease in air pollutants
  - Reduced noise pollution



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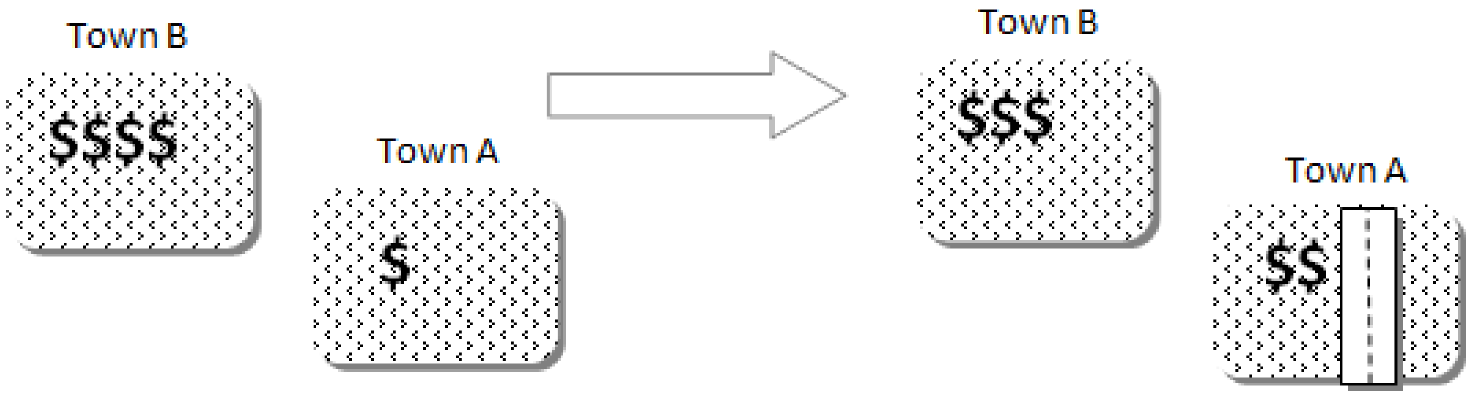
Redistributive Impacts

- If benefits come at the expense of another's well-being (such as creating a bottleneck elsewhere, or shifting businesses & households to a new area), the project has had a **redistributive** economic impact.
- What may appear to be a positive impact at one geographic scale (e.g., **local**) may be a redistributive impact *at* a larger scale (e.g., **interstate** moves of firms).

Example: *Generative* vs. *Redistributive* Impacts

- **Town A** adds a new roadway, causing **land values** to increase near the new roadway. But values in nearby **Town B** decreases.



Redistributive Impact:
Net Loss for Town B and Net Gain for Town A in Land Value

This is a **generative impact** for **Town A**, but a **loss** for **Town B**'s land values. This can mean no net gains, but rather a **redistribution** of values.

Project Value vs. Impact

- A project's economic impact is ***not*** its economic value.
- Both benefit-cost analysis (BCA) & economic impact analyses (EIAs) may start with the same set of data, but their methods differ, resulting in *two different products*.
  - BCA is about NPVs
  - EIA is about anticipating economic impacts

BCA vs. EIA

EIA seeks to identify whether a project will …

- **Stimulate** & **grow** jobs & income.
- **Attract** high-quality jobs.
- Impact prices & traveler **welfare**.
- Enhance equity for **vulnerable** populations.

BCA is designed to …

- Ensure **efficient use** of scarce resources.
- **Maximize cost** effectiveness among competing alternatives.

Input-Output (I-O) Modeling

- I-O modeling **tracks all inputs & outputs between industries**.
- This mapping of inter-industry relationships allows economists to determine how a **change in demand** for one or more industries' products (e.g., increases in final demand for vehicles) **affects other industries** (e.g., retail sales & electronics).
- I-O modeling is **the most common approach** for anticipating how spending on transport projects affects the wider economy.

I-O Modeling Examples

Texas Study	Summary/ Description
Guide to the Economic Value of **Texas Ports** (Siegesmund et al. 2008)	To demonstrate the importance of the Texas ports to the state & the economy & to assist with port planning.
The Economic Impact of General **Aviation in Texas** (Wilbur Smith Associates, 2005)	To better understand the relationship between general aviation in Texas & the statewide economy.

I-O Modeling Goals

- To **anticipate changes** in business **outputs**, personal income, jobs & government revenue in response to changes in final demand (e.g., government or household spending).
- To **compare changes** across sectors.
- To anticipate **life-cycle effects** (energy & environmental factors) in an EIA.

New Tool

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Direct, Indirect, & Induced Effects

- ***Changes*** of economic indicators for **directly affected** businesses & households are called ***direct effects*** (e.g., DOT spending, private business investment in a PPP port, & changes in household spending on transportation).
- Due to inter-industry relationships, *I-O models* anticipate ***indirect effects*** on suppliers & other businesses **supporting** the directly-affected industries.
- **Changes in personal income** of affected industry workers leads to **induced or secondary** effects.

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Direct, Indirect, & Induced Effects (2)

Example: Buying a car **directly** impacts the auto manufacturer & **indirectly** impacts steel, glass, & plastic manufacturers. These changes **induce changes** on retail, service, & other upstream industries, who serve those working in steel, glass, etc.

- Together, these three effects of **direct**, **indirect**, & **induced** are called the **multiplier effects**.
- **Multipliers** quantify these indirect & induced effects on economic activities.
- An **input-output transactions table** is used to compute such values.

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The IO's Transaction Table

Gray cells show monetary exchanges between two industries (or within an industry).

		Purchases from (inputs for)		Final Demand				
		Industry Sector A	Industry Sector B	Household/ Consumer Spending (C)	Private Investment (I)	Net Exports (X)	Government Spending (G)	TOTAL OUTPUT
Sales from (outputs from)	Industry Sector A	150	500	50	150	100	50	1000
	Industry Sector B	200	100	400	900	250	150	2000
Value Added	Household Income	300	500	50	25	0	25	800
	Business Profit	250	750	300	50	25	25	1400
	Government Taxes/Fees	100	150	100	25	0	25	400
	TOTAL INPUT	1000	2000	900	1150	375	275	5700

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Creating the Input-Output Model

- **Define** the economic area for direct, indirect & induced impacts.
- **Select** industry **sectors** of interest.
- **Gather data** on the inter-industry flows within a pre-defined time period

Creating the I-O Model (2)

- The U.S. Department of Commerce **collects information** on business establishment's production accounts (BEPAs).

Business Establishment Production Accounts (BEPAs)

Debit	Credit
Purchases from	Sales to
Industry sector A	*Industry sector A*
Industry sector B	*Industry sector B*
Wages and Salaries	Sales to Households
Profits	Government Purchases
Other Value Added	Other Final Demand
Total Expenses and Profit	Total Revenues

- Firms with similar products are **grouped** by North American Industry Classification System (***NAICS***) code

North American Industry Classification System (NAICS)

NAICS level	NAICS Code	Example
Very general	2-digit	Construction
General	3-digit	**Construction of Buildings**
Somewhat general	4-digit	**Nonresidential Building Construction**
Specific	5-digit	Commercial and Institutional Building Construction
Very specific	6-digit	Commercial and Institutional Building Construction

Creating the I-O Model (3)

- BEPA information for each firm (prior slide) is then **added** together for **all** firms in the **same industry**, leading to a National Income & Product Account (**NIPA**) table.

National Income and Product Account

Debit	Amount	Credit	Amount
Wages and Salaries		**Sales to Households**	
Industry sector A		*Industry sector A*	
Industry sector B		*Industry sector B*	
Profits		**Government Purchases**	
Industry sector A		*Industry sector A*	
Industry sector B		*Industry sector B*	
Other Value Added		**Other Final Demand**	
Industry sector A		*Industry sector A*	
Industry sector B		*Industry sector B*	
Total Charges Against GNP	**SUM**	**Total Contributions to GNP**	**SUM**

Creating the I-O Model (4)

- NIPA table is re-organized to create the I-O (Leontief) **Transactions Table**.

		Purchases from (inputs for)		Final Demand		
		Industry Sector A	Industry Sector B	Household Spending	Other Final Demand	**TOTAL OUTPUT (X_j)**
Sales from (outputs from)	Industry Sector A	150	500	50	300	1000
	Industry Sector B	200	100	400	1300	2000
Value Added	Household Income	300	500	50	50	900
	Other Value Added	350	900	400	150	1800
	TOTAL INPUT	1000	2000	900	1800	5700

I-O Modeling: Technical Coefficients

		Purchases from (inputs for)				
		Industry Sector A	Industry Sector B	Household Spending (endogenous)	Other Final Demand (Y_i)	TOTAL OUTPUT (X_j)
Sales from (outputs from)	Industry Sector A *(Row 1)*	0.15	0.25	0.0556	0.1667 (Y_1)	X_1
	Industry Sector B *(Row 2)*	0.20	0.05	0.4444	0.7222 (Y_2)	X_2
Value Added Sectors	Household Income *(Row 3)*	0.30	0.25	0.0556	0.0278 (Y_3)	X_3
	Other Value Added *(Row 4)*	0.35	0.45	0.4444	0.0833	---
	TOTAL INPUT	1.0	1.0	1.0	1.0	---

Source: A portion of this table is from Miller & Blair (2009)

Technical Coefficients
= $ of input i for $1 of output j
= Value of input in each cell divided by column sector's total output = $\mathbf{z_{ij}/X_j} = a_{ij}$

I-O Modeling

Finding Direct, Indirect & Induced Effects – Using ***matrix algebra*** (to invert the matrix of technical coefficients, **A**).

Type of Multiplier Effect	How to Find Using Input-Output Analysis
Direct	The change in final demand in the sector.
Direct & Indirect	The new total output calculated from **$X = (I-A)^{-1} Y$** when household income and spending are *excluded* from the A matrix.
Direct, Indirect & Induced	The new total output calculated from **$X = (I-A)^{-1} Y$** when household income and spending are *included* in the A matrix.

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I-O Modeling: Key Steps

- Develop the **input-output transactions table** of $ flows between industries.
- Calculate **technical coefficients (a_{ij} values)** from information in the input-output transactions table to create the direct requirements table (**A** matrix).
- Specify **final demand** (**Y** column vector), *or* the change in final demand ("Y" = Δ**Y**).
- Solve for **new total output** (*or* change in total output) in each industry sector (**X** matrix): $X = (I-A)^{-1} Y$
- Compute **multipliers** by summing column values generated by a $1 change in a Y_i value.

Multiplier Analysis: Anticipating Indirect & Induced Effects

- A **multiplier** is a number extracted from I-O analysis calculations that can be **multiplied by** either the **final demand** (the **direct effect)** to instantly obtain a measure of **total, indirect & induced effects** (throughout the [modeled] economy).

- **Multipliers** provide estimates of effects *throughout an economy* in the region/location of interest (*rather than effects on* specific sectors).

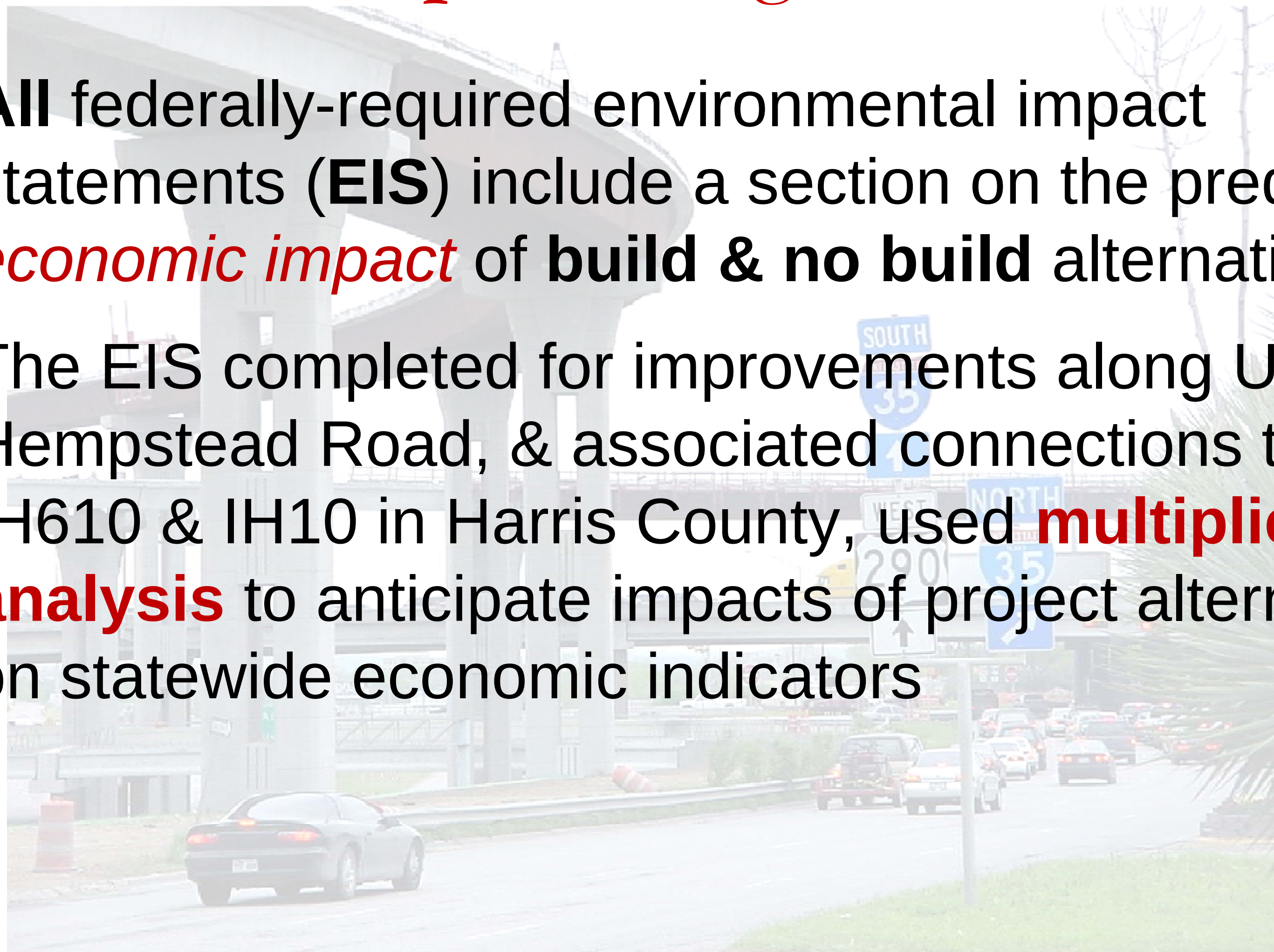
- **These are the ripple effects** of added (or lost) spending.

Multiplier Types

(1) **Simple = Type I** (direct + indirect effects)
(2) **Total = Type II** (direct + indirect + induced)

	Simple (Type I)	**Total (Type II)**
	direct + indirect effects / change in the sector's final demand	direct + indirect + induced effects / change in the sector's final demand
Examples	A local government will spend $10M on local transportation projects (which is a near-term increase in final demand). With a simple multiplier for industry output of 1.2, the local community will experience $12 M in added production.	An employment multiplier of 0.2 per $1M of construction spending by local government means an additional $200,000 in wages are created (in the short term) by direct, indirect & induced effects for every $1 M spent.

A Texas Example: Background



- **All** federally-required environmental impact statements (**EIS**) include a section on the predicted *economic impact* of **build & no build** alternatives.
- The EIS completed for improvements along US290, Hempstead Road, & associated connections to IH610 & IH10 in Harris County, used **multiplier analysis** to anticipate impacts of project alternatives on statewide economic indicators

Texas Example (2)

- Table 26 shows the results presented in the EIS with **Type II** multipliers (TxDOT 2007).

Alternative	Cost*	Income			Additional Employment**			Statewide Effect***
		Direct	Indirect	Total	Direct	Indirect	Total	
290-A	$1,316,000,000	$380,587,200	$763,148,400	$1,143,735,600	19,850	19,259	39,110	$4,854,066,000
290-B	$1,317,000,000	$380,876,400	$763,728,300	$1,144,604,700	19,865	19,274	39,139	$4,857,754,500
290-C	$1,320,000,000	$381,744,000	$765,468,000	$1,147,212,000	19,911	19,318	39,229	$4,868,820,000
290-D	$1,323,000,000	$382,611,600	$767,207,700	$1,149,819,300	19,956	19,362	39,318	$4,879,885,500

Cost includes ROW, construction, Utilities, and Engineering services.
** Additional jobs added as a result of the proposed alternative.
*** Dollars added to the Texas economy.
Source: Texas State Office of the Comptroller 1986

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Word of Caution on Multipliers

- However…
  - Government **can't create** jobs.
  - Government spending ultimately comes from taxpayers, thus creation of **"new" jobs** has **redistributive impacts**.
- Example:
  - $3 billion government spending program financing highway construction increases construction employment by 100,000 jobs.
  - If $3 billion came from individual income taxes, people will spend less on clothing, appliances, etc (thus negatively impacting employment in those industries).
  - If $3 billion came from corporate taxes, companies will raise prices on goods, lower wages for workers, decrease number of employees, or lower returns for investors.

I-O Modeling Assumptions

- **No Substitution**
  - Inputs are used in **fixed (expenditure) shares** (tech. coeficients are constant), regardless of demand & supply.
- **Fixed Prices & Unlimited Resources**
  - **Ignores prices & monetary policies,** which affect input choices, interest rates & other factors relevant for production & demand.
  - Resources are so abundant that prices won't rise as demand rises. This **introduces risk of overstating** output effects.
- **One-Period Analysis**
  - Inter-industry flows depend only on demands in the same time period. Model **does not reflect trade dynamics over time** (e.g., past purchases).

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Critical Issues, present in many EIAs…

- Lack of **Transparency**
  - Reports produced by private consultants typically give only a brief overview of study methods & assumptions.
- Lack of **Perspective**
  - Reports often do not put changes in economic indicators in perspective.
- Inaccuracies & **Uncertainty**
- **Double-Counting**

DATA ANALYSIS FOR TRANSPORTATION APPLICATIONS

Data Analysis

- **Econometrics** uses **statistics** to analyze economic & behavioral data, in order to *find relationships between variables* & **forecast the future**.
- **Regression** is a **key econometric tool**:
  - **Example:** Predict a household's VMT as a function of household size & income, neighborhood density, & vehicle types owned.
- Regression provides **objective, numerical** ***estimates*** of relationships.
  - **Examples:** What is one's value of time? To what extent does neighborhood design encourage walking? If we add a lane, how will long-run AADT be impacted?

What do Regression Models help predict?

- AADT & crash counts
- Project costs
- Values of homes, businesses, & ROW
- Values of time & reliability
- Mode & time of day travel preferences
- Destinations & vehicle choices
- Firm production & consumer preference functions
- Vehicle emissions & project durations
- ***Pretty much anything!***

Data Types

- Types of **Variables:**
  - **Discrete** data are limited (binary [0 or 1, male or female, yes or no], categorical [SOV, HOV, walk, transit], ordered [levels of educational attainment], integer [crash counts])
  - **Continuous** data can take on any values within accepted range (e.g., speeds on a network link)
- **Cross-sectional data sets**
  - Offer a snapshot of **multiple categories** of data at one specific moment in time (e.g., state Workforce Commission's number of jobs & population in each county in January 2011).
- **Time-series** data sets
  - Track **only one variable** *over time* (e.g., retail jobs in Bexar County every year over the past 50 years).

Data Types (2)

- **Panel data** sets:
  - Combine features of cross-sectional & time-series data
  - Require information on observational units (persons or places, typically) over time.

Examples:

- Number of retail jobs in each Texas county over each of the past 50 years
- AADT on various freeway segments in Austin over each of the last 365 days
- Annual assessments of property values along a corridor for the past 10 years

Data Set Examples

Data Set	Source	Variables
National Household Travel Survey (NHTS)	FHWA	1. Household demographics 2. Trip purposes, modes, & duration of trips over one travel day 3. Trip timing & destinations 4. Vehicle ownership details
Commodity Flow Survey (CFS)	U.S. Census Bureau	1. Shipment industry (NAICS) 2. Shipment value & weight 3. Mode of transportation 4. Origin & destination region of shipment
Fatality Analysis Reporting System (FARS)	National Highway Traffic Safety Administration (NHTSA)	1. Vehicle & traveler details involved in fatal motor vehicle crashes 2. Roadway type, speed 3. Weather & daylight conditions 4. Presence of alcohol, use of seatbelts 5. Severity of all injuries

Regression Model Examples

- Nature of response variable (Y) impacts model type…
- Continuous Y → **Least-squares** (LS) regression is most common (ordinary & weighted LS, linear & non-linear LS)
- Discrete Response → **Many distinctive model options…**

Discrete Model	Response Variable (Y) Type
Binary Logistic	Binary (Y = 0 or 1, yes/no, go/no go, …)
Binomial Logit or Probit	Binary (from random utility maximization)
Multinomial & Nested Logit & Probit Models	Categorical: Multiple unordered outcomes (e.g., choice of car, truck, or minivan)
Ordered Probit & Logit	Ordered (i.e. categories that can be ordered [e.g., poor, neutral, good, great]).
Poisson & Negative Binomial	Integer (from underlying rate of occurrence)

These are all **discrete outcome** types.

What is Linear Regression?

- The **classic** **linear** **model**:

Dependent Variable (y)

Explanatory Variables (x)

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$

Unknown Parameters (β)

Error Term (ε)

- **Goal** is to **estimate all β** parameters.

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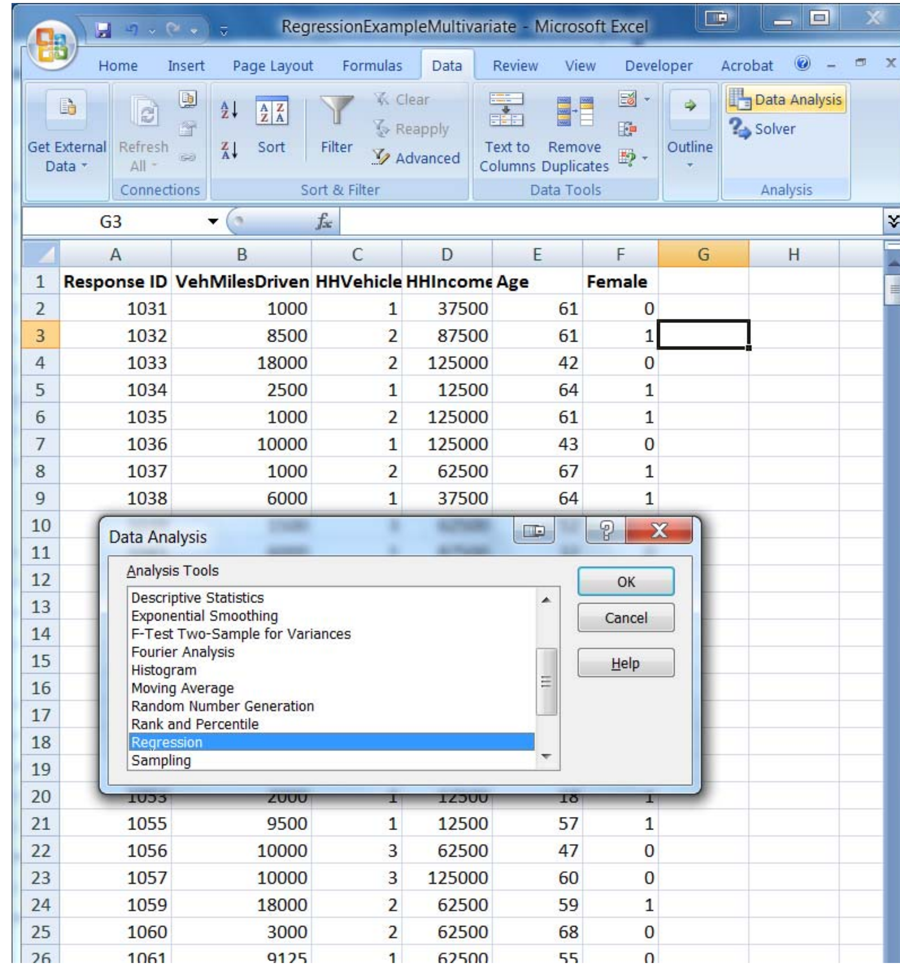
MS Excel: Regression Example

- **MS Excel Data Analysis** pack performs linear regression.

- **Example Application**: How is annual **vehicle miles driven (VMD)** impacted by **gender, age, household income** and **vehicle ownership**?
  - Nationwide survey data of over 1000 licensed American drivers.

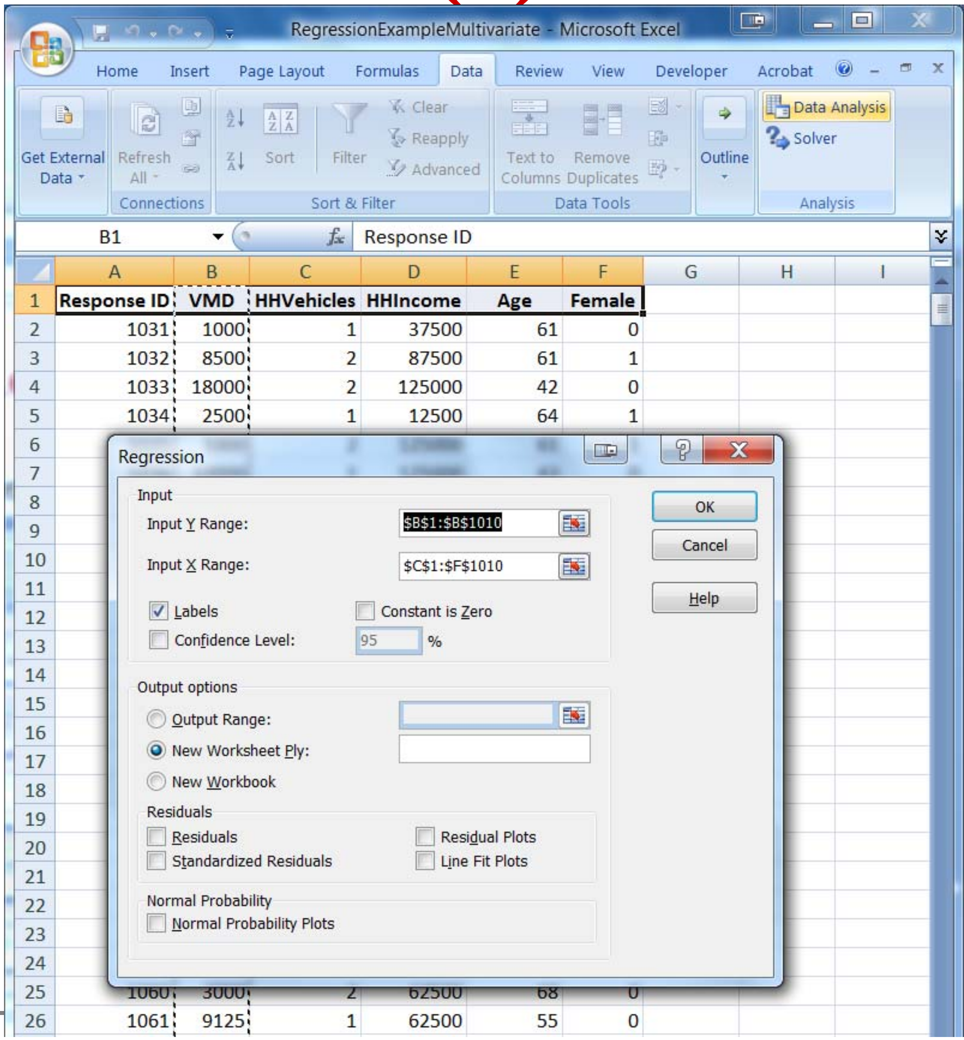
MS Excel: Regression Ex. (2)

- **Regression** tool is available under **Data Analysis** menu
- **Independent variables** (x_i) must be in **adjacent** columns



MS Excel: Regression Ex. (3)

- Input **Y** range corresponds to **dependent** (response) variable **VMD**, in column B.
- Input **X** range corresponds to **independent** variables **HHVehicles, HHIncome**, **Age**, & **Female** (binary variable), in columns C to F



MS Excel: Regression Output

	Coefficient (β)	Standard Error	t-Statistic
Constant	15260	1999	7.63
HHIncome ($1000)	19.32	11.18	1.73
HHVehicles	1386.82	550.86	2.52
Age	-128.69	30.57	-4.21
Female	-1427.36	998.87	-1.43
R	0.1777		
R-Squared	0.0316		

VMD = 15,260 + 19.32HHIncome + 1386HHVehicles – 128.7Age – 1427Female

How do we estimate the best β's?

- Ordinary Least Squares (OLS) Regression
  - Seeks to **minimize** the sum of squared residuals
    - Minimize

$$SSR = \sum_{i=1}^{n} (y_i - x_i'\hat{\beta})^2$$

- Maximum Likelihood Estimation (MLE)
  - Seeks to **maximize** the probability (likelihood) of observed response values in data set
    - Maximize

$$Likelihood = \prod_{i=1}^{n} f(y_i | x_i;\ \beta)$$

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Advanced Specifications

- Models exist to allow for **multiple responses** simultaneously
  - **Example:** Price & quantity of airline seats for the DFW-NYC market
- They allow **discrete & continuous** responses simultaneously:
  - **Example:** Studies of household vehicle choice (discrete) & use (VMT) of those vehicles (continuous).

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A Texas Example: Estimating ROW Acquisition Costs (Heiner & Kockelman 2004)

- Developed a model to predict ROW acquisition cost for budgeting purposes
- Data sources: TxDOT **ROWIS** data, CoStar sales data, county tax appraisal district parcel data
- *Y* = cost of each property
- **X's** = land use type indicators (single-family vs. multi-family units, agricultural, & various commercial property types), parcel size & shape, region of Texas, size of remainder, etc.
- **Weighted Least-squares** regression used.

Estimating ROW Acquisition Costs (2)

Each property's total cost comes from square feet (SF) of acquired land (*ACQSF*), of acquired improvement (*IMPSF*) & any remainder area (*REMSF*):

$$TOTALCOST = \beta_0 + ACQSF \sum_i (\beta_{i,land} X_{i,land})$$

$$+IMPSF \sum_j (\beta_{j,imp} X_{j,imp}) + REMSF \sum (\beta_{k,rem} X_{k,rem}) + \varepsilon$$

where $X_{i,land,}$, $X_{j,imp}$, & $X_{k,dam}$ are explanatory variables characterizing land use, location, building age, & other factors.

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Understanding the Data: Summary Statistics

Table 1. Description of Variables for Texas Corridor Data Set

Description of variables for Texas corridor sample			
Variable name	Variable description	Mean	Standard deviation
TOTCOST	Total acquisition cost (dollars 2003)	245,300	894,400
LNTOTCOST	Natural log of total cost	10.36	2.091
ACQSF	Land area of part acquired (SF)	12,120	23,850
FRONTAGE	Length of frontage (ft)	211.1	314.9
DRIVEWYS	Number of driveways for original parcel	1.323	0.600
SHAPEIRR	Indicator variable for irregularly shaped original parcel	0.2491	0.4333
CORNER	Indicator variable for corner parcels	0.3614	0.4813
TIME TREND	Trend variable for year of acquisition (1=1997, 2=1998, ..., 7=2003)	4.393	1.517
IMPSF	Area of improvements taken (SF)	1,545	6,276
IMPAGE	Age of improvements taken (years)	35.746	21.226
IMPCOND	Appraised condition of improvements (1=poor, 2=fair, 3=average, 4=good)	3.136	0.846
IMPSF2	Area of improvement squared (SF^2)	41,640,000	448,300,000

Reporting the Results: Parameter Estimates

- **High model fit** ($R^2 = 0.906$)
- LN = natural log
- **Low p-values**

  → Low probability that any of these coefficients are zero

  → Reject those null hypotheses.

Variables	Coefficient	Std. Coef.	p-value
(Constant)	2.73786		0.000
LN(ACQSF)	-	-	-
*LN(ACQSF*CORNER)*	0.02105	0.0422	0.047
*LN(ACQSF*TIMETREND)*	0.49643	0.3612	0.000
*LN(ACQSF*VACANT)*	0	n/a	n/a
*LN(ACQSF*AGRI)*	-0.04532	-0.0536	0.081
*LN(ACQSF*SFAM)*	0.08536	0.1765	0.000
*LN(ACQSF*MFAM)*	0.07404	0.0538	0.020
*LN(ACQSF*RETAIL)*	0.13481	0.2176	0.000
*LN(ACQSF*SERVICE)*	0.07239	0.0556	0.096
*LN(ACQSF*OTHER)*	0.07900	0.0609	0.011
*LN(ACQSF*CORPUS)*	0	n/a	n/a
*LN(ACQSF*ELPASO)*	0.24731	0.4545	0.000
*LN(ACQSF*FTWORTH)*	0.12397	0.1731	0.000
*LN(ACQSF*HOUSTON)*	0.33290	0.5822	0.000
*LN(ACQSF*SAN ANTONIO)*	0.40861	0.5443	0.000
LN(IMPSF)	0.72522	1.3190	0.003
*LN(IMPSF*TIMETREND)*	-0.38778	-0.8360	0.020
*LN(IMPSF*SFAM)*	0	n/a	n/a
*LN(IMPSF*RETAIL)*	-0.06910	-0.0716	0.038
*LN(IMPSF*SERVICE)*	0.05461	0.0328	0.324
*LN(IMPSF*POPDENSITY)*	-0.10035	-0.3606	0.094
LN(REMSF)	0.03095	0.0769	0.040
*LN(REMSF*CHGHBUSE)*	-0.04654	-0.0689	0.005
*LN(REMSF*SHAPECHG)*	-0.01723	-0.0232	0.258
*LN(REMSF*FRNTLOSS)*	-0.01251	-0.0320	0.145

ROW Cost Results: Example Findings

- Parcel **land use** impacts acquisition cost
  - Retail property costs are most consistent (easiest to predict)
  - Multi-story office buildings are valued the highest
  - Industrial use properties valued the lowest
- Presence of a **remainder** is a key variable
- Property **condition** is important:
  - TCAD data suggest **$22** more per SF & CoStar shows **$28** more (per SF) for Excellent vs. Fair condition properties.
- **Parking access** significantly impacts property value.
  - CoStar data suggest that **each** parking spot adds **$6,000** to commercial property values.

Applying the Results: A Houston Forecast

- 10-parcel corridor in Houston.
- **Estimated** purchase prices lie above & below actual values.
- Model estimates $15M total cost, vs. actual $20.5M.

Table 7. Application of CoStar Model Prediction for 10-Parcel Corridor in Fort Bend County (Houston)

Property description	*Beta*	Community center *Beta* X1*	Fast food restaurant site *Beta* X2*	Restaurant *Beta* X3*	Veterinary hospital site *Beta* X4*	Auto repair and car wash *Beta* X5*	Drug store site *Beta* X6*	Airplane hangars site *Beta* X7*	Restaurant site *Beta* X8*	Strip center site *Beta* X9*	Fast food restaurant site *Beta* X10*	Total cost
(Constant)	538,440	538,440	538,440	538,440	538,440	538,440	538,440	538,440	538,440	538,440	538,440	
LANDSF	0.5541	253,313	25,328	17,486	24,137	37,749	45,254	1,518,650	52,422	57,650	34,582	
LANDSF∗ FRONTAGE	4.4E−5	−8,822	−298	−224	−294	−781	−908	−233,342	−1,799	−1,808	−551	
LANDSF∗ COMRCL	0.1482	0	6,774	0	6,456	10,096	12,104	0	14,021	15,419	9,249	
LANDSF∗ INDUSTRIAL	0.2556	0	0	0	0	0	0	700,536	0	0	0	
LANDSF∗ RETAIL	5.625	2,571,536	0	177,514	0	0	0	0	0	0	0	
LANDSF∗ FORTBEND	−0.344	−157,264	−15,724	−10,856	−14,985	−23,436	−28,095	−942,818	−32,545	−35,791	−21,470	
IMPSF	21.16	2,363,043	0	91,348	0	0	0	0	0	0	0	
IMPSF∗ IMPAGE	−0.6854	−765,420	0	−41,424	0	0	0	0	0	0	0	
IMPSF∗ IMPCOND	9.228	4,122,148	0	159,349	0	0	0	0	0	0	0	
IMPSF∗ NUMFLOORS	2.079	232,172	0	8,975	0	0	0	0	0	0	0	
IMPSF∗ INDUSTRIAL	−13.85	0	0	0	0	0	0	0	0	0	0	
IMPSF∗ OFFICE	14.97	0	0	0	0	0	0	0	0	0	0	
IMPSF∗ RETAIL	−13.89	−1,551,166	0	−59,963	0	0	0	0	0	0	0	
IMPSF∗ FORTBEND	9.308	1,039,471	0	40,183	0	0	0	0	0	0	0	
PRKCOVER	6,026	0	0	0	0	0	0	0	0	0	0	
UNCONFIRMED	206,405	0	0	0	0	0	0	0	0	0	0	
Subtotal		**8,637,452**	**554,519**	**920,827**	**553,754**	**562,069**	**566,795**	**1,581,466**	**570,539**	**573,910**	**560,252**	**$15,081,582**
Actual sales price		13,227,581	602,411	1,149,199	313,601	389,722	1,229,199	1,830,686	682,988	542,050	516,038	$20,483,475
Percent difference		35	8	20	−77	−44	54	14	16	−6	−9	26

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Review of Presentation

- What are some economic indicators used in EIA?
- Changes in workers' personal income is a direct, indirect, or induced effect?
- Changes in direct, indirect, and induced effects are quantified by what measure?
- A shift in economic gain from one region to another is considered what kind of impact?
- What are some disadvantages of I-O Models?
- Which type of data combines features of cross-sectional and time-series data?
- What are the predict effects of independent variables on dependent variables in a regression model called?

Questions?

Thank you for your time!

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