Pricing Risks in Delivery and Management of Transportation Assets

Ivan Damnjanovic
Assistant Professor, TAMU
Northwestern University, November 11, 2010
Project Development and Delivery (PDD)

PROJECT DEVELOPMENT AND DELIVERY DECISIONS

- Financing Method
- Engineering Design Characteristics
- Delivery Method and Contracting Type
- Risk Mitigation and Transfer Strategies

SUSTAINABILITY GOALS

- Cost
- Schedule
- Quality
- Financial Feasibility
- Energy Preservation
- Environmental Protection
- Hazard Mitigation
Innovation and Research Emphasis

SUSTAINABILITY GOALS

- Financial Feasibility
- Energy Preservation
- Environmental Protection
- Hazard Mitigation

PROJECT COMPLEXITY

- Toll Road Projects
- Securitization of Natural Hazard Risks
- Risk Management
- Dynamics of Post-disaster Reconstruction
- PHEV Interface Infrastructure
Toll Road Projects

Valuing Strategic Network Flexibility for Highway Toll Projects

(Co-authors: Jennifer Duthie and S. Travis Waller)
Motivation

Flexibility without network effects (e.g., Ford et al., 2002; Garvin 2004; Huang and Chou, 2006; Zhao and Fu, 2006)

Network effects without flexibility (e.g., Lam and Tam, 1998; Chen et al., 2001, 2003; Yang et al., 2004)
System Performance (Total system travel time/cost)

Project Performance (Revenue, Debt Obligations, etc.)
What is the impact of network improvement actions on project revenue and other financial measures?
Toll Road Project Development Model

\[ z_R = \max_{x \geq 0} E_{\xi} \left[ Q_R (x, \xi(\omega)) \right] - \gamma x \]

s.t.

\[ Q_R (x, \xi(\omega)) = \max_y \left\{ \sum_{t=1}^{T} \left( r v^*_{l=TR,t} (x, y, \xi(\omega)) \right) \frac{(1+i)^t}{(1+i)^t} - \rho \max \{0, L_t (x, y, \xi(\omega))\} \right\} - \gamma y \mid y \geq 0 \]

s.t.

\[ L_t (x, y, \xi(\omega)) = \Psi_t - r v^*_{l=TR,t} (x, y, \xi(\omega)), \quad \forall t \in T \]

\[ v^*_{l=TR,t} (x, y, \xi(\omega)) = \arg \min \left\{ \sum_{l \in L} \int_{\kappa=0}^{v_l (x, y, \xi(\omega))} c_l (\kappa, x, y) d\kappa \mid v \in V \right\}, \quad \forall t \in T \]

\[ V = \{v \mid v = Ah, d_t (\omega) = Bh, h \geq 0\}, \quad \forall t \in T \]

EXTERNALITY - Network User Equilibrium
Results

Parameters:
- Link 1: (v1, h1)
- Link 2: (v2, h2, h3)
- Link 3: (v3, h2)
- Link 4: (v4, h3)

Graph showing VNR vs. V_ξ[d] with different initial values:
- u(1,0) = 500, u(2,0) = 400, u(4,0) = 300, p = 3
- u(1,0) = 550, u(2,0) = 400, u(4,0) = 300, p = 3
- u(1,0) = 600, u(2,0) = 400, u(4,0) = 300, p = 3
Results

\[ V \]

\[ \begin{align*}
  u(1,0) &= 500 \quad u(2,0) = 300 \quad u(4,0) = 300 \quad p = 3 \\
  u(1,0) &= 500 \quad u(2,0) = 400 \quad u(4,0) = 300 \quad p = 3 \\
  u(1,0) &= 500 \quad u(2,0) = 500 \quad u(4,0) = 300 \quad p = 3
\end{align*} \]

Link 1
(v_1, h_1)

Link 2
(v_2, h_2, h_3)

Link 3
(v_4, h_3)

Link 4
(v_4, h_3)

VNR

\[ V_{\xi}[d] \]
Managerial Implications

- Value of recourse is higher when uncertainty is greater.
- Value of recourse is higher when the capacity of the competing route is high, and feeder link is low.
- Greater uncertainty implies lower initial toll road capacity.
- Greater penalty for failing to repay debt implies lower initial toll road capacity.
**Buy-back vs. Salvage Options**

Buy-back option:
\[ C = \max(\text{E}[\text{PV}(t_1)] - K_c, 0) | \text{AR}^n(\Delta t) > UB \]

Option to abandon:
\[ P = \max(K_p - \text{E}[\text{PV}(t_1)], 0) | \text{AR}^n(\Delta t) < LB \]

Projects service life (years)

---

Slide showing a graph with the following annotations:

- UB (Upper Bound)
- LB (Lower Bound)
- \( \text{AR}^n(\Delta t) \)
- \( \text{AR}^1(\Delta t) \)
- Rev ($) on the y-axis
- Projects service life (years) on the x-axis

Legend:
- Path 1
- Path n
Results

- Link 1: \((v_1, h_1)\)
- Link 2: \((v_2, h_2, h_3)\)
- Link 3: \((v_3, h_2)\)
- Link 4: \((v_4, h_3)\)

The graph illustrates the value of the option to buyback to the owner as a function of capacity (veh/time unit). The curves represent different links:

- **Competing link 1**
- **Competing link 4**
- **Feeder link 1**
Probability of Default and Real Losses

\[ RL = EAD - \sum_{i=t_i}^{T_i} R_i \]
Risk Weighted Assets

\[ RWA = PD \times \frac{(VaR - EL)}{0.08} \]

L(y) – probability density function of losses

UL

99.9% CI

EL

Value-at-Risk [VaR]
Results

![Graph showing the probability of default (%) vs. capacity (veh/time unit). The graph includes a network diagram with links labeled as follows:

- **Feeder Link**: Link 1 (v1, h1)
- **Competing Link**: Link 3 (v3, h2)

The graph shows a downward trend in probability of default as capacity increases, with a distinct separation between the feeder and competing links.]
Innovation and Research Emphasis

SUSTAINABILITY GOALS

- Financial Feasibility
- Energy Preservation
- Environmental Protection
- Hazard Mitigation

PROJECT COMPLEXITY

- Toll Road Projects
- Securitization of Natural Hazard Risks
- Risk Management
- Dynamics of Post-disaster Reconstruction
- PHEV Interface Infrastructure

Externalities, Incentives, Communication, etc.
Risk Management

Impact of Crude Oil Market Behavior on Unit Bid Prices in Highway Sector

(Co-author: Xue Zhou, PhD Candidate)
Motivation

Assess how contractors price the risk related to anticipated changes in crude oil prices.

HYPOTHESIS 1: The unit bid prices are affected by anticipated volatility in crude oil prices.

HYPOTHESIS 2: The unit bid prices are affected by the expected change in crude oil prices.
Data Processing

- TxDOT Data
  - Unit Cost Bids
  - Project Characteristics

- NYMEX Data
  - Futures Options
  - (3 months)

- INFOR’s DATASTREAM
  - Futures Prices
  - (3 months)
  - Spot Prices

- Assumption
  - Black-Sholes Model

- Approximation
  - Implied Volatility

Final Data Set Specification

- Testing Variables
- Other Explanation Variables

Data transformation and WLS regression
Testing Method - EBA

\[ Y = I \beta_i + M \beta_m + Z \beta_z + \mu \]

- \(I\) - free variables, “always-included” variables
- \(M\) - variable being tested for robustness
- \(Z\) - doubtful variables from prior studies
Results: Implied Volatility

![Graph showing probability density function for duration-based implied volatility.](image-url)
Results: Future – Spot

expected change in price of oil

probability density function
Managerial Implications

- There is a positive relationship between the unit bid prices and both the expected change and volatility in crude oil prices.
- The impact of expected change in prices is greater than the impact of implied volatility.
- To mitigate the effects of market price volatility, the owners should consider adding price adjustment clauses.
Innovation and Research Emphasis

SUSTAINABILITY GOALS

- Financial Feasibility
- Energy Preservation
- Environmental Protection
- Hazard Mitigation

PROJECT COMPLEXITY

- Toll Road Projects
- Securitization of Natural Hazard Risks
- Risk Management
- Dynamics of Post-disaster Reconstruction
- PHEV Interface Infrastructure
Securitization of Natural Hazard Risks


(Co-authors: Zafer Aslan John Mander)
Motivation

Assess the impact engineering design decisions on financial instruments used to transfer risks associated with occurrence of earthquakes, hurricanes, and other natural catastrophes.

There is no counterparty risk associated with CAT bonds.
CAT Bonds Overview

Cedant → SPV → Investors

PREMIUM → COVERAGE → PRINCIPAL + COUPON

A → B → C

A → C → B

Trust Account

PRINCIPAL + PREMIUM → RISK-FREE INTEREST

Diagram showing the flow of payments and relationships between Cedant, SPV, Investors, and Trust Account.
Capital Losses – Survival Function

- $S(x)$: Area under the curve $S^*(x)$
- PFL: Exceedance Probability
- EAL: Area under the curve $S^*(x)$
- EER: Area between the curves $S(x)$ and $S^*(x)$
- PE: Area under the curve $S(x)$
Managerial Implications

Parameter Changed by 10 percent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Percent Change in Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>$IM_{DBE}$</td>
<td></td>
</tr>
<tr>
<td>$b$</td>
<td></td>
</tr>
<tr>
<td>$k$</td>
<td></td>
</tr>
<tr>
<td>$c$</td>
<td></td>
</tr>
<tr>
<td>$\theta_{DBE}$</td>
<td></td>
</tr>
<tr>
<td>$\theta_{c}$</td>
<td></td>
</tr>
<tr>
<td>$\theta_{on}$</td>
<td></td>
</tr>
</tbody>
</table>
Other Research - Reconstruction

SUSTAINABILITY GOALS

- Financial Feasibility
- Energy Preservation
- Environmental Protection
- Hazard Mitigation

PROJECT COMPLEXITY

- Externalities, Incentives, Communication, etc.
Agents' Multi-domain Environment

Agent Architecture

Data Requirements

Behavioral Rules and Utility
Spatial Recovery Patterns

State of Env
Actions
Other Research - PEV

SUSTAINABILITY GOALS

Financial Feasibility
Energy Preservation
Environmental Protection
Hazard Mitigation

PROJECT COMPLEXITY

Externalities, Incentives, Communication, etc.
NSF I/UCRC Center for Transportation and Electricity Convergence (CTEC)
Smart Garage Location Problem

![Diagram showing the concept of smart garage location problem](image)

- **Origin**
- **Smart Garage**
- **Destination**

- **Incentive**

- **Driving Link**
- **Walking Link**

- Distance: \( L \)
Thank you!