Option-Games on Infrastructure Investment in Vietnam: Focused on Smart City Project

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***Abstract*--Successful countries provide economy and society with infrastructure needed to maintain growth. Over the last decade, the Government of Vietnam has maintained high level of infrastructure investment. However, the electricity shortage, the natural disasters and the emission of greenhouse gasses still have been challenges that Vietnam has to confront to sustain high economic growth in the long term. Japan, one of the most developed nations, is moving forward aggressively to become a major global player in Smart Cities. For this reason, we focus on this promising 'Smart City' project for considering the investment in Vietnam.**

This project requires huge investment financial amounts and long term to profitability under uncertainty. Hence, Public-Private Partnership (PPP) is an attractive scheme to optimize the trade-off between Vietnamese government-owned corporation (seeking for technology and capital) and foreign private firms (for market demand and regulation knowledge).

In a context of a strategic partnership as a coopetition method, how the option-games as a methodology can find the optimality on the trade-off between flexibility and commitment for irreversible investment under uncertainty and competitiveness. Then the result is proposed to value the boundary of cooperate investment opportunities for both sides in this project.

I. INTRODUCTION

Along with macroeconomic stability, other factors evaluated by investors as some of the main constraints to operating in Vietnam are lack of adequate and reliable electricity, poor quality of infrastructure in industrial areas, then being ranking with the almost lowest score of 123rd in 142 countries[1]. Therefore, Vietnam has spent about 10% of GDP for infrastructure investment in recent years; however, it still has not kept pace with population growth, the rate of urbanization and GDP growth. This has been causing pressure on the existing infrastructural system and a negative impact on the country's ability to sustain high economic growth in the long term. Transportation and electricity, two most essential activities, but proved to be still poor infrastructure areas in Vietnam when the power outages, traffic congestion, and greenhouse gas emissions occur more often. In this condition, management of technology investment is also important for the sustainable industrial development as a result and continual goal of economic progress of Vietnam. As a cutting-edge technology management topic to both sustainable energy and city planning including transportation, one of the most potential projects which concern infrastructure development is Smart City in Japan.

However, this kind of project is a large-scale, long-term and big-budget investment that requires cooperation among many stakeholders, not only the Vietnamese government, but other domestic or foreign investors under the Public-Private Partnership (PPP) model. On the other hand, making decision should be carefully considered under uncertainties over demand, market, policy and other risks. Hence, this paper here searches for a possibility of option-games as an experimental methodology to optimize a trade-off of both concepts of flexibility and commitment between the Government owned-corporation and Private investors in order to find the optimal value for corporative investment in this project.

Research questions

This paper's main research questions are as follows:

- How can the Government obtain long term, huge financial amount, and lower free-riding risk investment possibilities from foreign firms under uncertainty?
- How can Vietnam attract foreign technology and capital investment from a perspective of win-win relationship and mutual benefits in PPP model?
- How option-game methodology can be applied to find the irreversible investment optimal in such an innovative but risky project of Smart City under uncertainty, competition, and cooperation for both sides?

Research objectives

Froward to the above research questions, this paper's main research objectives are as follows:

- Explain the application of PPP model to investing in infrastructure and service market in this area.
- Using game-options to analyze the relationship of competition and partnership between foreign firms and the Government owned-corporation.
- Find the possibility of positive NPV for sharing strategy of development findings by players through sensitivity analysis under changing values of some parameters.

II. PROMISE OF SMART CITY IN INFRASTRURE DEVELOPMENT

Smart City Project in Japan

With great endeavor to create a better society, Japan has designed a grand picture in which all aspects of human life could be rebuilt in a smart grid and green environment by utilizing clean technologies. This integrated environment for human living is considered to be in a comprehensive action plan called Smart Community or Smart City.

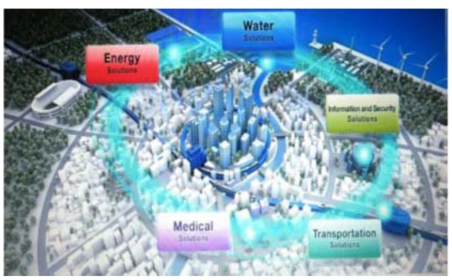
A smart community (Fig 1&2) is defined that the way for every Government can be used to develop "Smart" solutions for the community as a whole by utilizing information and communications technology (ICT) while promoting the introduction of renewable energies and achieving the integrated management and optimized control of all manner of infrastructure, including electric power, heat, water, traffic, healthcare and lifestyle information[2]. Moreover, this project will help to create smart communities that strike a balance between environmental considerations and comfortable lifestyles with solutions that include the implementation of large scale of renewable energy, home energy conservation, and smart life environment, proliferation of electric vehicles and transportation systems, and more green technology business models.

In the aftermath of the massive earthquake and tsunami in 2011, Japan has placed heightened urgency on building smart, sustainable cities, but it was moving in that direction even before then[3]. Today, there are four cities being conducted as experiments around Japan (the City of Yokohama, Toyota City, Keihanna Science City (Kyoto Prefecture), and the City of Kitakyushu) to identify the suitable models and then export this technology to overseas.

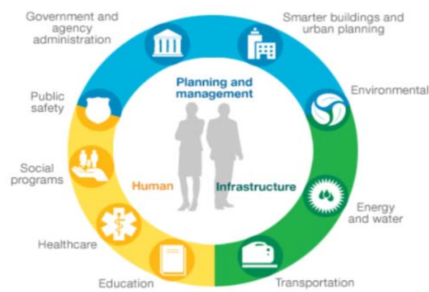
For the resource shortage problem in Japan, renewable energies such as solar and wind are introduced through this project as important alternatives for the nation's energy security and the global warming. Despite that, in order to apply these renewable energies on a large-scale, companies involved in Smart city project should evaluate requirements of market, and make the efficiency of power use and balance between supply and demand.

Vietnam- one of potential places for Smart City

According to the national energy development plan, in the 2010-2020 period, Vietnam may see an imbalance of supply and demand for energy resources. Although Energy Investment Construction Association showed that Vietnam ranks third in ASEAN and the 31st in the world in oil production, the output is shrinking. And Bach Ho oil field is expected to be closed in 2020. If no new sources are found, Vietnam will basically run out of oil and gas resources by 2025 (Table 1).



Source: TOSHIBA-Smart Community[2]
Figure 1: Smart Community



Source: IBM - Smart Cities[4]
Figure 2: Combination of Planning and management, Infrastructure and Human solutions for Smart city.

TABLE 1. ENERGY BALANCE AND EXPLOITATION OF PRIMARY ENERGY SOURCES IN 2010-2025[5]

ENERGY TYPES	2010		2015		2020		2025	
	Natural units	KTOE	Natural units	KTOE	Natural units	KTOE	Natural units	KTOE
Primary Energy Demand		59346		89534		123009		157407
Exploitable Energy Sources		77386		94828		108004		130538
- Coal	50 mill tons	28000	62,7 mill tons	35112	79 mill tons	44240	110 mill tons	61600
- Crude oil	19,86 mill tons	20217	20 mill tons	20360	20,7 mill tons	21073	21,7 mill tons	22091
- Gas	8,16 bill m^3	7349	11,82 bill m^3	10641	13,2 bill m^3	11908	17,8 bill m^3	16012
- Hydro Power	30,13 TWh	6478	56,8 TWh	12219	60,17 TWh	12938	60,7 TWh	13051
- Small Hydro Power	1,99 TWh	428	4,17 TWh	896	9,79 TWh	2105	12,8 TWh	2754
- Renewable Energy (tons of fuel wood equivalent)	45,2 mill tons	14914	47,2 mill tons	15600	47,7 mill tons	15740	45,5 mill tons	15031
Surplus (+) Shortage (-)		**18040**		**5294**		**-15005**		**-26869**

In the context that non-renewable fuels are increasingly running out, and fuel prices constantly increase, the discovery of a new clean and renewable energy to replace conventional energies is very urgent. While Vietnam has lots of renewable energy sources that are not yet fully exploited[6], they can be huge potential power resources for future if they are exploited by high technology such as Smart City.

Geo-thermal:

More than 300 sources of hot mineral water existing (30°C – 105°C)
- Focus Area: North Western and Central part
- No available assessment of potential

Solar energy
- Average sunshine hours: 2000 – 2500 hours/year
- Total of average heat radiating energy: 150kCal/cm^2/year
- Estimated potential: around 43,9 billion TOE/year

Wind energy

Small potential, Distribution of wind energy density:
- Island area: 800 – 1400kWh/m^2/year
- Coastal and highland area: 500 – 1000kWh/m^2/year
- Other area: below 500 kWh/m^2/year

Bio-mass energy

+ Total potential reserves (wood, straw, sub-farming products): 43 – 46 MM TOE/year:
  - Wood energy: 60% (26 – 27 MM TOE)
  - Straw and sub-farming products energy: 40% (17 – 19 MM TOE)
+ Producing reserves: 10%

However, nowadays, renewable energy accounts for a very low proportion in Vietnam. Expectedly, clean and renewable energies will account for 5 % of the power output by 2020 and 10 % in 2040.

Moreover, huge capital requirements and long term to profitability under high risk perception for innovative solutions and uncertainties can make the financial burden on the public if only the Government invest in this project. Nowadays, PPP model will be a promising solution to help government reduce the burden of capital guarantees, solve the problem of attracting investment in infrastructure and also provide an investment opportunity for private investors.

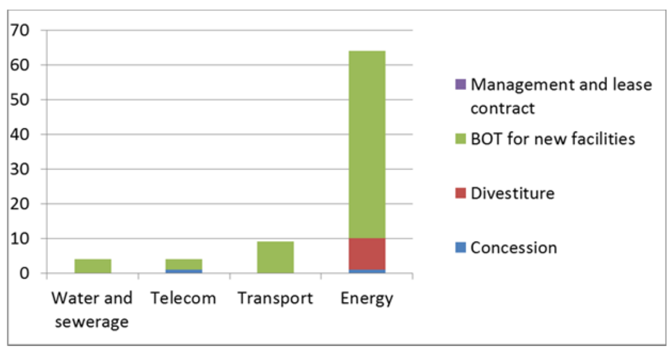
III. APPLICATION OF PUBLIC-PRIVATE PARTNERSHIP (PPP) TO SMART CITY PROJECT

Overview of Vietnam application

Moreover, in the uncertain and competitive high-tech industry, one of the most important factors related to make an investment decision is capital. In fact, none of government can afford to invest the entire infrastructure system; the private investors also cannot do this independently because this needs long term to get back return from investment with a lot of risks. In the condition of massive infrastructure investment needs coupled with budget constraints, making private involvement is an attractive option for the Government. Also, the industry for such kind of Smart City Project is characterized by intense technological and market competitions. Thus the government must create fairly competitive market for attracting corporation from foreign investors in this project. Rapid responses to technology improvements are critical to succeed in getting the latest-generation architecture, construction, and management technologies in such high-tech energy industry.

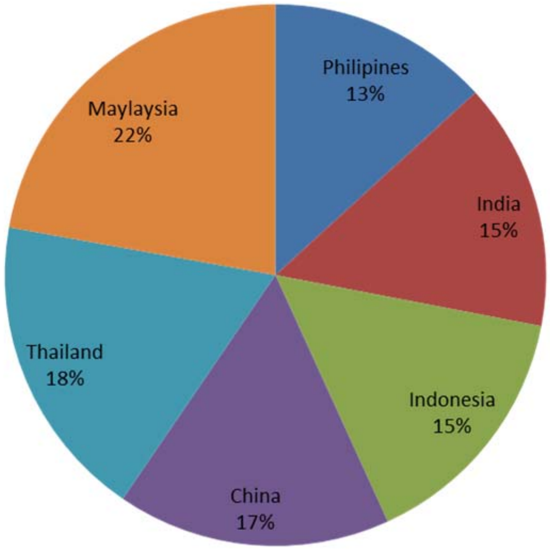
A PPP is a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. PPP involves a contract between a public sector authority and a private party, in which the private party provides a public service or project and assumes substantial financial, technical and operational risk in the project. The effect that this model provides reduced risks and costs, particularly, create a highly competitive environment.

In Vietnam, in the period 1994 - 2010, 64 projects have been implemented under the PPP model with total committed capital of about 8.37 billion US dollars. Like other countries, most of them are BOT (Build, Operate and Transfer) and BOO (Build Own Operate) models (Fig.3). Two areas account for the largest share are energy and transportation[7].



Source: World Bank PPI database[7]
Figure 3: Types of private investment projects in Vietnam (1994-2010)

However, private investment has been limited, due to the bureaucratic obstacles and rigidity of the internal market. In addition, as a unified tariff is applicable across the country, and artificially low, capped prices have long made it unprofitable for foreign infrastructure companies to invest in the power sector. As a result, the Electricity of Vietnam (EVN), as an example, has enjoyed a monopoly over distribution in Vietnam's electricity market (Fig.4). However, in early 2006, the Government approved EVN's master plan for the development of a three-step competitive power market by 2022. This will be expanding to the wholesale market between 2015 and 2022 (Table.2) [8].



Source: Vietnam Institute of Energy 2011[8]
Figure 4: Proportion of the Electricity Suppliers in 2011

TABLE 2: VIETNAM'S POWER DEVELOPMENT ROADMAP

Implement By	Programme	Type
2010	Competitive Generation Market	Pilot Operation
2011		Full Operation
2014	Electricity Wholesale Market	Pilot Operation
2016		Full Operation
2022	Electricity retail Market	Pilot Operation
2024		Full Operation

Source: Electricity Regulatory Authority of Vietnam[8]

Tax incentives from the Government for foreign investors[9]

Under the provision of the Law on Cooperate Income Tax: the current income tax rate is 25%. However, depending on the industries or areas that regulated terms encourage investment, investors may be eligible for the preferential income tax rate as follows:

- The preferential rates: from 10 % to 20 % (applied within 15 to 30 years or for the duration of the project).
- The duration of tax exemption (corporate income): maximum 4 years.
- The duration tax reduction (50 %): up to 9 years

In details:

For manufacturing industries such as software, high technology investment and infrastructure works: the preferential tax rate of 10% within 15 years.

On the import duty for goods as raw materials, machines imported as fixed assets, which cannot be produced in domestics, investors can be considered to get import and export tax exemption.

IV. APPLICATION OF OPTION-GAMES TO STRATEGIC PARTNERSHIP

Definitions of main concepts and framework

It can be clearly seen that discounted cash flow (DCF) method is not suitable to give a right decision because it cannot account for uncertainty and competition in the real market[9].

However, Real Options Analysis (ROA) is a financial approach that values a flexible response to future uncertainties. The ROA enables stakeholders to consider when it is suitable to initiate or stop a project[10]. On the other hand, ROA can allow decision makers to accurately estimate the expected value of an investment by reducing negative risks and increasing opportunities[11]

Game theory is an economic approach concerned with the effect of competitor decisions. The game theory analyzes the multi-decision making process when there is more than one decision maker[12]. Each player's payoff depends on the actions taken by other players.

As a methodology here, the procedure is consisted of basically comparing both the value of flexibility by real options and the commitment value by game theory in a game tree, and then of utilizing it for the optimal strategic decision as figure 6 through the backward induction[14]. In other words, a two-stage game tree divided into two cases includes the alternative actions of a pioneer firm to make a first-stage strategic investment in R&D (under sharing strategy) or not (base case) at time 0 through quantitative competition. Thus, based on the presumption of duopoly competition form in game theory, the objective is to find a possibility of positive NPV for sharing strategy of research and development findings by an initial investing company, and to find the optimal agreement for strategic partnerships (license and cooperative development) between Government owned-corporation and Private company (as pioneer), and further the opportunities for open innovation[13].

At a quantitative competition, consider the game where pioneer (Private company) can make a first-stage strategic R&D investment that results in a deterministic operating cost advantage in the second stage (commercialization). In the second stage, either Private or Government owned-company can invest money in follow-up production capacity, depending on subsequent random demand moves (up or down). And then, each NPV is compared in the Cournot-Nash equilibrium, Stackelberg leader/follower equilibrium, and monopoly.

Nevertheless, there are still have some issues existing in these previous papers. They researched on option-game focused only on the changing of market demand and the players with fair right since second year. Therefore, the outstanding point of this paper supposes the market factor, especially tax, which affects directly to both players and then would change their behavior under different circumstances.

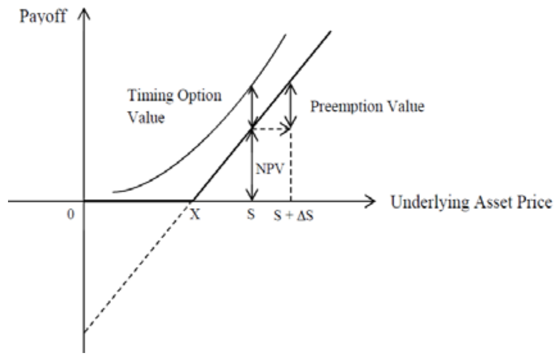


Figure 6: Trade-off between Commitment and Flexibility[12]

Partnership Strategy in Quantitative Competition

Here, each result of numerical calculation is examined of the base case, and sharing strategy of development findings in the quantitative competition.

Base Case in Quantitative Competition[13]

At first, own positioning policy for maximizing NPV becomes possible to use, by the optimal arrangement of each decision type among the commitment priority, the flexibility priority, and the balance between them, on the basis of demand and volatility parameters.

Here it is assumed a two-player game between player i and j (or the government-owned corporation and Private), initial demand θ_0=19.5, up or down with binomial parameter u=1.25 and d=0.8, each player's cost c_i=7 and c_j=7, initial R&D investment I_0 =20, follow-up commercialization investment I_1=100, risk-adjusted discount rate k=0.13, and risk free interest rate r_f = 0.1. If constant asset payout yield for perpetual project is:

$$\delta = \frac{k}{1+k}$$

risk neutral probability is

$$\text{p} = \frac{(1+r-\delta)-d}{u-d} = 0.411 \ldots \approx 0.411$$

where $\text{u} = \exp(\sigma\sqrt{\Delta t})$, $\text{d} = \exp(-\sigma\sqrt{\Delta t})$ with volatility σ

In base case at second stage:

General equation of Cournot-Nash equilibrium (C) is

$$NPV_i(C) = \frac{\left(\theta_t - 2c_i + c_j\right)^2}{9k} - I_1$$

For example, when both i and j select D (Defer) first and I (Invest) next, and a Cournot- Nash equilibrium is attained, so

$$NPV_i(C) = \frac{(\theta_0 \times u^2 - 2c_P + c_G)^2}{9k} - I_1$$
$$= \frac{(19.5 \times 1.25^2 - 2 \times 7 + 7)^2}{9 \times 0.13} - 100$$
$$= 370.754 \ldots \approx 371.$$

General equation of monopoly (M) is

$$NPV_i(M) = \frac{(\theta_t - c_i)^2}{4k} - I_1$$

For a specific calculation case is

$$NPV_i(M) = \frac{(\theta_t - c_i)^2}{4k} - I_1 = \frac{(\theta_0 \times u^2 - c_P)^2}{4k} - I_1$$
$$= \frac{(19.5 \times 1.25^2 - 7)^2}{4 \times 0.13} - 100 = 959.197 \ldots \approx 959.$$

General equation of Stackelberg leader equilibrium (SL) is

$$NPV_i(SL) = \frac{\left(\theta_t - 2c_i + c_j\right)^2}{8k} - I_1$$

For instance,

$$NPV_i(SL) = \frac{(\theta_0 \times u^2 - 2c_P + c_G)^2}{8k} - I_1$$
$$= \frac{(19.5 \times 1.25^2 - 2 \times 7 + 7)^2}{8 \times 0.13} - 100 = 429{,}598 \ldots$$
$$\approx 430$$

And equation of Stackelberg follower (SF)

$$NPV_i(SF) = \frac{\left(\theta_t - 2c_j + c_i\right)^2}{16k} - I_1$$

So,

$$NPV_i(SL) = \frac{(\theta_0 \times u^2 - 2c_G + c_P)^2}{16k} - I_1$$
$$= \frac{(19.5 \times 1.25^2 - 2 \times 7 + 7)^2}{16 \times 0.13} - 100 = 164{,}799 \ldots$$
$$\approx 165$$

Then, Abandonment (A)

$$NPV_i(A) = 0$$

At first stage, by sharing the same equation with second stage, the general equation of Cournot-Nash equilibrium (C) is

$$NPV_i(C) = \frac{\left(\theta_t - 2c_i + c_j\right)^2}{9k} - I_1$$

For example,

$$NPV_i(C) = \frac{(\theta_0 \times u - 2c_P + c_G)^2}{9k} - I_1$$
$$= \frac{(19.5 \times 1.25 - 2 \times 7 + 7)^2}{9 \times 0.13} - 100 = 158.026 \ldots$$
$$\approx 158.$$

General equation of monopoly (M) at first stage is

$$NPV_i(M) = \frac{pV_u + (1-p)V_d}{1+r_f} - I_1 + \frac{\pi M}{1+k}$$

where, $\pi M =$ monopolistic profit limited only at first stage. For specific,

$$NPV_i(M) = \frac{pV_u + (1-p)V_d}{1+r_f} - I_1 + \frac{(\theta_t u - c_i)^2}{4} \times \frac{1}{1+k} =$$
$$\frac{0.411 \times 959 + (1-0.411) \times 200}{1+0.1} - 100 + \frac{(19.5 \times 1.25 - 7)^2}{4} \times \frac{1}{1+0.13} =$$
$$325.564 \ldots \approx 326.$$

The general equation of deferment is

$$NPV_i(D) = \frac{pNPV_u + (1-p)NPV_d}{1+r_f}$$

For instance,

$$NPV_i(D) = \frac{pNPV_u + (1-p)NPV_d}{1+r_f} = \frac{0.411 \times 165 + (1-0.411) \times 0}{1+0.1}$$
$$= 61.577 \ldots \approx 62.$$

Base case illustration: consider the game where pioneer is Private company (P) does not make a first-stage strategic R&D investment that results in a deterministic operating cost advantage in the second stage (commercialization) and government-owned corporation (G) is a follower. There are two circumstances for base case:

First, without any government regulation on tax policy, the base case value is symmetric for both firms. Then, (66,66) is for (P,G).

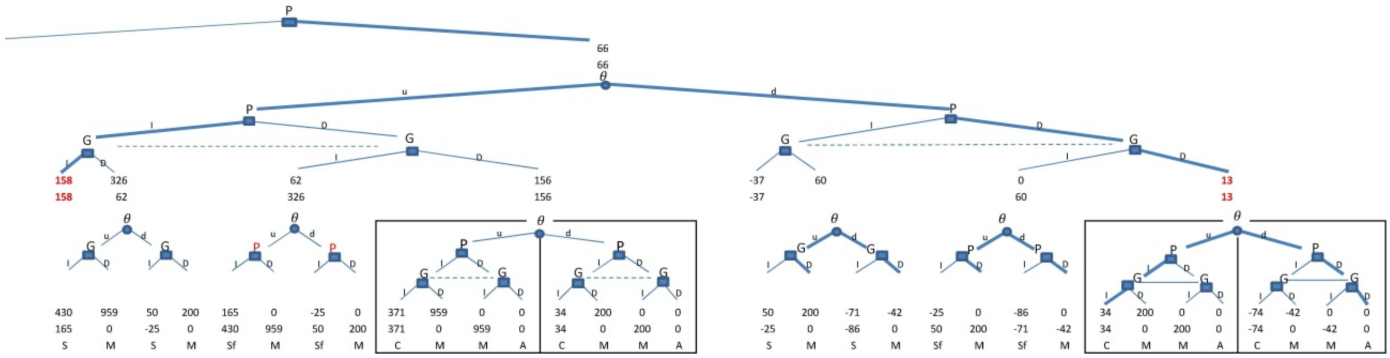


Figure 7: Base Case (without tax policy condition): Two-Stage game in extensive form under Different Market Structures.

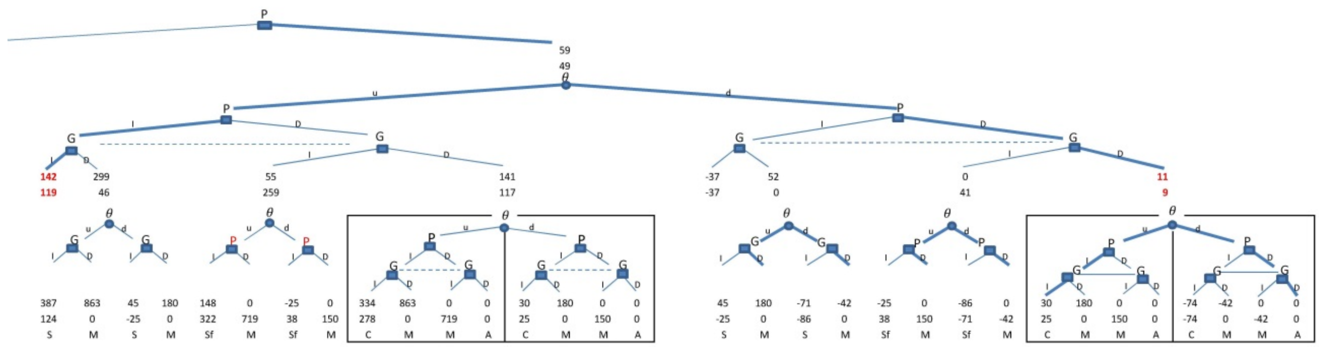


Figure 8: Base Case (with tax factor): Two-Stage game in extensive form under Different Market Structures.

Second, based on the tax incentives for Private investors mentioned above, it is assumed that the tax for government-owned corporation is 25%, whereas, just 10% incentives for Private company. Hence, the value declines to (59,49) for (P,G).

Sharing Strategy of R&D Findings in Quantitative Competition

In figures 9 and 10 illustrate the shared case, where Private company R&D results in more cost-effective technology that both players can exploit ($c_i = c_j$=2). If a pioneering company with initial R&D investment shares development findings with the Government-owned corporation under constant conditions, the pioneering company position becomes disadvantageous because of equal market share when the pioneer invested earlier in R&D in first stage, compared it with a base case (without market condition).

After paying tax, the value of both players at second stage is (138,115), and because Private must pay initial payment I_0=20, the NPV of Private is 118 that is still bigger than that of the Government owned-corporate and that of the base case equilibrium value 59. Therefore, while the Private would invest in R&D rather than retain a flexible wait-and-see position to get the tax incentives from the Government, the Government also gets high technology from the Private. For example, the payoff of Government-owned corporation increases from 49 to 115. And the sum of both payoffs also expands from 118 to 253. That means they both can reach cooperative strategy through agreement about profits.

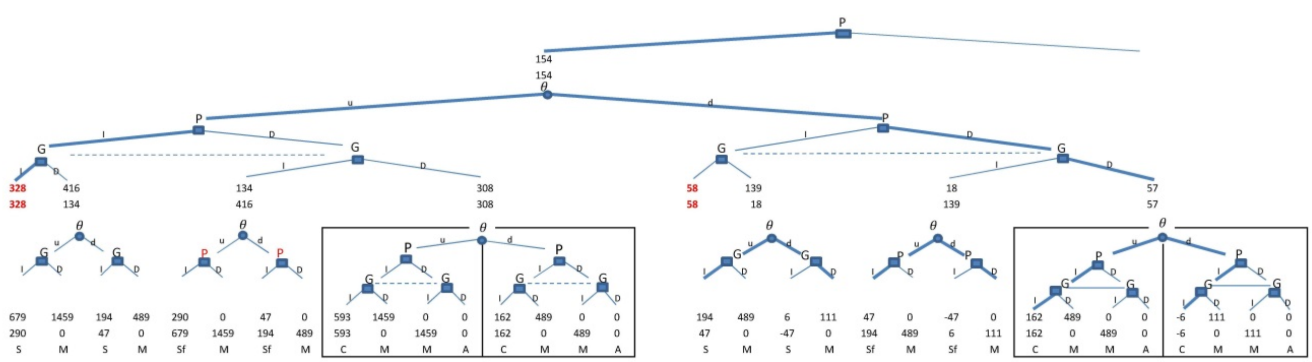


Figure 9: Shared Strategic Investment Game (without market condition) in extensive form under Different Market Structures.

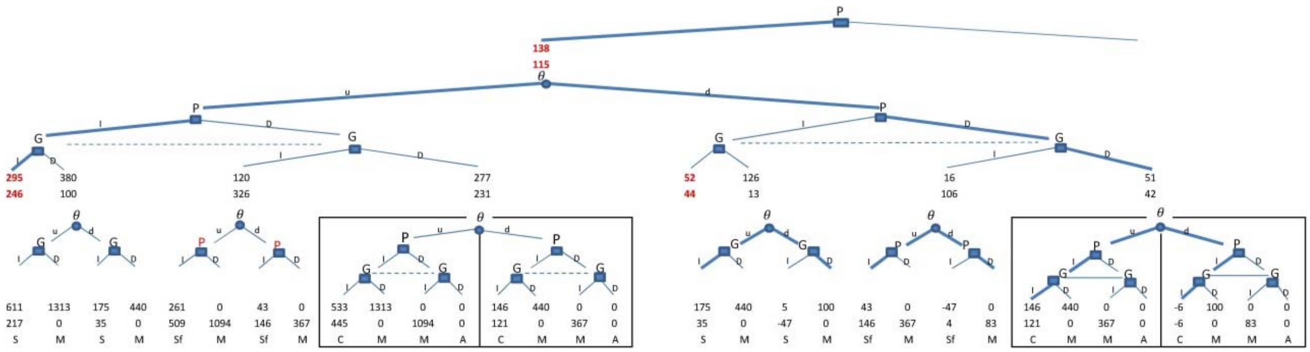


Figure 10: Shared Strategic Investment Game (with tax factor) in extensive form under Different Market Structures.

Sensitivity analysis under the Sharing Strategy of Investment

The impact on NPV of the Private Firm with tax factor

Here analyzing the impact on NPV of the Private Firm due to the simultaneously changes of the amount of investment (from 50 to 200) and the tax rates (0-0.25). As can be seen from figure 11, it is possible to find the optimal NPV level of each firm on the basis of tax shifts and investment amount changes. In the consideration of initial investment, the pioneer firm (the Private Firm) has the ability to share development findings with the Government owned-firm if it can receive lower tax rate, especially, it can reach the optimal value without tax and the lowest investment amount.

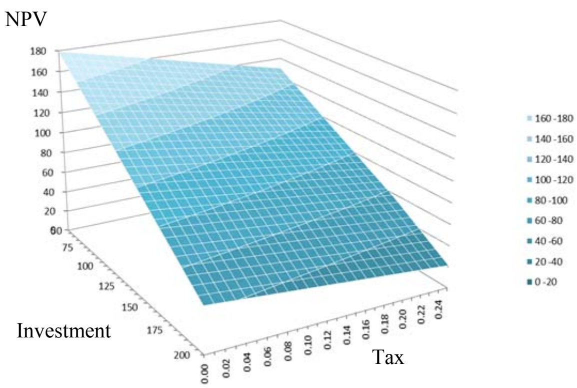


Figure 11: The changing NPVs of Private with the shifts of two parameter values, investment I and tax.

The changing behaviors of the pioneer under the comparison between NPVs of both players

The comparison is created by changing NPVs of the Private Firm with shifts of investment and tax and another of volatility and demand and those of the Government owed-corporation. And the figure 12 illustrates that if the tax rates are almost 0 (without tax), the pioneer will invest money at any time in range of investment amount. By contrast, the pioneer will refuse to invest large amount of money with the increasing tax and it decide not to invest at all if tax is bigger than 15%.

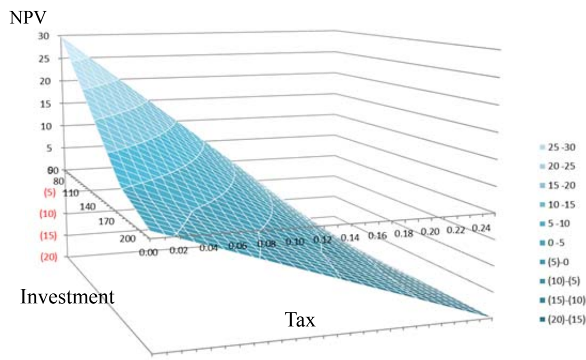


Figure 12: The changing behaviors of Private's NPVs compared with Government owned-corporation with the shifts of investment I and tax.

Otherwise, we can see the significant influence of volatility of demand in Vietnam market on the profits of Private. When the demand goes up with higher volatility, it will create larger and larger NPV for the pioneer. This is potential mechanism in Vietnam that convinces outside investors not only domestic but foreign ones to make R&D investment for this project.

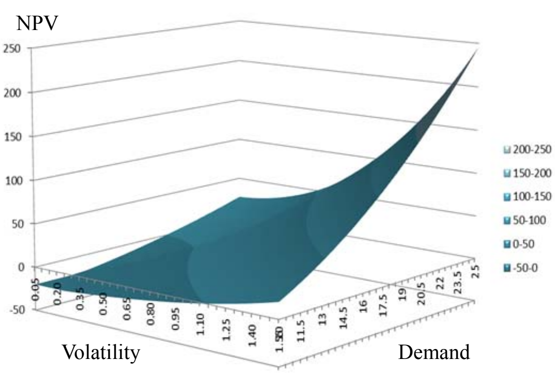


Figure 13: The changing NPV's behaviors between Private and Government owned-corporation with shifts of volatility and demand.

In 3-dimension models on NPV of quantitative competition, there are several factors can contribute to a rise of NPVs. From each type of option game trees, it was found that volatility of demand or tax is specially related to the commitment and the volatility. From both parameters, it becomes possible to select the optimal strategy to maximize NPV on game theory and real options. It can be shown that a sharing strategy provides for a pioneering company an opportunity for benefits if they invest the initial investment for R&D. However, it is possible to get loss from investing, depending on the conditions of high tax and large amount of investment. Nonetheless, it may be said that a sharing strategy is basically superior from Pareto optimum for both players, if summing up both NPVs of a pioneering company and a follower. Therefore, it is still advisable to select a sharing strategy with partnership, through a method of distributing other incentives and then redistributing a total returns among the parties before closing a sharing contract. For that reason, it may utilize results here as a preparation of guideline forming.

V. CONCLUSION

Smart City is a large-scale investment on infrastructure for the developing country as Vietnam. And the Government has to make futuristic decisions under poor technology and capital shortages. Hence, the Public-Private Partnership model (PPP) investment in improving the quality of public services is considered to be the correct direction of Vietnam in this period. However, it is necessary to have appropriate PPP approach in order to bring the desired benefits and achieve the result of better infrastructure. In the context of shortage of investment capital in Vietnam, private investors should rather focus more on public-private partnership model in which they can participate as sponsors of projects like BOT, BOO than just contribute experienced management capabilities. Particularly for private foreign investors in many countries should cooperate with the Government owned-corporation in order to overcome the limitations of scale, financial strength and minimize investment risks. However, how the Government can convince private partners investing in Smart city project. This question can be answered by using option-games methodology for both public and private sectors to quantify payoff options before making decisions on large-scale investments as Smart city. Real options allow decision makers to accurately estimate the expected value of an investment by making the project sufficiently flexible regarding productive opportunity versus abandon in light of future risks. On the other hand, game theory can quantify competitive pressure under different strategies. The option-games approach addresses an existing need in infrastructure management, which is characterized by big budgets, uncertainties, competition and coorperation.

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