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GAME THEORY APPROACH FOR PUBLIC RENTAL HOUSING INVESTMENT

FARIDA RACHMAWATI[1], CONNIE SUSILAWATI[2], and ADHIKA NANDI WARDHANA[1]

[1] Civil Engineering Department, Institut Teknologi Sepuluh Nopember

[2] Faculty of Business and Law, Queensland University of Technology

ABSTRACT

Affordable housing provision in major cities is an ongoing challenge for governments. Issues related to demand for public housing provision include affordability and accessibility to housing finance systems, resulting in subsidised low rental prices for low-income families. Meanwhile from the supply side, the issue is a lack of housing supply from housing developers related to building regulations associated with the capping of prices, the cost of construction, and land prices, which resulting in some financial risks for housing developers.

This paper is conceptual paper which explores the use of game theory for decision making related to risk allocation in housing investment between two parties: government and housing developers. The findings provide a summary of the use of game theory for financial risk allocation in order to enhance future implementations including objects and approaches. Some game theory strategies are also discussed, which could be adopted for further empirical studies.

Keywords: investment, financial risk, game theory, rental housing

1. Background

Due to its high level of urbanisation, Indonesia suffers from a significant housing backlog. Major urban areas face problems related to the demand for basic services due to a lack of affordable housing investment (REI, 2020). Based on housing data, the Indonesian Ministry of Public Works and Public Housing predicts that the need for housing (ownership), termed a 'housing backlog', will reach 800,000 units per year (Indonesian Ministry of Public Works and Public Housing, 2020). This number will increase the current housing backlog (ownership concept), which has not yet been met: 7.64 million units in 2020 (Indonesian Ministry of Public Works and Public Housing, 2020). A public housing program has been initiated to urgently reduce this housing backlog.

In general, there are two types of public housing dedicated to low-income communities: low-rise housing (single housing) and high-rise apartments (public housing). Public housing is provided through ownership or a rental scheme. Most public rental housing in Indonesia is allocated for relocated communities and low-income people, with local governments making some adjustments in relation to tenants' ability and willingness to pay (Purnamasari et al., 2020). Responding to the scarcity of land for landed houses in areas near major city centres and in order to regulate development, ownership, mortgages, and occupancy management, the Indonesian Government issued the first Act regarding high-rise apartments, known as *Public rental housing act,* 16 (1985) (Indonesia). This regulation was further updated by *Public rental housing* act, 1 (2011)(Indonesia), which regulates public housing specifically.

In Indonesia, both central and local governments are key players in low-cost housing provision, with private developers building only a small number of low-cost housing units (Kusuma, 2018). The government builds a limited amount of public housing, and remaining housing needs are met by the unplanned informal housing sector – self-built housing (Tunas & Darmoyono, 2014). In short, the aim of housing policies is to initiate programs to help low-income families to own their own homes, to reduce the housing backlog, and to reduce the amount of illegal housing and squatter settlements. Policy therefore focuses on housing supply and housing finance, with housing finance policy intending to ensure that low-income communities have the opportunity to access finance systems that will help them to own or to rent a home.

There are some major issues related to public housing supply, which is not favourable for private housing developers, including financial risk due to regulations and low-income tenants' affordability issues. Financing affordable housing in urban centres is more challenging than other residential properties (Susilawati & Yakobus, 2010). One issue is that land costs in urban centres are very high (Bakhtyar et al. 2013). This study observed that increased land costs due to high demand has triggered land scarcity. As a result, development of new affordable rental housing is risky due to the difficulty in acquiring appropriate locations for affordable housing. In addition, the rental price is low as it cannot be determined high, and it is not able to cover operational and maintenance costs. According to government regulation, the public rental housing units provided by the Indonesian Government operate on a not-for-profit basis.

The rent price consists of operational costs that cover officers' salaries, tax, insurance, and public infrastructure utilities, while maintenance costs include building components such as rehabilitation and replacement. According to *Public Rental Housing Tariff Determination* Ministry of Public Works and Public Housing 2018 s.1 (Indonesia)). Housing providers or investors normally expect sufficient and appropriate return at minimal risk to their investment. When an investment has no clear prospects, investors will not risk their capital by channelling their investment into affordable housing projects.

There are two different interests in a public private partnership (PPP): 1) public interest, which concentrates on economic feasibility (socio-economic, environmental and other external effects), and 2) private interests, which focus on financial feasibility (financial revenue and expenditures). On the other hand, the rental price, which is the main revenue of low-cost apartment is kept low (Rachmawati et al. 2018), resulting in financial risk for investors. A study pertaining to the partnership model related to risk allocation in low-cost apartment is therefore required to attract private sector involvement.

Therefore, in order to increase the public housing supply by attracting private housing developer's involvement, some efforts are formulated related to financial risk allocation. Risk allocation is the definition and division of responsibility associated with a possible future loss or gain arising from an identified risk. The sharing and allocation of risk assumes greater importance when examining infrastructure investments. The process of risk allocation between public and private sectors in public housing provision could be then analysed as a bargaining process between these two agents (Liang et al. 2019).

Game theory (GT) can be used to deal with a group of players acting in their own self-interest to allocate risk and maximise their profits (Wardhana et al. 2021). There have been several studies related to game theory, such as Shuai (2019), who studied the strategy for electrical plant development; while Wang (2020) discussed the selection model in optimising the subsidy scheme to maximise the efficiency of the subsidy calculated by environmental benefits per unit of monetary subsidy. The current study aims to explore the use of game theory for decision making related to financial risk allocation in public rental housing investment between two parties: governments and housing developers. Some strategies related to public housing provision are also provided in this paper.

2. Literature review

2. 1. Public housing

Research related to affordable housing has been growing rapidly over the last decade across Europe, followed by a variety of policies formulated by governments (Czischke & Bortel, 2018). This stemmed from the need for subsidised housing, as low-income experiences have created an overburden due to low household incomes. Governments in some countries have initiated low-cost housing provision. In Poland and Italy, social housing is known as public rental housing, which primarily accommodates low-income communities and those with special needs (Czischke & Bortel, 2018).

People want to live in a good, affordable housing environment (Chen et al., 2014). However, those conditions are difficult for low-income people to achieve. As major cities offer many important and attractive facilities, land downtown, which is mostly close to workplaces, is very expensive and becoming scarce (Susilawati & Yakobus, 2010).

In general, housing problems are related to housing demand and supply (Othman & Abdellatif, 2011). Housing supply issues are largely due to limited land in states and territories, as well as local planning and approvals processes, lack of coordination between infrastructure planning and housing supply, and skills shortages in the housing construction industry. In particular, housing problems for poor or low-income communities are caused by some combination of low income and high housing costs, leading to affordability issues such as lack of effective housing finance systems and difficulty accessing land with secure tenure (Mukhtar et al. 2016).

Specifically, public housing in Indonesia is mostly provided by ministry government. The local government/institution then assumes responsibility for managing the public housing, management, which consists of operation and maintenance activities of public utilities. During the operational stage, local governments (province and district/municipality) are required to subsidise operational and maintenance costs (Indonesian Ministry of Public Works and Public Housing, 2012; Rachmawati et al. 2015) in order to maintain low rental prices – which are so low that they cannot cover these costs – being determined at lower than 30% of the inhabitants' income based on affordability concept (Yap & Ng, 2018).

*2. 2. **Risk Allocation***

Generally, risk management encompasses the identification, assessment, treatment and allocation of risks (Chan et al. 2011; Roumboutsos & Anagnostopoulos, 2008). It is one of the topical research areas in PPP studies (Ke et al. 2009). Essentially, a thorough risk assessment and proper risk allocation guarantees value for money (Grimsey & Lewis, 2004). Thus, it is crucial for project parties to ensure systematic risk management throughout the PPP project's life cycle (Chan et al. 2011).

Risk is defined as the uncertainty of future events that might influence the achievement of one or more objectives such as the organisation's strategic, operational and financial objectives. Project risk management includes the processes of conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project. The objectives of project risk management are to increase the probability and impact of positive events and decrease the probability and impact of negative events in the project (PMBOK, 2008).

In the context of partnership, risk allocation should be clearly defined. Some researchers have argued that risk in a partnership project should always go to the party most capable of reducing and managing it (Wang et al. 2019). Almarri et al. (2019) also argued that it is necessary to transfer the risk to the right party. In particular, private investors pay particular attention to risk allocation, because government tends to transfer the risks to private partners (Wang et al. 2019). Partnership projects have many kinds of risk, including project-level risks (e.g., design, construction, finance, and ownership risks) and market-level risks (e.g., demand and investment environment risk). Risk management, including risk allocation and risk transfer, will impact the quality of public and private partner relationships.

A bargaining process between two agents confronts decision making on risk allocation. Risk allocation among the parties in a partnership employs cooperative decision-making techniques. Cooperative decision-making techniques are one method of game theory. GT applies when two or more groups of operators facing disagreement between their interests, which triggers confrontation (Peckiene et al. 2013).

*2. 3. **Game theory`***

As previously mentioned, risk allocation should go to the party best able to tackle the risk (Wang et al. 2019). Risk allocation should always be based on a realistic assessment that needs to be performed in order to determine the capacities of both parties and should never follow the interest of a single sector. There are some tools to support risk allocation, with one being GT.

GT is a method of studying a mathematical model that describes the interaction between two or more players who are rational (Wardhana et al. 2021). GT can be used to deal with a group of players acting in their own self-interest to maximise their profits. This fits perfectly with investors who want to maximise their own profits rather than sharing excess profits with the government sector, or what is

called the non-cooperative game model. In addition, GT can also be used to share risks in a job for the players. This model is a cooperative model where both parties benefit from each other (win-win solution). Another example is Wu's (2017) research applying cooperative and non-cooperative game models, where at the initial stage, a non-cooperative game model is used that knocks down other players and a cooperative game model is then used where players (other than players in the first model) cooperate with each other as a response to the first model to minimise risk.

In general, partnerships involve two or more parties where each has interests. Governments have social interest to provide public infrastructures, while investors have an interest in gaining greater profits (Rachmawati et al. 2018). One critical issue frequently reported is the lack of efficient allocation of risks and responsibilities in PPP projects, resulting in excessive risk transfer to the point that the private sector can no longer manage the risk burden. Governments and private sector bodies must pay close attention to the procurement process while negotiating contracts for PPP to ensure an equitable risk allocation between them (Xu et al. 2010). GT supports the decision-making process by modelling the behaviour of the involved parties more accurately to reach a unique point that is desirable and equitable for all players (Nasirzadeh et al. 2016). Bargaining GT provides participants in PPP projects with the ability to cope with the bargaining process of risk allocationStrategies from each player should be defined, with the payoff to be calculated to achieve maximum benefit with respect to the responses of other players.

Studies related to risk allocation using a GT model have been conducted in some sectors. Nasirzadeh et al (2016) employed GT for risk allocation in a pipeline project, with strategies made to obtain desirable contractor and client costs. Meanwhile, Xiao and Ao (2019) studied GT for risk allocation between the government and the private sector in village PPP projects. GT for risk allocation can not only be used for construction, but also for rural development (Xie et al. 2022) and subsidised rental housing (Liu et al. 2022). Furthermore, GT is not only conducted for risk allocation issues, but also for determining concession periods in build-operate-transfer (BOT) projects (Shen et al. 2007), and to offer final arbitration to discuss two players' behaviours when opposing objectives occur during risk allocation in PPP projects.

The elements of method include (Abapour et al. 2020):

1. Player
'Player' refers to individuals or organisations who act in decision making where they have the right to choose a set of actions to be carried out.

2. Rules
In this model, there must be a rule that explains which players should play, when they should play, what the player knows when playing, and what actions can be taken.

3. Strategy
The strategy in question is an action that can be carried out by the player. The optimal strategy is the strategy that maximises the player's pay-off.

4. Pay-off
Each strategy taken can have consequences in the form of pay-offs that will be obtained by the player. The pay-off is the utility that players can receive for each strategy they take. This pay-off can be in the form of value, a certain amount of money, prestige, emotion, or risk.

The best strategy is obtained based on the best pay-off from the strategy carried out by player 1 against several strategies carried out by other players. The value of the pay-off is obtained in various ways, one of which can be obtained from linear equations, observations, interviews, and so forth. The

best response from one strategy compared to another is called the Nash Equilibrium. The Nash Equilibrium is important because in every game it assumes every player is rational. GT classification based on game value is divided into zero-sum strategy games and non-zero sum games (Wang et al. 2019).

The goal of the theory is to suggest which strategies are more likely to be played by the players, or to recommend to players which strategy to implement (or not to implement). Here, we present several concepts that allow one to achieve these goals. The first concept introduced is domination (strict or weak), which provides a partial ordering of strategies for the same player, it describes when one strategy is "better" than another strategy.

Based on the type of game, there are several types of game, including:

1. Cooperative game theory
   In cooperative games, decision makers will cooperate when they agree. Basically, its outcome will be better than the Nash or Stackelberg Equilibria (Wang et al. 2022). It is assumed that players adhere to a jointly chosen strategy, which can be externally enforced.

2. Non-Cooperative game theory
   Non-cooperative games are games in which players selfishly try to maximise their utility, conditional on the rational choices made by the other players who try to do the same. A stable distribution of utilities can only be enforced through self-enforcing agreements such as a Nash Equilibrium (Hamidi et al. 2016).

3. Revolutionary game theory
   The evolutionary game develops a non-cooperative game formulation by introducing the population concept, which relegates to a set of players. Mainly, the evolutionary game concentrates on the overall behaviour of population that is different from a non-cooperative game. The evolutionary equilibrium in this game is similar to a Nash Equilibrium in a strategic game. The revolutionary game has broad usage in engineering science due to its efficiency (Abapour et al. 20208)

3. Research Methodology

The aim of this paper is to provide a comprehensive review of applications of the GT approach to the solution of public rental housing provision problems. The main classification of such approaches is studied and analysed based on type of games, number of players and most possible strategies. Issues related to public rental housing provision are investigated and linked to strategies and the type of game.

4. Game Theory Approaches Applied to Public Housing Provision

Risk allocation for public housing provision

There are some risks related to public rental housing provision, of which the most dominant risks are financing and cost recovery (Rachmawati et al. 2018). In the context of public housing investment, which involves private housing developers, financing and cost recovery are the major issues. However, the government will support public housing program, as public housing provision is the government's domain. The basic principle is the greater the private sector's involvement, the less government subsidy is required. However, effort should be made to attract the private sector to invest in public housing projects. Supply side government subsidies on low-cost apartments are land and

tax deductions, while subsidies on public rental housing are land and part of the construction, such as public utilities.

Financial risk allocations on public rental housing

First risk is lack of private housing developer to contribute to public housing provision due to unfavourable investment. The Indonesian Government caps rental or selling prices; however, investment by housing providers is required to accelerate public housing supply. In public housing, the government allocates subsidised units for low-income community, which the rent price is lower than non-subsidised units. More subsidised unit will decrease housing provider's revenue. Therefore, there is an evident gap in housing supply between public housing tenants/buyers' affordability and project viability for housing providers' investment. One

In existing practice, price determination for public rental housing in Indonesia is characterised by a lack of balance. As noted, rental prices are low, and cannot cover operational and maintenance costs, as they are determined at lower than 30% of the tenants' household income, without any consideration of factors such as location or neighbourhood (Soemitro & Rachmawati, 2020). Public rental housing units provided by the Indonesian Government operate on a not-for-profit basis. As a result, government subsidies for operational are very high (Rachmawati et al. 2015).

Second risk is related to tenant's affordability. Therefore, future public housing investment should not only be affordable for low-income tenants, but also feasible for private housing developers and government. The Indonesian Government should allocate subsidies effectively, as more subsidies will hinder more government programs. The financial analysis should support risk allocation, which is able to accommodate this condition. In relation to the partnership of public housing investment between the Indonesian Government and private housing developers, GT can support risk allocation, especially in financial matters.

Based on the brief explanation above, the public rental housing provision issues, risks are listed as follows:

Table 1. Mapping on affordable issues and the use of game theory (GT)

Risk	Issue	Proposed solutions	The use of GT
Lack of private developers involve in public housing provision	More subsidised units will decrease the profit	It needs the proportional determination of subsidised and non-subsidised units	To model the portion of subsidised and non-subsidised unit
	The price cannot be determined high as public housing is dedicated to low-income community	It needs government subsidy, in terms of initial cost (land or construction cost) or operation cost.	To determine most suitable government subsidy, which reduce the investor's capital investment
	Lack of investment's profit	It needs the allocation of commercial area for cross subsidy	To model the portion of commercial area

		and to raise the investment's profit	among residential area
	Length of concession period	It needs to determine the most suitable length of concession period	To calculate the length of concession period
Tenant's affordability	Availability of subsidised units	It needs the proportional determination of subsidised and non-subsidised unit	To model the portion of subsidised and non-subsidised unit

1. Number of subsidised and non-subsidised units
   The housing developer's strategy would be in the form of the number of subsidies and non-subsidised unit provision. The government will grant a subsidy for non-subsidised units and incentives to private housing developers who provide non-subsidised units in their public rental housing.
2. Government subsidy
   In public rental housing, governments also subsidise the land provision for the building. Governments also subsidise some parts of the building, such as public utilities depending on the investment costs and the complexity of the investment.
3. Length of the concession period
   The model would obtain the proposed length of the concession period to control private investors' profits within a reasonable range, while achieving a fair allocation of financial risk between governments and housing developers. The objective is to find the maximum length of the concession period under some possibilities of given ROI max. To achieve this, the government needs to decide to what extent it will allow private investors to enjoy overly lucrative conditions.
4. Maximum operating government subsidy
   The government decides the subsidy scheme to maximise the efficiency of the subsidy. The housing developer then sets the sale price of units to maximise its profit.
5. Financing strategy
   Public rental housing is built on local government's asset land, and further, the local government will operate the public rental housing. However, it still needs central government's involvement in financing using some financing platforms. Cooperative GT would be used to obtain the best strategies in the operational stage, which involve the local government, central government, and housing developers.
6. Determining the commercial and residential area
   In order to raise the project's financial viability, a commercial area is built. Furthermore, the existence of commercial units is expected to support the daily needs of the tenants. However, the type and number of commercial units should be defined to obtain the optimum net present value.

Using game theory as a decision-making support tool in allocating financial risk

Players and rules

Relevant stakeholders in the housing sector include public rental housing tenants, government ministries, local governments, and housing providers. There are two players minimum for GT. Therefore, according to the required players to implement GT, the players could be defined as follows:

Player 1: Government (ministry and local)
Player 2: Private housing developers

Research conducted by Liu (2022) related to government-subsidised rental housing, which attempted to involve non-government organisations to build and operate public rental housing. Therefore, there are three players: the government, market, and society.

Meanwhile, some studies related to financial risk allocations on public private partnership (Jin, 2019; Xiao, 2019; Xie, 2022), showed that normally there are two players: the government and private sector. The sample case of those studies including determining the length of the concession period to control private investors' profit within a reasonable range while achieving a fair allocation of financial risk between governments and private investors. Another case is financial risk allocation in village projects. The outcomes also indicate that, before determining the optimal length for the concession period, governments may need to make a choice between better financial risk allocation or stringent profit control for private investors.

Type of game

Table 2. Type of GT for solving public housing issue

	Cooperative	**Non-cooperative**
To model the portion of subsidised and non-subsidised unit	**v**	
To determine most suitable government subsidy, which reduce the investor's capital investment	**v**	**v**
To model the portion of commercial area among residential area	**v**	
To calculate the length of concession period	**v**	
To model the portion of subsidised and non-subsidised unit	**v**	**v**

As previously mentioned, in cooperative GT, all players are coalited (Wang et al. 2022). In order to raise public rental housing supply, the government supports private sector investment. The most commonly used type of game is incentive mechanisms. Incentive measures are used for investors with different kinds of profitability outlooks or applied to different stages of a project. Players act together as any entity improve their payoff in the game (Abapour, 2020). In the context of partnership on public housing provision, there should be a risk sharing mechanism. In a collaborative game among the government, market, and society (Liu, 2022), the three subjects constantly adjust their strategy choices and finally reach the collaborative supply stage of government intervention, market, and social participation.

Nguyen et al. (2013) used a cooperative GT approach in their study to solve risk allocation. Such theory was incorporated with agent-based concepts to obtain the mentioned interests between producer/consumer agents and network agents. Meanwhile, Jia and Yokoyama (2003) employed cooperative GT for allocating profit to independent power producers, where a novel method was proposed for formation of coalition in retail markets. The results of that study found that more profit will be attained by the cooperation of producers concerning their competition. These two strategies could be adopted for public rental housing to determine the proportion of commercial and residential area to achieve more profit.

Game strategy and payoff

Cooperative strategies mainly discuss the best strategies to be formulated and what payoff could be achieved. In a partnership where the government provides an incentive to investors in government projects, the strategies include a form of guarantees. A simple incentive mechanism is proposed: the government will pay a bonus to investors if they make every effort to complete the project and will penalise them if they are found to exhibit speculative behaviour (Wang et al. 2019). The options were government chosen to establish incentives, meanwhile the investors exhibited a high level of effort, and vice versa.

Commonly, partnership project cases use a cooperative game, as each player is coalited to improve their payoff in the game to ensure a win-win solution. A non-cooperative game in partnership is mostly used in conditions to decide the partners (Ouenniche et al. 2015). Furthermore, these conditions could be conducted using perfect or imperfect information. However, perfect information is a common cooperative game, as each players knows its opponent's payoff functions.

5. Conclusion

Partnerships between governments and private housing developers for public rental housing provision to low-income tenants are challenging, as the investment should not only affordable for tenants, but also feasible for housing developers. Therefore, governments do not need to grant higher subsidies for public rental housing operation. Financial risk is considered high risk, as well as cost recovery. Strategies can be used in order to allocate financial risk in terms of subsidy and cost. The game theory approach is defined as an effective concept for handling decision making processes of different sciences. Some studies related to financial risk allocations were found for some sectors, such as green building, toll roads, and power plant.

This paper provides some strategies based on the application of the game theory approach for decision making associated with public rental housing. First, the basic foundation and use of game theory for the above-mentioned sciences was introduced. Then, the basic concepts of game theory for cooperative/non-cooperative, symmetric/asymmetric, zero-sum/non-zero-sum, simultaneous/sequential, perfect information and the imperfect information were introduced. Moreover, applications of these concepts for the accomplishment of financial risk allocation for public rental housing were analysed and discussed in detail. The contribution of this paper in the area of application of game theory to public rental housing provision problems can effectively help researchers in decision making for such systems.

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