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-RESEARCH ARTICLE-

GAME THEORY: HISTORICAL OVERVIEW AND SYNTHESIZING CRITIQUE

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─Abstract─

According to scholars, the period of intense activity in evolutionary game theory in the mid to late 1990s had two goals, firstly to justify Nash equilibrium and secondly to give some consistent and simple the selection criterion for favouring some Nash equilibria over others. Therefore, the primary goal of this paper is to provides a historical overview, synthesis and critique of the game theory. However, we find that game theory is the most appropriate approach for making decisions in the fields of construction, engineering and project management in order to solve the problem of rivalry in real life. Game theory is also found to be particularly useful for multi-criteria decision-making as well. Game theory assumes that each player has information about the actions of the other players. In addition, the review shows that many scholars have been conducting studies into different research areas and the game theorem has been applied in a wide and varied range of discipline, including computer science and logic, political science, project management, economics, business, and many other fields. It is clear that game theory has played an important role in the development and practical application of construction, as well as in many other fields. However, this theory has been surprisingly less used in some other areas. For this reason, this study is important for providing guidance and insightful information for future and hitherto unexplored research areas.

Keywords: Game Theory, Economics, Review, Historical Overview, Synthesizing, Critique

1. INTRODUCTION

Game theory is the best method for evaluating the dynamics of a circumstance in which the decision of multiple agents affects the reward of each individual agent. Game theory deals with synergistic optimization problems. Many economists have worked using the game theory model for a few decades now. John Neumann and Oskar Morgenstern were two prominent names who can take fair credit as the founders of advanced game theory. In their modern handbook, "Theory of Games and Economic Behaviour" (Morgenstern, 1994), they summarized the basic principles of game theory as developed at that time. Different authors have explored the various concepts of game theory, including the concepts of equilibrium, games with imperfect information (Kuhn, 1953) cooperative games (Aumann & Hart, 1992; Marden & Shamma, 2018) and auction games (Vickrey, 1961). Game theory has been successful in many areas, disciplines and fields. From 1970 to 2000, game theory was the most popular approach for analysing conditions, and it was being increasingly used in economics as well as in law.

As game theory moved through economics and related philosophies, one of its many benefits has been new insights into central business rivalries. Game theory is dependent on operational research. Different authors have suggested different classifications of the operational research process, and these are not meant to be fixed classifications.

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Operational analysis approaches such as multi-criteria, multi-attribute, and multi-objective decision-making methods are used in game theory. Reasonable decision-making is guided by Multiple Criteria Decision Making (MCDM) approaches and is focused on the weak rationality of single-objective optimization problems (Inamdar et al., 2018; Yanie et al., 2018; Zionts, 1990). The method for solving a problem is different for different features. This difficulty is solved by applying MCDM in small alternative numbers, and the alternatives are evaluated based on the measurement of group performance (Marttunen, Lienert, & Belton, 2017). Complex evaluations may also be successfully made if one-third of the attributes of several parameters are available (Mareschal, 1986). Convenient means are considered when studying disputes in games. The term “game theory”, which is an initiated branch of science, was introduced by Neumann (1928).

Over time, game theory has come to include an analysis of how a social state changes when agents change their strategies. Agents are bound by rationality, in keeping with a more natural interpretation of human mentality and psyche. The process by which they select their actions on the basis of some simple behavioural rules is called revision protocol. An evolution is then triggered by the revision protocol, a derivative equation system which typically includes a description of how changes occur in a social state. For example, a protocol that is initiated by a current dissatisfaction with reward involves a number of imitators of selected populations, who randomly mimic each other’s behaviour. The most popular evolution is created by the dynamics of the replicator (Taylor, 1978). If the reward for an action exceeds the mean reward for all the strategies, then the relative agents’ plan increases a particular behaviour in these dynamics.

A decision analysis involves a game theory approach to the problem of setting up a package to capture a contract that has been achieved in a recent publication (Mishra & Smirnova, 2021; Hassan, et al., 2020). It has been argued that a game theory approach is required for the proper modelling of a problem; and that an organization that applies a decision analysis approach will not gain as much as an organization that applies a game theory approach. There is a fair distinction between the fields of game theory and decision analysis within these debates, and it is important to differentiate between the two. For instance, a decision analysis focuses on a single decision maker facing an uncertain environment, whereas game theory also examines the strategic interaction between decision makers.

Game theory has four features that are the counterparts of the key attributes of decision analysis, namely, the collection of strategies, the moves of nature, the mapping of payoffs, and the concept of equilibrium. However, unlike decision analysis, game theory has the following two elements, namely, the other players, and the dependence of the payoffs on the actions of the other players. Thus, having many players does not necessarily mean that a game theory analysis is required. A decision analysis can, in many situations, be equivalent to a game theoretical analysis because, in many cases, it

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is possible to model the dependence of the payoff on the actions of the other players as chance nodes (Marx, 2007). This study particularly elaborates on and describes game theory, its types, history and applications in various areas, and in different studies and businesses.

1.1 Game Theory

According to Tamosaitiene (2010), who did a wide review of game theory, a letter written by James Waldegrave in 1713 was the first known discourse on game theory. In it, Waldegrave offered a minimum-maximum mixed strategy solution to a two-person version of a card game. In 1913, a skilled mathematician from Germany named Ernst Zermelo published “Uber eine Anwendung der Mengenlehre auf die Theorie des Schachspiels”, after which, game theory made a comeback in the modern era. He proved that every two-person competitive game has an action that is best for two players, where both are provided with complete information about each other’s aim and orientation. Each player knows about his own strategy and reward, and also about those of the other player (Turskis, 2010). Zavadskas, Peldschus, Ustinovičius, & Turskis (2004) presented a classification of game theory, as shown in Fig.1, together with the progress of game theory (Borel, 1921; von Neumann, 1928). A contradictory orientation was introduced by von Neumann and Morgenstern (1944). They focus on the perfect and imperfect concepts of information, while acknowledging that each player is fearful of the other player’s action. Moreover, game theory focuses on a finite number of players and distinct games. A problem only becomes theoretical when there are two or more players. Luce & Raiffa (1957) analyses games with an infinite number of players. They developed a model in which a single person is better than others. Arrow et al. (1951) particularize an elementary minimum-maximum rule.

1.2 Types of Game Theories

1.2.1 Cooperative/non-cooperative

Gameplay is typically conducted in the players' own self-interest, even when the players work together to achieve a common goal; collaboration is the most effective strategy under the circumstances for maximising individual payoffs for the players. In such games, cooperative behaviour, if it does occur, is motivated by selfish interests and is only temporary in nature. These kinds of games are referred to as "non-cooperative games." Non-cooperative game theory is a branch of game theory that studies games in which players do not cooperate with one another. When playing a cooperative game (or coalitional game), players band together to create coalitions or groups (typically in response to external pressure to cooperate), and the competition is between these coalitions (Bashir, Mahnaz, & Malik, 2021).

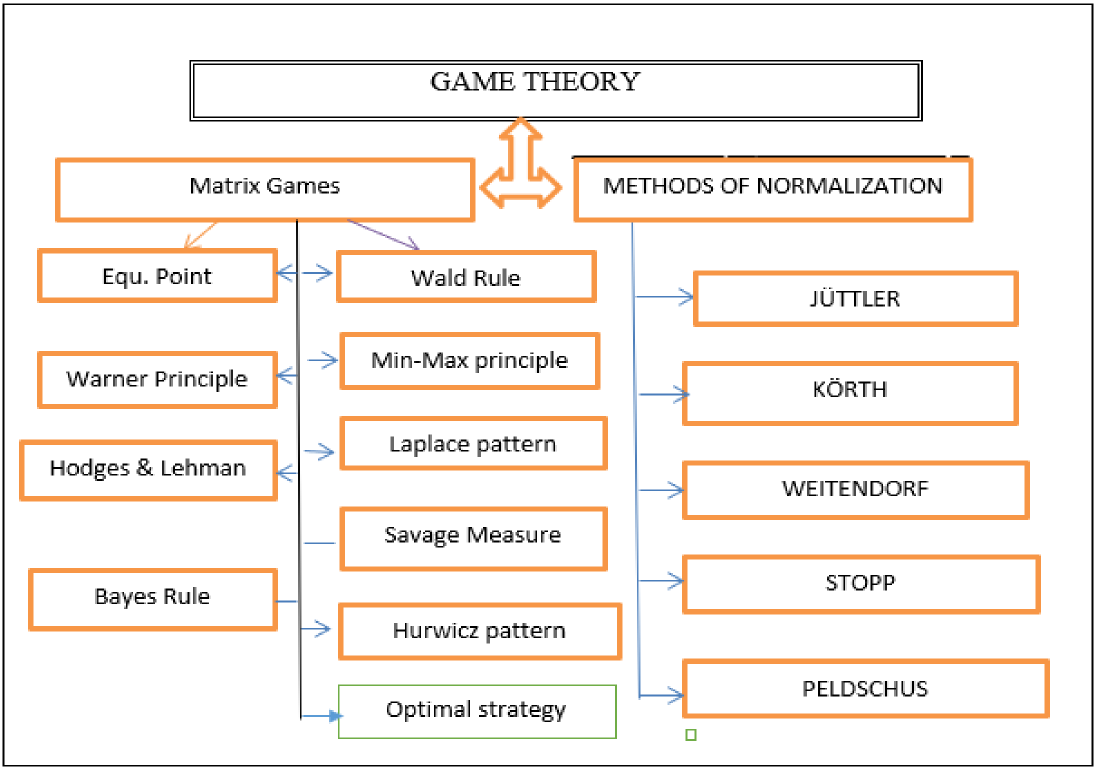

Figure 1. Depiction of game theory by Zavadskas (2004)

Cooperative games are studied through the lens of cooperative game theory, which predicts the formation of coalitions as well as the payoffs that result from these coalitions. Cooperative game theory is concerned with the distribution of surplus or profit among coalition members in situations where the coalition is guaranteed a specific level of pay-off as a result of the formation of the coalition. A cooperative game performed in a system is frequently identical to the conclusion of a limited optimization process (Bellhouse, 2015), and as a result, many the studies we analyse use a linear programming framework to solve the cooperative games they describe (Sohrabi & Azgomi, 2020).

2.1.2 Symmetric / Asymmetric

Symmetric games are those where the reward for applying a specific strategy depends solely on the other strategies that are applied, and not on who the players are. This means that if the rewards for applying the strategies remain unchanged when the identities of the players are changed, then the game is a symmetric game. Symmetric games that are normally studied are of the 2x2 kind. Some common and standard examples of symmetric games are Chicken Dilemma, the Prisoner's Dilemma, and the Stag Hunt (Abapour et al., 2020; Elhadef, 2017).

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More specifically, in a symmetric game, all of the participants are aware of their opponents' preferences. While in the asymmetric game, the participants have asymmetric information about each other's preferences, in the symmetric game, the converse is true. The simplified models of symmetric and asymmetric games are shown in Figures 2. It is assumed that player A is aware of the preferences of player B, whereas player B is unaware of his opponent's preferences; in other words, player A has entire knowledge, whereas his opponent does not have complete knowledge. The Bayesian game (Abapour et al., 2020) can be used to model this issue in detail.

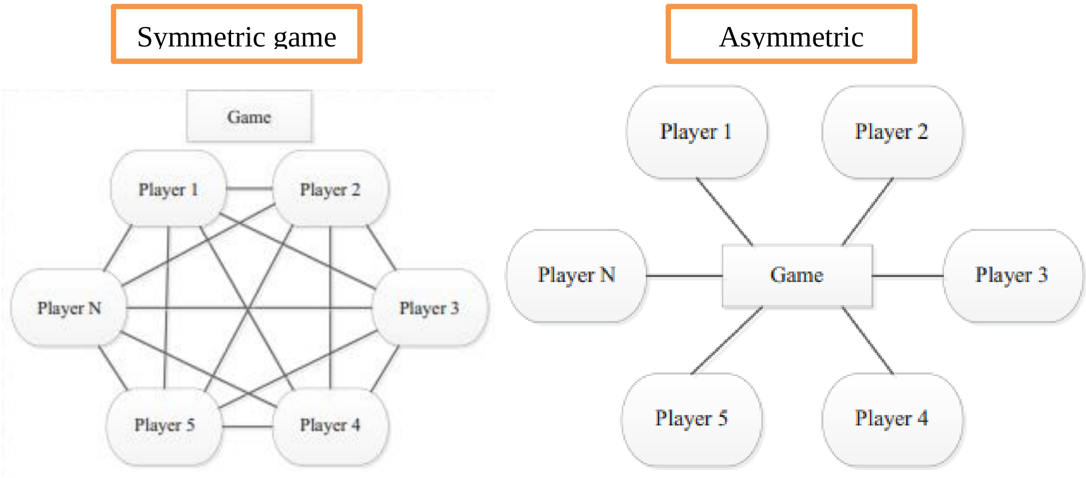

Figure 2. Simplified models of symmetric and asymmetric games (Abapour et al., 2020)

1.2.2 Zero-Sum / Non-Zero-Sum

Games with a zero-sum outcome are strictly competitive, while games with a positive outcome allow for the possibility of both players winning. In a zero-sum game, the sum of all payoffs received by a decision maker or group of players equals the sum of all losses received by that decision maker or group of players for every possible conclusion of that game (Abapour et al., 2020). Those games in which one player's gain does not necessarily equal the loss of another player are referred to as non-zero-sum games. In other words, the gains and losses in a non-zero-sum game do not always total up to zero while the game is played. The Prisoners' Dilemma is a famous example of a non-zero-sum game that is still used today. Non-zero-sum games, in contrast to zero-sum games, will not be fully competitive, allowing for a wide range of degrees of cooperation to exist within them. The strategy of each player can change as a result of the degree to which the players cooperate with one another during the game (Başar & Zaccour, 2018).

More specifically, if the participant's selection cannot increase or decrease the allocated resources, the game is called a zero-sum game. The total gain for all the players for all combinations of strategies in a zero-sum game is always zero (Newton, 2018). Some

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examples of zero-sum games are poker, where a player wins precisely the amount that is lost by his opponents, matching pennies, and many traditional board games like Go and chess. Game theorists have also studied many non-zero-sum games because the final results are usually greater or less than zero. In other words, a gain by one player does not necessarily result in a loss by another.

1.2.3 Perfect Information and Imperfect Information

Perfect information games are a crucial group of sequential games. In a perfect information game, all the players are aware of the earlier moves of all the other players. Studies into game theory have mostly focused on perfect information games such as checkers, infinite chess and Go (Young & Zamir, 2014). Meanwhile, many card games such as poker and bridge are imperfect information games (Newton, 2018). Perfect information is not to be confused with complete information, although they both share a similar concept. For there to be complete information, every player must know the strategies and rewards available to the other players but need not know the actions taken. However, incomplete information games can become imperfect information games by bringing in "moves by nature" (Dastyar & Pannek, 2019; Tehseen, et al., 2020).

1.2.4 Combinatorial Games

Combinatorial games, for example chess and Go, are those in which it is difficult to find an optimal strategy from among a range of potential moves. Imperfect information games such as backgammon have the potential to be strongly combinatorial in character. There is no integrated theory on combinatorial elements in games, but there are certain problems that can be solved and general questions that can be answered by means of mathematical tools (Bewersdorff, 2021). Combinatorial game theory has been used to study perfect information games, leading to the development of new representations, for example, surreal numbers, and combinatorial and algebraic methods to solve particular types of games, including "loopy" games that generate a substantially long series of moves.

These methods are used for games with more complex combinatorial elements than those that are commonly considered in game theory (Albert, 2007). Hex is a typical strategy board game that is solved in this manner. Game complexity is a field of study that has emerged from the computational complexity theory and it seeks to estimate the difficulty of computing optimal strategies (Miller, 2017).

1.3 Evolutionary Game Theory

Evolutionary game theory is used to study players who adapt their strategies over a period of time to suit rules that need not be rational or forward-looking (Newton, 2018). In general, the development of strategies over time based on such rules follows a Markov chain model with various conditions such as the present strategy profile or how the game has been played recently. Such rules may be characterised by imitation, optimization, or

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survival of the fittest. In biological terms, these models can indicate evolution, where the offspring assume the strategies of their parents, and parents with more successful strategies have more offspring. Such models in social science usually represent strategic adjustments by players who, in their lifetime, play a game many times, and change their strategies now and then, either deliberately or unintentionally (Uchihara, Webb, & Yanagisawa, 2019).

1.4 Non-cooperative Static Games

Games in which the players select their actions at the same time and are thereafter attached to their chosen strategies are called non-cooperative static games. In non-cooperative static games, participants choose strategies at the same time and are then committed to the strategies they have chosen (Abapour et al., 2020). The solution notion for these games was formally established for the first time by John Nash (1950), however there have been some instances of comparable concepts being used for several centuries prior to that. Best response functions are the most effective way to describe the notion. Examples of these are coincidental motion and single-crack games. Non-cooperative static games seek intellectual forecasting of how a game will be played in practice (Amin et al., 2020). The solution concept for these games was officially presented by Nash (1960).

1.5 Setup of Games

Basic game theory annotations are introduced as the background to this section. For the sake of brevity, some details in the review paper have been intentionally left out. More precision is required in the texts. The games are described here in their normal form. In normal conditions, a game consists of three strategies. First, the players are indicated by I = 1 to X; second, the actions or, most commonly, a collection of actions, are expressed as Ni, I = 1 to N, for every player, and third is the reward ∑i (n1, n2, Nn), I = 1 to N obtained by every player. Every action is outlined as a collection Xn, xn ∈ Xn, thus, it is called Xi × Xii ×⋯× Xn, at the place of action. Every playing member may have a one-dimensional action or a multidimensional action. Every action is outlined as a collection Xn, xn ∈ Xn. For this reason, it is claimed that Xi × Xii ×⋯× Xn is the place of action in large supply chain management applications. Every player has a multidimensional strategy or a one-dimensional strategy. That is why one-dimensional strategies were adopted expressly or implicitly in this review paper.

From a set of strategies, a player can randomly select any action or a particular strategy. A player can select an unmixed action in any form or sometimes players can select mixed strategies. Mixed strategies can be used in marketing and economics for research frameworks and for publicity frameworks (Melzack & Casey, 2013). However, mixed strategies have yet to be applied in supply chain management as it is still unclear how this can be done, as, for example, it would be absurd for the senior manager of a company to “flip a coin” to decide between different levels of capabilities. A mixture of actions

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with unique pure strategy equilibrium does not subsist in games. Therefore, the tendency would be to control unmixed actions within the general confines of those games. Hence, in this review paper, only pure strategies were considered, where the players are unable to make binding commitments before choosing their strategies in a non-cooperative game but are able to make binding commitments in a cooperative game. Therefore, they are able to make side-payments and form alignments in a cooperative game.

1.6 Nash Equilibrium

In game theory, the Nash equilibrium is a proposed solution of a non-cooperative game. It was named after the mathematician, John Forbes Nash Jr., and involves two or more players, where it is assumed that each player knows the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy (Marden & Shamma, 2018). In terms of game theory, if each player has selected a strategy, and no playing member can increase his proportionate reward by changing his strategy while the other playing members maintain their strategy, then the current collection of strategy choices constitute Nash equilibrium. This concept of the Nash equilibrium has been used for the analysis of hostile situations such as wars and arms races (Schelling, 1960, 1980) to determine how conflicts may be mitigated by recurrent interactions. It has also been used to study the extent to which people with different partialities are willing to cooperate, and to take risks to achieve a final cooperative outcome.

1.6.1 Existence of Equilibrium

A first-order system is in Nash equilibrium or there may not be equilibrium. A conceptual problem probably arises with the nonexistence of equilibrium because the outcome of the game is unclear. Nevertheless, the Nash equilibrium exists in many games, and there are some rational and simple methods to show the strategies for at least one Nash equilibrium. The Nash equilibrium gives a fixed point for better planning. Therefore, a fixed-point equilibrium theory can be used. According to Brouwer (1990), there are three key fixed-point theorems. However, it is quite difficult to directly apply these theorems and that is why it is generally not done. Nevertheless, Li (1997) and Groenevelt (2001) conducted validations that were dependent on Brouwer's fixed-point proposition. Alternative players derived from this fixed-point hypothesis have been developed since. The verification of the concavity of players' rewards is the simplest and the most frequently used technique for demonstrating the existence of the Nash equilibrium.

The following is a formal definition of Nash equilibrium in mathematical terms. Let *(S, f)* denote a game with n players, where Si is the strategy set of the player i with the specified number of players. In this case, $S = S_1 \text{ x } S_2 \text{ x } S_3 \text{ x } S_n$ would be the strategy profile comprising of the strategy sets of all players, and S would be the profile consisting of the strategy sets of all players. Suppose that the pay-off function for strategy set $x \in S$ is defined as $f(x) = (f1(x), \ldots\ldots, f_n(x))$. Let us suppose that strategy x_i is the strategy set of all players except for player *i* as a result, when each of the players $i \in 1, \ldots\ldots, n$ chooses strategy x_i, the strategy set $x = (x_1, \ldots\ldots., x_n)$ is produced, the player receiving the pay-off $f_i(x)$ is determined by both the strategy chosen by that player (xi) and the strategies chosen by the other players (x_{-i}). $x^* \in S$ is in Nash equilibrium if no single player's unilateral divergence from the strategy would result in a better utility for that player [38]. Nash equilibrium is achieved if is satisfy the following equation.

$$\forall i, x_i \in S_i : f_i(x_i^*, x_{-i}^*) \geq f_i(x_i, x_{-i}^*)$$

1.6.2 Uniqueness of Equilibrium

It is quite useful to have a game with a unique Nash equilibrium from the perspective of generating qualitative insights to characterize equilibrium actions that are not accompanied by much equivocalness. The existence of equilibrium is generally much stronger than demonstrated in Oddity. Several methods for proving the uniqueness equilibrium are provided in this section. There is no simple method, and all of them may have to be attempted to find the one that works. i.e., the existence of the Nash equilibrium must be shown separately. Furthermore, one should be careful to recognize that these methods assume the existence of equilibrium. Finally, the best response of the game function and the unique result of the Nash equilibrium in super modular games is that there is no general method.

1.6.3 Multiple Equilibriums

The best situation is to have a few equilibriums because many gamblers would demand a new equilibrium. Rational players need a number of equilibriums, while no equilibrium at all would be the worst situation. When the players do not know which problem to avoid with the equilibrium, the obvious problem will be the one with multiple equilibriums. Therefore, there will be no equilibrium outcome because one player would have a strategy for one equilibrium, while it would be entirely possible that a second player would select a member connected with equilibrium. It is possible that the players would finally find themselves in one specific equilibrium when a game is repeated. Moreover, that equilibrium may not be the most suitable one. It could be argued that one equilibrium is more sensible than the others when there is no desire to admit the alternative of different consequences due to several equilibriums. For example, there may be only one collective equilibrium, and one may decide to debate that asymmetric equilibrium (Wan, Britto, & Zhou, 2020). Additionally, it is mostly not too difficult to certify the uniqueness of a symmetric equilibrium. The first-order system and multiple conditions can be reduced to a single equation when the players have one-dimensional strategies, where to prove the symmetric equilibrium is unique, one need only show that there is a unique solution. A symmetric equilibrium can be discovered to reduce and

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determine whether a system of equations has a compound solution when the players have m-dimensional strategies, where m > 1.

2. METHODOLOGY

The selection of papers for inclusion in this review was accomplished in a number of stages. After identifying the journals that were identified in the first stage, major research publication data-bases such as “Ebsco”, “Emerald”, “JSTOR”, “ABI Inform”, and others were used to locate the journals that were identified in the second stage, and relevant research studies regarding game theory were selected for review. Second, the references offered in the research studies picked in the second step were browsed through, and relevant research studies were then studied at length in the third and final stage.

"Game Theory" was the term that was used in the search. In order to begin, a search was conducted for research publications that contained the aforementioned keyword in their title or abstract. Second, the abstract was reviewed and, if it was deemed relevant to the topic, it was included. Only research papers that had been published in peer-reviewed journals were considered for inclusion in the study. After this, the research articles were coded in order to make the review process more efficient. Later on, each research report was carefully studied to ensure that the research topic and methodology employed were understood. Based on the research topic that was indicated in the research articles, they were divided into a number of different themes to consider. The different criteria that were used to arrange the research papers, as well as detailed information about the articles, were recorded into a Microsoft Excel worksheet to make the review process more efficient and systemized overall.

2.1 Comparative Statics in Games

In modern game theory models, just as in the non-competitive supply chain management system, different results and targets are achieved through comparative statics, such as unconditional desirable settlements.

2.2 Dynamic Games

2.2.1 Simultaneous Moves: Repeated and Stochastic Games

Dynamic games occur when both players take action in different forms in several time periods. Local additions to these stock models should be multi-period games because these stock samples that are used in SCM literature usually include inventory replacement decisions that are made over and over in the game. Two major forms of time period games that exist are those that are time-dependent and non-time-dependent. A multiple game is a game that is repeated over and over by the same player. At all periods of time, every player has strategies in a series of activities, where new vendors select a strong quantity for the first time, demand is felt, and then, to recover the surviving stock, more than the one-time version of the new vendor game has to be

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considered. In such cases, if the player took the entire time previously to memorise the action to be taken, then there will be no relationship between other successive periods. It is the rule in an SCM setting to consider that there is no relationship with the game; logically, in SCM, there are few conversions of inventory and/or comebacks between periods, although more than the one-time game has been broadly analysed in economic literature. As a result, many applications in SCM literature have a repeated game, and thus variations have not been found in which characteristic effects have been analysed as the mean of activities of the organization in place of the exclusively traditional contract (Hamdan & Diabat, 2019; Uivarosi & Munteanu, 2017).

2.2.2 Differential Games

So far, dynamic games have been described in only one game time, i.e. the games including a series of decisions split in time. Distinctive games hand over a pure expansion for a decision that has to be built forever. It is natural to consider that differential games should find various applications in SCM literature because many SC models rely on continuous progress in time. However, often the SCM model involves probability in one form or another. Only the method for determining the differential model in SCM is known due to logical difficulties implicit in differential games. Applications are actually limited, according to Olsder (1995). In these areas, marketing and economics have been more lucrative by far in applying differential games because they are invaluable in determining the pattern. Hence, some new concepts are compulsory to realize the theory of differential games.

2.2.3 Cooperative Games

Developments have been made in formative work with regard to the subject of cooperative games (Neumann, 1944). However, the literature in economics, including non-supportive and cooperative game theories, has not been considered for a long time. Nevertheless, they are becoming more famous in the context of studies on supply chain management. Researchers are employing the supportive game theory in their papers.

Compared to non-supportive game theory, the cooperative game theory signifies a major shift: where previously, the attention was on the distant actions of players, the games in this form were valued but did not specify the move that each player, as a subset of players, would make. Hence, the process could at times be challenging to decision-makers. In supportive game theory, the players agree to a pattern of results for a complex business e.g. discussions, and answers to more unusual questions from the opposing firm (Nagy et al., 2018). However, as will be discussed, there are also boundaries to supportive game theory.

2.3 Biform Games

Biform games, introduced by Brandenburger (2006), are for rewards. These are win-or-die cooperative games, and can be considered as non-supportive cooperative games. A

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group of players are associated with biform games, similar to the non-supportive games (supply chain management function in biform games), where a cost application is associated with each strategy and there is also a set of strategies for each player. Biform games have been successfully accepted by several supply chain management players (Bartoletti et al., 2017). These games are at their own location as well as at many integrated locations, where multiple retail stocks are held. A strong retailer decision is made at the first stage (non-cooperative). In the second stage, which is the cooperative stage, an assessment is made as to how the results can be stabilized to obtain extra profits and to transfer more stock between locations from one ship to another for better supply and demand. The retailer observes the demand (Bartoletti et al., 2017). This game has an uninformed compulsory inference with regard to a necessary characteristic. However, it has been found that the rent distributor in the biform games base is not vacant.

2.4 Signalling Games

In its simplest form, a signalling game has two players, one of whom has better access to data than the other. It is the player with the improved data that makes the first move. For example, Bolandifar, Feng, & Zhang (2018) designs a pattern with one supplier and one fabrication. The producer had a better demand prediction than the supplier that the latter must build his capacity for a key component to the processed product. For the database to continue, some meaning, and ideas are needed, whereas the reader should refer to Bolandifar et al. (2018) for the facts of the game. The manufacturers have the complete information and demand forecast.

2.5 Screening Games

In screening games, a player lacks more information about the other, for example, the supplier, who is offering a contract. There are a variety of screening games with promises by suppliers, as described by researchers (Bolandifar et al., 2018). In fact, the agreement is selected via a list of options from the supplier to get the attention of the manufacturer. In economic literature, the supplier pays a charge for designing a structure to gain information about the manufacture, which is why the design structure is mentioned. The screening game by De Giovanni (2020), which closely resemble this one, is one example.

2.6 Shapley Value

The core idea is that some unsatisfactory properties are automatically attractive, for example CSR (Al Halbusi, & Tehseen, 2017). As mentioned, some compulsory moves are empty ones, but for some reason, there is the desire to find ideas for unrepeatable outcomes in supportive games, or to have a unique solution in non-supportive games (Shapley, 1953), and therefore, roles are offered and followed to solve ideas based on those roles. Firstly, a player's provision should not be taken as the player's value, i.e. what matters is the player who has been indicated as the assigned player, and not the player's roles. Second, a player is adding a value to generate a benefit or, in other words,

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if the partnership is zero, the added value of the player should not be given by the partner (Al Halbusi, et al., 2020).

3. COMPARISON OF GAME THEORY APPROACHES WITH DIFFERENT POINTS OF VIEWS

Debates on two-player games were held long before the growth of mathematical game theory, with the first known debate on game theory having taken place in 1713 in a letter supposedly written by Charles Waldegrave, an active Jacobite and uncle of British diplomat James Waldegrave (David, 2007). However, the true identity of the original writer is unclear in view of the limited details and proofs available, and the subjective nature of its interpretation. One theory suggests that Francis Waldergrave was the actual writer, but this has yet to be verified (Bellhouse, 2015). In this letter, Waldergrave came up with a minimax mixed strategy solution for a two-player card game, and today, the problem is known as the Waldegrave problem. A solution was also presented in 1838 in Recherché sur les principles mathématiques de la theories des richesses (Researches into the Mathematical Principles of the Theory of Wealth). In 1913, Ernst Zermelo published the Über eine Anwendung der Mengenlehre auf die Theories des Schachspiels, which proved that the best chess strategy is rigorously determined. This paved the way for more general theories (Zermelos, 1913). In 1938, Frederik Zeuthen, the Danish mathematical economist, used Brouwer’s fixed point theorem to prove that the leading strategy lies in using a mathematical pattern (Kim, 2014). In his book, Applications aux Jeux de Hasard, written in 1938, and in his previous notes, Emile Borel verified a minimax theorem for two-player zero-sum matrix games when the reward matrix is symmetrical, and provided a solution to a non-trivial infinite game. Later, von Neumann proved that the claim that a mixed strategy did not exist in finite two-player zero-sum games was false.

Until 1928, when von Neumann published his paper, which led to a standard method in game theory and mathematical economics, game theory did not actually exist as a set of unique fields (Neumann, 1928). In his original verification, von Neumann used Brouwer's theory on the continuous mapping of fixed points into a compact convex set. This led to the publication of his co-authored book, Theory of Games and Economic Behaviour, in 1944. The second edition of this book carried an axiomatic theory of utility, which revives the old theory of utility of money by Daniel Bernoulli as a separate discipline. This book represents the culmination of von Neumann’s efforts at game theory and presents the underlying basis for a way to find solutions that are mutually consistent. Later on, he focused his attention mainly on cooperative game theory to analyse the best strategies for groups of people on the assumption that they are able to reach agreement about the right strategies (Kawasaki, Wako, & Muto, 2020).

The first mathematical discussion of the Prisoner’s Dilemma was held in 1950, when the renowned mathematicians, Merrill M. Flood and Melvin Dresher, conducted an experiment as part of the investigation into game theory by the RAND Corporation in

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view of its potential application in nuclear strategies worldwide (Epstein, 2007). At the same time, the Nash equilibrium was developed by John Nash to determine whether the strategies of players are mutually consistent. The Nash equilibrium in mixed strategies is possessed by every finite n-player in a non-zero-sum, non-cooperative game. There was a lot of excitement about game theory in the 1950s, when repeated games, the Shapley value, and core concepts were developed. It was also during this period that game theory was first applied to political science and philosophy. Robert Axelrod attempted to design computer programs to function as players in 1979. He discovered that in tournaments, the champion was frequently a simple "tit-for-tat" program that worked together on the first step, but in the following steps, did whatever the opposing player did in the previous step. In fact, natural selection also often produced the same winner, and this is often used to explain the phenomenon of cooperation in evolutionary biology and social science (Wolfram, 2017).

4. GAME THEORY APPLICATIONS

Game theory has been applied in different fields since 2004 (Gao et al., 2019) such as in economics (Chakrabarti & Topolyan, 2009); in conventional rail systems (Hsu, Lee, & Liao, 2010); for idea designs (Hu and Rao 2009); for active market analysis (Kacprzak, Palka, Kaleta, Smolira, & Toczylowski, 2010); for cooperation among several team agencies (Cheng et al., 2019) for software markets (Tan et al. 2010), and for production (Liu et al., 2018). Game theory has various applications. It has been applied to solve problems in construction engineering and management (Zavadskas, Peldschus, Ustinovičius, & Turskis, 2004). An equilibrium model was proposed to set up a public urban traffic network (Sun & Gao, 2007). It has been used to measure the performance, and to allocate and analyse the cost of joint risk capital (Jensen & Sørgard, 2016). In construction management, game theory has been reviewed as a function of experience (Peldschus, 2008), and has been applied in technology and management (Elbert & Franzke, 2014), inanalysing the allocation of prices (Meszek, 2008), for analysing investment projects (Tamošaitienė, Turskis, & Zavadskas, 2008) and calculating different levels of risk in the selection of contractors (Gu et al., 2018), and to measure the risks involved in site selections (Turskis, 2010). Professor Friedel Peldschus is one of those exceptional authors who have extensively worked on game theory as a function of construction engineering and management. His achievements have been further reviewed.

4.1 Game Theory Application in Economics and Business

Mathematical economics and business use game theory mainly for modelling the rival behaviours of interacting agents (Martin, 1981). A wide range of economic functions and methods are included in its applications, such as auctions, bargaining, mergers and acquisition pricing (Agarwal & Kwan, 2017), fair division, duopolies, holdings, social network formation, and economic computing based on agents (Morovat, 2017). Thus,

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the main focus of this discipline of research is on particular sets of strategies called "solution concepts" or "equilibria". It is usually assumed that players act in a rational manner in non-cooperative games. If every player represents the best response to the other strategies, then that set of strategies is a Nash equilibrium. If all the players are using the strategies in a Nash equilibrium, they have no one-sided motivation to deviate because their strategy is the best they can do after taking into account what others are doing (Hart, 1992, 1994, 2002).

The utility of individual players is generally represented by the rewards of the game. In economics, a typical paper on game theory starts by presenting an abstract of a specific economic situation in the form of a game. One or more solutions are selected, and the author shows which sets of strategies in the game are equilibria of the correct type. Two main uses of this information, as suggested by economists and professors of business, are for descriptive and prescriptive purposes (Kagel & Roth, 2020).

4.2 Applications in Project Management

The success of projects is highly dependent on the making of sensible decisions. In project management, the decision-making process of players such as stakeholders, contractors, project managers, subcontractors, governments and customers, is modelled using game theory. Very often, game theory is more suitable for modelling project management situations because these players have rival interests, and at times their interests are directly harmful to other players. A review by Piraveenan (2019) provides several examples of game theory being used to model project management situations. For example, an investor usually has several investment choices, and each choice will probably give rise to a different project. Therefore, an investment choice has to be made before coming up with the project charter. In the same way, in any large-scale project that involves subcontractors, for example, a building project; there is a complex interaction between the main contractor and subcontractors when it comes to decision-making. According to Piraveenan (2019), games involving two players are primarily used to model project management situations, and five different types of games are used in project management, based on the identity of the players.

i. Government sector- private sector games (that model partnerships between the public and private sectors)

ii. Contractor-contractor games

iii. Contractor-subcontractor games

iv. Subcontractor-subcontractor games

v. Games involving other players

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4.3 Application in Political Science

In the field of political science, game theory is applied mainly in areas such as fair division, political economy, civil choice, war bargaining, political theory and social choice theory, which overlap each other. In each of these, theoretical game models have been developed, where the players usually comprise voters, special interest groups, politicians and states. In his book, An Economic Theory of Democracy, Anthony Downs provided examples of the application of game theory to political science (Downs, 1957). One such example was the application of the Hoteling firm location model to the political process. In his model, political candidates bind themselves to ideologies in a one-dimensional policy space. First, he demonstrates how the political candidates will merge towards the ideology that is the choice of the median voter, provided the voters are well-informed. However, if the voters prefer to remain rationally uninformed, then, the political candidates will diverge from their ideology. During John F. Kennedy's presidency, game theory was applied to the Cuban missile crisis in 1962 (Kiryluk-Dryjska, 2016). The stability of any type of political government can also be explained by means of game theory. In the case of a monarchy, for example, the king, as a single individual, is unable to maintain his authority by physically controlling all or the majority of his subjects on his own. Instead, the king exercises control through the fact that all the citizens acknowledge that they are expected to submit to the king. Effectively, the citizens are not allowed to replace the king as conspiracy against the monarch is generally considered to be a punishable crime. Thus, in a model that is a variant on the Prisoner's Dilemma, when a country is stable, no rational citizen will act to replace the king, even if all the citizens believe that it would be to their advantage to act together (Morrison, 2013). According to game theory, democratic peace means that in a democratic country, clear and solid information about its objectives is conveyed to other countries through public and open debates.

On the other hand, when it comes to leaders of non-democratic countries, it is not easy to discover their objectives or the effects of concessions or whether they will fulfil their promises. Thus, if even one party in a disagreement belongs to a non-democracy, there will be doubt and a reluctance to give in to any demands (Spolaore & Wacziarg, 2016).

4.4 Computer Science and Logic

Game theory is playing an increasingly significant role in logic and computer science. Game semantics are at the root of many logical theories. Moreover, games have been utilised by computer scientists for the modelling of interactive computations, and multi-agent systems are based theoretically on game theory (Seifi, 2021). Apart from that, game theory has played a role in online algorithm games, which were previously known as games with moving costs and request-answer games (Algorithmica, 1994). The game theory technique known as Yao's principle is used to prove the lower limits on the computational complexity of randomized algorithms, especially those that are online (See Figure 3). The development of algorithms for discovering equilibria in games,

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computational auctions, markets, peer-to-peer systems, and security and information markets has been spurred by the introduction of the Internet. Economic theory is mixed with the design of computational algorithms and the analysis of complex systems by algorithmic game theory and mechanism design (Lai & Cai, 2019; Halpern, 2008).

4.5 Future Research Directions

Incorporating game theory with economics, business, operational and organizational research, it is possible to provide satisfactory answers to studies of organisational decision-making challenges and characterizations of user behaviour (Al Halbusi et al., 2020; Semsar-Kazerooni & Khorasani, 2009). On the one hand, researchers have proposed a formula and an algorithm that can be used to evaluate the game problem. On the other hand, scholars have proposed a formula and an algorithm that cannot be employed. Participants' diverse gaming behaviours, on the other hand, can be recorded in a variety of organisational situations. Future research topics are proposed for game-theoretic approaches in this section, depending on the inadequacies of current game-theoretic approaches. First and foremost, the most appropriate game model and profit function must be chosen. It is critical that when researchers depict distinct game models in their study, they appropriately map the definitions in each model to one another. Models are deficient in that they do not include complete theoretical analyses. Other issues to consider are the absence of involvement, as well as how to extract the preferences of participants and choose appropriate models and profit functions from their data. Aspects of game theory are not limited to two or three players on a team. A collection of spatial locations on game simulations can be compiled by parties in order to demonstrate the trend of different strategy combinations and to receive the relevant analytical findings.

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Applications of Game Theory

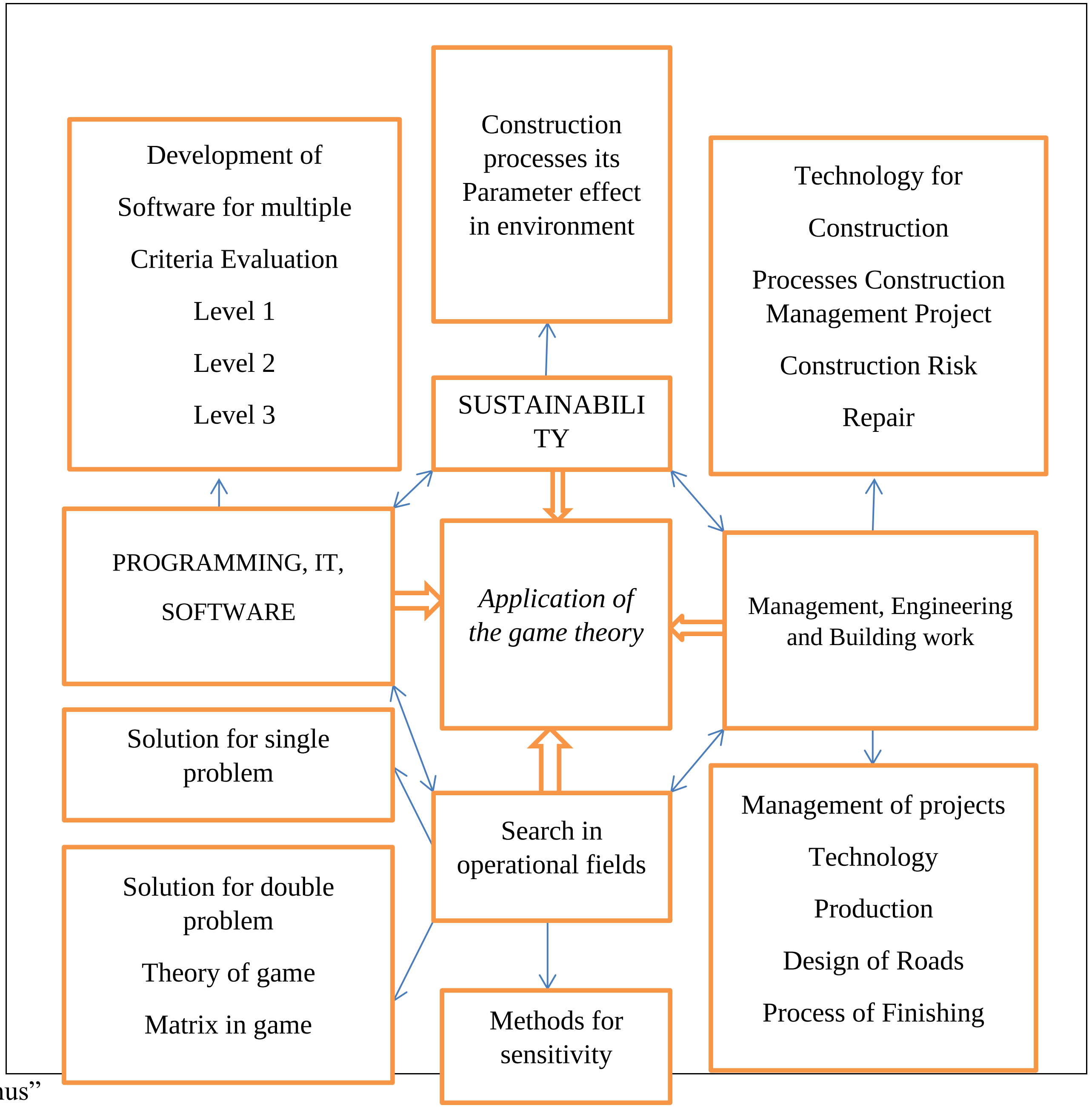

Figure. 3 According to "Professor Friedel Peldschus"

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Second, although game theory has the potential to bring the virtual world closer to reality, it is critical to take into account all relevant elements in order to make future theoretical assessments realistic. The majority of contemporary research has concentrated on mathematical formulas or abstract theories, which may lead to discrepancies between theory and reality. Model factors have a significant impact on the correctness of problem analyses. After taking into account a number of additional elements, various conclusions may be reached. Future research can take stock of a variety of factors, including psychological characteristics, interaction length, emotional fragility, intimate degree of users, and the diversity of the interactive content. The roles change based on the situation; nevertheless, identifying them in real life is challenging. The use of drugs may be considered normal in one group, yet unlawful in another. It is necessary to improve the effectiveness of the integration of the virtual world and reality. Third, it is necessary to increase the accuracy of the sample data analysis. Before undertaking a number of user information data analysis, it is important to perform some preliminary processing. The removal of users who exhibit anomalous behaviour allows us to receive more accurate findings than before. Finally, future theoretical research can benefit from the utilisation of multiple platforms and additional samples.

5. CONCLUSION

As illustrated in other review papers, the acquiring of an operations management for game theory is a slow and time-consuming process. Game theory is best applied in the field of supply chain management, as discussed in this review paper. Some of the concepts of game theory have been discussed in previous reviews and research papers, but in this review paper, the discussion has been emphatically focused on the concepts of non-cooperative static games as well as many other concepts such as cooperative, repetitive, differential, signalling, screening, and symmetric/asymmetric, zero-sum/non-zero-sum, perfect information and imperfect information, combinatorial, dynamic, and biform games. The concept of the Nash equilibrium and the existence of equilibria have also been discussed.

Game theory is the appropriate approach for making decisions in the fields of construction, engineering and project management in order to solve the problem of rivalry in real life. Game theory is also useful for multi-criteria decision-making. In game theory, it is assumed that each player has information about the actions of the other players. In this paper, an attempt was made to discuss the background and history of game theory. The review shows that many scholars have been conducting studies into different research areas and that game theory has been applied to diverse disciples including computer science and logic, political science, project management, economics, business, and many other fields. It is clear from the publications in research journals on the applications of game theory that Professor Friedel Peldschus has made a significant contribution to the developmental and practical application of game theory in

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construction as well as in many other fields. For this reason, a part of this study is also dedicated to his accomplishments and contributions.

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