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***Alina Czapla*** [F]
*Uniwersytet Ekonomiczny w Katowicach*
*ORCID 0000-0001-6027-495X*

# THE GAME THEORY IN MANAGEMENT

# TEORIA GIER W ZARZĄDZANIU

**Abstract:** The game theory (GT) is not only a part of mathematics, but also one of the most popular optimization techniques supporting decision making. Its achievements are currently used in many fields. However, this theory has a special place in economics and management. Operating on the market, companies make a number of decisions that resemble a game with moves made by players. It turns out that GT can also be successfully translated into management needs. The aim of the article is to answer the question about the possibilities of using game theory in management. A wide range of applications of this theory has been shown. Limitations related to its use in management were also indicated.

**Keywords:** game theory, management, decision-making, mathematical model

**Streszczenie:** Teoria gier (TG) to nie tylko dziedzina matematyki, ale też jedna z najbardziej popularnych technik optymalizacyjnych wspomagających podejmowanie decyzji. Jej osiągnięcia są aktualnie wykorzystywane w niezliczonej ilości dziedzin. Jednak szczególne miejsce zajmuje ta teoria w ekonomii i zarządzaniu. Działając na rynku, firmy podejmują szereg decyzji, które przypominają grę, z poszczególnymi posunięciami odpowiadającymi ruchom wykonywanym przez graczy. Okazuje się, że TG może również zostać z sukcesem przełożona na potrzeby zarządzania[1]. Celem artykułu jest odpowiedź na pytanie, jakie są możliwości wykorzystania teorii gier w zarządzaniu. Pokazano szeroki zakres zastosowań TG zarówno w teorii, jak i w praktyce oraz korzyści wynikające z rozwoju tej dziedziny. Wskazane zostały również ograniczenia związane z jej stosowaniem w zarządzaniu.

**Słowa kluczowe:** teoria gier, zarządzanie, podejmowanie decyzji, model matematyczny

## Introduction

It is rather parlor games such as poker, bridge or chess that the term of game theory can be associated with. One can agree with the statement that these games laid the foundations for creating interesting mathematical models[2]. At present, GT constitutes a branch of modern mathematics that has numerous both theoretical and practical applications.

Game theory is applied by practitioners from various fields, including biology, psychology, international relations and philosophy[3]. It is increasingly popular in sociology, military sciences and IT. GT is also used in cybernetics, geology and politics. GT models are applied in national security and artificial intelligence research. Scientists even seek GT situations in the Bible[4] and Talmud[5]. The above-mentioned areas certainly do not cover all possible applications of GT, they show its versatility, nevertheless.

Game theory can also be treated as one of the quantitative optimization techniques supporting decision making. Solutions to decision-making problems consist in formulating the problem in the form of a mathematical model, using the appropriate procedure to solve such a task and proper interpretation of the results[6].

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[1] I. Szwedziak-Bork, *Zastosowania ekonomicznej teorii gier w zarządzaniu*, [in:] K. Klincewicz (ed.), *Zarządzanie, organizacje i organizowanie – przegląd perspektyw teoretycznych*, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa 2016, p. 285.

[2] E. Drabik, *Kilka uwag o formalnych zasadach matematycznego modelowania zjawisk ekonomicznych i interakcji społecznych*, „Ekonomika i Organizacja Gospodarki Żywnościowej" 2009, No. 79, p. 23.

[3] J. Watson, *Strategia. Wprowadzenie do teorii gier*, Wydawnictwo Naukowo-Techniczne, Warszawa 2002, p. 2.

[4] S.J. Brams, *Biblical games: a strategic analysis of stories in the Old Testament*, MIT Press, Cambridge 1980.

[5] R.J. Aumann, M. Maschler, *Game theoretic analysis of bankruptcy problem from the Talmud,* „Journal of Economic Theory" 1985, No. 36.

[6] D. Kopańska-Bródka, R. Dudzińska, *Modele liniowe badań operacyjnych w zadaniach,* Wydawnictwo Śląskiej Wyższej Szkoły Zarządzania im. gen. Jerzego Ziętka w Katowicach, Katowice 2005, p. 7.

It therefore comes as no surprise that GT occupies a special place in economics, and mainly in management. The theory describes situations in which participating entities consciously make various decisions that lead to a resolution which may change their position. It mainly deals with conflict situations, but also in situations where players' interests are compatible, but due to communication problems, it is difficult for them to determine the course of action[7]. All these aspects are extremely important in relation to enterprises, markets, economies or consumers.

The aim of the paper is a compilation look at game theory in relation to management. Close attention was paid to indicating a wide range of GT applications both in management theory and practice, as well as the benefits of developing this field. The limitations related to the use of GT in management were identified, too.

The desk research method was used to collect and organize basic information concerning GT. As part of exploratory research, a review of scientific and popular literature, as well as academic textbooks was conducted. Less attention was paid to the strictly mathematical approach to GT.

## 1. Development of game theory

The year 1944 is considered the beginning of game theory, when a book by John von Neumann and Oskar Morgenstern titled "Theory of Games and Economic Behavior"[8] was published. The authors noted that mathematics had so far been used with great success in many other fields of science and that there was no compelling reason for this not to happen in economics, too. They indicated the possibility of applying the mathematical "games of strategy" theory to solve economic problems.

In subsequent decades, mathematicians and economists strengthened the foundations of the theory, gradually creating the most effective and comprehensive toolset of contemporary social sciences[9]. What proved to be of great significance to the development of GT was the 1994 Nobel Prize in Economics awarded to three mathematicians who dealt with the topic. John Nash, John Harsanyi and Reinhard Selten – the Nobel Prize winners evoked a wave of interest in both the theory itself and its applications[10]. The significant role that GT plays in modern science is demonstrated by numerous Nobel prizes awarded to scholars in this field.

Such concepts as game, players and strategy appear in the theory. The general concept of the game corresponds to the one we are used to in parlor games, but the player can be, for example, a company owner, a client, a military commander, an or-

[7] M. Malawski, A. Wieczorek, H. Sosnowska, *Konkurencja i kooperacja. Teoria gier w ekonomii i naukach społecznych*, Wydawnictwo Naukowe PWN, Warszawa 2004, p. 12.
[8] J. von Neumann, O. Morgenstern, *Theory of games and economic behavior*, Princeton University Press 1944.
[9] J. Watson, *Strategia. Wprowadzenie do…*, p. 2.
[10] M. Malawski, A. Wieczorek, H. Sosnowska, *Konkurencja i kooperacja…*, p. 7.

ganization or a country. It can be a single individual or a coalition (a group of players), and in less typical cases even a computer program or a machine. A game consists of a series of successive moves, in each of which one player chooses from several options, in addition to random moves such as rolling a dice or tossing a coin[11].

*Strategy* is a player's complete action plan, taking into account all possible situations. *Decision* is the choice of one of the options in a particular situation. A player's winning or losing is called a *payoff*, whereby it can be expressed not only numerically, as it is in the case of an increase or decrease in turnover, but also e.g. as a set of factors such as: an increase in customer satisfaction, better future prospects, time saving.

Initially, *zero-sum games* were analyzed, i.e. games in which the interests of players are opposite, and increasing the payoff of one of them reduces the payoff of the others. If anyone wins something, someone else must lose as much or all the other players lose as much, because in a zero-sum game, the sum of all players' payoffs equals zero. The simplest example of such a game is a zero-sum game which only two players take part in. Two-person zero-sum games are sometimes referred to as strictly competitive games[12]. There is no place for cooperation here, the interests of players are opposite, the increase in the payoff of one of the players automatically increases the loss of the other one. In this situation, we can call players opponents. In such games it is relatively easy to determine *optimal strategy*, i.e. such a safe strategy that leads to the most advantageous result from the point of view of a given player, assuming that the strategies of all other players are known and established.

In economics, situations that can be described as zero-sum games are relatively rare. This mainly applies to markets where we are dealing with an oligopoly. A small number of companies in a given industry can compete for customers who are willing to buy a certain number of products. An increase in the market share of one of them automatically reduces the market share of the others. A classic example of a two-person zero-sum game is competition in the aircraft industry between the two tycoons - Airbus and Boeing. Any contract won by Airbus means a contract lost by Boeing, and vice versa[13].

Games describing economic situations, however, are not usually zero-sum games. In practice, it often happens that both players can gain through cooperation, but also in the event of conflict, both can lose, e.g. as a result of protracted negotiations. Such situations are called *constant-sum games* (zero-sum games are a special case)[14]. These games are governed by completely different laws, first and foremost the concept of optimal strategy does not make sense here[15].

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[11] G. Owen, *Teoria gier*, Państwowe Wydawnictwo Naukowe, Warszawa 1975, p. 11.
[12] Ibidem, p. 19.
[13] K. Obłój, M. Grudziński, *Walka o dominację w powietrzu: Boeing kontra Airbus*, https://www.idg.pl/autor,Krzysztof-Obloj,3815.html [access: 13.07.2019].
[14] G. Owen, *Teoria gier*…, p. 121.
[15] M. Malawski, A. Wieczorek, H. Sosnowska, *Konkurencja i kooperacja*…, p. 28.

In a two-player constant-sum game, the sum of all players' payoffs can be a positive number, therefore such strategies are possible in which both players win, or one of them gains more than the other loses.

Models derived from game theory can describe, with the use of constant-sum games, cases of both cooperation and competition of enterprises. The extensive literature on the topic shows that especially in the long run these forms of enterprise cooperation are definitely more beneficial. M. Malawski and others analyze these phenomena using game theory.

An interesting type of games are *cooperative games* in which all such forms of cooperation are allowed[16]. In such a situation, a *coalition* may be formed by a group of players. The condition for creating such a structure is that all its members will benefit from it. If a coalition is to be formed and maintained for some time, then its individual members should achieve some kind of balance or stability[17]. A distinctive feature of cooperative games are those elements of the game that allow to describe the phenomenon of interaction between players, leading to the formation of a coalition[18].

One of the most important concepts of game theory is the so-called *Nash equilibrium*. *Nash equilibrium*, or simply *equilibrium*, is an n set of strategies (one chosen by each player), each of which is the best response to the strategies chosen by the other players. The name comes from John Nash, who proved that every constant-sum game (with a finite number of each player's strategies) has a balance. Whereas, the use of *mixed strategies* must be allowed, i.e. the choice of strategies by drawing lots. It is commonly considered that the only balance not consisting of mixed strategies (if any) is the "solution" of the game[19]. In games with many Nash equilibria, an additional way is needed to find the one that appears in the solution[20].

At present, scientists no longer focus exclusively on n-player games, but also consider cases which infinitely many players take part in. Moreover, next to games with an infinite number of players $g_n$, where nN, the so-called games with *a continuum of players* are considered, i.e. those in which players match all numbers (rational and irrational) in the range . Games of this type are not just art for art's sake. Thanks to the development of this theory, new possibilities of using the methods of measure theory as well as infinitesimal and integral calculus appear, unavailable for games with a finite number of players. In addition, these games allow to describe particular phenomena that cannot be included in the scheme of games with a finite number of players, or can be only partially described.

[16] G. Owen, *Teoria gier*…, p. 121.
[17] Ibidem, p. 135.
[18] M. Malawski, A. Wieczorek, H. Sosnowska, *Konkurencja i kooperacja*…, p. 192.
[19] Ibidem, p. 30.
[20] A.K. Dixit, B.J. Nalebuff, *Sztuka strategii. Teoria gier w biznesie i życiu prywatnym*, MT Biznes Sp. z o.o., Warszawa 2009, p. 151.

Some of the welfare economics models, such as the *pure exchange model*, can serve as an example. In this model, production processes are omitted, only consumers who exchange, buy or sell certain goods remain. The general *competitive balance* is understood in this model as a system of prices and a certain system of consumption vectors of individual consumers, at which each consumer achieves maximum satisfaction according to their resources, and the quantity of all goods consumed is equal to the quantity of goods available on the market. Creating a model of pure exchange with a continuum of consumers allowed to formulate and prove the claim that in a model with a continuum of consumers, none of them has a noticeable impact on the functioning of the entire market (we can speak of perfect competition).

There are two mainstreams in research on games with a continuum of players: non-cooperative and cooperative games. These games are used to describe various situations in which an action of a single player does not affect the payoffs of other players. It is only a joint action of a large group of players that can have such an impact. Games with a continuum of players constitute a mathematical nucleus of various economic models with a large number of participants, for example, producers or consumers. Thanks to these models, it is possible to study such phenomena in more detail[21].

## 2. Application of game theory in management

### 2.1. Game theory as a tool for economic phenomena analysis

In order to manage effectively, it is necessary to know and understand the principles that govern economic phenomena. One of the goals of game theory is to help understand the elements of various economic and social situations through formal models. Among others, they include: market structure, conclusion of contracts, competition between enterprises, tenders, internal organization of companies or interpersonal relations. All the aforementioned situations are very complicated, it is thus impossible to investigate them in a complete way. Therefore, attempts are being made to describe them in the form of a model, in a simplified way - as a game. Such a model allows analyzing the studied phenomena and the behavior of the participants of events[22]. Game theory tries to recognize basic economic processes in the form of models, the processes are: production, transportation, distribution of streams of goods, economic growth, theory of business cycles, all kinds of decision-making processes, as well as competition, cooperation and negotiations. By means of mathematics the processes are examined and conclusions concerning economic content are drawn[23].

[21] M. Malawski, A. Wieczorek, H. Sosnowska, *Konkurencja i kooperacja…*, p. 192-194.
[22] J. Watson, *Strategia. Wprowadzenie do…*, p. 47.
[23] E. Drabik, *Kilka uwag o formalnych zasadach matematycznego modelowania zjawisk ekonomicznych i interakcji społecznych*, „Ekonomika i Organizacja Gospodarki Żywnościowej" 2009, No. 79, p. 28.

For example: J. Kałuski proposes and justifies a hierarchical, two-person non-zero sum game as a model of a decision-making situation - planning and controlling material needs occurring in a mining enterprise[24]; W. D. Li and others describe a planning process with the use of game theory; D. Krenczyk and M. Olender model the application of game theory in production planning using advanced simulation systems[25]; A. Naimi Sadigh and others deal with the possibility of using game theory to coordinate price and marketing decisions[26]; G. P. Cachon and S. Netessine show the possibility of applying game theory in supply chain analysis[27]. The literature concerning model presentation of economic problems using game theory is very rich.

Mathematicians – specialists in game theory, also analyze current economic problems, such as the trade dispute between the USA and the PRC. Experts quoted by the "South China Morning Post" assessed that from the point of view of GT the dispute can be classified as a "war of attrition," in which each participant holds their position, expecting the other party to surrender eventually[28].

Reasoning methods based on game theory are also used in many economic issues when studying equilibrium states. In this case, the best balance for individual players is replaced by a general balance in the sense of Nash equilibrium. In other words, if individual players give up their available but globally undesirable ways of acting, they can achieve a global equilibrium. It was since the times of J.M. Keynes, that attempts have been made to use this knowledge by shifting points of economic balance, i.e. increasing production, raising demand, lowering taxation, raising retirement benefits, encouraging private and public investment through guarantees and other discounts granted to businesses, etc.[29]

## 2.2. Game theory in developing a corporate strategy

A.M. Brandenburger and B.J. Nalebuff proposed to use game theory in developing strategy. They noticed that one of the basics of game theory is focusing on others, putting yourself in the role of another player. Anticipating competitors' moves

[24] J. Kałuski, *Zastosowanie teorii gier w planowaniu i kontrolowaniu potrzeb materiałowych w przedsiębiorstwie górniczym*, „Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie" 2011, No. 57.

[25] D. Krenczyk, M. Olender, *Zastosowanie teorii gier w planowaniu produkcji z wykorzystaniem zaawansowanych systemów symulacyjnych*, „Zarządzanie Przedsiębiorstwem" 2014, vol. 17, No. 4.

[26] Ibidem.

[27] G.P. Cachon, S. Netessine, *Game Theory in Supply Chain Analysis*, [in:] D. Simchi-Levi, S.D. Wu, Z.J. M. Shen (ed.), *Handbook of quantitative supply chain analysis: Modeling in the E-Business Era*, Springer Science + Business Media, New York 2004.

[28] Forsal.pl, Dziennik "SCMP": *Spór handlowy USA-Chiny w teorii gier przypomina wojnę na wyczerpanie*, https://forsal.pl/artykuly/1415203,dziennik-scmp-spor-handlowy-usa-chiny-w-teorii-gier-przypomina-wojne-na-wyczerpanie.html [access: 14.07.2019].

[29] E. Drabik, *O roli gier towarzyskich w tworzeniu rozwoju teorii gier oraz jej ekonomicznych zastosowań*, „Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania Uniwersytetu Szczecińskiego" 2016, No. 45(2), p. 34.

and planning responses allows to build an effective business strategy. It involves shaping the game the company plays, not just finding it.[30]

The application of game theory in developing the corporate strategy of a company is in the center of many authors' attention, for example AK Dixit and B. Nalebuff write about the art of strategy in business based on game theory[31], P. Cabała analyzes games of extensive character as a tool for modeling strategic decisions in a company[32], and O. Aigbokhaevbolo describes the application of game theory in business strategy in the underdeveloped countries[33].

Experimental research results show that people with the knowledge of game theory behave more rationally and achieve higher profits, although these people often consciously choose non-equilibrium strategies, expecting better results[34]. Knowledge of a balanced strategy does not mean that its use proves to be the most beneficial in a particular economic situation. Knowing when a competitor is "unbalanced" allows to adapt a strategy to the situation and take advantage of these moments.

## 2.3. Examples of the application of game theory in management practice

It is much more difficult to find examples of the practical application of game theory in management. When GT is used in the real world, problems become much more complex and difficult to define[35].

In the mid-1990s, the US Federal Communications Commission (FCC) applied the second price principle in first radio frequency tenders. GT offers an unusual approach to bidding. Still, the one who has offered the most wins, but the winner pays only as much as the second offer amounted to. Then buyers offer more, because everyone assumes that if they win, they will pay less than they offered. The financial result confirmed the assumptions, but it was difficult to convince ordinary people that taking a lower price, FCC earned more than if it had traditionally taken the highest price. Politicians may even believe that this mechanism works, but they probably do not believe that they will be able to convince the voters[36].

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[30] A.M. Brandenburger, B.J. Nalebuff, *The right game: Use game theory to shape strategy*, "Harvard Business Review" 1995, vol. 73, No. 4.

[31] A.K. Dixit, B.J. Nalebuff, *Sztuka strategii. Teoria gier w biznesie i życiu prywatnym*, MT Biznes Sp. z o.o., Warszawa 2009.

[32] P. Cabała, *Gra w postaci ekstensywnej jako narzędzie modelowania decyzji strategicznych w przedsiębiorstwie*, [in:] R. Krupski (ed.), *Zarządzanie strategiczne. Rozwój koncepcji i metod*, Wałbrzyska Wyższa Szkoła Zarządzania i Przedsiębiorczości, Wałbrzych 2014.

[33] O. Aigbokhaevbolo, *Application of Game Theory to Business Strategy in Undeveloped Countries: A Case for Nigeria*, „Journal of Social Sciences" 2011, No. 27(1).

[34] P. Kusztelak, *Determinanty stosowanych strategii osiąganych zysków w grach w postaci normalnej – podejście eksperymentalne*, „Decyzje" 2013, No. 19, p. 66.

[35] K. Jameson, *Game Theory and its Applications*, Sr. Seraphim Gibbons Undergraduate Symposium 2014, p. 21.

[36] R.J. Aumann, wywiad dla czasopisma „Polityka", 2008, https://www.polityka.pl/tygodnikpolityka/spoleczenstwo/259140,1,rozmowa-z-noblista-prof-robertem-aumannem-o-grach-spolecznych.read [access: 30.06.2019].

Sometimes, GT is also used in transport management. It explains the occurrence of the so-called Braess's paradox in which building a road in addition to the already existing communication system can, in some situations, contrary to common expectations, increase traffic jams[37]. The new connection may increase the time it takes to reach the destination[38]. Based on this theory, it turns out that some streets or parts of them are closed to improve driving conditions in the city. In 1990, temporary closure of the 42nd Street in New York reduced traffic jams in the area[39]. In 1969, road investments in the center of Stuttgart led to a significant deterioration of traffic conditions in the Schlossplatz area, which was only remedied by closing a part of Königsstraße to traffic[40]. A similar situation occurred in Seoul, where traffic around the city was accelerated after removing a part of the highway[41].

Game theory is crucial to the development of cryptocurrencies and is one of the reasons why Bitcoin has managed to survive over a decade, despite numerous attempts to disrupt its network. It plays a significant role while designing a secure and trustless system such as Bitcoin. The Bitcoin blockchain network is designed as a distributed system - with many nodes located around the world. The nodes cannot simply trust one another, but the network is protected against malicious activity by the Proof of Work consensus algorithm. The mining nodes operate in a highly competitive environment, the digging process is very expensive and demanding in terms of computing power. The risk of losing the invested resources motivates mining nodes to act in a fair way. Therefore, the most probable and rational decision taken by the miner is honest operation and maintenance of the blockchain network security - both for their own good and for the safety of the general public. The use of GT in the context of cryptocurrencies has laid the foundations for cryptoeconomics. Thanks to a balanced and harmonized combination of the achievements of cryptography and game theory, the Proof of Work consensus algorithm has contributed to the creation of Bitcoin blockchain as a decentralized system that is also highly resistant to various types of attacks. The same applies to other cryptocurrencies[42].

However, it should be taken into account that many cases of real application of game theory in management have not been described in literature. Knowledge on the theory can give companies a competitive advantage, hence the attempts to apply it in real business management are not disclosed.

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[37] D. Braess, *Über ein Paradoxon aus der Verkehrsplanung,* "Unternehmensforschung" 1968, No. 12.

[38] A.L.C. Bazzan, F. Klügl, *Case studies on the Braess Paradox: Simulating route recommendation and learning in abstract and microscopic models*, "Transportation Research" 2005, part. C, No. 13, p. 300.

[39] G. Kolata, *What if they closed 42nd Street and nobody noticed?*, „New York Times", 1990-12-25.

[40] W. Blum, *Ewig lockt die Schnellstraße*, „Süddeutsche Zeitung", 2006-01-24.

[41] Cornell University, *Seoul and Braess' Paradox,* https://blogs.cornell.edu/info2040/2016/09/16/seoul-and- braess-paradox/ [access: 9.07.2019].

[42] Binance Academy, *Teoria gier i kryptowaluty,* https://www.binance.vision/pl/economics/game-theory-and-cryptocurrencies [access: 9.07.2019].

## 3. Limitations to the application of game theory

It should be remembered that each mathematical model is an idealized image of reality and captures the impact of only a number of factors considered important by its creators. Some qualitative factors are very difficult to measure, so they cannot be taken into account[43]. The main reason for the current failures to use optimization methods in practice is due to their incorrect application – attempts have been made to apply them directly. However, these models focus on one or more aspects, and do not capture, for example, complex human interactions[44].

In game theory, it is assumed that a player is "ideal," i.e. they can clearly identify all the necessary decision-making factors, their computational possibilities are unlimited and their behavior is rational in every situation[45]. Today we are aware that the assumption of classical and neoclassical economics that human is homo economicus, who strives to maximize profits as a producer and maximize utility as a consumer, cannot be taken for granted. In addition to rationality, human activities are governed by such factors as habits, relationships and fashion. Moreover, even if market players have equal access to information, there is a problem with the limited ability to process it. The amount of available information increases geometrically, whereas the degree of rationality of entities is related to the percentage of information used in relation to the information available[46]. Another basic assumption of game theory is not met frequently, namely common knowledge of the applicable rules of the game. A Nobel Prize winner in economics for game theory, R. J. Aumann emphasizes another important issue. In fact, there is always a number of different games going on simultaneously. What is rational in an obvious and scientifically certain way in one game can appear seriously harmful in another. Each game we play has an impact on another[47].

Therefore, it should not be forgotten that the results of research based on game theory should be taken with extreme caution. For theoretical models do not always fit reality.

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[43] Z. Pierścionek, *Praktyka optymalizacji w przemyśle*, Państwowe Wydawnictwo Naukowe, Warszawa 1986, p. 144.

[44] Ibidem, p. 165.

[45] M. Malawski, A. Wieczorek, H. Sosnowska, *Konkurencja i kooperacja…*, p. 12.

[46] M. Jurek, R. Rybacki, *Model homo oeconomicus i jego dostosowanie do współczesnych uwarunkowań*, „Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach" 2014, No. 180, part 1, p. 69-70.

[47] R.J. Aumann, wywiad dla czasopisma „Polityka", 2008, https://www.polityka.pl/tygodnikpolityka/spoleczenstwo/259140,1,rozmowa-z-noblista-prof-robertem-aumannem-o-grach-spolecznych.read [access: 30.06.2019].

## Conclusions

The study showed that game theory is currently in the center of attention of mathematicians, who develop this theoretical tool, and a wide range of scientists from various fields. Hundreds of publications on the subject are written, entire sections devoted to it appear in libraries. The importance of game theory should be appreciated in order to understand the way our world functions[48].

At present, game theory is used in management surprisingly frequently to describe occurring phenomena and to solve decision-making problems. It can be said that it is a kind of a scientific fashion, or even a fascination. The achievements of this contemporary field of mathematics are truly impressive and give hope for further development. The search for its possible applications is also of great potential. New research and applications are emerging.

However, it should be remembered that theoretical models do not always fit reality, they are not able to take into account all conditions. It is necessary to be very cautious and reckon with significant deviations of theoretical predictions from actual events[49].

However, the study has limitations. The size of the present paper forces to raise only the most important, basic aspects of the theory. It is advisable to carry out further study to complement the results obtained. What seems to be an interesting direction is the analysis of the threats of using game theory in economics and management, often by people without mathematical preparation. There is a danger of using the study results as guidelines for making decisions also in situations when a mathematical model does not quite correspond to reality.

Nevertheless, game theory undoubtedly constitutes a huge step forward in the development of science. Its future results and applications in the field of management will certainly astound us more than once.

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***Author's resume:***
***Alina Czapla** – PhD student at the University of Economics in Katowice (Department of Organizational Relationship Management, Faculty of Informatics and Communication). Graduate of Mathematics (Jagiellonian University in Kraków) and postgraduate studies Business English (University of Economics in Katowice).*

***Nota o Autorze:***
***Alina Czapla** – doktorantka w Katedrze Zarządzania Relacjami Organizacji na Wydziale Informatyki i Komunikacji Uniwersytetu Ekonomicznego w Katowicach. Absolwentka matematyki (Uniwersytet Jagielloński w Krakowie) oraz podyplomowych studiów Business English (Uniwersytet Ekonomiczny w Katowicach).*

***Contact/Kontakt:***
*Alina Czapla*
*e-mail: alina.czapla@edu.uekat.pl*