



GAME THEORY APPLICATIONS IN CONSTRUCTION ENGINEERING AND MANAGEMENT

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Abstract. Game theory usually analyses decision-making processes in various fields. There are different methods of solving decision related problems. Game theory focuses on problem solution from one player's point of view, while game theory emphasizes its analysis in the interaction among many players. Much of game theory is concerned with finite, discrete games, which have a finite number of players, moves, events, outcomes, etc. Many researchers in different research fields' work applied the game theory in: construction engineering, management area. The article presents review of 42 years of scientific work of Professor Friedel Peldschus in the fields of game theory application in construction engineering and management. A review of scientific achievements and activity of Professor Friedel Peldschus, focusing on his research.

Keywords: MCDM, game theory, activity, construction engineering, management, review, Peldschus.

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1. Introduction

Game theory depends on groups of operational research methods. Many authors have proposed various classifications of operational research methods, and have not presented an undivided classification. Moreover, operational research methods include matching groups: MCDM – *Multi-Criteria Decision Making*, MADM – *Multi-Attribute Decision Making Methods*, MODM – *Multi Objective Decision Making Methods*, game theory, etc. MCDM methods support a decision maker in rational decision making, and are considered to be enrichment to

the poor rationality of the single objective optimisation problems (Pomerol and Barba-Romero 2000; Rogers *et al.* 2000; Vincke 1992; Zionts 1990). The solution problem methods applying MCDM so far, differ from each other in quality and quantity of additional information required. Applying MCDM, the problem is solved in a finite number of alternatives and there is a family of performance measures on which the alternatives are evaluated. According to Mareschal (1986), the problem could also have a third dimension if it involves multi-criteria and/or uncertainties in performance measure evaluations. Operational research methods attempt at solving certain problems for scientific and practical use in various fields.

2. Review of game theory

A broad review of game theory rise and progress is published in Peldschus *et al.* (2010). The first known discussion of game theory occurred in a letter written by James Waldegrave in 1713. In this letter, Waldegrave provides a min-max mixed strategy solution to a two-person version of the card game *le Her*. Game theory in the modern era returned with the publication in 1913, of a German mathematician Ernst Zermelo, of “Uber eine Anwendung der Mengenlehre auf die Theorie des Schachspiels”. He proved that every competitive two-person game possesses a best strategy for both players, provided both players have complete information about each other’s intentions and preferences. In a game of complete information, players know their own strategies and pay-off functions, and those of other players. In addition, each player knows that the other players have complete information (Peldschus *et al.* 2010).

The classification of game theory is presented in Fig. 1 (Zavadskas *et al.* 2004).

As to the progress of game theory: Borel (1921) and von Neumann (1928), Luce and Raiffa’s (1957) focus on conflicting preferences, von Neumann and Morgenstern (1944) focus on concepts of perfect and imperfect information with reference to information each player has concerning the actions of the other player. Furthermore, game theory is concerned with finite, discrete games and a finite number of players: it is only with two or more players that a problem

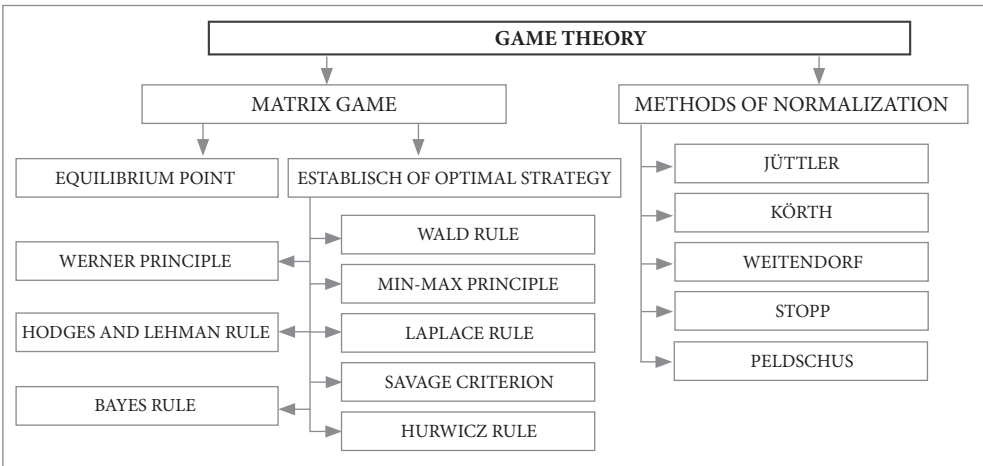


Fig. 1. Game theory classification by Zavadskas *et al.* (2004)

becomes theoretical. Luce and Raiffa (1957) analysis concentrated on an infinite number of players. They have developed a model in which one individual does better at another's expense (zero sum games). Arrow *et al.* (1949), Arrow (1951) specialize in a simple min-max principle.

Game theory analysed by Muschik (1975); Muschik and Müller (1986); Aumann (1989); Hollert (2006); Meszek (2007); Zavadskas and Turskis (2008) developed a new logarithmic normalization method. Peldschus *et al.* (2010) focus on particular sets of strategies known as equilibrium in games. From the point of usability, a number of problems of construction technology investigated in the past have become limited. Implementation by mediated equilibrium is presented in Peleg and Procaccia (2010).

Mapping to the dimension-less interval (normalization) was the Professor's interesting achievement. He proposed quadratic and cubic functions. A quadratic function is used for maximization, while a cubic function for minimization. Such an approach was used in many PhD theses written under his supervision, and in a number of articles (Kapliński 1995, 1997). The comparison with other normalisation functions is widely known and well interpreted (Peldschus 2009a).

3. Game theory applications

In this review, applied game theory in different research fields is presented in its development since 2004: in optimization (Annanddas and Rao 2009; Aumann 2010); economics (Aliprantis *et al.* 2009); in conventional rail systems (Hsu *et al.* 2010); for optimal design (Hu and Rao 2009); for energy market analysis (Kacprzak *et al.* 2010); for multi-agent team cooperation (Semsar-Kazerooni and Khorasani 2009); for investigation of the software market (Tan *et al.* 2010); for manufacturing (Zhang and Huang 2010).

Applications of game theory are varied. Many authors have applied game theory to solve problems in construction engineering and management: Zavadskas *et al.* (2004) solved construction technology and management problems; Peldschus and Zavadskas (2005) investigated fuzzy matrix game in construction; Su *et al.* (2007) proposed a model of urban public traffic networks; Sun and Gao (2007) applied an equilibrium model for urban transit assignment; Homburg and Scherpereel (2008) analysed the cost of joint risk capital to be allocated for performance measurement; Motchenkova (2008) applied a differential game to describing interactions between a firm that might be violating competition law and the antitrust authority; Peldschus (2008a) presented a review of the game theory application experience in construction management; Podvezko (2008) applied game theory in technology and management of construction solutions; Schotanus *et al.* (2008) analysed unfair allocation of gains under the equal price allocation method in purchasing groups; Meszek (2008) analysed investment projects; Tamošaitienė *et al.* (2008) – modelling of contractor selection taking into account different risk levels; Gu *et al.* (2009) analysed Chinese strategies for energy-efficient housing development from an architect's perspective; Zhao and Jiang (2009) presented optimisation model between project risk set and measure set; Peldschus *et al.* (2010) demonstrate construction site selections.

One of the exceptional authors working on game theory application in construction engineering and management is Professor Friedel Peldschus. The achievements already mentioned are further analysed.

4. Professor Friedel Peldschus' research and achievements

Professor Friedel Peldschus most characteristic achievements are quoted below, as well as his contribution to development of game theory application in construction and management, and to development of international academic collaboration. The Professor's research profile is presented in the following areas:

- Main aspects of his research biography;
- Results of 42 years of research and scientific work;
- Contribution to collaboration between other academic centres.

4.1. Professor Friedel Peldschus' biography review

Professor Friedel Peldschus is celebrating his seventieth birthday. He was born on the 7th of April in 1940 in Heydekrug (Šilutė, Lithuania). After graduating from the school in Mühlhausen in 1958, he worked as a professional driver for the "Deutsche Post". From 1959 to 1965 he studied at the TH (Technische Hochschule) of Leipzig and received his construction engineering diploma. After graduation, he gained experience in production: he worked as a welding engineer and as information processes engineer. In addition, he had practical experience in construction processes and steel construction. He worked as a design engineer, structural engineer, and programmer.

He had begun research work in 1968. F. Peldschus was a Senior Assistant to the Head of Department of Theory of Construction Processes at the TH of Leipzig. He lectured in the following subjects: Fundamentals of Construction Technology, Cybernetics in Civil engineering and Application of Mathematical Methods in Construction Technology. His main research area was the development of game theory methodology and its applications with the view to optimise solutions for construction management.

Within this research field, he presented his doctoral dissertation in 1972 (Peldschus 1972) and Post-Doctoral thesis in 1986 (Peldschus 1986).

In the autumn semester of 1989, he was a guest lecturer at Vilnius Civil Engineering Institute (VISI).

He was a member of the "DDR working group on multi-criteria decisions making" and "Multi-criteria Aid for Decisions" European Working Group where he has worked since 1991. In 1991, in recognition of his research activity in the fields of creating mathematical methods and their application in construction technology, Professor Friedel Peldschus was granted a Honorary Doctorate (Doctor Honoris Causa) at Vilnius Technical University (Fig. 2).



Fig. 2. Professor Friedel Peldschus was granted an Honorary Doctorate at Vilnius Technical University in 1991

There have been attempts at a synthesis of Professor Friedel Peldschus' academic heritage in numerous publications by Sipavičiūtė and Varnienė (1991).

The former name of TH of Leipzig has changed to HTWK (University of Applied Sciences Leipzig) and he has worked there as a professor since 1992. Moreover, he played an active role in university life, and declared himself ready to take over the function of the Vice-Chancellor in 1993 and 1994. Since 2001, he has been a visiting professor at VGTU. Professor Friedel Peldschus worked in Civil Engineering Faculty, Leipzig University of Applied Sciences (Germany) until 2005.

4.2. 42 years of scientific research work

The general stress of Professor Friedel Peldschus' work is on game theory application in construction engineering and management. Software helping to solve problems of multiple criteria decision making was created. Application of game theory methodology, solving construction engineering and management problems, creating software, was meant to help sustainable development in construction and management, and harmonious development respecting the environment. The research fields shown in Fig. 3 developed over 42 years can be divided into:

- Operational Research;
- Construction engineering and management;

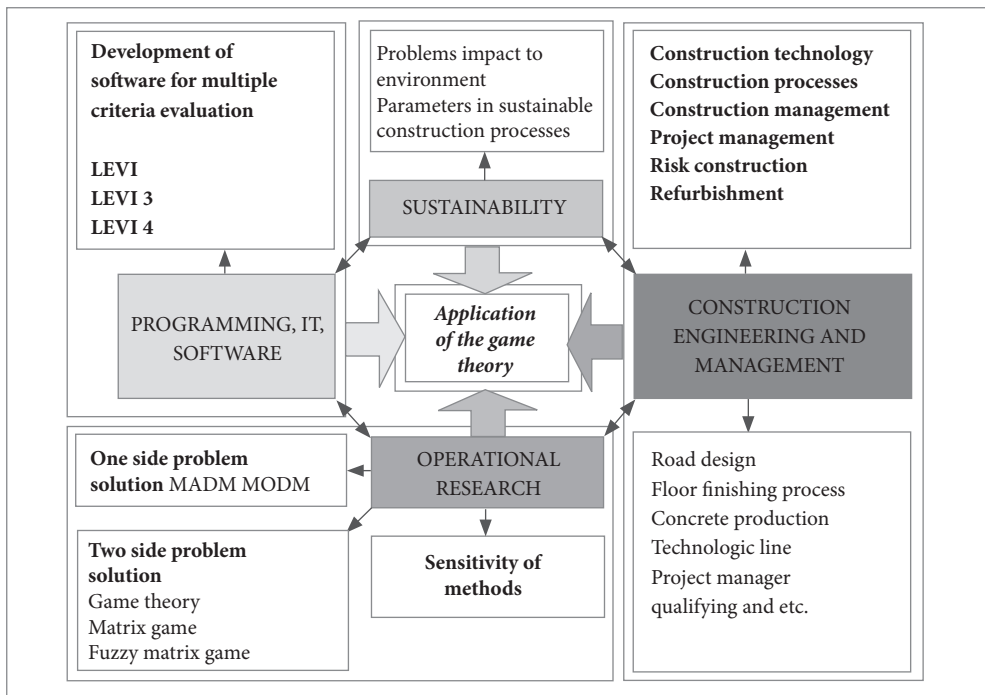


Fig. 3. Applications of game theory over 42 years of Professor Friedel Peldschus' research work

- Programming, IT and software;
- Sustainability.

His research focused on selecting problem solutions in construction processes applying game theory. The articles published by Professor Friedel Peldschus and co-authors include the following subjects: multiple goals solution (Peldschus *et al.* 1983); game theory application to problems in construction technology (Fiedler and Peldschus 1983; Peldschus 1985; Fiedler 1986); optimisation of floor finishing process by applying one criterion (Peldschus and Zavadskas 1984); matrix game for construction technology preparation (Peldschus and Fiedler 1984; Peldschus *et al.* 1986, 1988, 1990a); new concept of a dimension in concrete production line (Altmann *et al.* 1987); game modelling in preparation for construction production (Peldschus *et al.* 1989); rational machinery selection and combination for earthwork (Herschel and Peldschus 1989); construction problems solution models (Peldschus 1990); multi-criteria decision making support systems (Peldschus and Löhne 1991; Löhne and Peldschus 1993); calculation of management parameters in sustainable construction processes (Peldschus *et al.* 1990b); comparison analysis for construction management (Peldschus 1992, 1994a) and construction processes (Peldschus 1994b); assessment problems in multi-criteria decision making (Peldschus 1993; Zavadskas and Peldschus 2003); decision making theory program system (Löhne *et al.* 1990); LEVI was developed in 1993 – a multiple criteria decision aiding programme (Löhne and Peldschus 1993; Zavadskas *et al.* 1993) and in 2002 an improved version of multiple criteria evaluation program – LEVI 3.0 was developed (Peldschus 2000a; Peldschus *et al.* 2001, 2002; Zavadskas *et al.* 2002); development of software for multiple criteria evaluation (Zavadskas *et al.* 2003); sensitivity of decision making methods (Peldschus 2001); construction market analysis (Peldschus and Reichelt 2001); the assessment of crack mechanics for building renewal (Peldschus and Wild 2002); the improvement of efficiency of production planning in small and medium-sized construction companies (Wild and Peldschus 2002); risk management of construction and environmental in engineering projects (Reichelt and Peldschus 2005); fuzzy methods in construction (Peldschus 1995, 2003) and a fuzzy matrix games multi-criteria model for decision-making in engineering (Peldschus and Zavadskas 2005); quality problems in construction (Peldschus 1997); requirements of buildings refurbishment (Peldschus 1998); research into construction processes optimisation (Peldschus 1999); economic analysis of project management, considering multi-criteria decisions (Peldschus 2006); effectiveness assessments in multi-criteria decision making (Peldschus 2007a); game-theory solutions in construction operations (Peldschus 2007b); multi-attribute assessment of road design solutions by using COPRAS method (Zavadskas *et al.* 2007); decision making in road design (Peldschus 2004, 2005; Brauers *et al.* 2008a, 2008b); MADM in construction (Peldschus 2008a); experience of game theory application in construction management (Peldschus 2008b); game-theory solutions in construction operations (Peldschus 2008c); multi-criteria optimisation system in decision making in construction design and management (Turskis *et al.* 2009); qualification of construction design project managers by applying Analytic Hierarchy Process and Bayes rule (Vainiūnas *et al.* 2009); the analysis of the quality of results obtained with multi-criteria decisions methods (Peldschus 2009a); sustainable assessment of construction site by applying game theory (Peldschus *et al.* 2010).

4.3. Results of 42 years of research work

The books and monographs represent his main research achievements: investment phase methods, and the study of construction production (Fiedler *et al.* 1983); decision making methods in construction technology (Zavadskas *et al.* 1986); application of game theory in building production preparation (Zavadskas and Peldschus 1986); multiple criteria evaluation of projects in construction (Zavadskas *et al.* 1994); matrix games in construction technology and management (Peldschus and Zavadskas 1997); game theory in construction technology and management (Zavadskas *et al.* 2004). Most books and monographs have been published in collaboration with German and Lithuanian colleagues. The reviews of these books were published in scientific journals (Rutkauskas 1995; Skitmore and Koznan 1997; Ginevičius 1998; Podvezko 2008).

Professor Friedel Peldschus actively collaborated with his colleagues from abroad and wrote a number of forewords to (Peldschus 2000b, 2007c) and reviews of their books (Štercelis and Peldschus 1988; Peldschus 1988, 2008d).

His achievements in the field of game theory were further developed foreign scientists: Zavadskas and Vaidogas (2008, 2009) proposed the models based on games theory; Kapliński (2008a) presented the usefulness and credibility of scoring methods in construction industry; Ginevičius and Krivka (2008) implied the use of game theory in duopoly market analysis; Zavadskas and Turskis (2008) proposed a logarithmic normalization method; Zavadskas *et al.* (2008a) selected construction contractors applying the game theory.

In 42 years of his scientific and research work, Professor Friedel Peldschus has supervised 8 PhD dissertations, successfully participated the numerous PhD and Post DhD theses presentations, published about 40 articles in very high rated scientific journals, published about 15 proceedings; in total approximately 80 scientific papers. He participated in the publishing of 6 books. The articles and books were published in 4 different languages: English, German, Russian and Lithuanian.

Those achievements can be easily translated into parameters. In SCOPUS quotations statistics database, which includes articles written after 1995, there is a note (the status as of April 2010) to the effect that the Professor's works were, altogether, quoted 138 times. In this case, the base includes 11 publications. Hirsch's Index is 6 ($h = 6$). The most often quoted (43 times) publication was the one which appeared in the 2003 issue of *Informatica* where he published jointly with his Lithuanian colleagues. The article is entitled *Development of software for multiple criteria evaluation*. This publication is also noted in Google Scholar as the most often quoted (57 times) – see: Zavadskas *et al.* (2003).

4.4. Participation in colloquia in German–Lithuanian–Polish academic centres

Since 1986, Professor Friedel Peldschus has been the one of the founders of a programme of collaboration between three academic centres: German, Lithuanian, and Polish – Leipzig University of Applied Sciences, Vilnius Gediminas Technical University and Poznan University of Technology. Professor Friedel Peldschus has been actively collaborating in colloquia in the German–Lithuanian–Polish Scientific Triangle. Collaboration in exchanging research

achievements, consulting publications, cooperating in joint papers, supporting future research through organization of colloquia which were held every two years in different academic centres (Kaplinski 2009). Reports from colloquia, and academic achievement reviews have been published (see: Kaplinski 2000, 2008a, 2009; Zavadskas and Kaklauskas 2001; Kaplinski and Zavadskas 2002; Kaplinski *et al.* 2004; Kaklauskas *et al.* 2005; Peldschus *et al.* 2006; Zavadskas 2008; Tamošaitienė *et al.* 2010).

Over thirty years of academic collaboration, colloquia in Germany hosted by Professor Friedel Peldschus were organised five times, in: 1986, 1989, 1999, 1995, 2005, always with participants from other countries. Perhaps it is a coincidence that the 1st, held in 1986, and the 10th jubilee colloquium, in 2005, was also organised by Professor Friedel Peldschus. Each colloquium resulted in publication of research papers in a special issue of a scientific journal:

- Following the 6th colloquium, a special issue of the “*Journal of Civil Engineering and Management*” (Peldschus 1997) was published;
- Following the 7th colloquium, a special issue of the “*Journal of Civil Engineering and Management*” (Zavadskas and Kaklauskas 2001) was published;
- Following the 10th jubilee colloquium, a special issue was published, with the guest editor, Professor Friedel Peldschus – “*Technological and Economic Development of Economy*” (Peldschus 2006);
- Following the 11th colloquia, special issues, “*International Journal of Management and Decision-Making*” (Brauers and Zavadskas 2007) were published; Professor Oleg Kaplinski was the guest editor of “*Technological and Economic Development of Economy*” (Kaplinski 2008b); Professor Edmundas Kazimieras Zavadskas and Professor Arturas Kaklauskas were guest editors of “*International Journal of Environment and Pollution*” (Zavadskas and Kaklauskas 2008).

On the basis of collaboration during 11th and the 12th colloquia, the idea of setting up of a new EURO working group “OR in Sustainable Development and Civil Engineering (EWG-ORSDCCE)” was presented. The scientists approved of the proposal, placing their signatures on the document, and decided to submit this proposal to the EURO (Association of European Operational Research Societies) Executive Committee during the annual 23rd European Conference on Operational Research “OR creating competitive advantage”, which took place in Bonn, Germany 5–8 July 2009. Prof. Friedel Peldschus sat on the board of EURO.

He was a scientific committee member participating in the defence of PhD theses in Lithuania about twenty times. Professor Friedel Peldschus hosted the following academics from Lithuania: Prof. Dr Sc. E. K. Zavadskas (1980–1981); Assoc. Prof. Dr V. Kriukelis (1987); Assoc. Prof. Dr V. Glebov (1989); Assoc. Prof. Dr A. Karablikovas (1990); Prof. Dr S. Raslanas (1996–1997); Assoc. Prof. Dr A. Banaitis (1997; 1998); Assoc. Prof. Dr V. Maliene (1999); Assoc. Prof. Dr J. Šaparauskas (2000, 2001); Dr J. Tamosaitiene (2002) and other colleagues. He gave advice to colleagues from Lithuania and Poland.

We wish Professor Friedel Peldschus good health and creativity, so that we can continue to welcome him to our joint activities. On the day of his jubilee, we would like to congratulate the scientist of the greatest format, a person whose merits and contributions to the development of international collaboration of academic communities are numerous. On his Jubilee, we wish him all the best, lot of success and, most of all, satisfaction from witnessing the success of his colleagues from abroad.

5. Conclusions

Game theory is appropriate approach for decision making in construction engineering and management processes to solving different problem from real life. Game theory assumes that the players information about the strategies of the other players. Review showed that many researchers in different research fields' work applied the game theory in: construction engineering, management area.

It is clear from the review of games theory applications that Professor Friedel Peldschus has had an essential contribution in its development and practical applications in construction industry. This is why, part of the article is devoted to his achievements. His numerous articles and, most of all, authorship or co-authorship of six books, is a landmark of theory and practice in a few European countries. His methods have been applied not only to researching the phenomena of balance, but also to the development of multi-criterion optimisation methods.

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LOŠIMŲ TEORIJS TAIKYMAS STATYBOS INŽINERIJOS IR VALDYMO SRITYSE

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Santrauka

Taikant lošimų teoriją analizuojami sprendimų priėmimo procesai įvairiose srityse. Yra įvairių būdų spręsti problemas. Lošimų teorija gali būti orientuota į problemą vieno lošėjo požiūriu ir gali analizuoti daugelio lošėjų tarpusavio sąveiką. Daugiausiai lošimų teorija susijusi su galutiniais atskirais lošimais, kurių ribotas dalyvių skaičius, judėjimas, įvykiai, rezultatai ir t. t. Daugelis įvairių mokslinių sričių tyrėjų taiko lošimo teoriją statybos inžinerijos, valdymo srityse. Straipsnyje pateikiama prof. Friedel Peldschus 42 metų mokslinių tyrimų apžvalga apie lošimų teorijos taikymą statybos inžinerijos ir vadybos srityse, nagrinėjami moksliniai pasiekimai ir veikla, atkreipiamas dėmesys į pasiektus mokslinių tyrimų rezultatus.

Reikšminiai žodžiai: MCDM, lošimų teorija, veikla, statybos inžinerija, valdymas, apžvalga, Peldschus.

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