Development of MCDM Methods –
in Honour of Professor Edmundas Kazimieras Zavadskas
on the Occasion of His 70th Birthday

O. Kaplinski, F. Peldschus, L. Tupėnaitė

Oleg Kaplinski
Poznań University of Technology
Piotrowo 5, 60-965 Poznań, Poland
oleg.kaplinski@put.poznan.pl

Friedel Peldschus
Leipzig University of Applied Science
132 Karl Liebknecht St, 04227 Leipzig, Germany
friedel@peldschus.net

Laura Tupėnaitė*
Vilnius Gediminas Technical University
Sauletekio Ave. 11, Vilnius, LT-10223, Lithuania
E-mail: laura.tupenaite@vgtu.lt
*Corresponding author

Abstract: Multiple Criteria Decision Making (MCDM) substantially evolved during the past decades and became one of the most important areas in Operational Research/Management Science. The article presents a review of extensive scientific work of Professor Edmundas Kazimieras Zavadskas on development of MCDM methods on the occasion of his 70th birthday. The article also highlights his research carrier, and lists some of his publications.
Keywords: decision support, MCDM, methods, development, Edmundas Kazimieras Zavadskas.

1 Introduction

Multiple Criteria Decision Making (MCDM) methods have substantially evolved since 1970s, and had various types of real world applications. New MCDM methods have been developed, and existing methods improved, showing that research in the decision-making is still critical and valuable. One of the early and exceptional authors, continuously working on the development and improvement of MCDM methods since 1976, is Professor Edmundas Kazimieras Zavadskas (Fig. 1). This article is an attempt to summarise his research and achievements in development of the MCDM methods on the occasion of Professor˙s 70th birthday.

2 Achievements in Development of MCDM Methods

Edmundas Kazimieras Zavadskas was born on the 12th of May 1944 in Vilnius. He presented his PhD in 1973 – he researched the applications of polymer resins in reinforced concrete. This was the time when he took interest in optimising constructions, technologies and organisations. A selection of decision-making solutions dominated his research. This is how he significantly developed some elements of rational decisions theory. As a synthesis of research results, in 1987 E. K. Zavadskas defended his Post-Doctoral (Habilitation) Thesis where MCDA/MADM methods (TOPSIS, SAW, ELECTRE, ENTROPY, Game Theory, Utility Theory, Permutation

Method, Judgement Methods) were applied for construction tasks solutions. Furthermore, these methods were used for development of decision support systems [1].

There is a monograph summarising his achievements from that period [2]. This monograph has had a strong influence on research conducted by young academics working towards their PhD theses in number of countries, from Uzbekistan through Russia, Poland, Germany, Denmark, and Cuba to Syria. Another monograph [3] strengthened the Professor's position as a leader in this part of Europe, conquering the area of multi criteria decision aiding methods, and operational research applications in construction industry.

Synthetic works on multiple criteria decision support systems in construction have been published in individual monographs or in collaboration with his colleagues [4] – [6]. New methods of performing multiple criteria analysis in a project have been developed by Professor and his team, including:

- A method of COmplex PRoportional ASsessment (COPRAS) [5], COmplex PRoportional ASsessment of Alternatives with Grey Relations (COPRAS-G) – presented in publication [7] which was nominatd the New Hot Paper for January 2010 by Science Watch (Thomson Reuters) in the field of Engineering (see http://archive.sciencewatch.com/dr/nhp/2010/ 10jannhp/10jannhpZavaET/) and COmplex PRoportional ASsessment of Alternatives Applying Fuzzy Sets (COPRAS-F) [8];
- Additive Ratio Assessment (ARAS) method [9], Additive Ratio Assessment Applying Attributes Values Determined in Intervals (ARAS-G) method [10] and Applying Fuzzy Sets (ARAS-F) [11];
- A Selection of Rational Dispute Resolution Method by Applying New Step-Wise Weight Assessment Ratio Analysis (SWARA) [12];
- TOPSIS Method Applying Mahalanobis Distance Measure (TOPSIS-M) [13];
- A new Normalization method in Games Theory [14];
- A method of Weighted Aggregated Sum Product Assessment [15];
- Algorithm of Maximising the Set of Common Solutions for Several MCDM problems [16].

Furthermore, variety of the new MCDM methods and software was developed in collaboration with academic colleagues from abroad, i.e.:

- Software for Multiple Criteria Evaluation [17];
- A method of Multi-Objective Optimisation on the Basis of Ration Analysis (MOORA) [18];
- A method MULTIMOORA (MOORA plus Full Multiplicative Form) [19];
- COPRAS method for Group Decision Making in an Interval-Values Intuitionistic Fuzzy Environment [20];
- Extensions of LINAMP Model for Multi Criteria Decision Making with Grey Numbers [21];
- Fuzzy DEA Approach Based on Parametric Programming [22];
- Intuitionistic Fuzzy DEA for Efficiency Evaluation under Uncertainty [23];
- Stepwise DEA Analysis and Grey Incidence Analysis [24].

All the above listed methods had wide real world applications in such areas as: sustainable development in civil engineering, building life cycle, modelling of construction and real estate sector, quality control of construction projects, etc. Professor E. K. Zavadskas continuously develops new and researches existing MCDM methods for further improvements. Researches results, among many others, as illustration of Professor's works can be distinguished:

- Measuring Congruence of Ranking Results Applying Particular MCDM methods [25];
- Evaluation of Ranking Accuracy in Multi-Criteria Decisions, presented in paper [26] which was titled as Fast Breaking Paper for June 2009 by Science Watch (Thomson Reuters) in

Development of MCDM Methods –
in Honour of Professor Edmundas Kazimieras Zavadskas
on the Occasion of His 70th Birthday

307

the field of Mathematics (see
http://archive.sciencewatch.com/dr/fbp/2009/pdf/09junfbpVysh.pdf);

- Verification of Robustness of Methods when Assessing Alternative Solutions [27] – [31];
- Proposal of Multi-Criteria Assessment Model of Technologies [32] – [39] .

Professor E. K. Zavadskas, in collaboration with his colleagues, has also developed hybrid decision making methods by combining MCDM methods TOPSIS, SAW, ELECTRE, AHP and the methods proposed by the Professor (see, i.e. [40] – [45]). About 20 papers were nominated as Hot Papers in Thomson Reuters database. In one of these papers there is a published interview with the author (see http://archive.sciencewatch.com/dr/nhp/2011/11maynhp/11maynhpZavaET/).

Professor E. K. Zavadskas was granted a Lithuanian award for research achievements for a cycle of works ´Multiple Criteria Assessment of Construction Projects and Technological Solutionsą (1980–1996) in 1996, and for a cycle of works ´Modelling in construction (methods, simulation, decision support and information systems, web-based technologies, practical application)Ą (1996–2003) – in 2004. In 1996 he also was awarded the 4th class medal of the Lithuanian Grand Duke Gediminas.

3   Biography and General Data

Edmundas Kazimieras Zavadskas (Fig. 1) was born in 1944 Vilnius, Lithuania. He graduated from an elementary school in Vorkuta, USSR and secondary school in 1962, Dūkštas, Lithuania.

E. K. Zavadskas studied at Faculty of Construction Economics in Vilnius branch of Kaunas Polytechnic Institute (VISI) (1962–1967) (now – Vilnius Gediminas Technical University, VGTU). In 1968 he became an assistant, 1969–1972 he was a PhD student at VISI, lecturer – in 1974, associate professor in 1977 and became a professor in 1988.

The Professor became a Rector of Vilnius Civil Engineering Institute (VISI) in 1990. During the period between February-October 1990, he successfully reorganized the Institute, which became the Vilnius Technical University, and was nominated a Rector for period of 1990–1996. Later the University was renamed as Vilnius Gediminas Technical University (VGTU) and Prof. E. K. Zavadskas became a Rector for the period of 1996–2002. In 2002–2011, he was a Vice-Rector of VGTU. In this time, he worked towards making the University one of the largest universities in Lithuania, taking a leading position in technical and engineering education and research.

Since 1986 till now Professor Zavadskas has been a Head of the Department of Construction Technology and Management, Civil Engineering Faculty, VGTU.

His impressive academic carrier started in 1973 when he became a PhD student at the Vilnius Civil Engineering Institute (VISI, now VGTU) and defended his Post-Doctoral (Habilitation) Thesis at Moscow Civil Engineering Institute in 1987 (on Multi Attribute Decision Making in Construction). In 1993, he won laurea doctorali ad habilitationem at Technical Sciences at VGTU.

Professor E. K. Zavadskas was an Expert Member (1991–1993), Corresponding Member (1993–2011) and in 2011, became a Full Member of the Lithuanian Academy of Sciences. Furthermore, he has been granted a title of Honorary Doctor of three universities: Poznań, Kiev, and St. Petersburg (2001–2003) and the Honorary International Professor of the National Taipei University of Technology. He presides and participates in a number of scientific corporations and editorial boards of scientific publishing houses. He is a member of two Russian Academies, the Ukrainian Academy of Cybernetics, and many (17) scientific and research organisations, from Melbourne to Brussels. He also represents the Baltic States in international organisations. The Professor was a President of Operational Researchers Society in Lithuania and the Baltic States

Figure 1: R. J. Slowiński, B. Roy, E. K. Zavadskas at the 52nd Meeting of the EURO Working Group Multicriteria Aid for Decisions (MCDA), 6–7 October, 2000, Vilnius, Lithuania (organised by H. Pranevičius, L. Sakalauskas, E. K. Zavadskas, A. Kaklauskas)

in 2001–2012.

The Professor˙s research and teaching includes fields of construction materials, materials resistance, construction technology and management, operational research methods, decision support systems, life cycle analysis, etc.

Prof. E. K. Zavadskas has published over 50 books, including 5 textbooks and 16 monographs as single author, or in collaboration with other authors, 10 popular science books, over 400 research articles as well as several hundreds of articles on various social and cultural topics. He has edited over 20 collective volumes.

Professor E. K. Zavadskas has set up three famous international scientific journals: ´Technological and Economic Development of EconomyĄ (Editor-in-chief since 1994), ´Journal of Civil Engineering and ManagementĄ (Editor-in-chief since 1995) and ´International Journal of Strategic Property ManagementĄ (Editor-in-chief since 1997 till 2011). Since 2008 all three journals have been referred in Thomson Reuters Web of Science database, and since 2010 – have impact factor (IF). Furthermore, since 2010 these journals are published by VGTU publishing house ´TechnikaĄ in collaboration with a famous publishing house – Taylor & Francis.

The Professor is also a member of editorial boards of 16 international journals referred in Thomson Reuters Web of Science database and 17 other journals.

On various occasions special issues of journals and collective volumes were dedicated to Professor˙s works, i.e. Journal of Management and Decision Making: ´Normalisation in Decision Making methodsĄ (2007), International Journal of Environment and Pollution (2007, 2008), Automation in Construction (2010), Informatica (2001), Ecology (2007).

Professor E. K. Zavadskas was a chairman and member of organizing committees of numerous international conferences, as well as editor of conference proceedings, including:

- Modelling and Simulation of Business Systems (Vilnius, Lithuania 2003);
- 33rd Symposium International FESF Strasbourg: Recent developments in Environmental Protection (Vilnius, Lithuania, 2003);
- Simulation and optimization in Business and Industry: International Conference on Oper-

Development of MCDM Methods –
in Honour of Professor Edmundas Kazimieras Zavadskas
on the Occasion of His 70th Birthday   309

ational Research (Tallinn, Estonia, 2006);

- The 20th International Conference EURO mini Conference 'Construction Optimization and Knowledge-Based Technologies´ (EurOPT'2008) (Neringa, Lithuania, 2008);
- The 25th International Symposium on Automation and Robotics in Construction (ISARC 2008) (Vilnius, Lithuania, 2008);
- International Conference on Modelling of Business, Industrial and Transport Systems (Riga, Latvia, 2008);
- International Conference ´Modern Buildings, Materials and StructuresĄ, (Vilnius, Lithuania, 2004, 2007, 2010, 2013), etc.

Professor E. K. Zavadskas was one of the main initiators of international German – Lithuanian – Polish colloquium dedicated to Operational Research (OR) in Civil Engineering. The first one was held in 1986, Leipzig, Germany. The Colloquia are organized every two years. Since the first one, 14 colloquia have already been organized.

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 (EW-GORSDCE)Ą was presented. On the initiative of professor Zavadskas, the Working Group was established during the 23rd European Conference on Operational Research ´OR creating competitive advantageĄ, which took place in Bonn, Germany 5–8 July 2009 (http://www.euro-online.org/web/ewg/32/ewg-orsdce-or-in-sustainable-development-and-civil-engineering). Prof. E. K. Zavadskas is a Chairman of this working group.

Under E. K. Zavadskas supervision, 33 PhD dissertations were presented (four of his former students were awarded the title of Full Professor).

On the day of his Jubilee, we would like to congratulate Professor Edmundas Kazimieras Zavadskas – an exceptional scientist of greatest format. We wish the Professor good health and creativity in further contributions to MCDM methods.

4   Conclusions

Professor Edmundas Kazimieras Zavadskas has greatly contributed to development and practical applications of MCDM methods. This is why a part of the article was devoted to his achievements. His numerous articles and, most of all, authorship or co-authorship of books contribute to the MCDM theory and practice, as well as encourage continuous innovations in this field.

Bibliography

[1] Zavadskas, E.K. (1987); *Multiattribute Decision Making in Construction.* Dr.Sc. Dissertation. Moscow: Institute of Civil Engineering. 720 p. (in Russian).

[2] Zavadskas, E. (1987); *Complex Estimation and Choice of Resource-Saving Decisions in Construction.* Vilnius: Mokslas. 210 p. (in Russian).

[3] Zavadskas, E.K. (1991); *System of Estimation of Technological Solutions in Building Construction.* Leningrad: Stroizdat. 256 p. (in Russian).

[4] Zavadskas, E.; Peldschus, F.; Kaklauskas, A. (1994); *Multiple Criteria Evaluation of Projects in Construction.* Vilnius: Technika. 226 p.

[5] Zavadskas, E.K.; Kaklauskas, A. (2007); *Mehrzielselektion für Entscheidungen im Bauwesen.* Stuttgart: IRB Verlag. 276 p. (in German).

[6] Zavadskas, E.; Kaplinski, O.; Kaklauskas, A.; Brzezinski, J. (1995); *Expert Systems in Construction Industry. Trends, Potencial & Applications.* Vilnius: Technika. 180 p.

[7] Zavadskas, E.K.; Kaklauskas, A.; Turskis, Z.; Tamosaitiene, J. (2008); Selection of the Effective Dwelling House Walls by Applying Attributes Values Determined at Intervals, *Journal of Civil Engineering and Management*, 14(2): 85-93.

[8] Zavadskas, E.K.; Antucheviciene, J.; (2007); Multiple Criteria Evaluation of Rural Building's Regeneration Alternatives, *Building and Environment*, 42(1): 436-451.

[9] Zavadskas, E.K.; Turskis, Z. (2010); A New Additive Ratio Assessment (ARAS) Method in Multicriteria Decision-Making, *Technological and Economic Development of Economy*, 16(2): 159-172.

[10] Turskis, Z.; Zavadskas, E.K.; (2010); A Novel Method for Multiple Criteria Analysis: Grey Additive Ratio Assessment (ARAS-G) Method, *Informatica*, 21(4): 597-610.

[11] Turskis, Z.; Zavadskas, E.K. (2010); A New Fuzzy Additive Ratio Assessment Method (ARAS-F). Case Study: the Analysis of Fuzzy Multiple Criteria in Order to Select the Logistic Centers Location, *Transport*, 25(4): 423-432.

[12] Keršulienė, V.; Zavadskas, E.K.; Turskis, Z. (2010); Selection of Rational Dispute Resolution Method by Applying New Step-Wise Weight Assessment Ratio Analysis (SWARA), *Journal of Business Economics and Management*, 11(2): 243-258.

[13] Antuchevičienė, J.; Zavadskas, E.K.; Zakarevičius, A. (2010); Multiple Criteria Construction Management Decisions Considering Relations between Criteria, *Technological and Economic Development of Economy*, 16(1): 109-125.

[14] Zavadskas, E.K.; Turskis, Z. (2008); A New Logarithmic Normalization Method in Games Theory, *Informatica*, 19(2): 303-314.

[15] Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J.; Zakarevicius, A. (2012); Optimization of Weighted Aggregated Sum Product Assessment, *Electronics and Electrical Engineering = Elektronika ir elektrotechnika*, 122(6): 3-6.

[16] Dadelo, S.; Krylovas, A.; Kosareva, N.; Zavadskas, E.K.; Dadeliene, R. (2014); Algorithm of Maximizing the Set of Common Solutions for Several MCDM Problems and it's Application for Security Personnel Scheduling, *International Journal of Computers, Communications & Control (IJCCC)*, 9(2): 140-148.

[17] Zavadskas, E.K.; Ustinovičius, L.; Peldschus, F. (2003); Development of Software for Multiple Criteria Evaluation, *Informatica*, 14(2): 259-272.

[18] Brauers, W.K.M.; Zavadskas, E.K. (2006); The MOORA Method and its Application to Privatization in a Transition Economy, *Control and Cybernetics*, 35(2): 445-469.

[19] Brauers, W.K.M.; Zavadskas, E.K. (2010); Project Management by MULTIMOORA as an Instrument for Transition Economies, *Technological and Economic Development of Economy*, 16(1): 5-24.

[20] Razavi Hajiagha, S.H.; Hashemi, S.S.; Zavadskas, E.K. (2013); A Complex Proportional Assessment Method for Group Decision Making in an Interval-Valued Intuitionistic Fuzzy Environment, *Technological and Economic Development of Economy*, 19(1): 22-37.

Development of MCDM Methods –
in Honour of Professor Edmundas Kazimieras Zavadskas
on the Occasion of His 70th Birthday
311

[21] Razavi Hajiagha, S.H., Hashemi, S.S.; Zavadskas, E.K.; Akrami, H. (2012); Extensions of LINMAP Model for Multi Criteria Decision Making with Grey Numbers, *Technological and Economic Development of Economy*, 18(4): 636-650.

[22] Razavi Hajiagha, S.H.; Mahdiraji, H.A.; Zavadskas, E.K.; Hashemi, S.S. (2013); A Fuzzy Data Envelopment Analysis Approach Based on Parametric Programming, *International Journal of Computers, Communications & Control (IJCCC)*, 8(4): 594-607.

[23] Razavi Hajiagha, S.H.; Akrami, H.; Zavadskas, E.K.; Hashemi, S.S. (2013); An Intuitionistic Fuzzy Data Envelopment Analysis for Efficiency Evaluation under Ucertainty: Case of a Finance and Credit Institution, *E&M Economics and Management = E&M Economie a Management*, 1: 128-137.

[24] Razavi Hajiagha, S.H.; Zavadskas, E.K.; Hashemi, S.S. (2013); Application of Stepwise Data Envelopment Analysis and Grey Incidence Analysis to Evaluate the Effectiveness of Export Promotion Programs, *Journal of Business Economics and Management*, 14(3): 638-650.

[25] Antuchevičienė, J.; Zakarevičius, A.; Zavadskas, E.K. (2011); Measuring Congruence of Ranking Results Applying Particular MCDM methods, *Informatica*, 22(3): 319-338.

[26] Zavadskas, E.K.; Zakarevicius, A.; Antucheviciene, J. (2006); Evaluation of Ranking Accuracy in Multi-Criteria Decisions, *Informatica*, 17(4): 601-618.

[27] Zavadskas, E.K.; Antucheviciene, J.; Saparauskas, J.; Turskis, Z. (2013); MCDM Methods WASPAS and MULTIMOORA: Verification of Robustness of Methods when Assessing Alternative Solutions, *Journal of Economic Computation and Economic Cybernetics Studies and Research* (ECECSR), 47(2): 5-20.

[28] Brauers, W. K. M.; Zavadskas, E. K. (2012); Robustness of MULTIMOORA: a method for multi-objective optimization, *Informatica*, 23(1): 1-25.

[29] Brauers, W. K. M.; Kildienė, S.; Zavadskas, E. K.; Kaklauskas, A. (2013); The construction sector in twenty European countries during the recession 2008-2009 – country ranking by MULTIMOORA, International *Journal of Strategic Property Management*, 17(1): 58-78.

[30] Yazdani-Chamzini, A.; Yakhchali, S. H.; Zavadskas, E. K. (2012); Using a integrated MCDM model for mining method selection in presence of uncertainty, *Ekonomska Istraživanja - Economic Research*, 25(4): 869-904.

[31] Brauers, W. K. M.; Zavadskas, E. K. (2012); A multi-objective decision support system for project selection with an application for the Tunisian textile industry, *E&M Economie a Management*, 15(1): 28-43.

[32] Zavadskas, E. K.; Turskis, Z.; Volvačiovas, R.; Kildienė, S. (2013); Multi-criteria assessment model of technologies, *Studies in Informatics and Control*, 22(4): 249-258.

[33] Hashemkhani Zolfani, S.; Sedaghat, M.; Zavadskas, E. K. (2012); Performance evaluating of rural ICT centers (telecenters), applying Fuzzy AHP, SAW-G and TOPSIS Grey, a case study in Iran, *Technological and Economic Development of Economy*, 18(2): 364-387.

[34] Hashemkhani Zolfani, S.; Zavadskas, E. K.; Turskis, Z. (2013); Design of products with both international and local perspectives based on Yin-Yang balance theory and SWARA method, *Ekonomska Istraživanja - Economic Research*, 26(2): 153-166.

[35] Yazdani-Chamzini, A.; Fouladgar, M. M.; Zavadskas, E. K.; Moini, S. H. H. (2013); Selecting the optimal renewable energy using multi criteria decision making, *Journal of Business Economics and Management*, 14(5): 957-978.

[36] Hashemkhani Zolfani, S.; Esfahani, M. H.; Bitarafan, M.; Zavadskas, E. K.; Arefi, S. L. (2013); Developing a new hybrid MCDM method for selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents, *Transport*, 28(1): 89-96.

[37] Staniunas, M.; Medineckiene, M.; Zavadskas, E. K.; Kalibatas, D. (2013); To modernize or not: ecological-economical assessment of multi-dwelling houses modernization, *Archives of Civil and Mechanical Engineering*, 13(1): 88-98.

[38] Kracka, M.; Zavadskas, E. K. (2013); Panel building refurbishment elements effective selection by applying multiple-criteria methods, *International Journal of Strategic Property Management*, 17(2): 210-219.

[39] Brauers, W. K. M.; Kracka, M.; Zavadskas, E. K. (2012); Lithuanian case study of masonry buildings from the Soviet period, *Journal of Civil Engineering and Management*, 18(3): 444-456.

[40] Zavadskas, E.K.; Vainiūnas, P.; Turskis, Z.; Tamošaitienė, J. (2012); Multiple Criteria Decision Support System for Assessment of Projects Managers in Construction, *International Journal of Information Technology & Decision Making*, 11(2): 501-520.

[41] Hashemkhani Zolfani, S.H.; Aghdaie, M.H.; Derakhti, A.; Zavadskas, E.K.; Varzandeh, M.H.M. (2013); Decision Making on Business Issues with Foresight Perspective; An Application of New Hybrid MCDM Model in Shopping Mall Locating, *Expert Systems with Applications*, 40(17): 7111-7121.

[42] Fouladgar, M. M.; Yazdani-Chamzini, A.; Zavadskas, E. K.; Haji M., Hamzeh, S. (2012); A new hybrid model for evaluating the working strategies: case study of construction company, *Technological and Economic Development of Economy*, 18(1): 164-188.

[43] Rezaeiniya, N.; Hashemkhani Zolfani, S.; Zavadskas, E. K. (2012); Greenhouse locating based on Anp-Copras-G Methods – an empirical study based on Iran, *International Journal of Strategic Property Management*, 16(2): 188-200.

[44] Hashemkhani Zolfani, S.; Rezaeiniya, N.; Pourhossein, M.; Zavadskas, E. K. (2012); Decision making on advertisement strategy selection based on life cycle of products by applying FAHP and TOPSIS GREY: growth stage perspective; a case about food industry in IRAN, *Inžinerinė Ekonomika - Engineering Economics*, 23(5): 471-484.

[45] Zavadskas, E. K.; Sušinskas, S.; Daniūnas, A.; Turskis, Z.; Sivilevičius, H. (2012); Multiple criteria selection of pile-column construction technology, *Journal of Civil Engineering and Management*, 18(6): 834-842.