SUBJECTIVE GEOMETRY FOR PROBLEM MODELING IN THE ANALYTIC HIERARCHY/NETWORK PROCESSES

Hsu-Shih Shih[1]
Department of Management Sciences, Tamkang University
Taiwan, R.O.C.
E-mail: hshih@mail.tku.edu.tw

ABSTRACT

This paper is in memory of Professor Thomas L. Saaty, who died on August 14, 2017.

In a problem-solving process, the first step is to model a real-world problem. The modeling effort is one of the hardest parts of the process, and there is no universal way to do it. The initial step involves structuring the problem and obtaining a simplified problem so that any multi-criteria or statistical models can be applied. This paper intends to explain the modeling process through subjective geometry. Although creative thinking is critical in developing the hierarchies and networks in the Analytic Hierarchy or Network Process (AHP/ANP), models from business management and information theories can supply a verified ready-to-use relationship among elements and their clusters. We hope the exploration offers a guideline for utilizing the AHP/ANP in more detail.

Keywords: structure problem; subjective geometry; Analytic Hierarchy Process; Analytic Network Process; decision making; problem modeling

1. Introduction

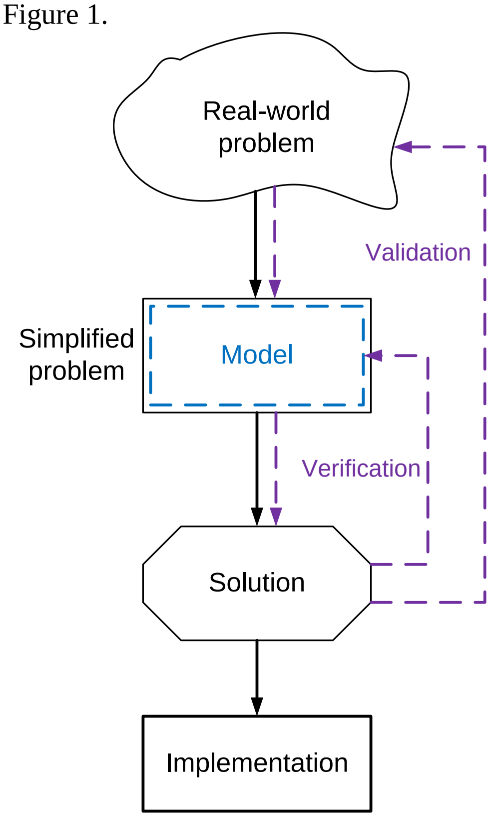
To solve a problem, one first needs to identify the problem. A problem is a question that results in inquiry, consideration, or a solution and generally appears when humans feel there is a difference or discrepancy between the current condition and the intended situation. People may feel uncomfortable if the problem remains unsolved or an unwanted situation exists. We may struggle to recognize the real issue and address the incorrect problem. It is always important to carefully recognize the real problem, which can often be difficult to see at first (Clemen, 1996). Aside from knowing the environment well, specific domain knowledge from experienced experts is helpful. Management tools such as 5W1H (What? Who? Where? When? Why? How?) (Robertson, 1946), brain storming (Osborn, 1953), an Ishikawa diagram or fishbone diagram (Ishikawa, 1968), TRIZ (a Russian acronym for Theory of the Resolution of Invention-related Tasks)

Acknowledgments: The author wishes to thank Professor David L. Olson at the University of Nebraska, U.S.A. for his valuable help with this study.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v14i2.1012

(Altshuller & Shapiro, 1956), or other creative techniques, could also help to discover the true problem. In addition to quantitative data illustrating the problem clearly, qualitative data or even a figure can provide an image of the possible problems that exist. Some graphic tools, such as the fishbone diagram, help structure the problem and understand the nature of the problem by roughly capturing its system components (Clement, 1996). These methods are beneficial, especially in the early stages of decision making. In addition, a hierarchy or network could assist in visualizing the problem and its relevant elements through a geometric representation (Saaty & Shih, 2009).

After identifying a problem, the decision maker (DM) reacts to it and attempts to solve it with his or her conscious and aware mind. This response starts the problem-solving process. Simon (1977) proposed an idea about the decision-making process, related to the problem-solving process, which includes the following phases: (i) intelligence, (ii) design, and (iii) choice. He later added another phase, (iv) implementation. From the perspective of management, the process usually involves a monitoring phase so that the consequences of implementation can be examined and that is can be confirmed that the consequences were as expected; otherwise, we need another cycle of the process for problem solving. Some experts have examined the cognitive role of the DM. Rowe and Boulgarides (1992) included a stimulation phase before the above phases. The cognitive stage views outside factors, such as potential advantages, dangers, or feedback from the current system, which are the root cause of the issue. Decision theory emphasizes preference, which is a technical term for selecting one option over another, in addition to the DM's cognition (Einhorn & Hogarth, 1981). It has a direct relation to desires and includes two contrasting options before choosing one. The general process for solving problems is outlined in Figure 1.



ISSN 1936-6744
https://doi.org/10.13033/ijahp.v14i2.1012

Figure 1 Problem-solving process (Shih & Olson, 2022)

The paper is organized as follows. Section 2 discusses hierarchies and networks in detail and provides many different forms of hierarchies and networks in decision making. Section 3 illustrates the relationships of these geometric structures. Section 4 discusses the use of these hierarchies and networks. Section 5 provides some conclusions.

2. Geometric structures

Geometry is concerned with properties of space that are related to distance, shape, size, and relative position of figures (Tabak, 2014). The shape or figure of the elements in relation to each other could help solve a problem. In a traditional managerial meeting that is promoting teamwork, the participants can use a whiteboard to draw figures to focus on the issue being addressed. Once the figures are drawn, even if they are not represented precisely, the participants can discuss the related elements analogous to the problem, stimulating critical thinking and modifying the figures as needed. An example of this process could be brainstorming or brainwriting (Hwang & Lin, 1987). The cognitive process is to identify the problem and realize its relationship via a visualized shape or figure. This is called “geometric cognition” or “spatial/visual reasoning in mathematics”, which offers the clearest and often unavoidable expression in mathematical cognition (Whiteley, 2015).

Though numerous figures could be considered in the process, hierarchies or networks are common types of figures used for this purpose. Saaty (1980, 1996) developed the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) to solve problems and provided solid theories to support the decisions. Both the AHP and ANP are structured frameworks for multi-criteria decision making (MCDM). However, we will concentrate on the modeling of the problem.

2.1 Hierarchical and networked structures

Saaty and Vargas (1994) defined a hierarchy as the ordering of parts or elements of a whole from the highest to the lowest, in a top-to-bottom fashion, and with connected relationships among them to fulfill the function of an organization (Saaty & Vargas, 1994). The simplest hierarchical structure consists of a goal, criteria, and alternatives. After the levels and their elements are chosen, pair-wise comparisons of the strengths of preferences are executed from the top-down, and the synthesis process is carried out from the bottom-up for the final decision (Saaty, 1980). Saaty (1980) also provided a benefit-cost analysis, in which benefit and cost hierarchies are involved in the modeling process. He originally suggested the ratio of benefit to cost (i.e., B/C) on alternatives as the standard to rank them. However, a few debates arose because the cutoff value for the ratio is the critical factor for the selection. Readers interested in this discussion can refer to Saaty (1996) and Shih (2008) for details.

To manage a complex problem, Saaty and Özdemir (2003) further introduced four merits of a decision: benefit (B), opportunity (O), cost (C), and risk (R). The basic idea is to establish four hierarchies for modeling the problem and synthesize them at the level of alternatives. They proposed four formulae for the synthesis which are as follows: (i)

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v14i2.1012

BO/CR, (ii) *b*B+*o*O+*c*(1/C)+*r*(1/R), (iii) *b*B+*o*O+*c*(1–C)+*r*(1–R), and (iv) *b*B+*o*O–*c*C–*r*R, where *b*, *o*, *c*, and *r* are the weights assigned to the corresponding merits. Though BO/CR is directly extended from benefit-cost analysis, they preferred the use of *b*B+*o*O–*c*C–*r*R. These four weights are obtained from a pair-wise comparison. Wijnmalen (2007) verified that the additive synthesis with properly weighted factor priorities based on relative magnitudes produces sound results.

A network is a system of connected travel routes or communication lines, where some elements are connected to influence others, be influenced by others, mutually influence each other, or have a feedback with a connected cycle. Its geometry does not have the simple linear top-to-bottom form of a hierarchy. Network representation is rather flexible and relies on the purpose of a system or what an organization is trying to achieve. Besides its flexibility, the network can formulate relationships of dependence and feedback or with interactions among elements. Hence, the figure could be any shape in geometry. Because of its flexibility, network formulation is challenging and needs a control hierarchy to guide the thought process whereby the function of the goal/focus is at the top of the hierarchy. Fortunately, Saaty (1996) provided the supermatrix from the priority vectors of positive reciprocal matrices, to deal with the problem under a control hierarchy, and suggested four measures to manage complex problems, opportunity, cost, and risk along with benefit.

2.2 Simplified structures

A network has various advantages in modeling real-world problems. In reality, the ANP suffers from a large number of similar questions given to experts if the structure is complex. To avoid this judgmental confusion, we need to take a very cautious step to avoid the phenomenon of "garbage in, garbage out." One option is to apply statistical methods to eliminate unimportant relationships in the network. Saaty and Takizawa (1986) suggested a simplified structure, including three steps, to deal with the dependence on elements. The first step, as in traditional AHP, only processes the influences without considering dependence. The second step considers dependence, and the final step combines the information from the first two to determine the final priority with dependence. Despite the fact that the proposal has limited capability for handling dependence, it is a tradeoff between network complexity and the ease of applicable procedure. For example, Shyur and Shih (2006) utilized a hierarchical structure with dependent relationships to solve the problem of vendor selection, in which there were four criteria among the seven encounter interactions. The simplified structure or this problem can be seen in Figure 2.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v14i2.1012

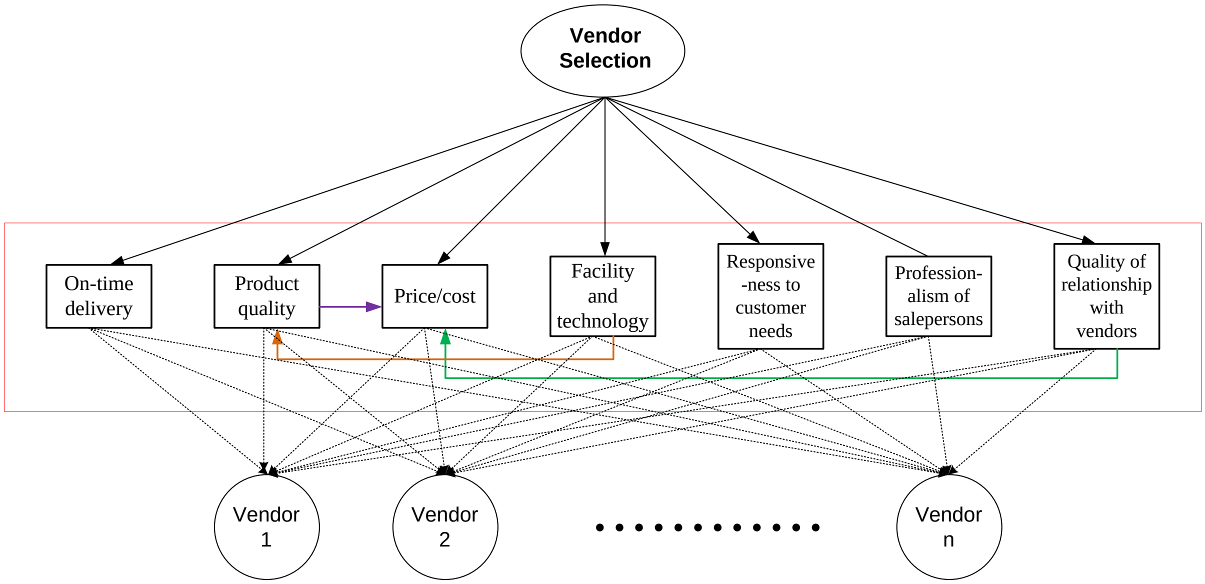


Figure 2 Simplified structure (Shyur & Shih, 2006)

The Decision Making Trial and Evaluation Laboratory (DEMATEL) technique by Gabus and Fontela (1972) has drawn much attention in recent decades. Ou Yang et al. (2008) combined DEMATEL with ANP, naming it DEMATEL-based ANP, to solve problems with dependence and feedback. Since DEMATEL also takes advantage of limiting operations on matrices, DEMATEL and ANP share some common characteristics so their combination does not have much effect. Gölcük and Baykasolu (2016) organized four types of combinations of DEMATEL and ANP. However, DEMATEL can only identify cause-and-effect relationships in a complicated system and is incapable of handling the structural dependence of the ANP. Hence, these combinations could be ambiguous in designing problem-solving processes. Interested readers could read Gölcük and Baykasolu (2016) to learn more about the four classes of dependence: criteria dependency (structural dependency, causal dependency, and preferential dependency) and criteria interactivity.

2.3 Other structures

As ANP has been prominent over the past two decades, various studies have applied it to business management under existing structures. By taking advantage of existing or modified structures, the ANP is able to formulate the influence of dependence and feedback in the analyses. For instance, Yüksel and Dadeviren (2007) utilized the ANP to measure the dependence among strategic factors under the structure of strengths, weaknesses, opportunities, and threats (SWOT). They used a four-level hierarchical structure with dependence only on the SWOT aspects and observed the change in strategy priorities for a textile firm. Nguyen and Truong (2022) also considered SWOT for modeling Vietnam’s strategic agricultural development in the context of a drought. Hsu et al. (2012) referred to the E-S-QUAL model (Parasuraman et al., 2005) to assess the electronic service quality (e-SQ) of online travel websites using the ANP. Considering the interdependence among its criteria and sub-criteria, the study sheds light on the truly important criteria and sub-criteria of e-SQ for future improvement. Poveda-

Bautista et al. (2012) exploited the ANP to prioritize 17 company competitiveness indicators (CCIs) under the structure of a balanced scorecard (BSC) with four aspects and for three companies. Managing the dependence and feedback on CCIs and the aspects, the research obtained the relative positions of the companies in the sector and the priorities of CCIs. Wu et al. (2012) employed the ANP to evaluate the current strategy by choosing the most important criteria under the structure of Porter's five forces model. The 30 criteria under five forces were evaluated to identify the important criteria under the current strategy for the case company.

In the area of information theories, there are also numerous structures. In particular, Chen and Shih (2014) examined the acceptance of wearable technology for consumers under the structure of the unified theory of adoption and use of technology (UTAUT) model (Venkatesh et al., 2003) through an ANP analysis. Because four constructs that include performance expectancy, effort expectancy, social influence, and facilitating conditions, are direct determinants of behavioral intention and use behavior, the ANP assessed 14 factors for the four constructs and three each for behavioral intention and use behavior, as shown in Figure 3. Nilashi et al. (2016) determined the importance of hospital information system adoption factors under the structure of the human, organization, and technology (HOT) fit model (Yusof et al., 2008) using the ANP. The 17 sub-factors under four factors (i.e., technological, organizational, environmental, and human) were weighted and ranked to determine the influences on adoption. There are innumerable theories in the areas of business management and information management. These existing structures or models can indeed provide fast and ready-to-use structures to apply the ANP.

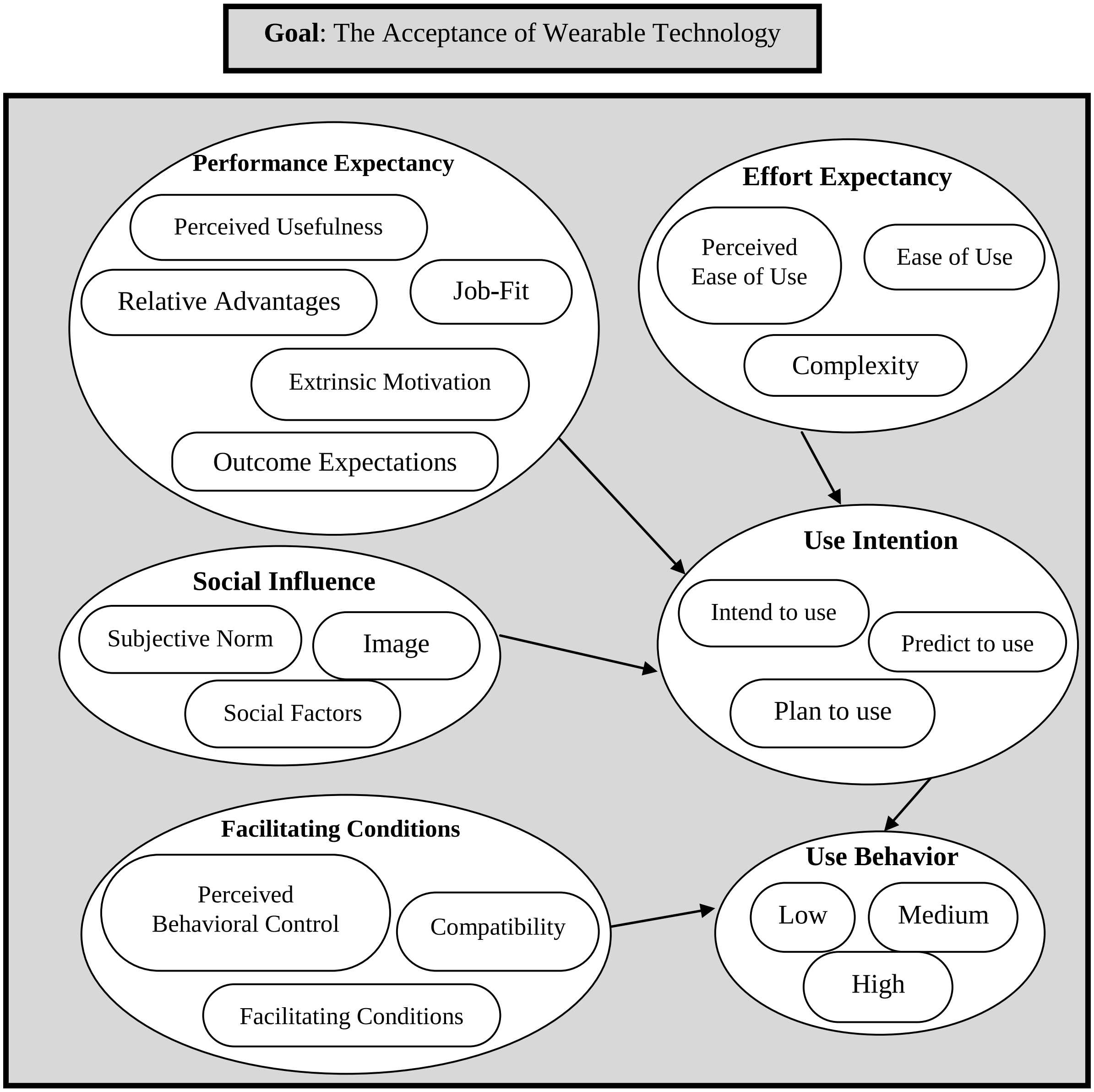


Figure 3 UTAUT model using the ANP (Chen & Shih, 2014)

It is obvious that the models from business management and information theories can supply a verified ready-to-use relationship among elements and their clusters. Hence, the ANP does not exert much effort on the relationship and concentrates on the intensity of the relationship. Therefore, the process saves time sorting out dependence and feedback. More networks can be found in Saaty and Özdemir (2005).

3. Structure relationships

Geometry is a branch of mathematics that deals with the measurement, properties, and relationships of points, lines, angles, surfaces, and solids. Its origins are in ancient Greece

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v14i2.1012

and it is one of the oldest branches of its field. The scope of geometry has been greatly expanded and the field has been split into many subfields (De Risi, 2015). In Euclidean geometry, which is the closest to our discussion, the elements begin with plane or two-dimension geometry. Plane geometry is taught in secondary or high school as the first axiomatic system and the first example of a mathematical proof. It then goes on to solid geometry which involves three dimensions. Much of the element's states are the result of what is now known as algebra and number theory, which are explained in geometrical language (Eves, 1972). For most of the decision-making process, only the simple elements, line segments and shapes are enough to establish relationships in a two-dimensional plane. For instance, in the fishbone diagram, the causes of imperfection are the sources of variation. The causes of the variation are usually grouped into major categories to identify and classify the sources (Ishikawa, 1968).

We may question the process that lacks a rigorous mathematical proof. Nevertheless, it is the first step to focusing our cognition on the targeted problem. This is the reason why it is called "subjective geometry." Although the question of mathematical proof is not answered, statistical tools or observations on brain responses could be helpful to ensure the relationships under the problem. For instance, Shih et al. (2014) organized criteria by the content validity ratio to delete the minor criteria and executed factor analysis to determine groups of the criteria and clusters to which they belong. Thus, the experts can manage a simplified questionnaire on the relationships between dependence and feedback in the network. Due to these helpful tools, the burden of cognition of DMs decreases so that right judgments can be generated. Note that though there are no perfect DMs, better decisions can be made through more structure and guidance (Clemen, 1996).

Within decision analysis, we are always concerned about whether we are dealing with the right problem. Validation is critical in guaranteeing that the true problem is being solved, but there is no universal way to do it. Saaty (2005a) discussed validation by comparing solutions to real world facts, and both outcomes are very close in numerous listed cases. This means that the analytic results of the AHP/ANP can solve real world problems if the judgments of experts are carefully handled. Saaty (2005a) also supported the idea that group decision-making is better than any wise individual because it can obtain benefits from multiple sources of knowledge and experiences so that the bias of the individual can be alleviated (Surowiecki, 2004). A sensitivity analysis allows DMs to examine the effect of varying the influences on the stability of the outcome in the AHP/ANP (Saaty, 2005b), but it is a verification process, as shown in Figure 1, and does not relate to dealing with the right problem.

4. Discussion

In Section 2, we discussed many types of networks and hierarchies. Using existing networks for business management and information theories is beneficial because the models have been verified and are ready to be applied. Nonetheless, the approaches appear to be lacking in innovation without incorporating our human potential (Saaty, 2001). In addition, there is a difference in the networks from business management and information theory compared to the ANP. They generally supply the relationships of the networks, but not the intensity of the relationships. However, the ANP could help prioritize the influences of the elements and their clusters/levels and provide more decision insights regardless of how it exploits networks, with or without the two areas.

5. Conclusions

Subjective geometry is a useful tool for extracting our cognition during the decision making process through the use of some common management tools. It introduces an initial structure for making a decision. We can thus make judgments about the AHP/ANP procedure through the fundamental scale. In spite of the fact that subjective geometry lacks a rigorous mathematical representation, it is a rapid form of approximation to the real problem. Creative thinking is critical in developing these hierarchies and networks. In addition, some statistical tools can help alleviate the burden of the cognitive process, which group decision making also does. The proposed merits of BOCR also play the same role in the cognitive process.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v14i2.1012

REFERENCES

Altshuller, G., Shapiro, R. (1956). About technical creativity. *Questions of Psychology, 6*, 37-49. (in Russian)

Chen, C.-C., Shih, H.-S. (2014), A study of the acceptance of wearable technology for consumers - An ANP perspective. *13th International Symposium on the Analytic Hierarchy Process, ISAHP 2014*. Washington, DC, USA. Doi: https://doi.org/10.13033/isahp.y2014.011

Clemen, R. T. (1996). *Making hard decisions: An introduction to decision analysis*. Pacific Grove, California: Brooks/Cole Publishing, Second Edition. ISBN: 9780534260347.

De Risi, V. (2015)(Ed.). *Mathematizing space: The objects of geometry from antiquity to the early modern age*. Cham, Switzerland: Birkhäuser, Springer. Doi: https://doi.org/10.1086/687011.

Einhorn, H. J., Hogarth, R. M. (1981). Behavioral decision theory: Processes of judgment and choice. *Annual Review of Psychology, 32*, 53-88. Doi: https://doi.org/10.1146/annurev.ps.32.020181.000413.

Eves, H. (1972). A Survey of Geometry (Volume One). White Plains, New York, Allyn & Bacon, Longman, Revised Edition. ISBN: 9780205032266.

Gabus, A., Fontela, E. (1972). *World problems, an invitation to further thought within the framework of DEMATEL*, 1-8. Battelle Geneva Research Center, Geneva, Switzerland.

Gölcük, I., Baykasoğlu, A. (2016). Analysis of DEMATEL approaches for criteria interaction handling within ANP. *Expert Systems with Applications*, *46*, 346-366. Doi: https://doi.org/10.1016/j.eswa.2015.10.041.

Hsu, T.-H., Huang, L.-C., Tang, J.-W. (2012). A hybrid ANP evaluation model for electronic service quality. *Applied Soft Computing*, *12*(1), 72-81. Doi: https://doi.org/10.1016/j.asoc.2011.09.008.

Hwang, C.-L., Lin, M.-J. (1987). *Group decision making under multiple criteria.* Springer-Verlag, Berlin. Doi: https://doi.org/10.1007/978-3-642-61580-1.

Ishikawa, K. (1968). *Guide to quality control*. Tokyo: JUSE. ISBN: 978-9283310365.

Nguyen, H.T., Truong, T.C. (2022). Integral SWOT-AHP-TOWS model for strategic agricultural development in the context of drought: A case study in Ninh Thuan, Vietnam. *International Journal of the Analytic Hierarchy Process*, *14*(1), 1-30. Doi: https://doi.org/10.13033/ijahp.v14i1.890.

Nilashi, M., Ahmadi, H., Ahani, A., Ravangard, R., Ibrahima, O.B. (2016). Determining the importance of Hospital Information System adoption factors using Fuzzy Analytic

Network Process (ANP). *Technological Forecasting and Social Change*, *111*, 244-264. Doi: https://doi.org/10.1016/j.techfore.2016.07.008.

Osborn, A. F. (1953). Applied imagination: *Principles and procedures of creative thinking*. New York: Charles Scribner's Sons. ISBN: 9781447417101

Ou Yang, Y.-P., Shieh, H.-M., Leu, J.-D., Tzeng, G.-H. (2008), A novel hybrid MCDM model combined with DEMATEL and ANP with applications. *International Journal of Operations Research*, *5*, 160-168.

Parasuraman, A., Zeithaml, V.A., Malhotra, A. (2005). E-S-QUAL: A multiple-item scale for assessing electronic service quality. *Journal of Service Research*, *7*(3), 213-233. Doi: https://doi.org/10.1177/1094670504271156.

Poveda-Bautista, R., Baptista, D.C., García-Melón, M. (2012). Setting competitiveness indicators using BSC and ANP. *International Journal of Production Research*, *50,* 4738-4752. Doi: https://doi.org/10.1080/00207543.2012.657964.

Robertson, Jr., D. W. (1946). A note on the classical origin of "circumstances" in the medieval confessional. *Studies in Philology,* 6-14.

Rowe, A. J., Boulgarides, J. D. (1992). *Managerial decision making*. New York: Macmillan. ISBN: 9780024041111.

Saaty, T. L. (1980). The Analytic Hierarchy Process. New York: McGraw-Hill. ISBN: 9780070543713.

Saaty, T.L. (1996). *Decision making with dependence and feedback: The Analytic Network Process.* Pittsburgh: RWS Publications. ISBN: 9780962031793.

Saaty, T.L. (2001), Creative thinking, problem solving and decision making. Pittsburgh, PA: RWS Publications. ISBN: 9781888603033.

Saaty, T.L. (2005a). Theory and applications of the Analytic Network Process: Decision making with benefits, opportunities, costs and risks. Pittsburgh, PA: RWS Publications. ISBN: 9781888603064.

Saaty, T.L. (2005b). Making and validating complex decisions with the AHP/ANP. *Journal of Systems Science and Systems Engineering*, *14*, 1-36. Doi: https://doi.org/10.1007/s11518-006-0179-6.

Saaty, T.L., Özdemir, M.S. (2003). Negative priorities in the analytic hierarchy process. *Mathematical and Computer Modelling*, *37*(9-10), 1063 -1075. Doi: https://doi.org/10.1016/S0895-7177(03)00118-3.

Saaty, T.L., Özdemir, M.S. (2005). The Eecyclicon: A dictionary of decisions with dependence and feedback based on the Analytic Network Process. Pittsburgh, PA: RWS Publications. ISBN: 9781888603057.

Saaty, T.L., Takizawa, M. (1986). Dependence and independence − from linear hierarchies to nonlinear networks. *European Journal of Operational Research*, *26*, 229-237. Doi: https://doi.org/10.1016/0377-2217(86)90184-0.

Saaty, T.L., Shih, H.-S. (2009). Structures in decision making: On the subjective geometry of hierarchies and networks. *European Journal of Operational Research, 199*(3), 867-872. Doi: https://doi.org/10.1016/j.ejor.2009.01.064.

Saaty, T.L., Vargas, L.G. (1994). Decision making in economic, political, social and technological environments: The Analytic Hierarchy Process. Pittsburgh, PA: RWS Publications. ISBN: 9780962031779.

Shih, H.-S. (2008). Incremental analysis for MCDM with an application to group TOPSIS. *European Journal of Operational Research*, *186*(2), 720-734. Doi: https://doi.org/10.1016/j.ejor.2007.02.012.

Shih, H.-S., Cheng, C.-B., Chen, C.-C., Lin, Y.-C. (2014), Environmental impact on the vendor selection problem in electronics firms – A systematic analytic network process with BOCR. *International Journal of the Analytic Hierarchy Process*, *6*(2), 1-25. Doi: https://doi.org/10.13033/ijahp.v6i2.256.

Shih, H.-S., Olson, D.L. (2022). *TOPSIS and its extensions: A distance-based MCDM approach.* Cham, Switzerland: Springer Nature. ISBN: 9783031095764.

Shyur, H.-J., Shih, H.-S. (2006), A hybrid MCDM model for strategic vendor selection. *Mathematical and Computer Modelling*, *44*(7-8), 749-761. Doi: https://doi.org/10.1016/j.mcm.2005.04.018.

Simon, H.A. (1977). *The new science of management decision. 3rd Ed.*, Englewood Cliffs, New Jersey: Prentice Hall. ISBN: 9780136161363.

Surowiecki, J. (2004). *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies and nations*. New York: Random House. Doi: https://doi.org/10.4324/9781912453184-22.

Tabak, J. (2014). *Geometry: the language of space and form*. New York: Infobase Publishing. ISBN 9780816049530.

Venkatesh, V., Morris, M.G., Davis, G.B., and Davis, F.D, (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*(3), 425-478. Doi: https://doi.org/10.2307/30036540.

Whiteley, W. (2015). Geometric cognition. In V Danesi, M. (ed.), *Interdisciplinary perspectives on math cognition*. 247-262. Cham, Switzerland: Springer. Doi: https://doi.org/10.1007/978-3-030-22537-7_13

Wijnmalen, D.J.D. (2007). Analysis of benefits, opportunities, costs, and risks (BOCR) with the AHP–ANP: A critical validation. *Mathematical and Computer Modelling*, *46*(7-8), 892-905. Doi: https://doi.org/10.1016/j.mcm.2007.03.020.

Wu, K.-J., Tseng, M.-L., Chiu, A.S.F. (2012). Using the Analytical Network Process in Porter's Five Forces Analysis – Case study in Philippines. *Procedia - Social and Behavioral Sciences*, *57*, 1-9. Doi: https://doi.org/10.1016/j.sbspro.2012.09.1151.

Yusof, M.M., Kuljis, J., Papazafeiropoulou, A., Stergioulas, L.K. (2008). An evaluation framework for Health Information Systems: human, organization and technology-fit factors (HOT-fit). *International Journal of Medical Informatics*, *77*(6), 386-398. Doi: https://doi.org/10.1016/j.ijmedinf.2007.08.011.

Yüksel, İ, Dağdeviren, M. (2007). Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile firm. *Information Sciences*, *177*(16), 3364-3382. Doi: https://doi.org/10.1016/j.ins.2007.01.001.