THE ANALYTIC NETWORK PROCESS: ASTRONOMY, ICEBERGS, AND BIG BOX STORES

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ABSTRACT

The Analytic Network Process (ANP) is a disruptive technology that has had significant impacts in the field of decision-making. By drawing on an analogy to the field of astronomy we can see that even with all that has been developed we must avoid the illusion of thinking that the field is mature and fully discovered. The ANP has many parallels to icebergs from what portion is visible to the value of providing relevant warning products. One of the most important contributions going forward will be the discovery of the more complex and hidden relationships and tests that ANP decision makers can use to test their models. These discoveries will improve both the reputation of the ANP and decision maker's confidence in their models. Without these discoveries, the ANP runs the risk of becoming like a big box retail store.

Keywords: Analytic Network Process (ANP); dependence; data quality; judgmental data

1. Introduction

In 1888 Newcomb said, "We are probably nearing the limit of all we can know about astronomy" (Wolff, 1999). Later in 1903 Newcomb said, "What lies before us is an illimitable field, the existence of which was scarcely suspected ten years ago, the exploration of which may well absorb the activities of our physical laboratories, and of the great mass of our astronomical observers and investigators for as many generations as were required to bring electrical science to its present state" (Newcomb, 1903). "About 7/8^{ths} of an iceberg is below the water line" (US Coast Guard, 2018). "Big box retail stores are losing relevance, while e-commerce and specialty stores grow in appeal" (Yohn, 2016).

With all that has been published regarding the Analytic Network Process (ANP), one may be tempted to say the same as Newcomb said about astronomy - that we are reaching the limit of what can be known about the ANP. While applications of the ANP will obviously continue, there is also much yet to discover in terms of the theory of the ANP. This theory must be discovered and unraveled, otherwise the ANP may become much like big box stores. While big box stores will not entirely disappear in the near future, they are losing considerable market share. In 2008, the ANP had the largest "market share" in terms of published multi criteria decision making methods (Wallenius et al., 2008). The

direction of the ANP research in the next few years will be a major determining influence on how the ANP will be positioned going forward.

"A general network representing the appropriate connections among its elements" on page 258 of Saaty's 1977 publication regarding the AHP might be considered the first reference to the ANP. Two possible publications that qualify for the formal debut of the ANP are Saaty (1996) and Saaty & Takizawa (1986). The validity of the method has been demonstrated through case studies (Whitaker, 2007). Consistency, the most commonly used method to test for the quality of the judgement data, has received a great deal of attention (Brunelli, Canal, & Fedrizzi, 2013; Grzybowski, 2016). With all that has been done regarding the ANP, there are reasons to feel that the ANP is mature and identify with what Newcomb said in 1888 about astronomy. Looking back, it is easy to see that there was, and still is, so much more to discover about astronomy. The same can and will be said of the ANP. Recognizing the potential for further development of the theory of the ANP is an important first step. Searching for the new discoveries will uncover additional theory that once discovered and visible, will eventually become common knowledge that can increase the quality and scope of ANP applications.

2. Icebergs

Using an analogy of an iceberg when talking about the ANP is insightful. When one comes upon an iceberg, the great beauty and grandeur of what is above the water can be recognized. The visible portion provides a trove of information that can be studied and modeled. However, somewhere around $7/8^{ths}$ of the iceberg is unseen because it is below the water (US Coast Guard, 2018). To capture and more accurately model iceberg behavior, the unseen $7/8^{ths}$ must also be discovered, studied, and addressed, as well as continuing to study other properties about the visible portion. Scientists are still learning about and incorporating in the analysis these visible properties like the age of the ice or chemical make-up. There are also external factors like weather conditions that can be added to the analysis. In 1913, nations recognized the value of studying and tracking icebergs and formed the International Ice Patrol (IIP). Part of the IIP mission is to "provide relevant iceberg warning products" (US Coast Guard, 2017).

There are similarities between icebergs and the ANP. The part of the ANP that "can be seen" is amazing and has been used to solve complex problems. However, just as with the submerged portions of icebergs present unseen/undetected dangers that when uncovered have and will significantly improve iceberg models, the same applies to the "submerged portions" of the ANP. We should view the ANP as an iceberg and search for more than what is already visible. There may also be more to learn about what is already developed, as in the case of the part of the iceberg above the water. Careful analysis of external factors can lead to other important opportunities for integration to improve upon the ANP at present. Finally, other statistical and decision-making methods have relevant and sometimes very comprehensive warning products that can be assimilated with the IIP for icebergs. For example, in Structural Equation Modeling (SEM) there are different tests to check for many different types of validity and reliability. The most accepted "quality" tests for the ANP are the consistency index and case studies of comparing model results to actual values. The prestige and reputation of the ANP will increase as more "validity" and "reliability" tests are developed and integrated or even regulated as best practices as a type of IIP for the ANP.

Critics have tried to attack the validity of ANP, in some cases due to a lack of understanding, but possibly because they came across an issue that was still below the water. Reviewing those critiques is not the purpose of this article. The important point is to recognize there is more we can learn about the ANP theory. I had this experience during my doctoral studies while trying to build and validate ANP models to better understand each part of the Supermatrix. Some of the "simple" decisions I tried to model had other issues, and the final priority vectors seemed counterintuitive. I became frustrated and almost abandoned the method. Thankfully, shortly thereafter, I had the impression to try two more models; for one the final priority vector worked and for the other it did not. Comparing the two models led to the conclusion and mathematical proof that when converting the unweighted Supermatrix to a weighted Supermatrix to fully capture the dependency in ANP models, one should perform the cluster weighting comparisons individually for each alternative or criterion column and not just normalize all of the columns in a cluster equally. By making the additional cluster weighting comparisons for each column, the dependency of each individual criterion or alternative is more precise (Cooper & Liu, 2017).

In terms of capturing the full potential of the other "7/8$^{\text{ths}}$" of the ANP, it has not been done yet simply because we do not even know what it is at present – it is still submerged. By not pushing and testing the ANP theory, we have not yet discovered its full potential and current limits. The ability of the ANP to deal with intangibles can provide what on the surface appears to be a real challenge to validation; but intangibles do not have to be the red herring towards validation. It is also important to develop and prove the mathematical theory behind these new discoveries as they are more robust than using case studies alone. The integration of stakeholders into ANP models is one example of an ANP iceberg where many applications have been published and are now visible, but the theory is still submerged. For example, putting all the stakeholders in a criteria cluster and making connections to the related criteria will lead to significantly different outcomes than if the stakeholders are represented with different networks. The modeling of stakeholders varies widely even for similar decisions. There should be room for customization, but without a theoretical justification it is also fertile ground for hidden or unintended results. The theoretical implications of how to include stakeholders is an example of one important contribution yet to be uncovered.

Another area of the ANP iceberg that is "under the surface" which will provide some of the most significant contributions to the theory of the ANP is in data quality tests/checks. Both while peer reviewing an article and working with students with "good" models, I have seen that some models have worked very well and others did not. What made the difference? What test could I have told them to run to identify the difference? Consistency tests are necessary, but not sufficient. It will become more important going forward to have best practices, more testing/screening tools and the ability to identify more exceptions/problems for ANP models.

From the beginning, Saaty recognized that such tests were worth pursuing, "As yet there is no statistical theory (to the best of our knowledge) which would assist us in deciding how well judgmental data corresponds to reality. … *It is clear that this is an area of research that is worth pursuing*" (Saaty, 1977, emphasis added). There are relationships and tests that are more complex than what have been discovered that will help test the

models, designs, inputs, and relationships and in turn provide additional unrealized benefits. Coherency is one example of an innovative and important data quality check to test a sort of consistency at the level of the entire Supermatrix that is very crucial since without this check the decisions cannot be trusted (Cooper & Yavuz, 2016; Yavuz & Cooper, 2017). This however is just the beginning, both in terms of additional tests to improve/test data quality, and in terms of the idea of coherency testing. Bigger and brighter minds will take coherency and other data checks to a completely new level.

These additional tests will serve at least two important purposes. First, they will serve as a shield or filter to protect the integrity of the ANP and increase its reputation. The tests will help address the idea of garbage in leads to garbage out because then if a model does not pass the quality tests one can argue that the ANP is not being done. The filters and shields will also reduce misunderstandings about the ANP. Second, more ways to test or prove something is a good thing. ANP models, in particular, take a significant amount of work to design and complete. Intentional decision makers should be asking, 'what can we do to increase our confidence in the meaning of the final answers?' If they could show that the model passes this test, and this test, and this test, etc. then it could increase their confidence and motivation to engage in the work required to get "real" results.

3. Big box stores

The ANP works and is very useful in its current form and has been used in incredible applications. However, if we fail to continue to innovate, to differentiate and adapt to the market then the ANP may become like a big box store retailer in multi criteria decision making. Some may argue it is like differentiation that is universal, and will stand the test of time. However, it is also possible that newer methods that are able to use other means to achieve many of the same advantages of the ANP with cheaper costs or customized applications to specific types of problems will be similar to specialty stores that are challenging big box stores. Big data and biometrics have the potential to be the e-commerce that disrupts much of the need to use intangibles/ANP because metrics will be attainable/generated through these other tools. They also provide a tremendous opportunity for integration with the ANP. Unless the ANP theory continues to be developed, the magic of the ANP will likely never disappear, but other methods will provide similar benefits and potentially have other benefits or solve challenges that exist in the ANP.

Recognizing that the limits of the ANP theory have not been reached and thinking of the ANP as an iceberg, breaks down an important barrier and opens the door to making new discoveries. It is much like breaking the four-minute mile barrier, and opening the door for new and more rapid and frequent advancements. The theory of the ANP can be advanced in many ways. Some of the most valuable contributions will be in terms of the data quality tests that need to be developed. These discoveries will both improve the reputation of the ANP, and increase decision maker's confidence in their models. Without these advancements, the ANP may become synonymous with big box stores.

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