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# What Can AHP/ANP Do for SIX SIGMA? A Short Literature Survey

Marcin Nakielski*, Grzegorz Ginda**, Chellappa Vigneshkumar***

*Abstract.* Six Sigma offers a robust and widely applicable methodology for tackling practical decision-making challenges across various industries. Complementarily, the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) provide a universal framework for decision support in diverse applications. Given their inherent strengths, these methodologies appear to be a natural fit for one another. However, it remains uncertain whether this synergistic potential is fully leveraged within current Six Sigma practices and its derivative methodologies. This paper presents a concise literature survey to ascertain the extent to which Six Sigma practitioners utilize AHP/ANP. The findings from this survey will then be used to identify current trends and highlight existing gaps in harnessing the full potential of AHP/ANP within the Six Sigma framework.

*Keywords:* AHP/ANP, Six Sigma, DFSS, Lean, application, potential.

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*JEL Classification:* C44

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## 1. INTRODUCTION

Originating in the mid-1980s, Six Sigma has become a cornerstone data-driven methodology, widely adopted across industries to enhance process quality and product outcomes by effectively reducing variability and defects (Tengtarto et al., 2022). Its universality stems from its ability to integrate diverse tools, each addressing specific needs based on the nature of the decision problem at hand.

* AGH University of Krakow, AGH Doctoral School, Krakow, Poland, e-mail: nakielsk@agh.edu.pl
** AGH University of Krakow, Faculty of Management, Krakow, Poland, e-mail: gginda@agh.edu.pl
*** The Hong-Kong Polytechnics University, School of Design, Kowloon, Hong-Kong, PC, e-mail: vkumar.chellappa@polyu.edu.hk

While Six Sigma offers a robust framework for defect and variability reduction, the increasing complexity of modern business environments often necessitates more sophisticated decision-making tools. This is precisely where the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) can significantly complement Six Sigma, offering a structured approach to complex problem-solving.

This paper presents a concise literature survey intended to gauge current interest among Six Sigma users in applying AHP/ANP methodologies. Furthermore, it aims to provide practical insights that can help users fully leverage the potential of these integrated methodologies.

## 2. SIX SIGMA AND COMPLEMENTARY ROLE OF AHP/ANP

At its core, Six Sigma is a data-driven methodology that aims to reduce defects to an extremely low level, conceptually defined as six standard deviations from the mean in a normal distribution. This approach is built on several fundamental principles:

– Customer Focus: all improvement efforts are centered on meeting and exceeding customer needs and expectations.
– Data-Driven Decision Making: decisions are consistently backed by rigorous statistical data analysis.
– Continuous Improvement: quality enhancement is viewed as an ongoing process, not a one-time initiative.
– Cross-Functional Teams: problems are addressed collaboratively by multidisciplinary teams.

The most widely employed framework within Six Sigma is the DMAIC (Define, Measure, Analyze, Improve, Control) cycle, a five-phase process for refining existing processes:

– Define: clearly articulate the problem, project goals, and customer requirements.
– Measure: collect relevant data and establish key performance indicators (KPIs).
– Analyze: examine data to pinpoint the root causes of the problem.
– Improve: develop and implement effective solutions.
– Control: establish procedures to sustain improvements and prevent recurrence.

Beyond DMAIC, Six Sigma offers variations like Design for Six Sigma (DFSS), often characterized by the DMADV (Define, Measure, Analyze, Design, Verify) cycle, which focuses on designing new products and processes with quality built-in from the outset. Another popular adaptation is Lean Six Sigma, which integrates Lean principles to eliminate waste, thereby achieving both high quality and process efficiency.

Implementing Six Sigma typically yields significant benefits, including improved product and service quality through defect reduction and increased customer satisfaction. It also leads to reduced costs by eliminating waste and optimizing processes, shorter lead times due to enhanced efficiency, and ultimately, increased competitiveness through market differentiation.

Despite these compelling advantages, Six Sigma implementation is not without its challenges. Common obstacles include employee resistance, substantial upfront costs for training and software, the considerable time investment required, and the need for consistent effort to achieve lasting results. Nevertheless, Six Sigma remains a potent tool for organizations committed to elevating product and service quality. Successful deployment, however, hinges on unwavering commitment from top management, adequate resource allocation, and a deeply embedded culture of continuous improvement.

Meanwhile, the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) (Saaty & Vargas, 2012; 2013) offer powerful multi-criteria decision-making methods. They enable the hierarchical decomposition of complex problems and the systematic evaluation of various alternatives. By assigning weights to different criteria and conducting pairwise comparisons, AHP and ANP empower decision-makers to make more informed choices. When integrated with Six Sigma, these methodologies can significantly enhance the effectiveness of various phases within the core Six Sigma process improvement cycles.

## 3. RESEARCH METHODOLOGY

To investigate the joint application of Six Sigma and AHP/ANP, we conducted a systematic literature review using the Scopus bibliographical database (https://www.scopus.com). The search query was constructed as ("Six Sigma" OR "Lean Six Sigma" OR "DFSS" OR "Design in Six Sigma") AND ("AHP" OR "ANP"), applied to the "Article title, Abstract, Keywords" search fields on the main Scopus service webpage. Initially, this search yielded 109 literature entries published between 2003 and 2024 (as depicted in Figure 1). However, an initial screening process led to a reduction in this number. Specifically, one retracted paper and ten conference reviews were excluded, as they did not align with the criteria for detailed bibliographical analysis. Consequently, 98 essential entries were retained for comprehensive review.

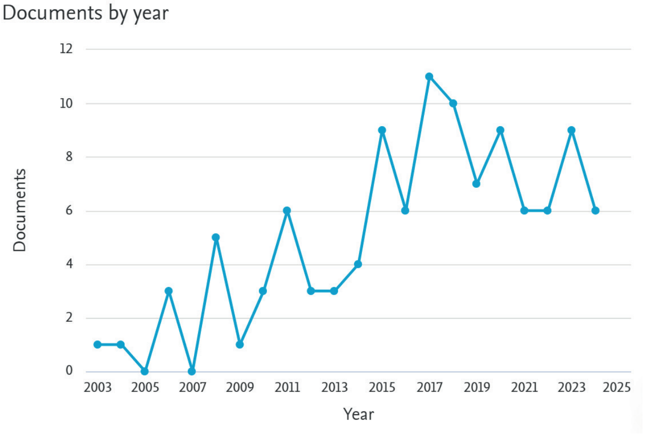


**Fig. 1.** *Number of publications per year as for November 15, 2024 (Source: Scopus bibliographical database)*

The detailed bibliographical analysis undertaken in this study aims to elucidate the precise role and extent to which AHP/ANP methodologies support Six Sigma applications. Specifically, this analysis seeks to:

- Uncover the actual functions of AHP/ANP within Six Sigma implementations.
- Map the diverse ways in which AHP/ANP contributes to various Six Sigma "flavors" (e.g., DMAIC, DFSS, Lean Six Sigma).

The insights gleaned from this analysis are anticipated to provide comprehensive knowledge regarding the current state of AHP/ANP integration within the Six Sigma paradigm. This foundational information is crucial for identifying opportunities and strategies to facilitate future developments and more fully leverage the potential of AHP/ANP in enhancing Six Sigma-related support.

## 4. RESULTS

As illustrated in Figure 1, the scholarly output concerning the integration of Six Sigma and AHP/ANP reveals two distinct phases of development. The initial "upward phase" spans 2003 to 2017, indicating a growing interest and increasing number of publications in this area.

Following this period, the second phase, beginning in 2018, exhibits a rather "flat" trajectory, with an average of approximately eight publications annually. It's noteworthy that despite its shorter duration, this latter phase accounts for a significant majority of the analyzed literature, encompassing 53 of the 98 publications. The plateau observed in the second phase could suggest that the interplay between AHP/ANP and Six Sigma has reached a certain level of maturity in the academic discourse. Further general insights from the literature analysis are presented in Figures 2–5.

The analysis indicates that the primary applications of AHP/ANP within Six Sigma have historically concentrated in engineering, which is a core domain for Six Sigma itself. Other significant areas of intersection include Business and Management, Decision Science, and Computer Science. However, as evidenced in Figure 2, there is a discernible trend of continuously increasing involvement from other, less traditional fields in the joint application of AHP/ANP and Six Sigma. This suggests a broadening scope for these methodologies beyond their established boundaries, indicating a dynamic evolution in their interdisciplinary reach.

Figure 3 clearly demonstrates that journal articles are the predominant medium for disseminating scientific research concerning the interconnections between AHP/ANP and Six Sigma. This indicates a preference for peer-reviewed, in-depth scholarly contributions in this field. Conference papers closely follow as the second most common publication, suggesting the importance of the timely sharing of preliminary findings and engaging with the research community at conferences. In contrast, book chapters appear to represent a very minor share of the total publications, implying they are not a primary route for the dissemination of this specific type of research.

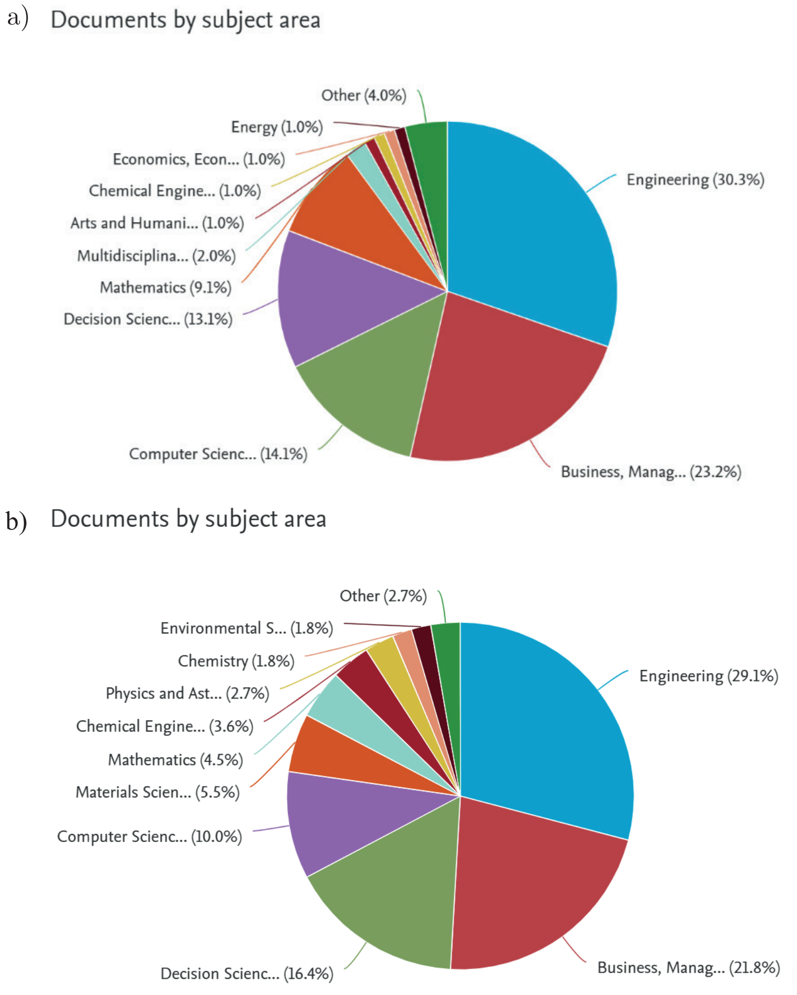


**Fig. 2.** *Structures of the area of AHP/ANP-Six Sigma applications in different development phases: a) upward phase (2003–2017); b) flat phase (since 2018) (Source: Scopus bibliographical database)*

The analysis further reveals a notable geographic distribution of authorship, with the majority of publications originating from Asian researchers (as depicted in Figure 4). This suggests a strong research focus on AHP/ANP and Six Sigma integration within the Asian academic community.

In terms of dissemination outlets, the research on AHP/ANP-Six Sigma interactions is spread across a diverse range of sources. However, the *International Journal of Lean Six Sigma* stands out as a clear leader, contributing nearly 10% of all publications in this area (Fig. 5). This indicates its prominence as a key venue for scholarly work at the intersection of these methodologies.

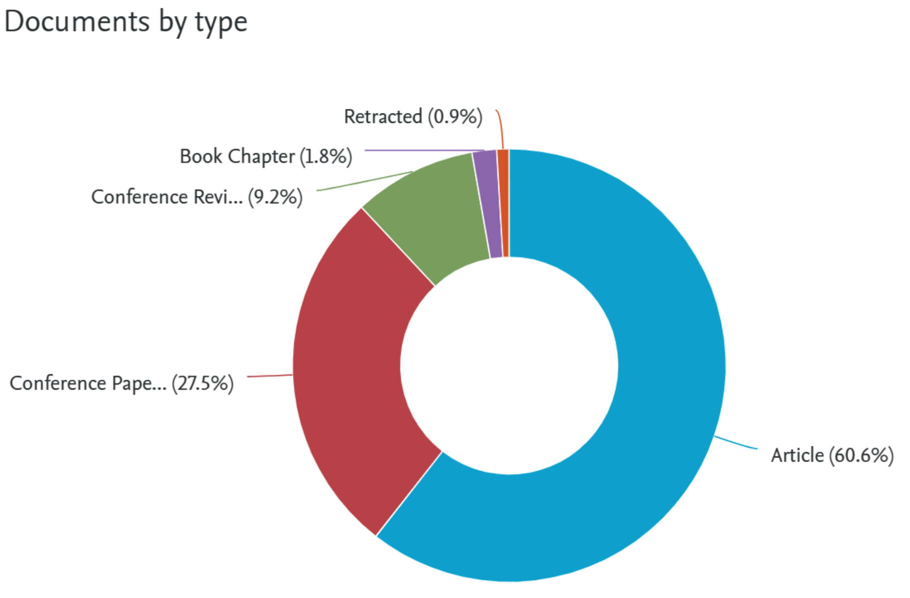


**Fig. 3.** *The share of different publication types (Source: Scopus bibliographical database)*

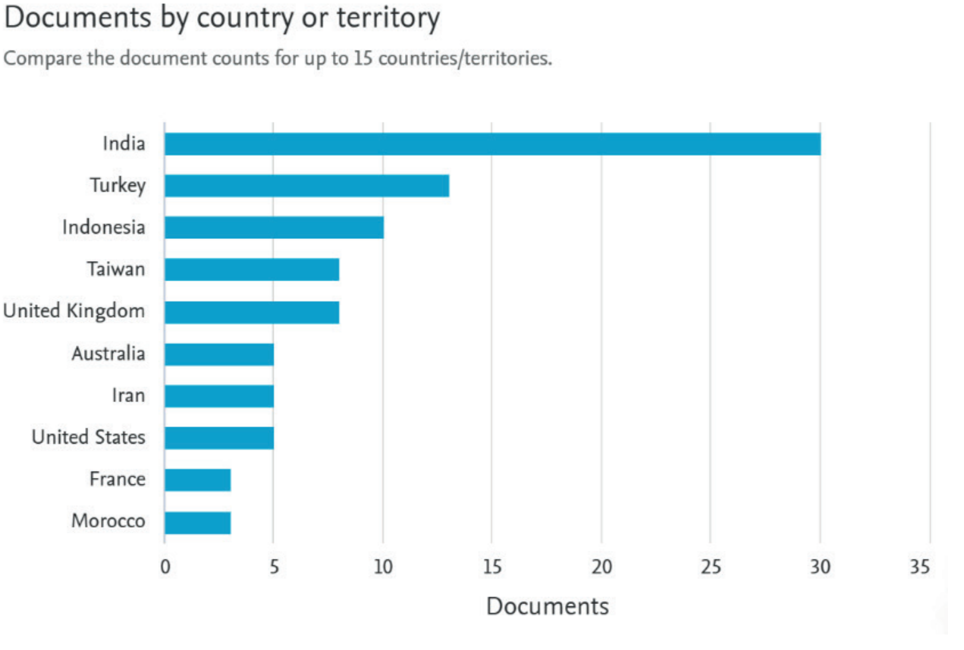


**Fig. 4.** *Geographical share of publications (Source: Scopus bibliographical database)*

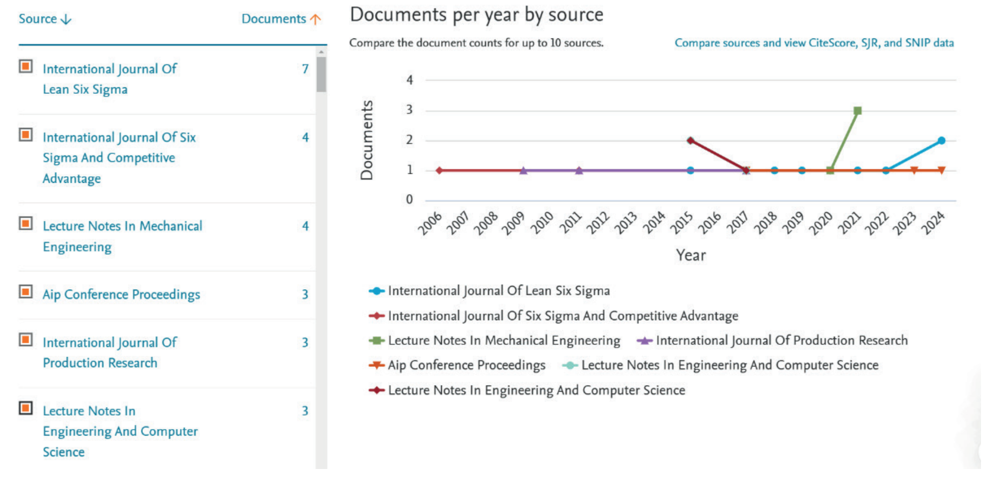


**Fig. 5.** *Leading sources*
*(Source: Scopus bibliographical database)*

The analysis of the selected publications revealed a diverse array of specific topics, as visually represented by the word cloud generated from author keywords in Figure 6. This word cloud predominantly features terms characteristic of both Six Sigma and AHP/ANP methodologies, reflecting their core concepts and applications.

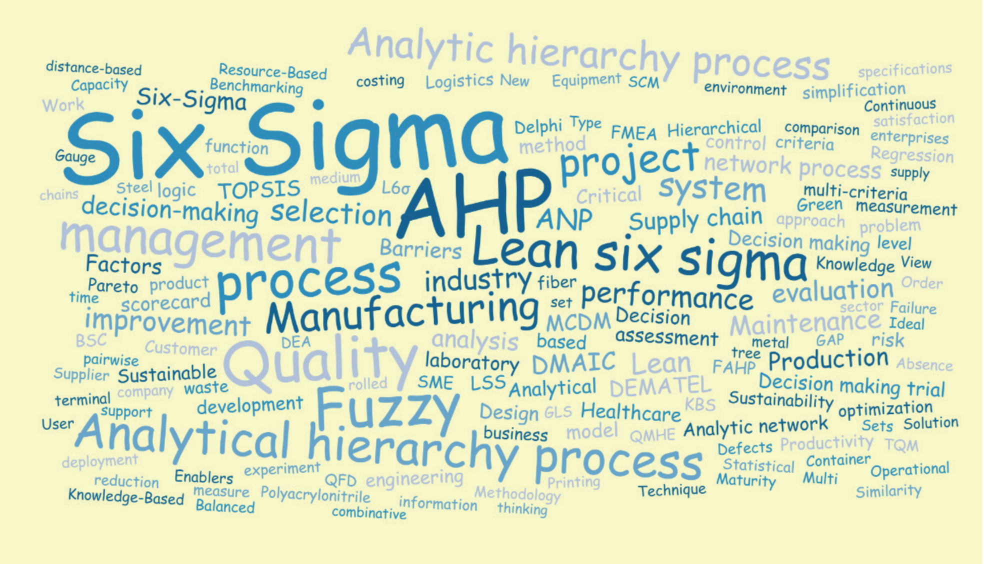


**Fig. 6.** *A wordcloud*
*(Source: Scopus bibliographical database)*

The analysis of citations reveals a varying impact among the publications, with a select few demonstrating exceptional influence within the academic discourse on Six Sigma and AHP/ANP integration. Notably, the works of Su and Chou (2008), Büyüközkan and Öztürkcan (2010), and Yadav et al. (2018) stand out, having garnered over 100 citations each.

Beyond these highly cited papers, other significant contributions that have received considerable attention include those by Bañuelas and Antony (2003), Yadav et al. (2017; 2018b), Vinodh and Swarnakar (2015), Kuei et al. (2011), and Pandey et al. (2018). These publications collectively underscore key research advancements and influential ideas in this interdisciplinary domain.

While overall citation counts highlight influential works, a per-year analysis reveals a different set of highly impactful contributions. Publications by Yadav et al. (2018a), Yadav et al. (2018b), Pandey et al. (2018), and Singh and Rathi (2022) demonstrate exceptional yearly citation rates, each exceeding ten citations annually. This sustained high impact underscores their ongoing relevance and significant contribution to the field. The above mentioned facts show also that this is a research team of Yadav et al. that is responsible for the highly acknowledged and cited publications about coupling of AHP/ANP and Six Sigma methodology.

Notably, the consistent appearance of "Yadav et al." across these highly cited works suggests that this research team has played a pivotal role in producing some of the most recognized and frequently cited publications concerning the integration of AHP/ANP and Six Sigma methodologies.

Thematically, the most cited publications predominantly focus on leveraging AHP/ANP for evaluating and selecting Six Sigma project alternatives or methodology components, often augmented by other decision support tools. They also frequently address the identification of barriers to adopting various Six Sigma iterations, with a particular emphasis on Lean Six Sigma. While other topics are explored in the broader body of literature, their recurrence is comparatively low.

## 5. CONCLUSIONS

Our analysis reveals that the application of AHP/ANP within Six Sigma largely centers on addressing external challenges. This includes the evaluation, prioritization, and selection of Six Sigma projects, as well as the identification of factors that enable or hinder the adoption of Six Sigma methodologies.

However, we believe the true potential of AHP/ANP in supporting Six Sigma is far from fully realized. Specifically, its robust capability to handle intangibles could be more extensively integrated throughout the entire DMAIC cycle, or similar process improvement frameworks. This would allow for a more reliable and quantifiable assessment of intangible elements crucial to project success. The results of the bibliographical analysis nevertheless show the evident positive effect of the implementation of AHP/ANP on broadening the range of Six Sigma application areas.

A significant concern is the current tendency in Six Sigma-related AHP/ANP applications to rely on what we consider to be questionable and often unnecessary representations of imperfect information, such as fuzzy sets. This is frequently done without adequate rationalization or validation, for example, through sensitivity analysis using crisp judgment scales. Furthermore, the potential benefits of utilizing alternative judgment scales in supporting Six Sigma are, surprisingly, almost entirely overlooked.

Despite these observations, the bibliographical analysis unequivocally demonstrates a positive impact of AHP/ANP in broadening the scope of Six Sigma applications. This expanding reach highlights the inherent value of integrating multi-criteria decision-making with process improvement.

A clear limitation of this current analysis is its reliance on a single bibliographical database. Future research should incorporate additional databases, including national-level resources, to ensure a more comprehensive understanding of the literature.

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