A Generalized Model for MCABC Analysis: Towards Efficient, Green, and Resilient Supply Chains

Masterarbeit

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Chapter 1

Introduction

1.1 Motivation for a new multi-criteria ABC analysis model

> *"Now, with signs pointing to slowdown of the global economy, demand is tightening, and the role of supply chain is evolving to become more strategic than before, with a keen focus on cost reduction, resiliency, and efficiency. Invariably, supply chains will be a target, as an estimated 50% to 75% of the cost of doing business is influenced directly by supply chains"* Dutta [2023]

The significance of an efficient and resilient supply chain to global trade and business performance cannot be overstated. Since the start of the pandemic, there has been unwavering focus on supply chains, but the challenges have shifted from merely meeting demand to adapting to a slowing global economy [Dutta, 2023, p.1]. Effective collaboration and coordination is essential to avoid bottlenecks, optimize inventory levels and ensure continuous delivery [Kulp et al., 2004, p.431]. Technological advances and innovative methods have evolved SCM practices, enabling companies to respond more flexibly and quickly to market demands [Rahman, 2004, p.31]. Companies that invest in their SCM systems see significant cost savings and efficiency improvements [Lee, 2004, p.1]. However, well-functioning SCM depends on all individual steps of the process also being well organized and executed. IM is a key component of SCM that focuses on planning, monitoring and controlling all aspects of a company's inventory [Singh and Verma, 2018, p.3868]; [Yu, 2011, p.3416]. Based on Bozarth and Handfield [2013] inventory consist of items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies) and customer service (finished goods and spare parts). The goal is to ensure optimal stock levels while minimizing storage costs, with a focus on meeting customer demand [Mekel et al., 2014, p.52]. Effective IM requires precise control of order quantities, storage and order fulfillment to ensure a good balance [Singh and Verma, 2018, p.3868]. An organization's inventory can include a large number of items. Theoretically, all of these items could be analyzed individually, but the effort involved would be enormous as the inventory can comprise thousands of elements while the required resources to manage them, such as time and money are often limited [Axsäter, 2006, p.296];[Hatefi et al., 2014, p.776]. The classification of items aims to predict the group membership of data instances within a specific data set [Jadhav and Channe, 2016, p. 1842]. ABC analysis is a widely recognized method for managing large numbers of inventory items, leveraging the Pareto principle to categorize stock into three distinct groups [Chen et al., 2008, p.776]: Category A (high-value, low-quantity items), Category B (items of moderate value and quantity), and Category C (low-value, high-quantity items) [Hatefi et al., 2014, p.776];[Lucas, 2023, p.29]. Traditionally, this classification relies on ADU to sort items, a straightforward yet oversimplified approach that does not account for the multifaceted nature of inventory management [Hatefi et al., 2014, p.776]. Acknowledging the complexity of inventory classification, it's argued that this task involves considering various criteria beyond just ADU, such as LT, profit, commonality, obsolescence, durability, inventory cost, and criticality [Flores and Whybark, 1986, p. 79]; [Chen et al., 2008, p.777]; [Yu, 2011, p.3416]. This broader perspective frames IC as a MCDA challenge, thus coining the term MCABC to describe this more nuanced approach [de Assis et al., 2020, p.454]. This analytical approach not only enhances decision-making transparency but also optimizes the management of inventory items to reduce total costs and address the dissimilarity of classes effectively Saracoglu [2022, p.1]. As articulated by Qaffas et al. [2023a, p.848], MCABC facilitates a clearer comprehension of inventory groups, thereby aiding in more informed decision-making processes. Moreover, this technique tackles critical operational questions, such as optimal order quantities per item class, requisite stock levels, safety stock requirements, and the frequency of inventory audits and checks, as highlighted by Saracoglu [2022, p.1]. The primary goal is the meticulous management of vital items (A-items) to prevent the squandering of resources on less critical items (C-items), thereby ensuring that inventory-related costs are kept in check Kaabi et al. [2018, p.1]. This strategic focus on item significance not only aids in controlling costs but also significantly enhances a company's competitive edge, as noted by Kaabi et al. [2018, p.1].

The earliest known MCABC analyses, including work by Flores and Whybark [1986], emerged in research as early as the 1980s. Despite the development of various models in this area over many years, none of these models have become available as commercial tools in the market, unlike the ABC analysis. Despite the challenge, research has yet to adopt an approach to develop an MCABC analysis model with the goal of achieving high practical applicability. We address this research gap by proposing a more generalized MCABC model approach that aims for greater suitability for application across various industrial settings, leading to the research question:

RQ: *What must a generalized, practically-oriented MCABC analysis model look like, and how can it be implemented to enhance its usability and applicability in various industrial contexts?*

1.2 Research Procedure

To ensure structured and clear exploration of the research question, a systematic framework is chosen as the foundation. The ADR methodology, as outlined by Sein et al. [2011], with its emphasis on the development of IT artifacts [Iivari, 2015, p.110], is particularly well-suited for designing a new MCABC model. This thesis is structured as follows to address the posed research questions effectively:

Initially, a theoretical background on MCABC analysis models is provided. This includes a brief explanation of how MCABC analysis models are integrated into the SCM.

In the third chapter, we describe the research design, methodology, and methods used. Adopting the ADR process from [Sein et al., 2011, p.41], we develop and present our research artifact in four stages. In the first stage, we identify our research problem by examining the availability of ABC and MCABC analysis as software tools. A literature review of 113 scientific papers facilitated the identification of key characteristics of MCABC analysis models and the challenges for their practical utilization. This review led to the adoption of identified requirements for a generalized model as our solution approach.

In the second stage, based on these requirements, the model is constructed in its individual components and presented as an assembled whole. The identification of the most relevant criteria for evaluating inventory items is conducted through a survey. The model's structure and functionality are evaluated in the context of a FGD and the subsequent case study.

In the third stage, within our discussion section, we reflect on the results obtained, highlight parallels to findings from the field of MCDA research, and provide implications for research along with an outlook for further research and practical applications.

Lastly, limitations are outlined, offering a comprehensive view of the challenges encountered during the research process and areas for future investigation.

Chapter 7

Conclusion

To address the issue that no MCABC analysis model has yet been developed as a commercial tool in the market for inventory item classification, we developed the generalized A-U-X-I MCABC analysis model based on the IT artifact-based ADR methodology by Sein et al. (2011). Unlike previous models that primarily focused on data analysis, our model also considers the inputs and outputs of the analysis to achieve higher practical applicability. Our selected four-stage research approach began with identifying the core problem: the absence of an MCABC analysis tool in the market, contrasting traditional ABC analysis. Through a literature review of 113 articles, we identified key characteristics of MCABC models and challenges for their practical application. Based on these insights, six requirements were established that the model needed to meet. In the second stage, the model was developed based on these six requirements. A survey conducted with 60 supply chain management experts yielded seven criteria for evaluating inventory items, with three related to resilience and four to cost efficiency. A FGD with four experts from research and industry assessed the research process, components of the model, and its practical applicability. To evaluate the actual functionality and relevance to practice, a case study with two industrial use cases was conducted. In the third stage, the results were reflected upon, drawing parallels to other AI approaches in the MCDA field and outlining implications for research and practice. Lastly, we noted limitations of our results, such as the need for high domain knowledge to interpret the model's visualizations and the sole reliance on clustering algorithms for classification, and provided an outlook for further research.
In summary, this study proposed an enhanced MCABC model that evaluates inventory items using a predefined, selectable set of criteria, along with an adjustable focus and global constraints as input. It analyzes the provided dataset using an unsupervised clustering method and interprets the results for mathematical stability and relevance to the problem at hand. This structure aims to contribute to the model's high generalizability and the actual knowledge discovery from data, making it significantly more relevant for practical application. Compared with previous research, our proposed model offers the following advantages:

1. Proposes a set of the most relevant criteria for evaluating inventory items.

2. Allows the user to adjust the classification focus towards either resilience or cost efficiency in the supply chain through a parameter.
3. Provides an extended feedback loop to ensure that the classification results actually provide a solution to the problem statement.

The set of criteria identified as most relevant for inventory item classification offers a foundational basis for extensive future research in the domain of inventory classification. In the realm of MCDA, the model we've developed stands as a framework, readily adaptable to inventory classification models to improve their practical application.

With the developed model, we demonstrate a way to increase the practical relevance of these models through generalization, allowing for actionable recommendations to be derived from the results, contributing to improved resilience or cost efficiency of the supply chain.