# A Neuro-Symbolic Approach for Purchaser-Centric, Concurrent, and Strategic Supplier Negotiations

***Jan-David Stütz***
*Robert Bosch GmbH & Leibniz University Hannover*
*Gerlingen & Hannover, Germany* *jan-david.stuetz@de.bosch.com*

***Oliver Karras***
*Leibniz Information Center for Science and Technology*
*Hannover, Germany* *oliver.karras@tib.eu*

***Allard Oelen***
*Leibniz Information Center for Science and Technology*
*Hannover, Germany* *allard.oelen@tib.eu*

***Sören Auer***
*Leibniz Information Center for Science and Technology & Leibniz University Hannover*
*Hannover, Germany* *soeren.auer@tib.eu*

**Abstract**

In today's competitive business landscape, efficient supplier negotiations are crucial for reducing procurement costs and securing favorable terms. We present Negotia, a neuro-symbolic, purchaser-centric approach that automates concurrent supplier negotiations via AI-generated emails and contracts. Following the neuro-symbolic paradigm, our approach combines neural AI methods with symbolic knowledge representations to maximize comprehension and automation while reducing hallucinations. Negotia streamlines the process by enabling simultaneous negotiations with multiple pre-sourced suppliers, significantly reducing time and effort. Additionally, the system enables supplier sourcing and incorporates customized purchasing strategies, further enhancing procurement efficiency. Key benefits of Negotia include cost savings, improved process efficiency, and alignment with sustainability and risk management goals. We employ the System Usability Scale and the Technology Acceptance Model 2 to evaluate usability and user acceptance, focusing on perceived usefulness and ease of use. The study also includes an expert evaluation of participants' email and contract drafts, assessing key attributes such as correctness, naturalness, completeness, benevolence, expertise, and credibility. The results reveal high usability (88.75) and strong user intention to adopt Negotia ($R^2$ of 0.888), with participants achieving high-quality outputs. Consequently, the system demonstrates the potential for substantial annual savings for large-scale procurement operations, ultimately driving digital transformation in procurement.

**Keywords:** Procurement Automation, Human-AI-Interaction, Neuro-Symbolic

## 1. Introduction

In today's highly competitive and dynamic business environment, effective supplier negotiations play a critical role in reducing procurement costs and securing favorable terms. External factors such as wars, sanctions, or global pandemics can further complicate these processes, forcing companies to renegotiate contracts or even seek out new suppliers in response to disruptions in supply chains [11]. However, negotiation processes are often time-consuming, especially when dealing with multiple suppliers, and large enterprises face significant challenges in sourcing suppliers and conducting negotiations efficiently [15]. This complexity is further amplified by

the need to balance cost reduction goals with considerations for sustainability, risk management, and strategic alignment [15]. Traditionally, companies have found it uneconomical to engage in extensive negotiations for every procurement deal, leading to missed opportunities for cost savings. Renegotiating prices is common, but at a Bosch, purchasers often accept initial offers from suppliers without further negotiations simply to avoid the resource-intensive nature of these negotiations. This practice results in significant financial losses, amounting to millions of Euros annually [16]. Furthermore, in a digitally transformed environment, personal negotiations are not always practical, particularly for low-risk, low-recurrence, or low-volume items, which are often managed via email.

To address these inefficiencies, we introduce Negotia, a novel approach that automates the negotiation process using AI-generated emails and contracts. By enabling simultaneous, automated negotiations with multiple pre-sourced suppliers, Negotia significantly reduces the time and effort required for purchasers to prepare for and conduct negotiations. The system utilizes predefined strategies to streamline the entire process, resulting in improved outcomes in terms of both price reduction and time savings. This approach is particularly effective for tail-end procurement, where a large number of products, while representing a small portion of the overall volume, offer substantial savings potential. For instance, in a typical large-scale operation with a procurement volume of €12 billion, tail-end items account for 20% of the volume, or €2.4 billion. Interviewed Bosch experts estimate that even a modest 3% savings on these items could result in €72 million in annual savings. Negotia provides an opportunity to capture these savings by automating negotiations that would otherwise be too costly or time-intensive to pursue manually. In summary, Negotia offers a scalable and efficient solution for companies looking to optimize their procurement strategies through AI-driven automation. By allowing purchasers to focus on more critical, strategic tasks while handling routine negotiations automatically, Negotia not only drives cost savings but also enables better alignment with corporate supply-chain resilience and risk management goals. This paper will explore Negotia's key components, implementation, and potential impacts in the evolving landscape of procurement automation.

Remaining structure: Section 2 reviews related work relevant to the approach detailed in Section 3. The methodology outlined in Section 4 describes the study design, while the results are presented in Section 5. Section 6 discusses the findings, and finally, Section 7 concludes the paper.

## 2. Related Work

AI in Supply Chain Management (SCM) has been extensively reviewed, highlighting common applications, research trends, and future directions [10], [1], [17]. These studies also identify research gaps and emphasize the transformative potential of AI technologies, particularly NLP and process automation in SCM [10], [1], [17]. Our approach builds on this foundation, focusing specifically on automated email and contract drafting for supplier negotiations, underpinned by strategies, procurement automation, and Large Language Models (LLMs). Therefore, the following section provides a detailed overview of related literature.

### 2.1. Negotiation Strategy Design and the Role of Automation

Procurement negotiations encompass a range of strategies, from cost-focused approaches to tactics designed to prolong discussions for strategic advantage. These methods are highly individualized and continually evolving, requiring ongoing adaptation by procurement professionals. Semuel, Siagian, and Arnius emphasize that strategic purchasing significantly shapes buyer-supplier relationships and influences organizational performance [19]. While a variety of negotiation strategies are discussed in the literature, Wang et al. advocate for price-centric negotiations and show that agent sourcing is best applied when bargaining power differentials

are significant [19], [28]. Complementing this, Chen and Xu propose a machine learning-based negotiation model within a multi-agent system, which enhances adaptive learning success and fosters mutually beneficial outcomes between buyers and suppliers [4]. Additionally, Cui, Li, and Zhang investigate how AI adoption affects supplier price quoting behavior, finding that the combination of automation and intelligence yields the greatest value [5]. On a broader scale, Viale and Zouari investigate robotic process automation in procurement, demonstrating its positive effects on supplier relationship quality, internal process optimization, and management efficiency [26].

### 2.2. LLM Applications

AI, and particularly LLMs, have been increasingly applied across academia and industry, often enabling human-in-the-loop collaborations or direct human-AI interaction [27]. Our approach similarly positions the user centrally, consistent with the work of Shakeri, Neustaedter, and DiPaola, who developed an LLM-based writing assistant for collaborative story creation [20]. Extending this paradigm, Rastogi et al. incorporate human feedback and LLMs to audit LLM outputs, reinforcing human-AI co-creation [18]. In consumer contexts, Gal and Zac demonstrate how LLMs assist users in informed decision-making regarding products and services [9], emphasizing their role in guiding purchasing processes [9]. Beyond transactional applications, Memmert explores LLMs' potential for enhancing collaborative brainstorming by co-generating ideas with users [14]. Furthermore, Shao et al. show that LLMs can emulate historical figures such as Beethoven or Cleopatra, a capability that could be adapted to model purchasing or negotiation experts [21]. They also introduce an intrinsic evaluation method, using LLMs to assess the fidelity of such emulations [21].

## 3. Approach and Implementation

Negotia is an approach that allows simultaneous negotiations with multiple previously sourced suppliers based on predefined strategies by AI-generated emails and contracts[1]. While Figure 1 now integrates both the user flow and screenshots illustrating the interaction between the neural and symbolic engines, Figure 2 continues to depict the different spaces that enable this flow. In summary, the neural engine drafts content based on a given context, while the symbolic engine provides and maintains that context. This context encompasses the negotiation strategies that a purchaser intends to incorporate into their drafts and the specified targets of the negotiation. Additionally, the symbolic engine facilitates the identification of suppliers that meet the desired criteria and are capable of delivering the required materials or services. In conclusion, Negotia keeps purchasers in the loop and allows interactions at every step while still being supported by AI suggestions.

### 3.1. Prepare Drafting

Before purchasers can draft emails and contracts, they have to select the suppliers they want to negotiate with, define their targets, and choose fitting strategies. Our approach combines all related user interactions and the possibility of interacting with Negotia in four distinguishable stages. Figure 2 briefly shows the user flow and indicates how purchasers stay in the loop of all four stages.

[1]We published a demo of Negotia here `https://github.com/J-x-D/negotia`

Fig. 1. Process of drafting emails and special contracts based on the de ned targets and selected strategies.

## Sourcing Suppliers

Figure 1 shows that sourcing suppliers is the rst stage a user enters. The sourcing stage both in- uences and is in uenced by data within the supplier space. Negotia leverages the advantages of Knowledge Graphs (KGs) to enhance the ef ciency of supplier sourcing. By representing suppliers within a KG, we streamline the process of nding the right suppliers for speci c material groups or services, reducing complexity and effort. In this scenario, the main bene t of using a KG is the ability to compare suppliers easily, lter them based on a wide range of attributes, and leverage the graph's structure to perform reasoning and uncover deeper relationships or patterns among suppliers. We created a KG that re ects the primary information of Bosch's suppliers, such as material groups, industry, focus, and more.

## De ning Strategies

Negotiations vary with each supplier, and every purchasing expert has a unique approach, so Negotia needs to allow users to adapt their strategies individually. Given our objective of integrating negotiation strategies into email generation and contract development, we have centralized all strategies in a single repository called the "strategy space." This community-driven repository serves as a comprehensive resource where experts in procurement and negotiations can document and re ne various strategies, which are then accessible to all other users of Negotia. These entries may include detailed step-by-step instructions, illustrative scenarios, and best practices, among other elements. Users of Negotia can explore and lter these prede ned strategies to suit their speci c needs. During the Drafting Stage, users select the appropriate strategies for their email and contract drafts. The selected strategies are then incorporated into the initial context provided to the GPT-4 instance, which is subsequently employed to generate the content. Consequently, these strategies establish the foundational tone and direction for the drafted material, enabling the neural engine to produce content aligned with the speci ed strategies. Typical strategies might include creating a win-win scenario or postponing further negotiations to gather additional offers.