Negotiation Automation Platform

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1 OVERVIEW

1.1 INTRODUCTION

This paper introduces the Negotiation Automation Platform (NAP), a cutting-edge and specific type of negotiation platform solution that utilizes AI technology to automate negotiations between economic entities (primarily in the manufacturing and logistics sectors) to streamline the process of reaching agreement between them. By enhancing supply chain efficiency, NAP can prevent potential losses from ineffective product procurement, delivery, and inventory management.

Traditionally, supply chain coordination has heavily relied on human labor, causing increased costs and reduced accuracy. By employing AI technology, NAP automates the negotiation process, reduces the dependence on manual efforts and improves the overall efficiency of agreement-making among economic entities. NAP also has a critical advantage over other data-sharing and collaborative control technologies. It only forms agreements when both parties find the terms acceptable, ensuring that sensitive and company confidential information is not disclosed unnecessarily.

Overall, NAP improves resource efficiency and contributes to economic and environmental sustainability across various sectors, supporting the achievement of Sustainable Development Goals (SDGs). In the manufacturing and logistics industries where supply chain efficiency is a pressing issue, NAP can effectively address everyday challenges requiring coordination with trading partners, such as sudden cancellations, supply shortages, and transportation delays.

1.2 PURPOSE

This article aims to inform and offer guidance to a wide range of stakeholders, encompassing manufacturers, logistics providers, and other supply chain entities, implementing and managing the Negotiation Automation Platform (NAP) within a supply chain network. The primary objective is to facilitate enhanced efficiency, seamless collaboration, and more effective decision-making processes.

1.3 SCOPE

In this article, we focus on applying NAP in the manufacturing, transportation, and shipping industries. However, it is worth noting that its potential extends to other sectors, including agriculture, energy and utilities, finance and banking, and retail. The ultimate vision of NAP is to establish a platform that facilitates automated negotiation processes, enabling more intelligent and efficient supply chains that swiftly match supply chain entities with their corresponding business counterparties regarding trade conditions. In Section 2 Motivation, we explore the general applicability of NAP within the manufacturing and logistics domains. Subsequently, we

delve into three comprehensive case studies regarding manufacturing and logistics in Section 5 Case Studies.

1.4 AUDIENCE

The primary audience of this article includes manufacturers, logistics providers, and other supply chain entities, with a particular emphasis on manufacturing and transportation and shipping sectors. Additionally, CxOs who are interested in enhancing social and economic efficiency, as well as contributing to the achievement of Sustainable Development Goals (SDGs), will find this information valuable.

1.5 USE

By leveraging the insights provided in this article, stakeholders in the supply chain can establish efficient and flexible coordination of trading conditions and foster cooperative relationships. An efficient and sustainable supply chain ecosystem can be constructed by adapting NAP to specific business requirements, benefiting all participants involved.

1.6 TERMS AND DEFINITIONS

The following terms and definitions that are key to understanding this document are:

- NAP (Negotiation Automation Platform): a system that streamlines the negotiation process by utilizing AI to facilitate efficient and effective communication and decision-making.
- Automated Negotiation: a process to facilitate negotiations between parties without direct human intervention.
- IIoT (Industrial Internet of Things): a system of intelligent, connected devices that collect, process, and analyze data for industrial applications, enabling enhanced performance, efficiency, and business value across various industry sectors.
- ATP (Available To Promise): the quantity of a product that can be promised to customers based on current inventory levels and production capacity.
- BOM (Bills of Materials): a list of raw materials, components, assemblies, and other items required to produce a product.
- BOP (Bills of Processes): a list of instructions, steps, and procedures required to produce a product.
- CTP (Capable to Promise): a metric to determine the earliest possible delivery date for a product based on manufacturing lead time, resource availability, and production capacity.

2 MOTIVATION

Enhancing supply chain efficiency is of utmost importance. Failure to procure or supply appropriate products or services from or to the right partners at the right prices, quantities, timings, and conditions can lead to significant losses, such as shortages of raw materials or essential resources, increased inventory, higher internal management costs, and breaches of customer contracts.

Supply chain efficiency has two main challenges. The first is based on a company's ability to consistently provide high-quality products and services at low costs with timely delivery. This involves continuous efforts to improve production methods by implementing technologies such as AI and IIoT. The second challenge concerns the ability to reach agreements with trading partners as quickly, accurately, and cost-effectively as possible. However, in most current business practices, coordination relies heavily on human labor, issues like increased labor costs, decreased accuracy, and longer lead times.

Failing to address these challenges can have a negative impact on the survival of companies as well as the preservation of essential societal functions. Factors contributing to this situation can include trends in manufacturing to reduce lot sizes (for mass customization) and the intensification of competition for resources driven by disasters, wars, pandemics, and aging populations. Additionally, the increasing complexity of products and services, diverse customer demands, and heightened competition among companies exert pressure for faster, more accurate, and sophisticated agreement-making processes.

In this article, we introduce the Negotiation Automation Platform (NAP), an innovative solution that employs automated negotiation AI technology to streamline agreement-making between economic entities. We will discuss the platform’s concept, technical and business overviews, and case studies, focusing on the application of the platform in coordinating conditions between sell-side and buy-side parties in manufacturing, trade and logistics service arrangement cases.

In Automated Negotiation, AI serves as an agent to conduct negotiations on behalf of individual companies with their trading partners. As an essential operation, automated negotiation AI can repeatedly create and send offers of agreement conditions to negotiation partners. It can also judge and respond to offers received from partners through messages via the platform, aiming to reach agreements with trading partners (Figure 2-1). Compared to human-led negotiations, AI agents can execute these operations with much greater speed, accuracy, and sophistication, resulting in a higher likelihood of reaching a better agreement with counterparties. The main motivation for adopting NAP is to contribute to the second aspect of supply chain efficiency and the efficiency of coordinating transaction conditions between economic entities.

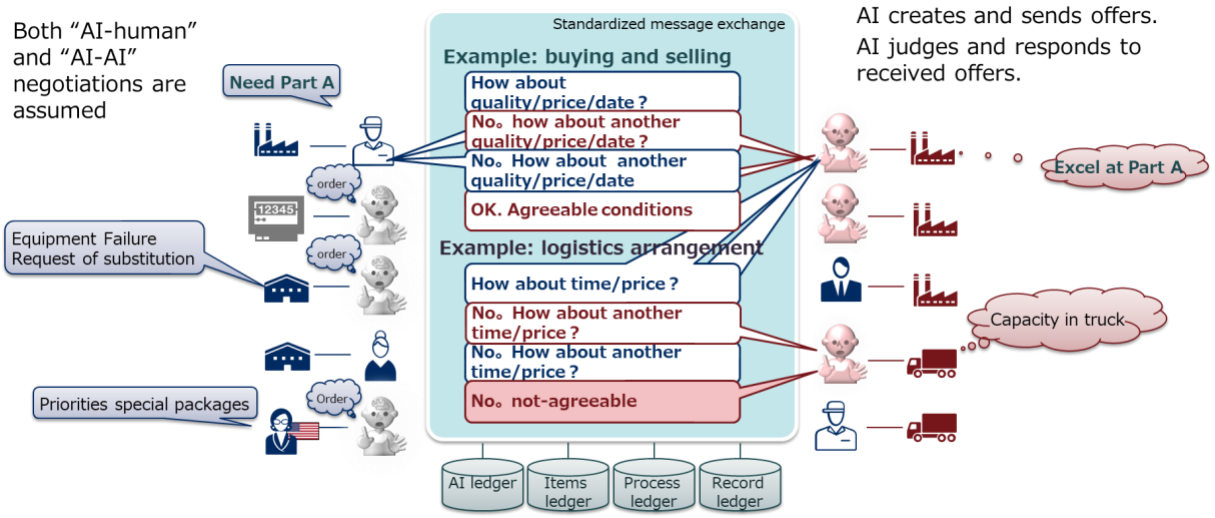

Figure 2-1: Automation of negotiation by AI agents.

It is important to note that solutions based on traditional data sharing and collaborative control technologies have been proposed as alternative approaches to Automated Negotiation. However, with these traditional technologies, the optimizer needs to centrally collect all data required for optimization. The issue with these solutions is that confidential information such as the availability of production resources and stock plans of components may be shared, leading to involuntary disclosure of sensitive data. These problems can be challenging to implement under a free-market capitalist economy.

NAP does not rely on these assumptions allowing it to be applied across various scenarios. It performs automatic offer creation and judgment based on internal company data such as inventory levels, available resources, production capacity, production plans, target profits, and safety margins. None of the sensitive information is included in the messages sent to trading partners. Additionally, agreements between partners are only formed when both parties deem it acceptable, meaning that there is no forced commitment to trading conditions predetermined by any rule. These advantages are among the primary motivations for introducing NAP to enhance supply chain efficiency.

NAP can also improve resource utilization efficiency by suppressing excessive inventory and production, enabling joint delivery, and facilitating changes to low CO2 emission transportation methods. As a result, NAP can contribute to economic and environmental sustainability across various sectors and support UN Sustainable Development Goals (SDGs)[1], especially "7: Affordable and clean Energy," "8: Decent Work and Economic Growth" and "9: Industry, Innovation, and Infrastructure."

[1] *https://www.un.org/sustainabledevelopment/sustainable-development-goals/*

2.1 TARGET DOMAINS FOR NAP

In this article, we focus on the manufacturing and logistics industries, where enhancing supply chain efficiency is imperative. We present an overview of daily inter-company coordination examples within these industries, illustrating the areas in which NAP can contribute to efficiency improvement (Figure 2-1). In Section 5 Case Studies we report the results of applying NAP to some of these scenarios.

2.1.1 MANUFACTURING

The fundamental operation of the manufacturing industry involves procuring materials and parts from suppliers, carrying out production, and selling the finished products to customers. Throughout this procurement and sales process, there is a need to coordinate trading conditions with counterparties especially when issues occur in manufacturing, such as sudden cancellations, difficulties in obtaining parts, delivery delays, and price increases due to part shortages.

Current Issue	Difficulty	Stakeholders
Daily activities: Procuring materials and parts	Coordination of procurements occurs daily or sometimes in shorter term requires human resources.	Company Supplier(s)
Daily activities: Selling the products	Coordination of selling and delivery occurs daily or sometimes in shorter term requires human resources.	Company Customer(s)
Sudden large order	All parts/components, production lines and workers shall be prepared.	Company Customer Supplier(s)
Some parts run short	It is difficult to find which and how many parts run short. Finding and negotiating with a new supplier is also difficult.	Company Supplier(s)
Some components may delay delivery	Specifying and evaluating delays is difficult. Negotiation with multiple suppliers is also difficult.	Supplier(s)
Parts price may suddenly increase	Price negotiation is usually a burden.	Company Supplier(s)

Table 2-1: Manufacturing negotiation examples.

Traditionally, such coordination tasks are carried out by humans, leading to concerns regarding the required human resources and the speed and accuracy of the operations. NAP can streamline these coordination tasks and enhance efficiency, as shown in Figure 2-2.

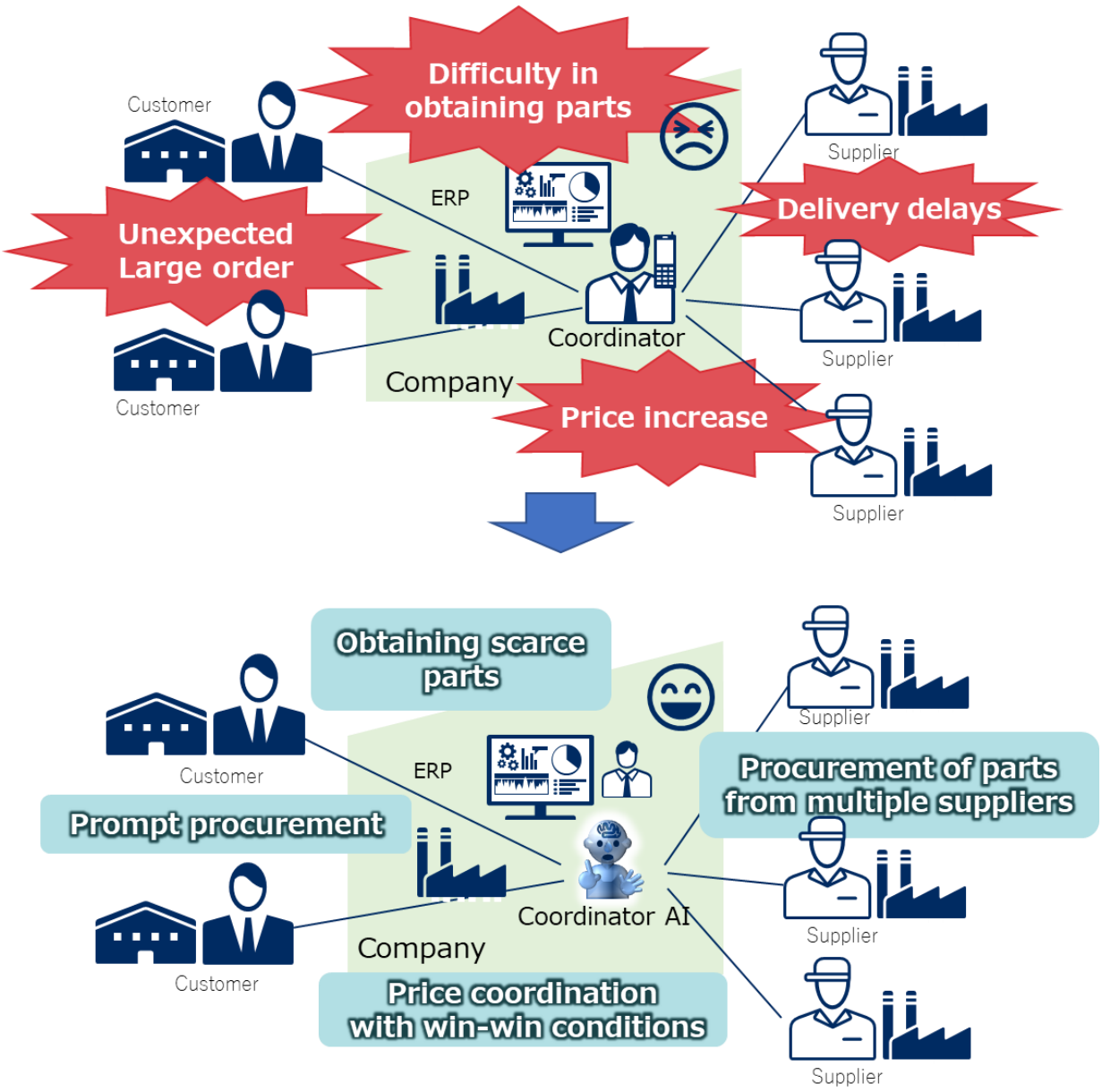

Figure 2-2: Contributions of NAP in the manufacturing industry.

2.1.2 LOGISTICS

In the logistics industry, the essential operation involves procuring transportation means and capacity from carriers and selling transportation services to customers. It is necessary to coordinate trading conditions with counterparties during this procurement and sales process. Additionally, the logistics field faces daily issues, such as sudden requests or cancellations, truck delays, and inefficient cargo distribution. In these situations, coordination with counterparties is also required.

Current Issue	Difficulty	Stakeholders
Procuring transportation means and capacity	Coordination of procurements occurs daily or sometimes in shorter term	Company Transportation company(s)
Selling transportation services	Coordination of selling occurs daily or sometimes in shorter term	Company Shipper(s)
Sudden delivery request	Finding available slot. If no slot is available, coordination with other shippers and transportation company should be taken.	Shipper(s) Transport company(s)
Sudden delivery cancellation	Coordination of delivery schedule change.	Shipper Company Transport company(s)
Uneven berth reservation	Inefficient use of berth. Lack of capacity.	Warehouse Company
Truck arrival delay	Delivery schedule should be changed. May cause another delay.	Transport company(s)
Search for shippers	Finding and negotiation with new shippers is difficult and a burden.	Company Transport company(s)

Table 2-2: Logistics negotiation examples.

Similar to the manufacturing industry, coordination tasks have traditionally been carried out by humans, leading to significant concerns regarding the required human resources as well as the speed and accuracy of the operations. In addition, the "2024 problem[2]" has emerged as an urgent issue in Japan. This refers to various challenges arising in the logistics industry due to stricter regulations on overtime work enacted by work-style reform-related laws. In particular, it raises such concerns as reduced transportation capacity (with logistics capacity expected to decrease by approximately 10%) due to driver shortages and increased transportation costs. NAP can contribute to addressing these problems, as shown in Figure 2-3.

[2] *https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/koyou_roudou/roudoukijun/gyosyu/topics/01.html* (in Japanese)

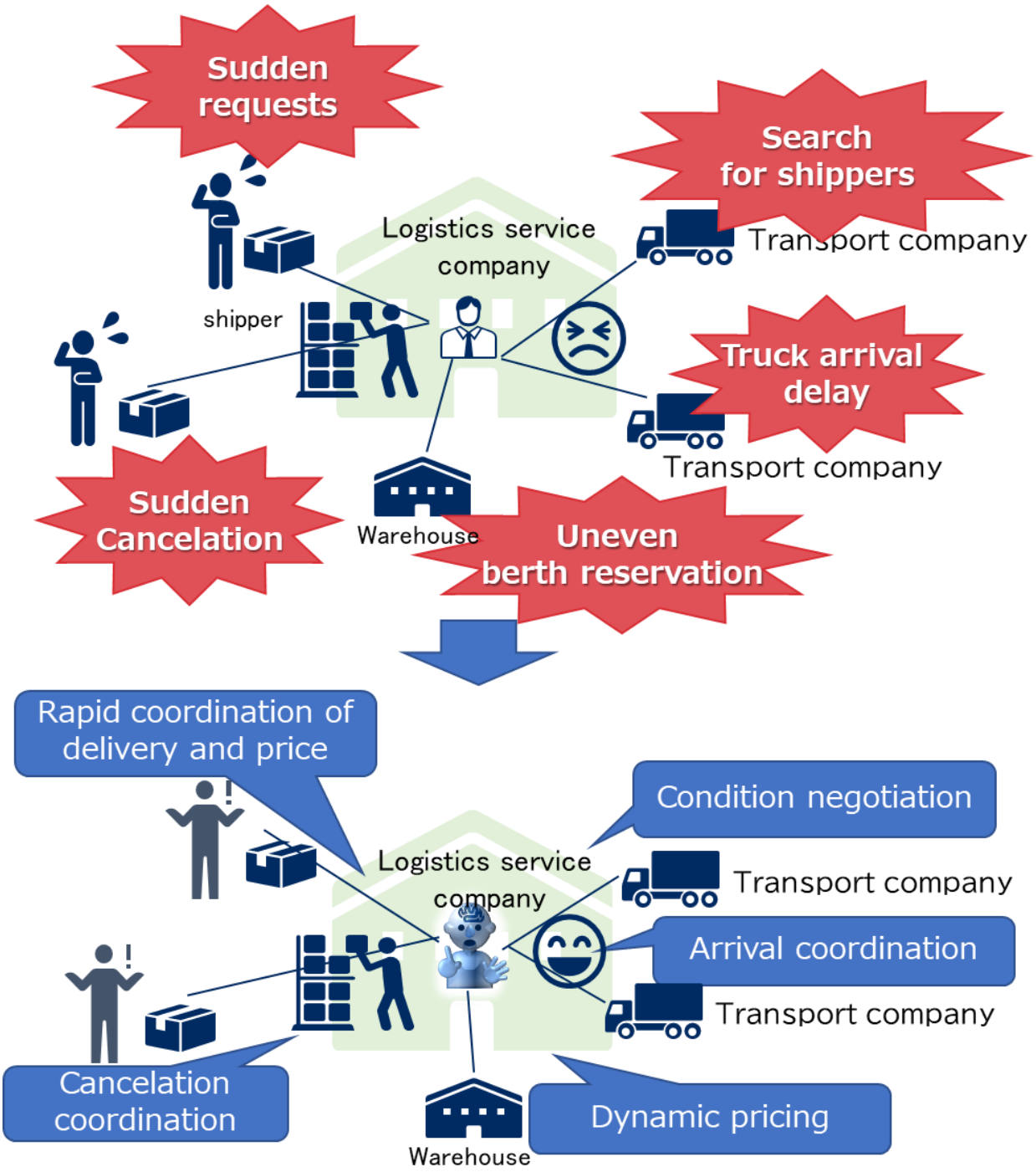

Figure 2-3: Contributions of NAP in logistics to respond sudden events.

3 TECHNOLOGY

Automated Negotiation Solutions primarily consist of the following components:

1. Negotiation AI that interacts with trading partners as the company's agent.

2. A negotiation communication platform that manages negotiation messages and related information exchanged between companies.
3. The company's information system is integrated with the negotiation AI, which can produce the necessary information for negotiations and process the results of the negotiations.

In the subsequent sections, we will elaborate on each of these components.

3.1 NEGOTIATION AI

Negotiation AI is an Automated Negotiation technology wherein AI carries out various coordination and negotiation tasks that are traditionally conducted by humans, aiming to automatically derive an optimal solution that satisfies both negotiating parties. In the NAP solution, each company possesses its Negotiation AI as an agent. The agreement formation process is executed through repeated message exchanges between these AI agents, involving a proposal of agreement terms and a response to whether the proposed terms are agreeable. Several negotiation protocols have been proposed, with one of the most fundamental being the "Alternate Offering" approach, in which parties make alternating proposals until they reach an agreement.

Implementing the previously mentioned use cases using Automated Negotiation technology can be based on an extended protocol that also includes option 3 above - declaration of cessation of negotiations. Here, negotiation AI agents negotiate with trading partners on behalf of the company, but instead of merely sending the counterparty an offer that is advantageous for the AI negotiator's owner company, the agent must make an offer that is also beneficial for the counterparty and can facilitate reaching an agreement.

This is because the counterparty can declare a cessation of negotiations, and once this is declared, the owner company will not be able to profit from this trade. Similarly, the agent must be cautious when deciding whether to agree to an offer, as the counterparty also has the option to declare a cessation of negotiations, preventing the owner company from profiting from the trade after that.

Negotiation AI technology has been actively researched and developed in recent years, with various algorithms proposed for generating offers and determining acceptance.[3] These algorithms operate by appropriately controlling and combining elements such as a utility function that represents the goodness of an offer for one's own company, an acceptance zone that indicates acceptable conditions for the company, and a model for estimating the counterparty's behavior and algorithm.

[3] *https://link.springer.com/book/10.1007/978-981-99-0561-4*

Within this framework, the utility function and acceptance zone are constructed based on internal company data, such as inventory levels, available resources, production capacity, production plans, target profits, and safety margins. The counterparty's behavior and algorithm are inferred from data like logs from past negotiations.

Furthermore, negotiation AI designed for humans and other AI counterparties have been developed. In one case, the negotiation AI can exchange negotiation messages in human-understandable language. Some of these systems can even recognize the counterparty's reaction based on differences in expressions for the same content of offers and replies.

Technologies have been developed to cope with such scenarios. In cases where the counterparty is also an AI negotiation agent, standardization of negotiation protocols is being undertaken to establish inter-agent connectivity and interoperability. These standardization efforts will be discussed in the subsequent section on the Negotiation Communication Platform.

3.2 NEGOTIATION COMMUNICATION PLATFORM

The communication platform manages negotiation messages and related information exchanged between companies. As such, it supports a range of functions, such as authentication for participating agents, connectivity capabilities with appropriate negotiation counterparties, management of negotiation protocols, and recording of negotiation messages and outcomes.

As mentioned previously, interconnectivity and interoperability are essential in negotiations between AI agents. Consequently, eNegotiation protocols for negotiation messaging are defined and standardized by the United Nations standardization organization, UN/CEFACT [4].

Among the five fundamental activities in business transactions, eNegotiation standardizes the "negotiation" layer and formalizes protocols and message expressions, as shown in Figure 3-1.

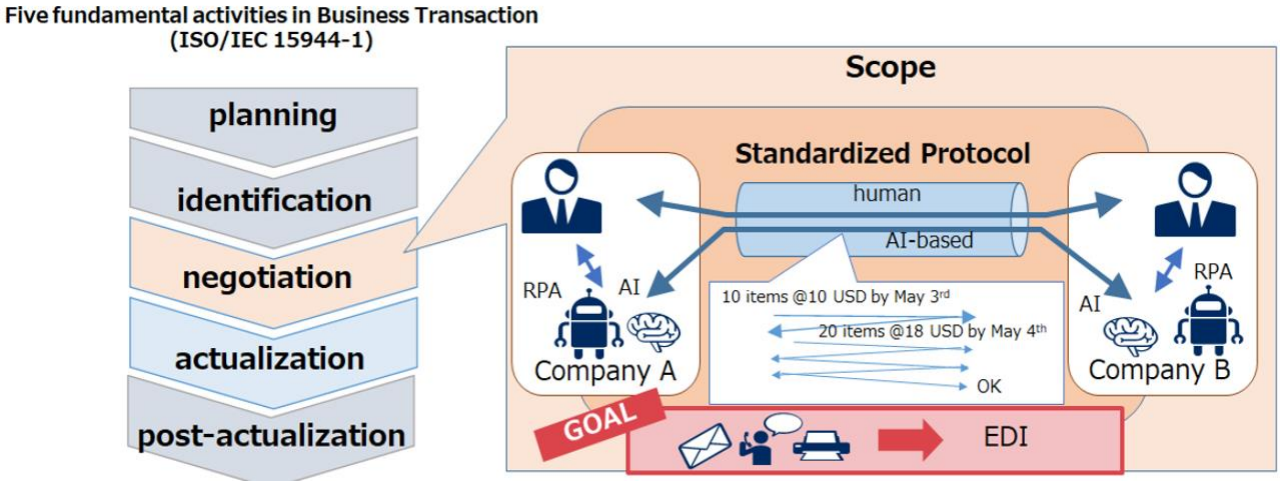

Figure 3-1: UN/CEFACT eNegotiation.

[4] *https://uncefact.unece.org/display/uncefactpublic/E+Negotiation*

In actual business situations, numerous complex types of coordination (negotiations) may be required. These scenarios are represented as patterns in the standard, with semantic protocols and data definitions specified for each pattern (Figure 3-2). In these complex negotiations, multiple negotiations can be handled as one combined negotiation thread. Examples include nested negotiation (where one negotiation includes other negotiations), competitive negotiation (which involves choosing one of several negotiations), and sync/async negotiation (waiting for other negotiation results or not waiting for other negotiation results).

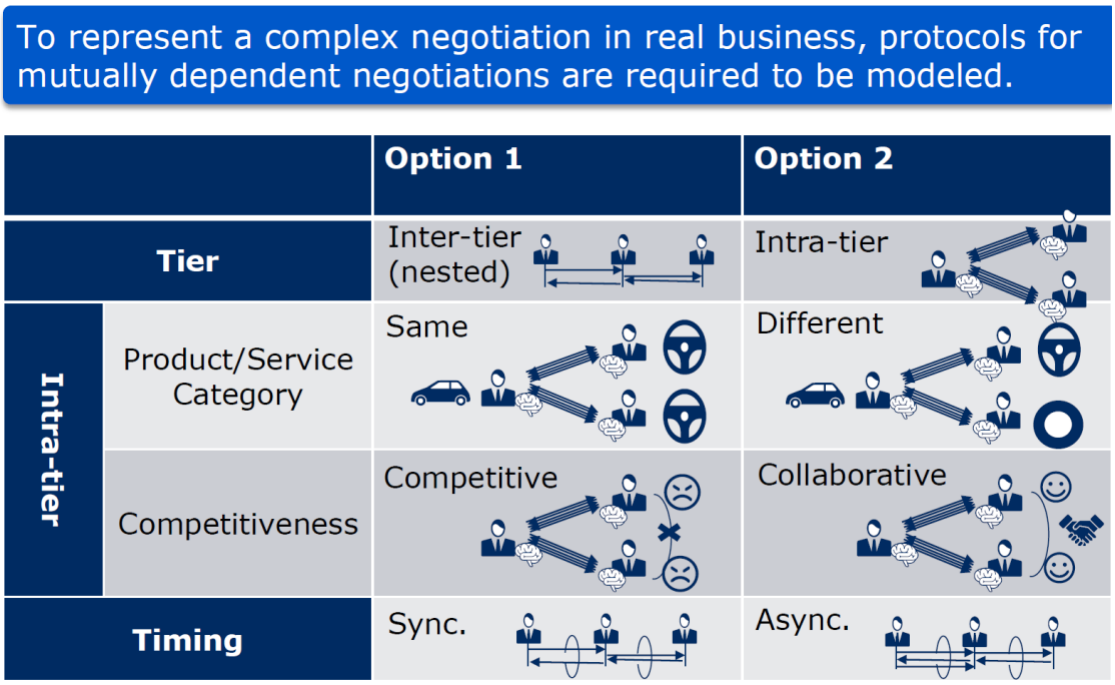

Figure 3-2: Negotiation patterns.

Additionally, three scenarios are referenced as use cases: ocean shipping, demand forecasting, and air cargo are explained in the implementation guidelines as part of the standardization activities.

3.3 ENTERPRISE SYSTEM

As previously mentioned, to generate appropriate offers and determine acceptance, negotiation AI requires access to internal company data, such as inventory levels, available resources, production capacity, production plans, target profits, and safety margins.

Typically, this information is stored in internal systems such as ERP (Enterprise Resource Planning Systems), PDM (Product Data Management Systems), and WMS (Warehouse Management Systems) and should be transferred to the AI platform accordingly. Furthermore, the results of the negotiations will be sent back to these systems via API as updates to planning information. Integration between the negotiation AI and internal systems, or collaboration through data lakes, is necessary to facilitate this transfer and write-back process.

Additionally, users of NAP solutions need to review the status, process, and results of negotiations. Therefore, it is essential to connect the system with a user interface that allows them to do so. The case study in Section 5.2 Procurement of Parts and Sale of Automobiles, introduces an example of a dashboard (Figure 5-5) that centralizes this information.

3.4 Negotiation AI System Architecture

Figure 3-3 shows the basic architecture of the negotiation AI system. The person in charge configures basic policies and strategies in the Negotiation Manager. In return, the Negotiation Manager offers negotiation status to that person and requests the final decisions.

Based on the defined policies and strategies, Negotiation AI executes individual negotiations. To decide precise offering/accept/decline activities, Negotiation AI refers to internal information from In-House Systems and uses Prediction/Planning functions. When the negotiation reaches some conclusions, Negotiation AI also changes in-house information.

Negotiation AI negotiates with other negotiators via eNegotiation protocol standardized in UN/CEFACT.

This architecture shows how all confidential information can remain inside the company (by design). Protocols and data used to negotiate with other companies are based on eNegotiation protocols which do not include internal information.

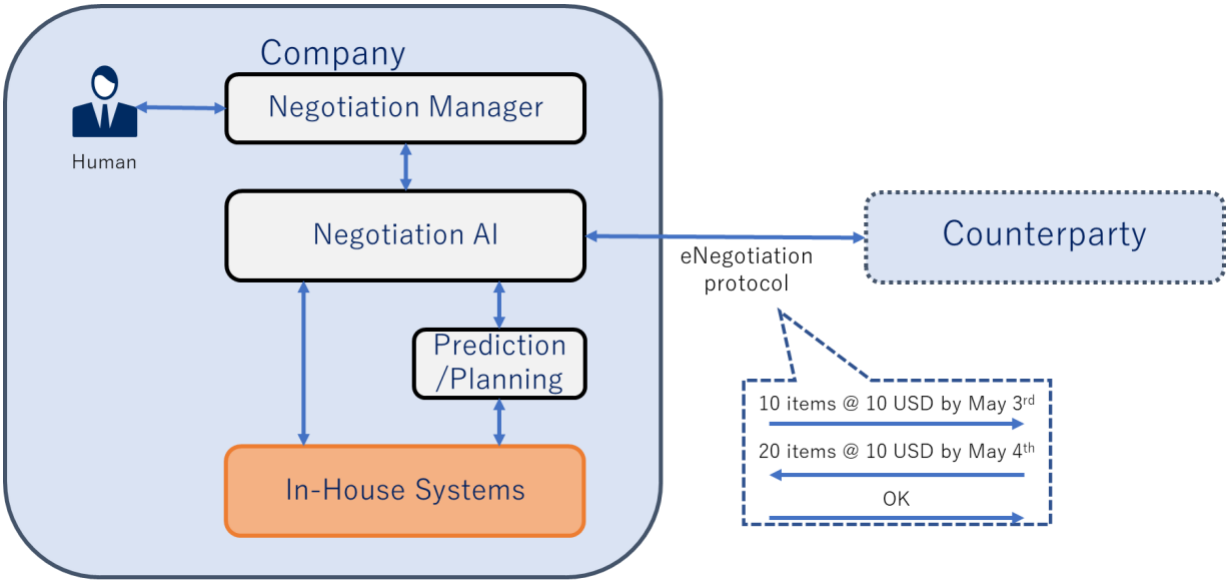

Figure 3-3: Architecture of Negotiation AI.

4 Business

4.1 Benefits and Issues

The first benefit of Automated Negotiation by AI is the reduction of human costs associated with coordination with counterparties during negotiations. Under current business practices,

coordination relies on human resources, with significant resources spent on interactions with counterparties and gathering information inside and outside the company. By replacing these tasks with AI, it is possible to significantly reduce the amounts of human resources required. We present the quantitative evaluation results of these case studies in Section 5.1 Electronic Component Procurement. Additionally, losses due to human error can also be minimized. While it is difficult to obtain precise statistics substantial losses, or numerous minor losses due to inappropriate coordination caused by operational mistakes, are undoubtedly occurring in the business. Automated Negotiation through AI can significantly reduce these losses.

The second benefit of AI-driven negotiation is the ability to form agreements under favorable conditions through fast and precise coordination. In negotiation situations, it is often challenging to reach better agreements, even when both parties can feasibly agree, due to limited interactions before the deadline or a lack of detailed evaluation when making offers and responses in a rush. As the negotiation AI can generate offers and decide on acceptance quickly and accurately, it increases the possibility of reaching better agreements.

The third benefit is the opportunity for business expansion or risk reduction, as the time it takes to reach an agreement is shortened. For example, in sales negotiations, presenting a favorable offer before rivals can increase the chance of winning contracts, while procurement negotiations can secure scarce resources in constrained environments or avoid excess inventory in surplus environments by determining the necessary amount just before the deadline.

The fourth, albeit indirect, benefit is the expansion of product/service lineups and the shortening of delivery times due to reduced overhead. By efficiently procuring necessary components/services and selling/providing them on time and at appropriate prices, the potential to reduce overhead, such as safety stock levels and safety lead times in manufacturing and logistics execution, increases. By simultaneously achieving these reductions, companies can improve their competitiveness.

It is important to keep in mind that there are also challenges to AI-driven Negotiation Automation which need to be addressed. Ensuring compatibility with current practices is essential. Presently, external coordination relies on human resources, utilizing communication channels such as phone calls and emails and input/output systems designed for human interaction. Introducing a NAP solution requires reforming internal business processes.

Companies implementing the solution will experience new tasks, such as selecting negotiations to automate based on their preferred level of automation and verifying negotiation progress and outcomes. Moreover, even if a company does not implement Automated Negotiation by itself, it must still adjust its business processes when dealing with companies using NAP, adapting to changes in communication channels, or utilizing faster responses from NAP users.

There may also be challenges in integrating with some existing internal systems. As discussed in Section 3 Technology, various internal information is required for negotiation AI to perform its

tasks effectively. The type of system needed to manage this information and its level of flexibility varies between companies. If that system is sufficiently flexible, integrating with NAP is achievable; otherwise, modifications to existing systems or introducing RPA (Robotic Process Automation) may be required. In some cases, essential information may not be system-managed but held only by human negotiators, necessitating the digitization of information management.

Furthermore, network externalities concerning the value of NAP solutions present additional challenges. Network externalities refer to the dependence of a solution's value on its performance and prevalence, as in the case of telephones and email. Similar to how telephones and email become more beneficial as more acquaintances use them, NAP solutions also become increasingly efficient at coordination as more trading partners adopt them. Raising the adoption rate of these solutions is one of the challenges that must be overcome to increase their added value.

4.2 PROMOTION OF NAP

As mentioned in the previous section, due to network externalities, the value users gain from the solution may vary depending on the number of adopters and the effectiveness of their negotiations. This section discusses some activities aimed at increasing user value from this perspective.

4.2.1 INDUSTRY IOT CONSORTIUM (IICONSORTIUM.ORG)

The Industry IoT Consortium (IIC) is an international organization committed to driving the advancement of industrial IoT initiatives. As a vendor-neutral association, the IIC focuses on promoting the development and implementation of cutting-edge technologies across various industries. Our principal activities in IIC involve showcasing the usefulness of the technology and its business prospects.

NAP is proposed as an IIC testbed[5] which became an approved testbed in August 2019. The members of the NAP testbed include NEC, Fraunhofer IOSB, KETI, BIRD INITIATIVE, National Institute of Advanced Industrial Science and Technology, TOYOTA TSUSHO, and OKI Electric Industry Corporation. Quarterly, we have reported business and technology progress.

In cooperation with the IIC, we held an Automated Negotiation demonstration (coordination among Dealer/CarMaker/PartsVendor) at the Smart Factory Expo 2020 and provided a podcast interview. The IIC awarded NAP for IIRA-compliant design, AI analytics utilization, and testbed activities. The NAP testbed is presented on the IIC web page "Tech Showcase" (Figure 4-1).

[5] *https://www.iiconsortium.org/technology-showcases/negotiation-automation-platform/*

Figure 4-1: NAP in IIC Tech Showcase.

4.2.2 AUTOMATED NEGOTIATION SCM CONSORTIUM (AUTOMATED-NEGOTIATION.ORG)

The Automated Negotiation SCM Consortium[6] aims to dramatically improve the efficiency of the "coordination of interests and behavior among companies, organizations, and individuals" that occur every day in the supply chain. The consortium primarily consists of Japanese companies and experts in the field. It promotes cooperation among members from various positions, such as solution providers, users, academic experts, and others, with the primary activities being the organization and verification of practical adjustment business flows utilizing advanced technologies and their development and dissemination.

The activities of the consortium include:

- Problem definition and target use case examination.
- Development of solution architectures and elemental technologies to solve problems.
- Implementation of Proof of Concept (PoCs) for problem-solving and social implementation.
- Examination of system linkage methods and international standardization activities of specifications.
- Personal network formation and information network formation (study group meetings, presentation meetings, and consultation meetings).

[6] *https://automated-negotiation.org/en/*

4.2.3 SUPPLY CHAIN MANAGEMENT LEAGUE

Increasing the adoption of NAP solutions means expanding the number of users, and it is also essential to increase the number of Automated Negotiation technology vendors to achieve this goal. As mentioned in Section 3.2 Negotiation Communication Platform, the standardization of negotiation protocols is an initiative to lower the barriers to entry for vendors. Similarly, we are promoting the development of Automated Negotiation technology for the same purpose.

Automated Negotiation AI technology has made rapid progress in recent years. However, it is still in its early stages compared to AI technologies such as image recognition, demand forecasting, and autonomous driving. To promote the development of Automated Negotiation AI, a competition called Automated Negotiation Agents (ANAC)[7] has been held, and we are organizing a competition focusing on the topic of this paper, "SCM Applications of Automated Negotiation Technology." A brief explanation of these competitions is provided below.

The ANAC is an annual event that brings together researchers, academics, and industry professionals from around the world to showcase the latest advancements in Automated Negotiation and multi-agent systems. In the SCM league of ANAC, we host a competition where AI agents negotiate the purchase and sale of components and products in a virtual economic space and schedule production plans for their factories using these components. The AI that achieves the highest profit after a certain period is declared the winner (Figure 4-2). In the league, we evaluate AI agents' performance, effectiveness, and impact.

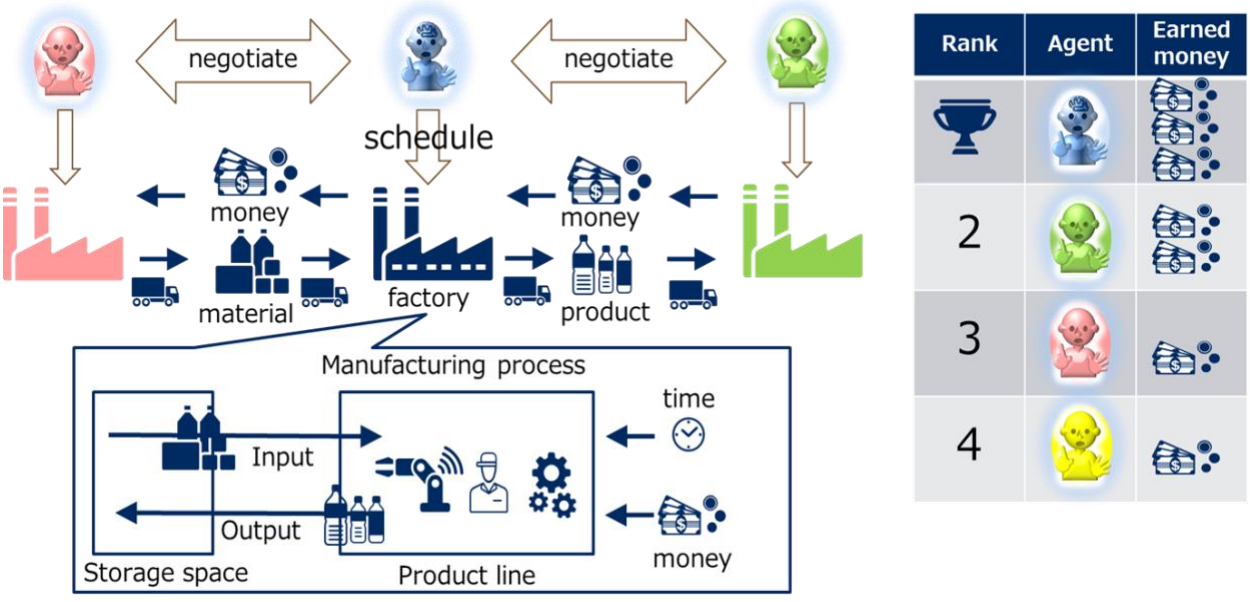

Figure 4-2: Supply chain management league.

[7] *https://scml.cs.brown.edu/*

5 CASE STUDIES

This section introduces three case studies of NAP solutions. The first case study involves automating procurement negotiations for electronic components against a human negotiation counterparty. For this case, we conducted experiments by introducing virtual fluctuations into the demand patterns. The second case study focuses on automating parts procurement and sales negotiations for automobiles, in which the counterparties also use AI agents for negotiation.

We conducted simulations where the negotiation for completed car sales and the procurement of missing parts were simultaneously and consistently executed, considering manufacturing lead time and pricing. The third case study involves automating procurement negotiations for air transport slots with carriers using AI negotiators and sales negotiations for transportation services with human clients. This case also simulates the simultaneous and consistent execution of combined procurement and sales negotiations.

5.1 ELECTRONIC COMPONENT PROCUREMENT

This section presents a case study of Automated Negotiation in manufacturing, focusing on procuring electronic components. Production plans are updated daily based on customer orders, and coordination regarding component delivery dates is needed. This coordination is frequent and costly.

Specifically, delivery date coordination can occur in cases such as:

- When a supplier informs that the delivery date for a component is delayed.
- When customer orders exceed or are significantly lower than initial forecasts.
- When some components are not available and production quantities need to be adjusted.

Delivery date coordination can have a ripple effect along the supply chain (Figure 5-1):

1. The customer requests to accelerate the delivery date.
2. The factory checks its production and delivery plans. The factory finds that procurement of some necessary components must be expedited. The factory then starts negotiations with the component supplier (trading company).
3. The component supplier, in turn, must negotiate with their parts suppliers to expedite delivery.
4. All negotiations are agreed upon, and the acceleration of delivery dates is accomplished.

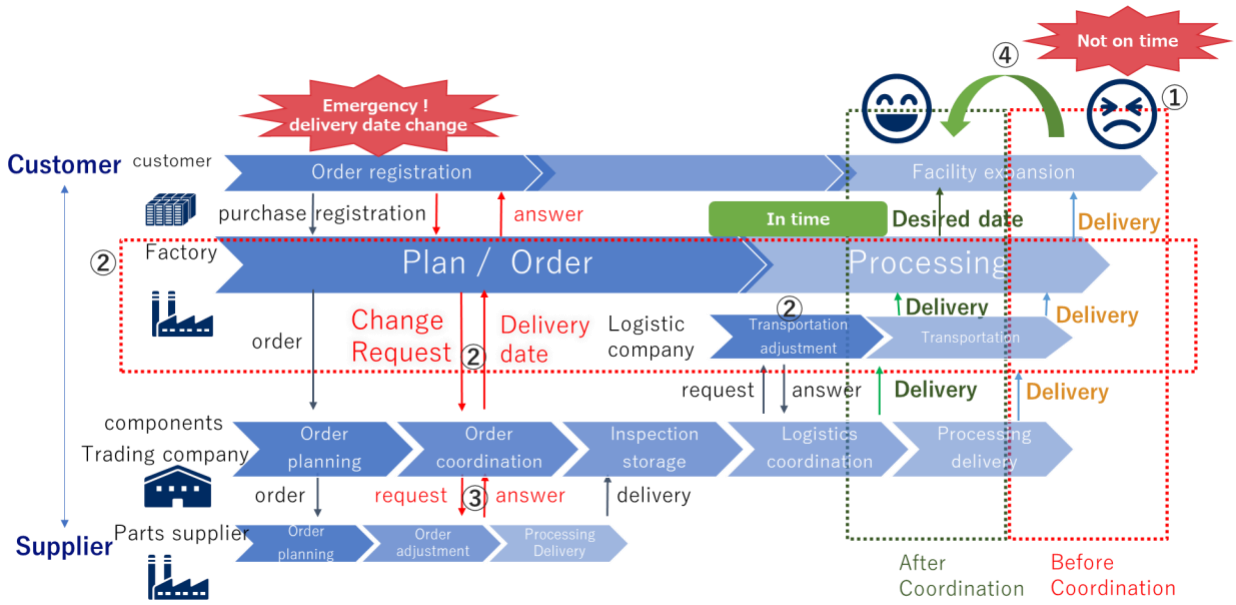

Figure 5-1: Coordination for delivery date acceleration.

In this case, numerous coordination efforts are required to fulfill the customer's request, such as coordination between the customer and factory, the factory and component supplier, and the component supplier and parts supplier. Furthermore, all of them should be coordinated quickly and accurately.

Here, we focus on one negotiation between the factory and the supplier in the case above. This case verifies whether it is possible to conduct negotiations promptly and accurately in response to demand fluctuations.

Figure 5-2 illustrates the system configuration for this case. In this system, the negotiation AI takes on the procurement officer's role and negotiates while considering the company's product inventory, production plans, and component inventory.

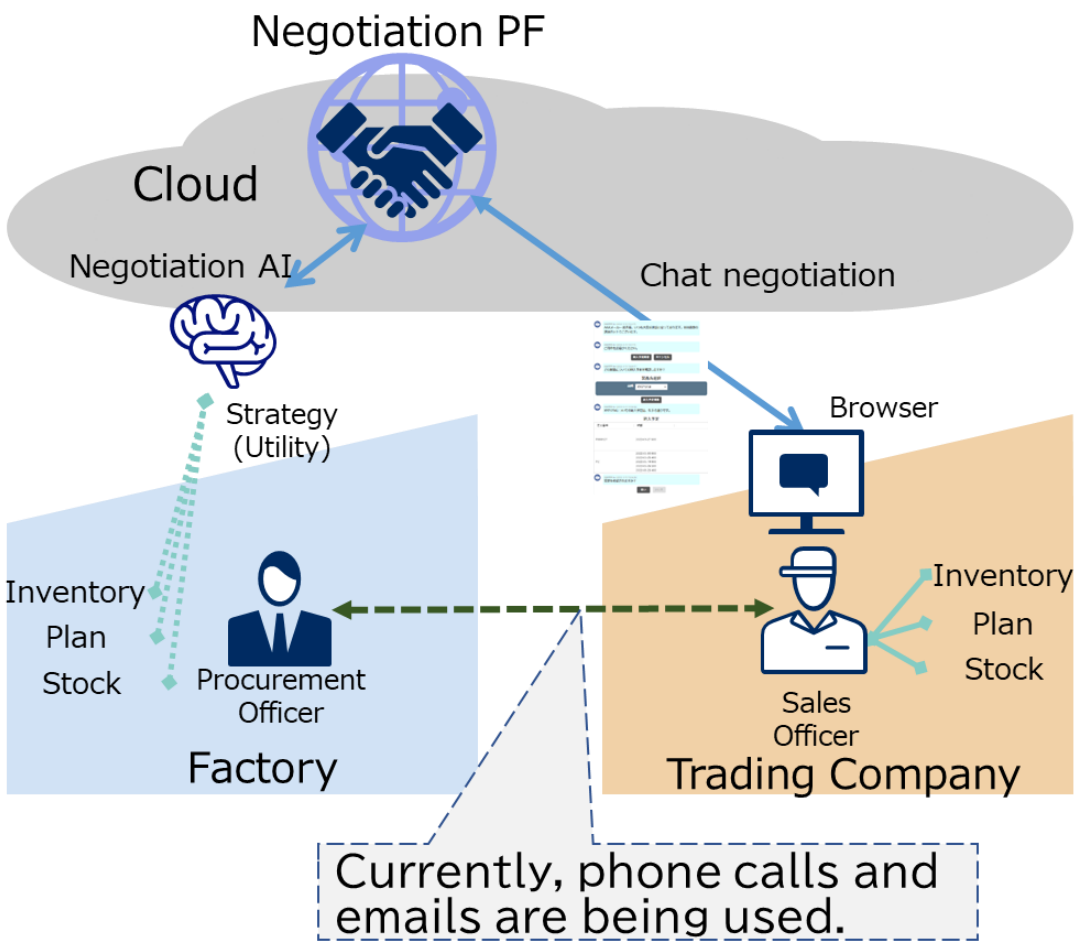

Figure 5-2: Replacement human-human negotiation to NAP solution.

When there is a fluctuation in demand and a change in delivery date negotiation is necessary to address it, the factory (buyer) side's negotiation AI issues a request to start a negotiation thread with the trading company and sends the first offer. The trading company (seller) side negotiator, a human in this case, evaluates whether the offer is agreeable. If it is agreeable, the seller accepts the offer and responds with an agreement. If not, the seller creates and sends a counteroffer based on their internal data. By repeating this process, the AI on the buyer and the human on the seller side coordinate the changes in delivery dates (Figure 5-3).

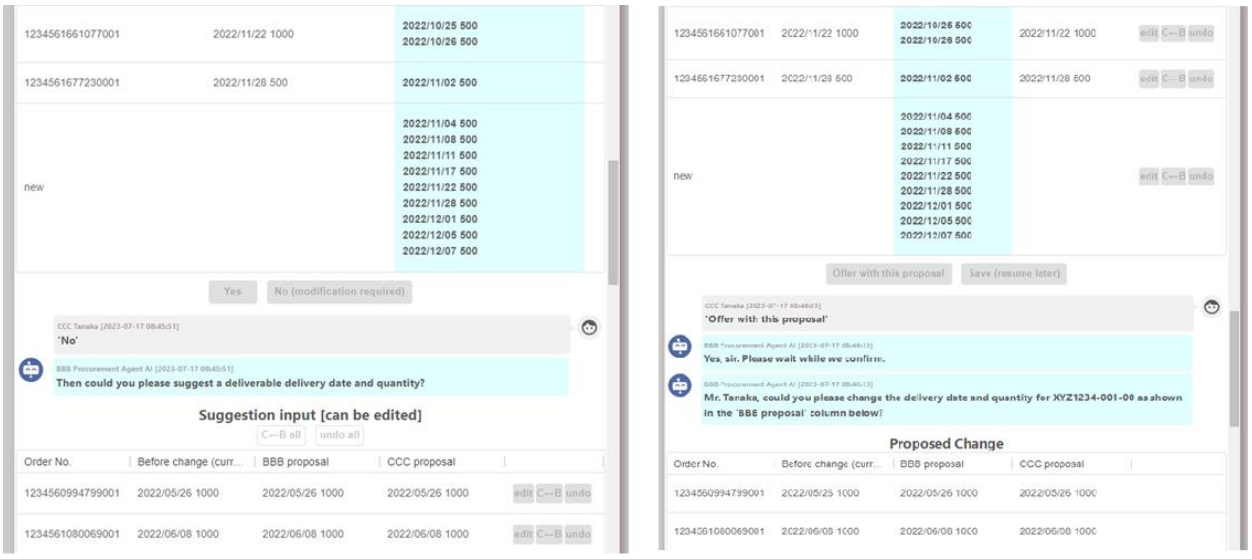

Figure 5-3: AI-human negotiation example.

We conducted a proof of concept (PoC) by introducing several patterns of virtual fluctuations in demand to an actual company and observing negotiations between the AI in that company and a human negotiator in a real supplier with an existing trade relationship with the company.

As a result of the experiment, agreements could be reached between the Automated Negotiation AI and the seller's representative in all cases where a mutually acceptable solution existed, given the seller's inventory. The time required for coordination and negotiation, including waiting times as perceived by the seller's representative, was significantly reduced, as shown below.

Verification details		Normal time to complete negotiation (without AI)	AI supported time to complete negotiation
Case 1	One order. Request to increase quantities.	5 days	46 sec.
Case 2	One order. Request to deliver forward.	5 days	5 min. 42 sec.
Case 3	Multiple order. Request to increase quantities.	1 month	13 min. 12 sec.
Case 4	Negotiation to decrease quantities of recorded orders.	10 days	4 min. 30 sec.

Table 5-1: Evaluation of time to complete negotiations.[8]

In the current coordination operation, before introducing an Automated Negotiation Platform, coordination is made through human-to-human emails. It takes hours or even days to receive replies from counterparties, resulting in a coordination period that spans several days. In these experiments, waiting times perceived by humans were reduced from several days to within one minute by merely replacing one side with AI. Consequently, this significantly reduced the overall coordination period.

5.2 Procurement of Parts and Sale of Automobiles

The second case study focuses on the automotive production supply chain. We conducted a simulation in which an automobile manufacturer's Automated Negotiation AI simultaneously and consistently executed the sales negotiations for completed cars and the procurement negotiations for missing parts, taking manufacturing lead time and pricing into account. In this case, the negotiation counterparties were also AI agents, and we confirmed the approach's effectiveness.

Automobile manufacturers procure parts to manufacture cars and then sell the completed cars. Procurement of parts requires negotiations with suppliers to agree on delivery schedules, quantities, prices, etc. To manufacture a vehicle, both parts and available production facilities are needed, making the management and planning of their availability essential. Selling completed cars necessitates negotiating with buyers on delivery schedules, prices, etc. To conduct procurement and sales negotiations coherently, it is necessary to establish multiple negotiations that satisfy both price and delivery consistency.

[8] *https://prtimes.jp/main/html/rd/p/000000158.000078149.html*

Price consistency means that the sale price is reasonable with the total procurement and other costs. In contrast, delivery consistency means having an adequate inventory of the necessary parts at the appropriate time in the vehicle manufacturing process and being able to use the critical processes in the required order. They require managing:

- which parts are needed to manufacture a specific vehicle,
- how many stock units each part has at each time considering the consumption and delivery results of manufacturing,
- the required order of processes for vehicle manufacturing, and
- when the manufacturing facility of each process will be available.

To achieve delivery consistency, Automated Negotiation AI refers to data called BOM/BOP (Bill of Materials/Bill of Process) and ATP/CTP (Available to Promise/Capable to Promise). The former is structured data of the necessary parts and processes for a specific vehicle. At the same time, the latter is structured data of when and how many units of each part and manufacturing facility can be consumed or used. Fundamentally, the former is static information determined by vehicle and production method designs. At the same time, the latter is dynamic information updated by delivery and usage plans for parts or booking production facilities.

Figure 5-4 shows a solution architecture that simultaneously and consistently executes procurement and sales negotiations by referring to BOM/BOP and ATP/CTP. At the center is the company itself; on the left side, negotiation AI conducts sales negotiations with customers, while the negotiation AI conducts procurement negotiations with suppliers on the right.

In sales negotiations, scheduling done by referring to BOM/BOP and ATP/CTP information makes it possible to identify when the delivery date of a completed vehicle will be during negotiation or which parts are missing to meet a specific delivery date, as well as when those parts should be delivered. The information on the missing parts and required delivery dates is passed to the negotiation AI on the right side, and procurement negotiations are conducted accordingly.

If the procurement negotiations succeed, the content of ATP/CTP is updated following the scheduled delivery (the planned inventory quantity increases according to the agreed delivery date). Suppose the completed car sales negotiation is established. In that case, the ATP/CTP content is updated following the manufacturing schedule (the planned inventory quantity of consumed parts decreases, and the available schedule for production facilities is reduced).

Such configuration and operation simultaneously enable consistent sales and procurement negotiations regarding delivery dates.

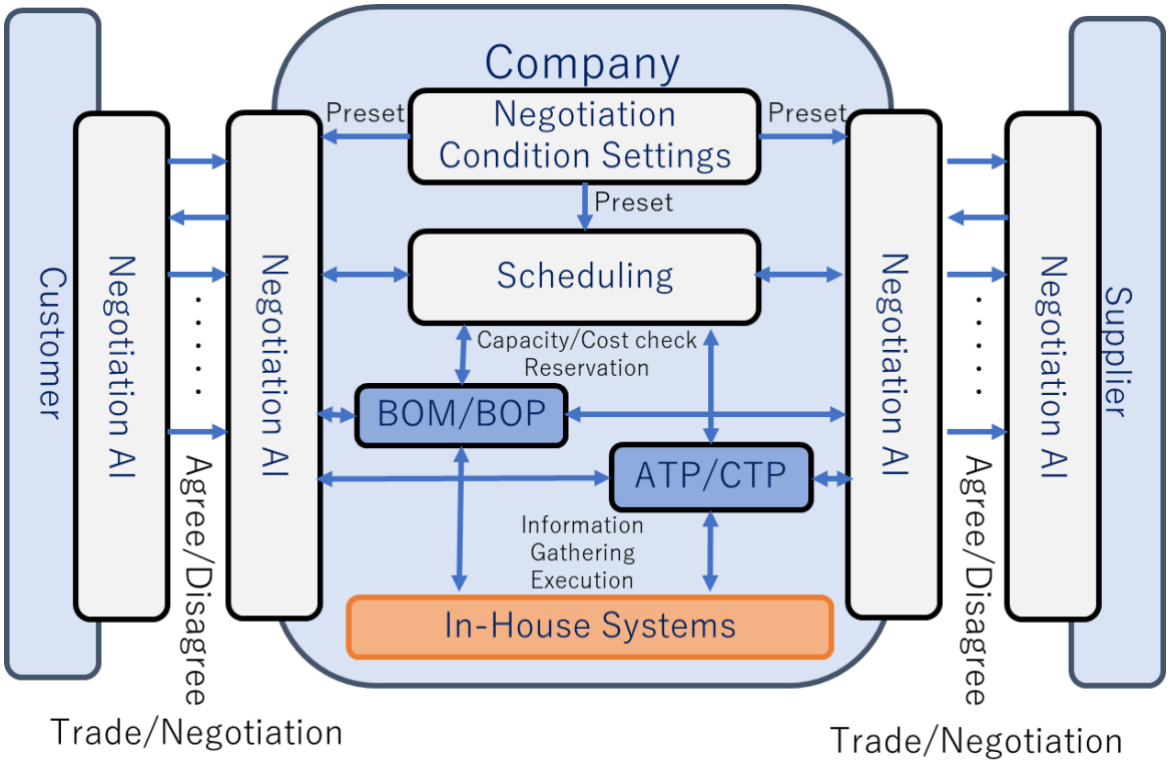

Figure 5-4: Negotiation AI Platform architecture.

We built this system for a virtual automotive supply chain and conducted simulations. Figure 5-5 shows the negotiation dashboard screen of an automobile manufacturer with the NAP solution.

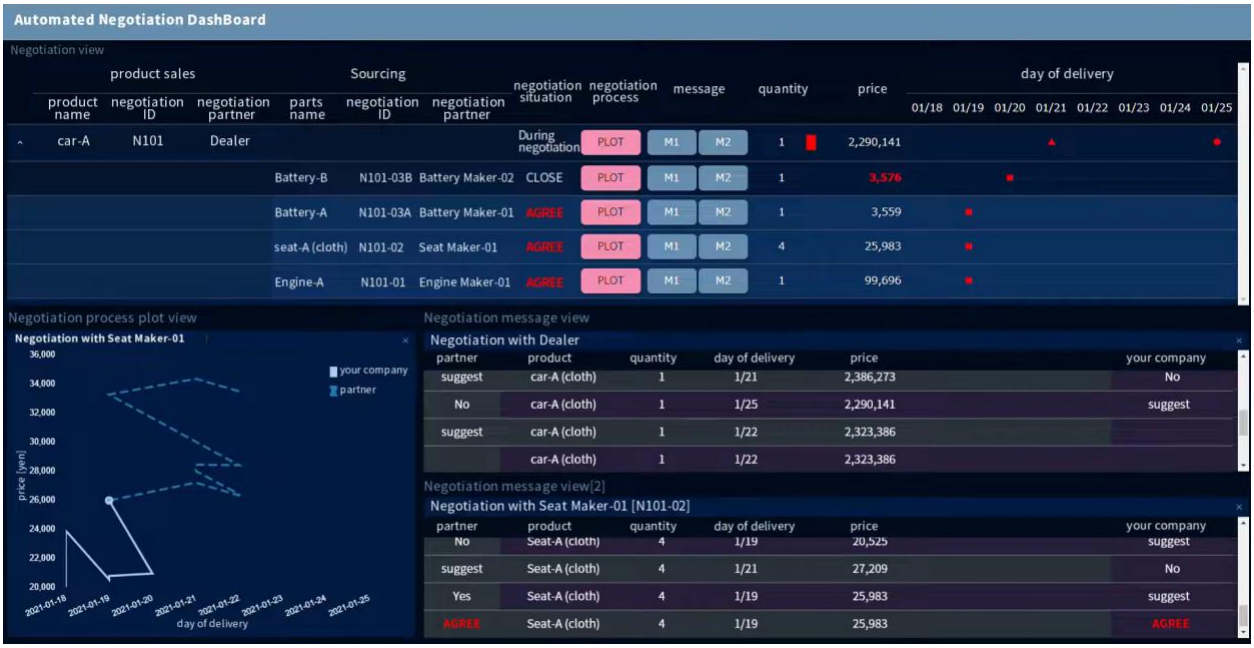

Figure 5-5: Negotiation dashboard.

On this screen, it is possible to view the status of simultaneous negotiations with the automotive dealer (customer) and the suppliers (of seats, engines, and batteries, in this case), which need to be improved in the production of the cars being negotiated. The table at the top provides a list of negotiations, the graph at the bottom left represents the negotiation process, and the table at the bottom right depicts the messages being exchanged in negotiation proceedings.

Assuming that the negotiation partners adopted a similar NAP solution, we conducted an Automated Negotiation simulation among these five companies. As a result, we confirmed that completing negotiations for procuring all missing parts and finalizing the sale of completed cars with consistent pricing and delivery dates, could be accomplished in just a few dozen seconds. In contrast to the several weeks typically required by current manual methods, we confirmed that a dramatic increase in efficiency is achievable through this approach.

5.3 AIR CARGO COORDINATION

The third case study focuses on the air cargo supply chain. We conducted a simulation where an air cargo forwarder's Automated Negotiation AI simultaneously and consistently executed negotiations for cargo slot allocations with airlines and cargo shipment schedule coordination with shippers. In this case, the negotiation partners were assumed to be humans.

The scenario is as follows (see Figure 5-6):

1. A shipper has an urgent transportation demand for their cargo, and negotiations with a forwarder begin.
2. However, upon checking the cargo space situation of the forwarder and airline, there are no available slots for the desired flight.
3. Delivering date changes are negotiated with other shippers who have already secured transport contracts to obtain cargo space. Simultaneously, spot cargo allocation negotiation with the airline is undertaken. If some coordination can fulfill all requirements and is concluded, other coordination efforts are closed, and the urgent cargo is transported as requested.

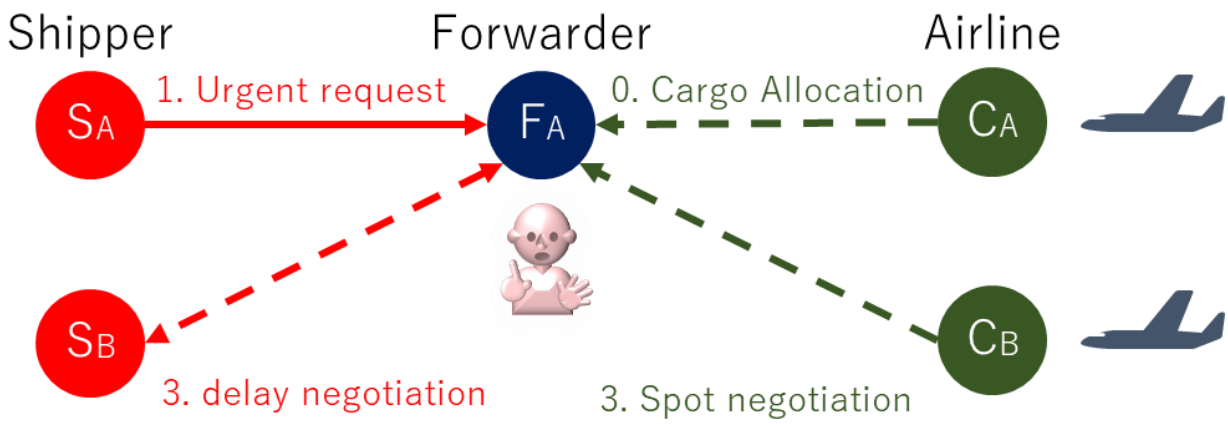

Figure 5-6: Air cargo transport coordination among stakeholders.

For the verification, we prototyped a simplified business system, negotiation system, and human-AI negotiation GUI and conducted simulations under the given scenario. Like the automobile case, the resource management system (ATP) was configured as a business system and connected to the negotiation system. Below, we provide an example of a forwarder system configuration (Figure 5-7).

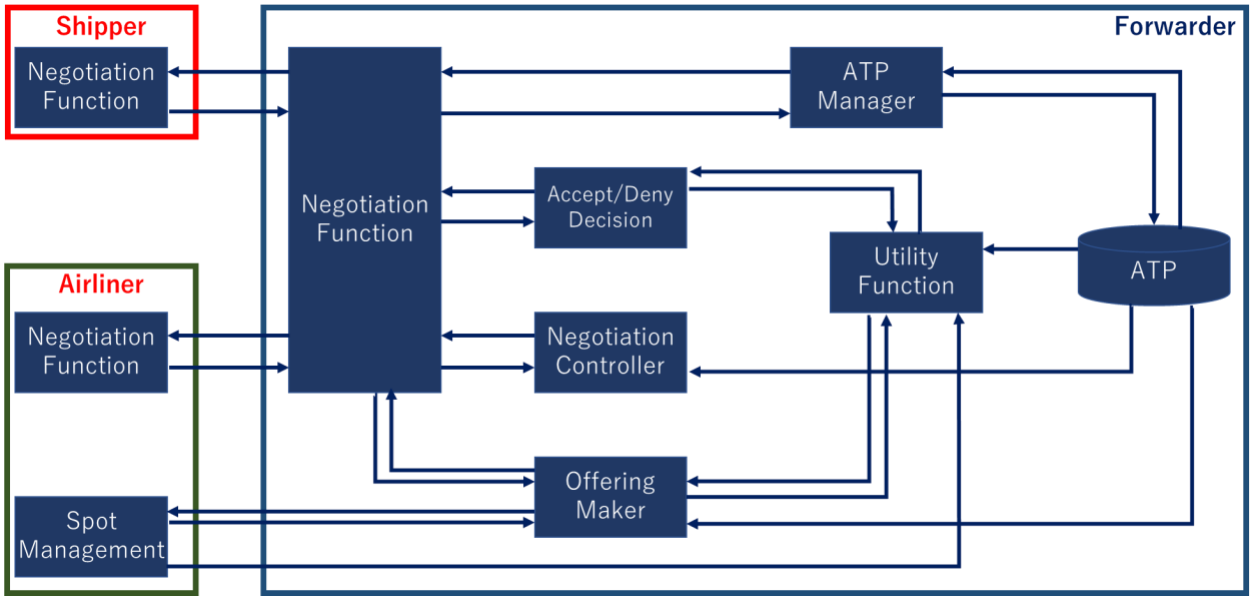

Figure 5-7: Forwarder system configuration.

For both forwarders and airlines, we confirmed that the primary functions – acceptance/denial judgment and offer creation – operated within a few seconds in the prototype system.

For that purpose, we prepared a human-AI negotiation interface with a GUI (Figure 5-8). Additionally, we prototyped a resource visualization GUI for the shipper to observe changes in the resource while negotiations progressed.

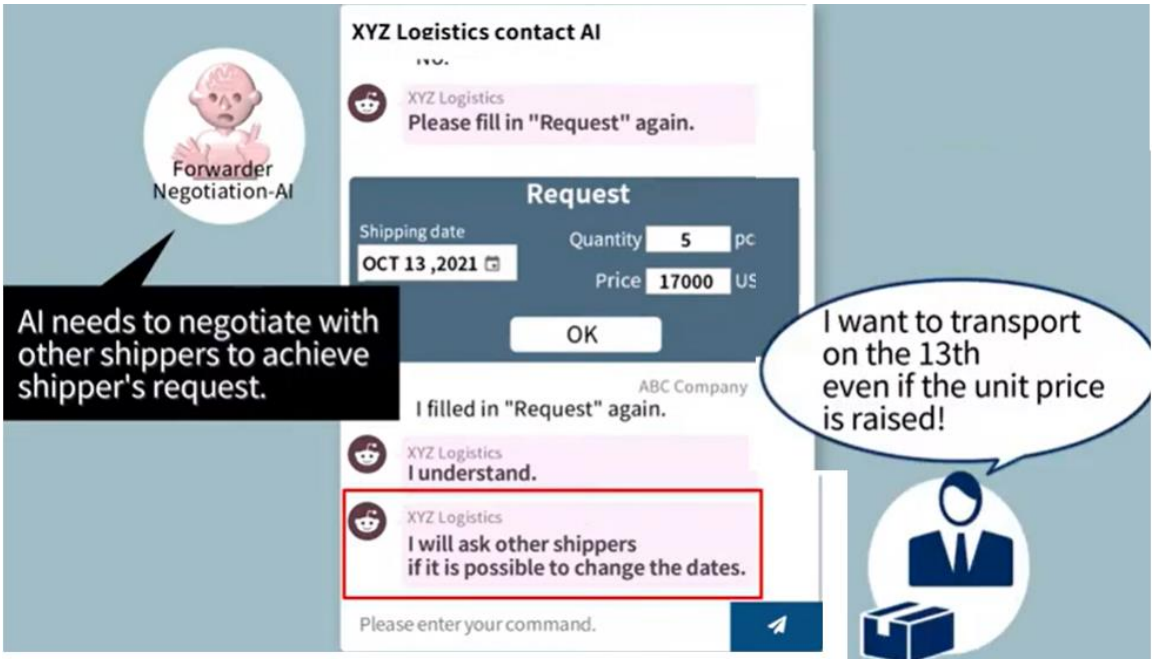

Figure 5-8: AI-human negotiation.

The experiment's results confirmed that coordination, which currently takes several hours to several days with human operation, can be completed in just a few dozen seconds. This finding demonstrates that in this domain as well, NAP has the potential to contribute to the efficiency improvement of supply chains.

6 INVITATION TO NAP TRIALS

We have been offering a demo since March 2023 that allows users to experience virtual negotiations with AI, focusing on delivery date negotiations in manufacturing supply chains through a chat-based interface (Figure 6-1). Users can experience the efficiency of the negotiation process and the reduction in time required for coordinating delivery dates. This is based on the "Electronic Component Procurement" case mentioned in Section 5.1 Electronic Component Procurement.

If you are interested in the virtual negotiation demo, please visit the homepage of the Automated Negotiation SCM Consortium[9]. There, you can find instructions and an overview of NAP activities. You will then be asked to sign an NDA to access detailed materials. After that, we can discuss

[9] *https://automated-negotiation.org/en/*

specific problem-solving approaches. (As mentioned, negotiation issues may involve confidential information, necessitating an NDA to discuss details.)

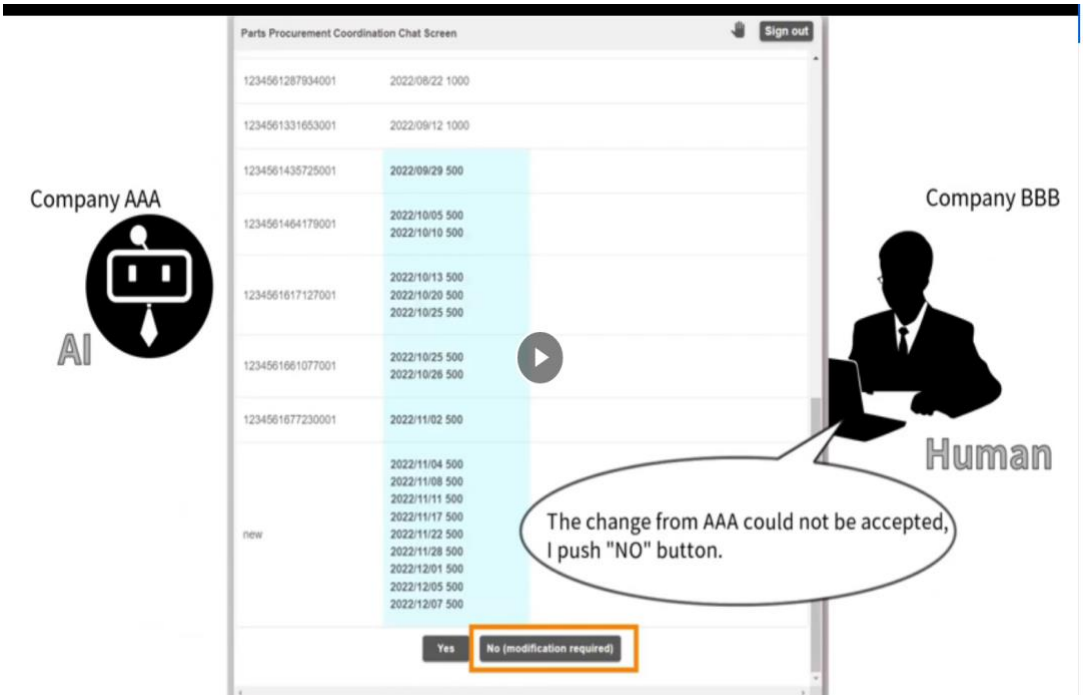

Figure 6-1: Virtual AI/human negotiation demo.

7 SUMMARY AND FUTURE DIRECTIONS

7.1 SUMMARY

In this paper, we introduced a NAP-based solution for enhancing supply chain efficiency using AI agents to negotiate on behalf of humans. This solution addresses a range of issues in inter-company coordination humans currently handle. Many problems could be mitigated, such as heavy consumption of human resources, lengthy time to complete coordination, low precision in considerations, and inappropriate agreements due to human errors.

We mainly focused on the manufacturing and logistics industries (Section 2 Motivation), providing a conceptual explanation of the NAP solution, an overview of its technical (Section 3 Technology) and business aspects (Section 4 Business), and an introduction to several case studies (Section 5 Case Studies). Each case study powerfully demonstrates the effectiveness of this solution.

We have developed a demonstration of the NAP solution accessible via the Internet (Section 6 Invitation to NAP Trials). Interested parties who wish to have a trial are encouraged to contact the authors.

7.2 FUTURE DIRECTIONS

The case studies introduced in this document will progress from proof of concept (PoC) and simulations to field tests. We will share the results of these endeavors as they become available.

While we focused on the manufacturing and logistics industries in this paper, we are also considering the application of NAP solutions in other sectors such as finance, human resources, data markets, and the circular economy. We plan to introduce our findings regarding these areas in future publications.

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