



Developing Supply Chain as a Service Through Standardized Digital Integration

Sampat Ramesh Acharya^{1*}, Shantall Marucia Cisneros Saldana¹, Heike Markus²

¹ Institute for Information Systems, Supply Chain Digitization, Hof, Germany

² Institute for Information Systems, Head of Supply Chain Digitization, Hof, Germany

Abstract

In today's dynamic business landscape, efficient supply chain management is crucial for maintaining competitiveness and sustainability. Traditional methods often lead to fragmented processes, lack of transparency, communication gaps, and higher operational costs. This research addresses these challenges through a case study, literature review, and comparative analysis, proposing a software platform solution named SuppliFlow. The study explores Digital Supply Networks, Distribution Management, Integrated Supply Chain Management, and sustainability practices aligned with Circular Economy. SuppliFlow advances the concept of Supply Chain as a Service, developing customizable workflows to meet specific supply chain needs from procurement to delivery. The integration of the Beckn Protocol, an open-source data protocol, is examined for its potential to establish decentralized networks and secure transactions. Additionally, the study investigates real-time order tracking and consolidated payments to enhance financial and data management efficiencies. A SuppliFlow prototype for assembly service providers was developed and tested to assess its effectiveness in standardizing procurement-to-delivery processes. The findings indicate that SuppliFlow can enhance supply chain efficiency, reduce operational costs, and improve visibility. This research presents a novel approach to supply chain management through the development and testing of SuppliFlow platform, suggesting potential pathways for future research and practical applications to improve organizational performance in the global marketplace.

Keywords: Circular economy, Digital Supply Networks, Distribution Management, Integrated Supply Chain Management, Supply Chain as a Service

1. Introduction

The rapid evolution of supply chain management (SCM) has been driven by the need to address inefficiencies, enhance transparency, and reduce operational costs (Bigliardia, et al., 2022), (Zhao, et al., 2023). Traditional SCM methods often result in fragmented processes, delays, and errors, hindering the ability of companies to meet consumer demands effectively (Suleiman, et al., 2022), (Hu, et al., 2018). This paper proposes a revolutionary approach to SCM by integrating circular economy principles and leveraging digital technologies to create a more sustainable and efficient supply chain ecosystem (Simonetto, et al., 2022), (Montag,

2022). This research paper explores the potential of a software platform named “SuppliFlow” to transform SCM practices and compares it with existing SCM platforms. Additionally, it introduces a prototype software platform and its initial application in the assembly service domain, demonstrated through an assembly machine at Hof University.

1.1 Background and Problem Statement

Supply chain management has undergone significant transformations over the past few decades, driven by technological advancements and changing market dynamics. The integration of digital technologies, such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI), has enabled the development of more efficient and transparent supply chains (Bigliardia, et al., 2022), (Zhao, et al., 2023). The concept of a circular economy, which emphasizes resource efficiency and sustainability, has also gained traction in SCM (Simonetto, et al., 2022). The SuppliFlow platform aims to combine these trends to create a comprehensive solution for modern supply chain challenges.

Inefficient supply chain management leads to fragmented processes, lack of transparency, and increased operational costs for businesses across industries. Traditional methods often result in delays, errors, and difficulties in coordinating with multiple service providers (Overcoming Fragmentation in Supply Chain Systems: A Comprehensive Guide, 2023), (Suleiman, et al., 2022), (Supply Chain Management: How To Overcome Challenges, 2022). This fragmentation and lack of real-time visibility make it challenging to track products, monitor supplier performance, and identify potential disruptions, leading to operational delays and higher costs. Empirical studies show that integrating digital technologies and adopting a circular economy approach can significantly mitigate these challenges, promoting sustainability and resilience in supply chain operations (Kalaiarasan, et al., 2022), (Alfaro & Chor, 2023). Developing and implementing platforms that leverage advanced technologies and circular economy principles offer promising avenues for overcoming traditional supply chain inefficiencies, thereby empowering organizations to meet evolving demands and gain a competitive advantage (Evolving Supply Chain Management with Data, 2023).

1.2 Research Objectives

The general objective of this research is to evaluate the effectiveness and advantages of the SuppliFlow application in optimizing supply chain management (SCM) processes by leveraging advanced concepts such as decentralized networks, circular economy principles, customizable workflows, and consolidated payments.

Specific Objectives:

- (1) Evaluating the SuppliFlow application compared to existing platforms.
 - To compare the features and functionalities of SuppliFlow with existing SCM solutions.
 - To assess the performance of the SuppliFlow prototype in real-world scenarios, focusing on metrics such as processing time, efficiency improvements, resource utilization, accuracy in real-time data sharing and user satisfaction.
- (2) Evaluating the advantages of using advanced concepts by utilizing insights from existing research:
 - To evaluate the impact of decentralized networks on transparency, security, and trust in economic transactions within the supply chain.
 - To analyze how the integration of circular economy principles in SuppliFlow promotes sustainability and resource efficiency.

- To assess the benefits of customizable workflows in enhancing flexibility and adaptability to specific SCM needs.

(3) Evaluating Supply Chain as a Service (SCaaS):

- To create a use case within the SuppliFlow prototype where a user can search for an assembly service, demonstrating the application of the SCaaS concept.
- To evaluate how SuppliFlow enables the integration of different supply chain services, such as procurement, logistics, assembly and delivery into a cohesive and efficient workflow.

1.3 Literature Review

The purpose of this literature review is to synthesize existing research on digital supply networks, distribution management, integrated supply chain management, sustainability practices toward a circular economy, and the concept of Supply Chain as a Service (SCaaS). This will provide a comprehensive understanding of the current state of SCM and the potential impact of SuppliFlow.

The integration of digital technologies and circular economy principles into supply chain management (SCM) has been a focal point of recent research. SuppliFlow, a software platform designed to revolutionize supply chain operations, embodies these advancements by leveraging digital technologies, promoting sustainability, and enhancing operational efficiency.

Digital transformation has been a critical driver of innovation in SCM. Technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI) have enabled real-time data sharing, improved transparency, and enhanced decision-making capabilities (Bigliardia, et al., 2022), (Zhao, et al., 2023). The integration of these technologies has led to the development of digital supply chains that are more agile, resilient, and efficient (Farajpour, et al., 2022).

The circular economy model focuses on extending the lifecycle of products through sharing, repairing, or recycling, thereby promoting resource efficiency and environmental stewardship (Simonetto, et al., 2022). Research has shown that integrating circular economy principles into SCM can lead to significant cost savings and sustainability benefits (Russo, et al., 2020).

Several SCM platforms are currently available, each with their unique features and capabilities. Notable examples based on a ranking of the most relevant tools in the market include SAP Supply Chain Management, Oracle SCM, and Infor SCM. These platforms offer various functionalities such as inventory management, order processing, and supplier relationship management (Shopify, 2024), (Predictive Analytics Today, 2023). However, platforms often lack comprehensive integration of circular economy principles and the decentralized, peer-to-peer network capabilities necessary to further improve flexibility and resilience.

The integration of Industry 4.0 technologies into supply chain management has been extensively explored in recent scholarly work, highlighting transformative approaches and the emergence of 'Supply Chain-as-a-Service' (SCaaS) models. Key sources such as Ivanov (Ivanov, et al., 2022) discuss how cloud-enabled networking of physical and digital assets can enhance the flexibility, visibility, and efficiency of supply chains. SuppliFlow contributes to advancing SCaaS by leveraging the Beckn Protocol for decentralized, efficient, and transparent supply chain operations. Sustainable supply chain management (SSCM) is a crucial aspect of integrating the circular economy into SCM (Ethirajan & Kandasamy, 2019). It focuses on reducing environmental impacts and enhancing long-term sustainability.

SuppliFlow's approach to promoting SSCM by facilitating product sharing can be directly related to these insights, as product sharing is one of the principles of a circular economy.

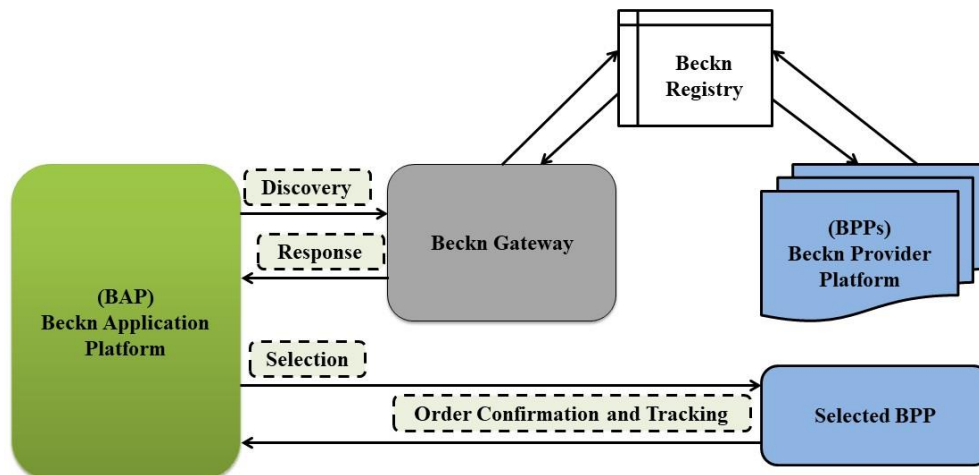
Transitioning to a circular economy within SCM presents challenges such as the need for new strategies and frameworks (Wilts, 2017). To address these challenges providing a structured platform can simplify the adoption of circular economy practices for businesses. This approach should not only implement the theoretical concepts of SSCM and circular economy but also address practical industry needs and challenges (MacArthur Foundation, 2023).

1.4 Decentralized Networks with Beckn Protocol

The mentioned gaps require new technologies to enable the implementation of innovative approaches. The Beckn Protocol is highlighted as a key technological stack used to facilitate open, peer-to-peer decentralized networks for cross-sector economic transactions. This ensures a secure and innovative foundation for supply chain management, which is essential in recent developments (He, et al., 2013), (Beckn For <Developers/>, 2021). Therefore, it is chosen as a technological basis in this paper.

The Beckn Protocol consists of a set of standardized specifications, including protocol Application Programming Interfaces (APIs), message formats, network design, and reference algorithms, which enable interoperability and communication between different service providers and consumers. By leveraging a peer-to-peer network architecture, the Beckn Protocol ensures that services and offers from multiple providers are universally discoverable and accessible through any Beckn-enabled application. This decentralized approach eliminates the need for a centralized platform, thereby enhancing security, privacy, and scalability. The ability of the protocol to integrate diverse services into a cohesive ecosystem makes it particularly suitable for complex supply chain operations, where it can streamline processes, improve transparency, and foster collaboration among stakeholders. Open standards and privacy-protected interactions positions the Beckn Protocol as a transformative technology for modern supply chain management (Beckn For <Developers/>, 2021). Figure 1 shows the structure and the communication flow of the Beckn protocol.

Figure 1: Beckn Structure and Communication Flow



Source: self-created

The structure includes the following components (Beckn For <Developers/>, 2021):

- **Beckn Application Platform (BAP)** is the client-facing component where users interact with the application. It includes the user interface (UI) and client layer, which handle user requests and communicate with the Beckn network.

- **Beckn Provider Platform (BPP)** is the provider-facing component that hosts service providers' catalogs and handles service requests. It includes APIs to accept requests from BAPs or Beckn Gateways.
- **Beckn Gateway (BG)** acts as a mediator, routing requests from BAPs to relevant BPPs and vice versa. It ensures that the requests are broadcast to all potential providers and the responses are collected and sent back to BAP.
- **Beckn Registry** is a decentralized directory that lists all the participants (BAPs and BPPs) in the Beckn network. It ensures that the participants are discoverable and can communicate with each other.

The communication flow consists of standardized phases (Beckn For <Developers/>, 2021):

- **Discovery:** When a user searches for a service, the BAP sends a search request to the Beckn Gateway. The gateway broadcasts this request to all registered BPPs.
- **Response:** The BPPs that can fulfill the request respond to the gateway, which then forwards the responses back to the BAP.
- **Selection:** The user selects a service provider from the list of responses. The BAP sends a selection request to the chosen BPP through the gateway.
- **Order Confirmation:** The BPP confirms the order and sends a confirmation response back to the BAP via the gateway.
- **Fulfillment and Tracking:** The BPP fulfills the order and provides real-time status updates to the BAP, which are displayed to the user.

This structured approach ensures secure, transparent, and efficient transactions within the supply chain, making the Beckn Protocol a transformative technology for modern supply chain management.

1.5 Supply Chain as a Service

Supply Chain as a Service (SCaaS) is an innovative approach to supply chain management that leverages cloud-based technologies and service-oriented architectures to provide flexible, scalable, and on-demand supply chain solutions. SCaaS enables organizations to outsource various supply chain functions to specialized service providers, allowing them to focus on their core competencies while benefiting from the expertise and resources of third-party providers (Ivanov, et al., 2022). The concept of SCaaS includes the following aspects:

- SCaaS is built on a **service-oriented architecture** (SOA) that allows different supply chain functions to be delivered as discrete services. These services can be easily integrated, scaled, and customized to meet the specific needs of an organization (Liu, et al., 2007), (Rajnala, et al., 2023).
- SCaaS leverages **cloud computing** to provide on-demand access to supply chain services. This ensures that organizations can scale their supply chain operations up or down based on demand without the need for significant capital investment in infrastructure (Ivanov, et al., 2022).
- SCaaS adopts a **modular approach**, where different supply chain functions such as procurement, manufacturing, logistics, and distribution are offered as individual services. Organizations can select and integrate the services they need, creating a tailored supply chain solution (Gyllenskepp & Martin), (Tripathi, 2023).

The concept leads to several benefits:

- **Flexibility and Adaptability:** SCaaS provides organizations with the flexibility to adapt their supply chain operations to changing market conditions and customer demands. On-demand services enable organizations to quickly scale their operations and respond to fluctuations in demand (Ivanov, et al., 2022).
- **Cost Efficiency:** By outsourcing supply chain functions to specialized service providers, organizations can reduce operational costs and avoid significant capital investments in infrastructure. This allows them to allocate resources more efficiently and focus on their core business activities.
- **Enhanced Collaboration:** SCaaS facilitates collaboration between different stakeholders in the supply chain, including suppliers, manufacturers, logistics providers, and customers. This collaborative approach enhances transparency, improves communication, and streamlines operations.
- **Improved Visibility:** SCaaS provides real-time visibility into supply chain operations, enabling organizations to monitor and track the status of their orders, inventory levels, and shipments. This visibility helps in making informed decisions and improving overall supply chain performance.
- **Scalability:** SCaaS allows organizations to scale their supply chain operations based on demand. This scalability ensures that organizations can handle peak periods and fluctuations in demand without compromising efficiency or service quality.

2. Methods

The research design for this study is based on a combination of a case study, literature review and comparative analysis. This approach was chosen to evaluate the SuppliFlow software platform, its integration of advanced concepts, and its potential to revolutionize supply chain management (SCM). The literature review provided an overview of existing research on digital supply networks, distribution management, integrated supply chain management, and sustainability practices towards a circular economy. Based on the literature review, relevant criteria were defined to conduct a comparative analysis. This analysis was used to assess SuppliFlow platform against existing SCM solutions, focusing on key features, performance metrics, and the integration of advanced concepts such as decentralized networks, customizable workflows, and consolidated payments. This approach allows for a comprehensive evaluation of SuppliFlow's effectiveness.

2.1 Criteria Considered for the Comparative Analysis

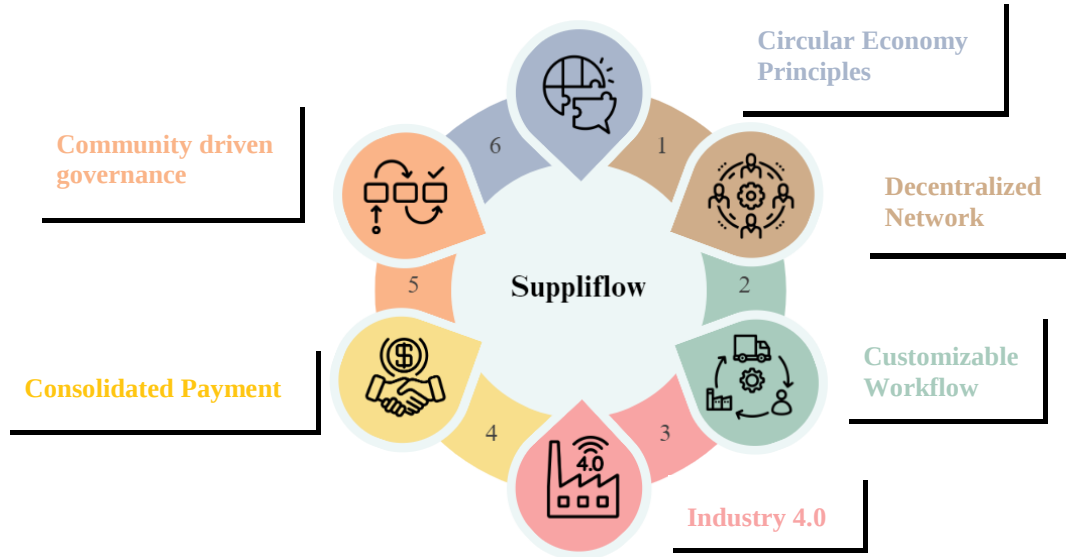
Figure 2 illustrates the criteria considered to analyze how the SuppliFlow platform integrates the above mentioned factors to create a more sustainable and efficient supply chain ecosystem as mentioned in the introduction. Due to their significant impact on sustainability, efficiency, and adaptability in supply chain management the following features and technologies are considered for the analysis.

Circular Economy Principles emphasize the continuous use of resources through recycling, reusing, and sharing. This approach aims to extend the lifecycle of products, minimize waste, and promote sustainability by creating closed-loop systems where resources are continuously repurposed (Simonetto, et al., 2022).

Customizable Workflows allow users to tailor supply chain processes to specific requirements, from procurement to delivery. Research indicates that customizable workflows

enable organizations to respond more effectively to changing market conditions and specific customer needs, thereby enhancing overall supply chain performance (Kalaivasan, et al., 2022), (Alfaro & Chor, 2023).

Figure 2: Features and Technologies considered for the Research



Source: self-created

Industry 4.0 Principles contribute to networked value creation, remote maintenance, robotics, digitalized control, and virtualization, significantly impacting the ongoing digital transformation of industries (Simonetto, et al., 2022).

Consolidated Payment Systems integrate various financial transactions into a single streamlined process. This approach simplifies financial management by reducing the complexity of handling multiple payments, thereby enhancing efficiency across the entire supply chain (Hu, et al., 2018).

Community-Driven Governance Models leverage collective intelligence, fostering inclusive, transparent, and democratic decision-making processes. This approach promotes a more collaborative and adaptive ecosystem by involving diverse stakeholders in governance activities, thereby enhancing the resilience and responsiveness of the system (Suleiman, et al., 2022).

2.2 Analysis of existing SCM platforms

Several SCM platforms are currently available, each with their unique features and capabilities. Notable examples include SAP Supply Chain Management, Oracle SCM, and Infor SCM. These platforms offer various functionalities such as inventory management, order processing, and supplier relationship management and are listed as the relevant platforms in the market (Predictive Analytics Today, 2023) and are also associated with the SuppliFlow platform. However, they lack the comprehensive integration of circular economy principles and decentralized, peer-to-peer network capabilities. Based on the criteria defined in the previous section, Table 1 provides an analysis of existing SCM platforms. The relevant data for the evaluation were collected from software provider websites and product descriptions (SAP SCM, 2024), (Oracle, 2024), (Infor, 2024), (Descartes, 2024), (Redwood, 2023), (Predictive Analytics Today, 2023).

Table 1: Analysis of existing SCM platforms

Feature / Platform	SAP SCM	Oracle SCM	Infor SCM	Descartes SCM	IBM Watson Supply Chain
Circular Economy Principles	Limited Integration	Limited Integration	Limited Integration	No Specific focus on Circular Economy	Limited Integration
Decentralized Networks	No, Centralized systems	No, Centralized systems	No, Centralized systems	No, Centralized systems	Yes, uses blockchain for transparency
Customizable Workflows	Yes, but with predefined templates	Yes, with integrated business planning	Yes, real-time orchestration	Limited, focused on logistics	Yes, with AI-driven customization
Consolidated Payments	Yes, integrated financial management	Yes, integrated financial management	Yes, integrated financial management	Limited, focused on logistics payments	Yes, integrated financial management
Real-Time Order Tracking	Yes, with advanced analytics	Yes, with real-time visibility	Yes, with real-time orchestration	Yes, with real-time visibility	Yes, with AI and predictive analytics.
Community-Driven Governance	No, traditional governance models	No, traditional governance models	No, traditional governance models	No, traditional governance models	No, traditional governance models
Industry 4.0 Alignment	Yes, supports Industry 4.0 principles	Yes, supports Industry 4.0 principles	Yes, supports Industry 4.0 principles	Limited, focused on logistics.	Yes, supports Industry 4.0 principles.

Source: Self-created

2.3 Chocolate Box Manufacturing Use Case

The primary data represents the implementation of SuppliFlow in the chocolate box manufacturing use case, where an assembly machine is used to assemble chocolate boxes in the lab at Hof University. It's important to note that while the primary data collection focuses on this specific use case, certain features of SuppliFlow, such as 3D printing service and logistics service are not yet implemented in the prototype project and are defined at a conceptional level based on the literature gap. The following details outline the specific aspects of this use case:

- **3D Printing Service (concept):** The 3D printer is used to manufacture chocolate boxes. Although this service is not yet integrated into SuppliFlow, it is a crucial part of the overall process.
- **Assembly Machine Prototype (implemented):** The prototype of an assembly machine (ETS Assembly) in the Hof University's lab assembles 3D-printed chocolate boxes.
- **User Interaction (implemented):** Users can register on the SuppliFlow application, search for the assembly service, and select the ETS Assembly machine based on location and rating filters.
- **Order Configuration (partly implemented):** Users provide configurations such as quantity and color of the chocolate boxes, delivery address, and payment. The

consolidated payment feature is not implemented for this prototype, the payment feature is simulated.

- **Real-Time Status Updates (implemented):** Upon order confirmation, the ETS Assembly machine starts the order and provides real-time status updates, which can be viewed in the SuppliFlow application.
- **Integration with Beckn Protocol (implemented):** The implementation of the Beckn Protocol has made SuppliFlow decentralized, ensuring secure and innovative economic transactions.
- **User interface Implementation (implemented):** The implementation of user interface for SuppliFlow which can integrate with the BAP module of the Beckn Protocol stack 1.4.
- **SuppliFlow's Backend Software (implemented):** The implementation of the backend software for SuppliFlow which can connect to the different assembly service providers registered in the Beckn Registry through Beckn Protocol stack 1.4.

The following data points are collected to assess the application:

- **Order Processing Time:** Time taken from order confirmation to completion.
- **Resource Utilization:** Efficiency in the use of the assembly machine and other resources.
- **User Satisfaction:** Feedback from users regarding the ease of use and effectiveness of the SuppliFlow application.
- **Real-Time Tracking Accuracy:** Accuracy and reliability of real-time status updates provided by the assembly machine.

2.4 Use Case Development

To evaluate the approach, the background of the use case development is explained in the following section. The first step in the development of the SuppliFlow platform was to integrate the Beckn Protocol. Integrating the Beckn Protocol is a major step to make the application decentralized, secure, and standardized for all stakeholders. To achieve this, the development focused on understanding the protocol, creating the application in the Beckn environment, and then implementing a use case involving the integration of an assembly service machine available in Hof University's lab. The use case development process for SuppliFlow involves creating detailed scenarios that demonstrate how users interact with the system to achieve specific goals. This section focuses on the chocolate box manufacturing use case, where an assembly machine is used to assemble chocolate boxes. The user can select a logistics service between different providers, thereby creating a workflow. Alternatively, the user can choose to manage their own logistics. However, this feature is not implemented in the prototype since only assembly service is integrated, making the logistics service unnecessary for this initial implementation. The next step in the use case development is the identification of actors, defining scenarios, establishing success criteria, and providing sequence diagrams.

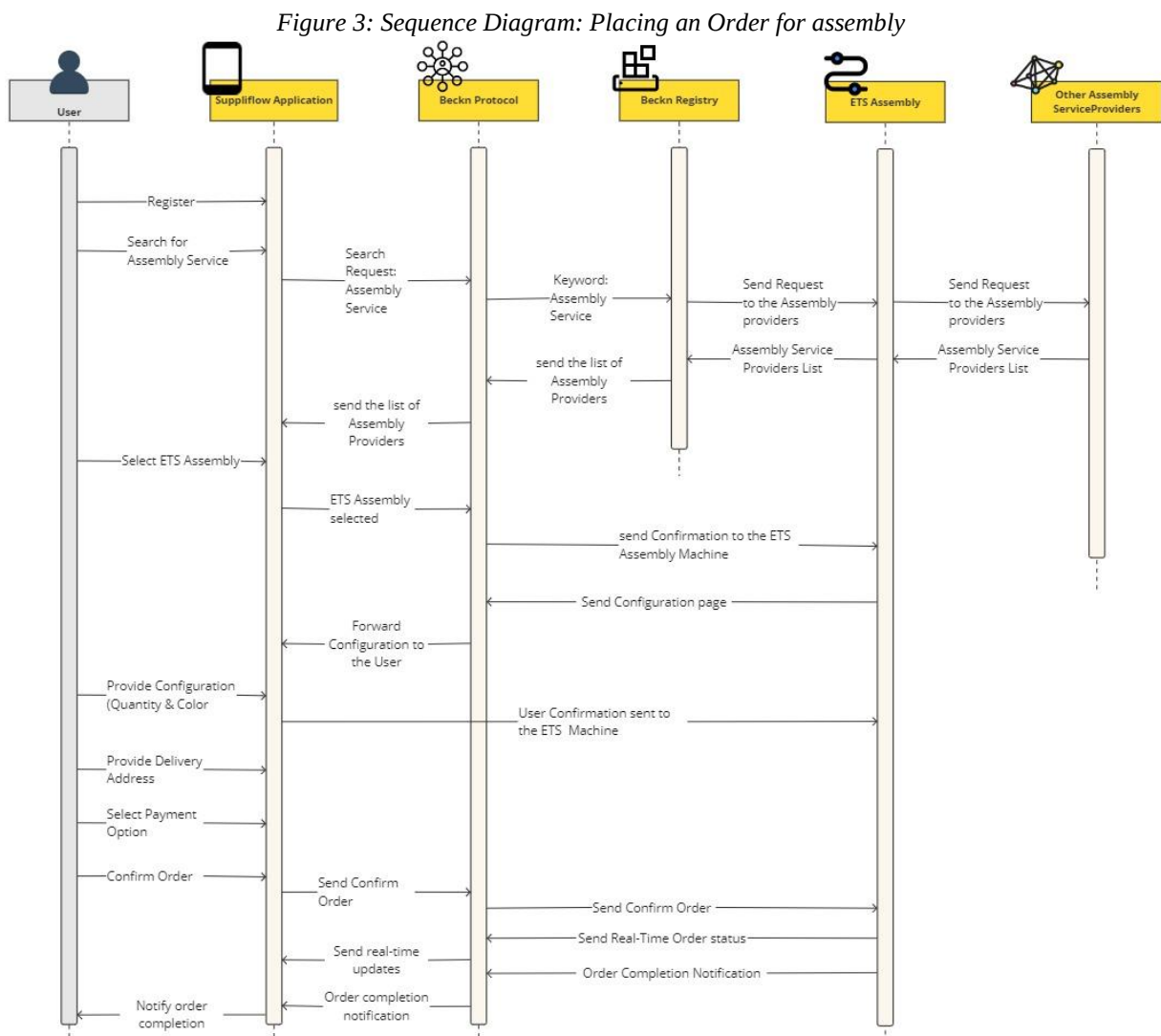
2.4.1 Identifying Actors

Actors are entities that interact with the system. In the context of SuppliFlow's chocolate box manufacturing use case, the primary actors include:

- **User:** The individual or business entity that requires the assembly service.
- **3D Printer:** The machine used to manufacture the chocolate boxes. Since this feature is not integrated into the SuppliFlow platform for this prototype, the boxes are 3D-printed manually from the 3D printer lab in the University.
- **Assembly Machine (ETS):** The automated machine that performs the assembly of the 3D-printed chocolate boxes.
- **SuppliFlow Application:** The platform that facilitates the interaction between the user and the assembly machine.
- **Beckn Protocol:** The decentralized network protocol that ensures secure and transparent transactions. For more details refer to section 1.4.

2.4.2 Defining Scenarios

Scenarios describe the sequence of actions and interactions between the actors and the system. Figure 3 shows the sequence diagram of the defined scenario. It outlines the typical use case for the chocolate box manufacturing process.



Source: Self-created

- **User Registration:** The user registers on the SuppliFlow application.
- **Search for Assembly Service:** The user searches for the assembly service using location and rating filters.
- **Request to Beckn Registry:** The user's request is sent to the Beckn Registry through Beckn Protocol stack. All the assembly service providers registered in the Beckn Registry will reply through the Beckn Protocol. The ETS assembly machine is already registered in the Beckn Registry. For more information refer to 1.4.
- **Select Assembly Provider:** The user selects the ETS assembly machine available at the University from the list of assembly service providers.
- **Configuration Page:** The ETS assembly machine sends a configuration page to the user.
- **Provide Configurations:** The user specifies the quantity and color of the chocolate boxes to be assembled in the configuration page provided by the ETS Assembly.
- **Provide Delivery Address:** The user provides the delivery address for the assembled boxes.
- **Select Payment Option:** The user selects the payment option which is simulated for this prototype and confirms the order.
- **Order Processing:** The order is sent to the ETS assembly machine, which reads the input, checks availability, and starts the order.
- **Real-Time Status Updates:** The ETS assembly machine provides real-time status updates, which can be viewed in the SuppliFlow application.
- **Order Completion:** Once the order is complete, the ETS Assembly machine sends an order completion notification to the SuppliFlow application, and the user receives a notification of completion.

2.4.3 Establishing Success Criteria

Success criteria are the conditions that must be met for the use case to be considered successful. For the chocolate box manufacturing use case, the success criteria include:

- **Order Processing Time:** The time taken from order confirmation to completion should be within the expected timeframe.
- **Resource Utilization:** The assembly machine should operate efficiently, with minimal idle time and optimal use of resources.
- **User Satisfaction:** Users should find the SuppliFlow application easy to use and effective in meeting their assembly needs.
- **Real-Time Tracking Accuracy:** The real-time status updates provided by the assembly machine should be accurate and reliable.

3. Results of the application assessment

3.1 Application Description

SuppliFlow is a comprehensive SCM application designed to optimize various aspects of the supply chain, including manufacturing, assembly, logistics, and other services. The application aims to address inefficiencies in traditional SCM methods by providing a user-friendly platform that enhances visibility, streamlines operations, and promotes sustainability

through the integration of circular economy principles. The key features and functionalities of the implementation are:

- **Circular Economy Principles:** The application promotes sustainability by integrating circular economy principles, such as resource sharing. This approach extends the lifecycle of products, reduces waste, and improves resource efficiency. SuppliFlow helps organizations achieve significant cost savings by connecting companies with surplus capacity to those in need, thereby minimizing operational costs.
- **Customizable Workflows:** SuppliFlow allows users to tailor their supply chain processes to meet specific requirements, from procurement to delivery. This customization feature includes the ability to select different supply chain services based on user requirements, thereby embodying the concept of Supply Chain as a Service (SCaaS). It also offers the option to select logistics services between different service providers, or to manage logistics independently, providing greater flexibility and adaptability in managing supply chains.
- **Search, Select, and Configure Services:** Users can seamlessly search for any supply chain services, select those that meet their needs, and configure them according to provider specifications. The application includes location and rating filters to help users find the best service providers.
- **Real-Time Order Tracking:** SuppliFlow provides real-time updates on order status, allowing users to stay informed about the progress of their orders. This feature enhances transparency and helps monitor the supply chain effectively.
- **Consolidated Payments:** The application simplifies financial management by centralizing all payments, streamlining the payment process and reducing complexities.
- **Community-Driven Governance:** SuppliFlow leverages a community-driven governance model that fosters inclusive, transparent, and democratic decision-making processes. This model utilizes collective intelligence to create a more collaborative and adaptive ecosystem.
- **Integration with Beckn Protocol:** SuppliFlow utilizes the Beckn Protocol to facilitate open, peer-to-peer decentralized networks for cross-sector economic transactions. This integration ensures secure and innovative transactions within the supply chain. For more information refer to 1.4.

3.1.1 Comparative Analysis of SuppliFlow with Existing SCM platforms

Based on the analysis in section 2.2, the comparative analysis of SuppliFlow with existing platforms is summarized below:

- **Circular Economy Principles:** SuppliFlow uniquely integrates circular economy principles, promoting sustainability through sharing. This is a distinctive feature compared to other platforms that have limited or no focus on circular economy practices.
- **Decentralized Networks:** SuppliFlow leverages the Beckn Protocol to facilitate decentralized, peer-to-peer transactions, enhancing transparency and security. For more information refer to section 1.4. Most traditional SCM platforms use centralized systems.
- **Customizable Workflows:** SuppliFlow offers highly customizable workflows, embodying the SCaaS concept. Users can select from various supply chain services according to their needs, making SuppliFlow more versatile and adaptable than other platforms, which offer limited customization options.

- **Consolidated Payments:** SuppliFlow simplifies financial management with centralized payments, similar to other leading SCM platforms.
- **Real-Time Order Tracking:** SuppliFlow provides real-time order tracking, a feature also available in other advanced SCM platforms.
- **Community-Driven Governance:** SuppliFlow's community-driven governance model, which leverages collective intelligence for decision-making, distinguishes it from traditional governance models used by other platforms.
- **Industry 4.0 Alignment:** SuppliFlow supports digital transformation with advanced technologies, aligning with industry 4.0 principles, similar to other leading SCM platforms.

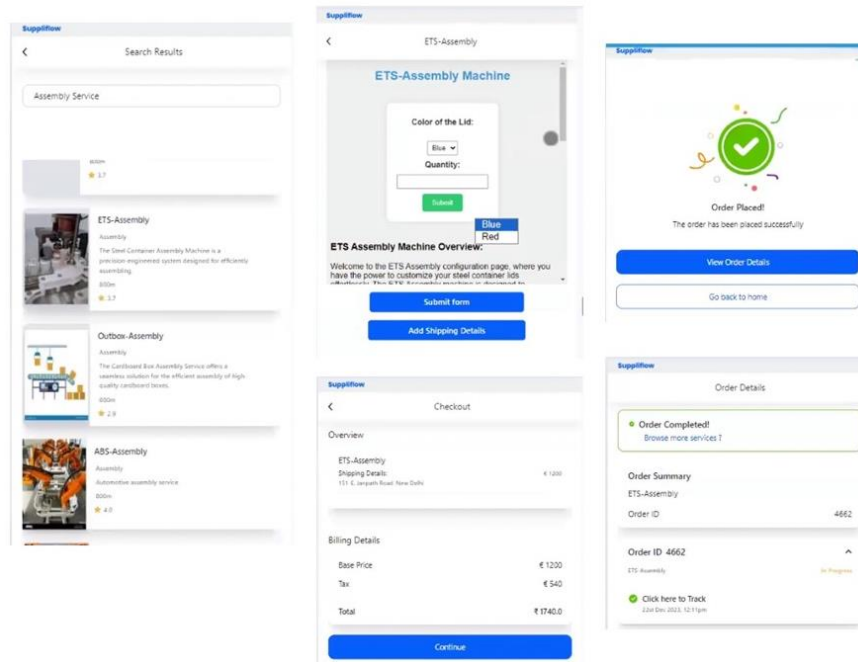
3.1.2 Prototype Development

The development of the SuppliFlow prototype involved several key steps, focusing on integrating advanced technologies and ensuring seamless functionality. The prototype was specifically tailored to connect with assembly service providers, demonstrating its capabilities in streamlining procurement-to-delivery processes. It showcases the concept of SCaaS, allowing users to select various services within the supply chain. It's important to note that certain features of SuppliFlow, such as circular economy principles, customizable workflows and consolidated payment feature are not yet implemented in the prototype project. Figure 4 shows the snippets of the SuppliFlow prototype application.

Development Process:

- **Initial Setup:** The initial setup involved defining the system architecture including the Beckn Application Platform, Beckn Provider Platform, and Beckn Gateway. These components interact to facilitate seamless communication and transactions within the supply chain. For more information refer to section 1.4.
- **UI Implementation:** Wireframes were created to visualize the user interface of the SuppliFlow application. Tools like Figma, Sketch, and Adobe XD were used to design the UI, ensuring a user-friendly layout and functionality. The wireframes included screen layouts, navigation bars, and interactive elements.
- **Backend Implementation:** The backend implementation involved developing a Python-based model to communicate with the Beckn Protocol. This model facilitates communication between the Beckn Protocol stack (BPP) and the ETS assembly machine.
- **Prototype Testing:** The prototype was tested in the lab setting at Hof University, focusing on the assembly service domain. The testing involved users selecting the assembly machine (ETS Assembly), providing configurations (quantity and color), and receiving real-time status updates through the SuppliFlow application. The prototype demonstrated seamless integration with the assembly machine and the Beckn Protocol.
- **User Interaction and Feedback:** Users registered on the SuppliFlow application, searched for assembly services, and selected the ETS assembly machine based on location and rating filters. They provided configurations, delivery addresses, and payment options. The assembly machine processed the orders and provided real-time updates, ensuring a smooth and efficient user experience.

Figure 4: SuppliFlow Prototype Application Snippets



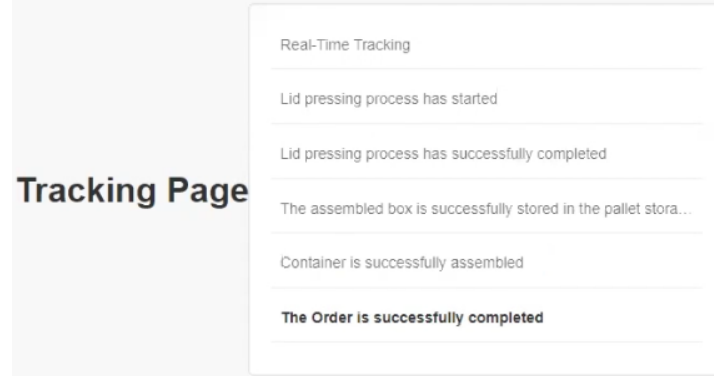
Source: Self-created

Key Outcomes:

The successful implementation of the SuppliFlow prototype, particularly in the assembly service domain, highlights its potential to streamline supply chain processes, enhance visibility, reduce operational costs, and improve overall efficiency.

- **Order Processing Time:** The time taken from order confirmation to completion is around 5 minutes indicating the efficiency of SuppliFlow in handling orders and reducing delays.
- **Resource Utilization:** Resource utilization is highly efficient. Order details, such as configuration and order confirmation, are only sent after the user confirms the order, ensuring optimal use of resources and minimizing waste.
- **Efficiency Improvements:** SuppliFlow's streamlined workflows and real-time data-sharing capabilities contribute to overall efficiency improvements in supply chain operations. The platform's integration with the Beckn Protocol ensures secure and innovative transactions, further enhancing operational efficiency.
- **User Satisfaction:** Although external user feedback was not gathered, internal team feedback suggests that the application is easy to use and provides clear instructions. This indicates that SuppliFlow has a user-friendly interface that can achieve user satisfaction.
- **Real-Time Tracking Accuracy:** Real-time tracking is reliable. It provides accurate updates on the machine and every step involved in the assembly process of the ETS machine. This feature enhances transparency and allows users to monitor their orders effectively. Figure 5 shows the real-time updates from the assembly machine.

Figure 5: Real-time Tracking updates from the Assembly Machine



Source: Self-created

By following this structured approach, the development and testing of the SuppliFlow prototype provided valuable insights into its capabilities and potential to revolutionize supply chain management. The integration of advanced technologies and user-centric design principles ensured a seamless and efficient user experience, paving the way for future enhancements and broader implementation.

3.1.3 Advantages

SuppliFlow offers several unique advantages that distinguish it from other SCM solutions. For more information refer to sections 2.2 & 3.1.1. These advantages are rooted in its innovative use of advanced technologies, SCaaS concept, and commitment to sustainability.

- **Increased Efficiency:** SuppliFlow enhances overall efficiency in supply chain operations by streamlining processes and reducing delays. The integration of real-time order tracking and decentralized networks ensures that all stakeholders have up-to-date information, enabling fast decision-making and minimizing the risk of errors.
- **Cost Reduction:** By promoting resource sharing and optimizing the use of idle machinery, SuppliFlow helps reduce operational costs. The platform's ability to connect companies with surplus capacity to those in need minimizes the need for investments in new machinery, leading to significant cost savings.
- **Enhanced Collaboration:** SuppliFlow's community-driven governance model fosters inclusive, transparent, and democratic decision-making processes. This model leverages collective intelligence, creating a more collaborative and adaptive ecosystem. The decentralized network facilitated by the Beckn Protocol further enhances collaboration by ensuring secure and transparent transactions.
- **Sustainability:** SuppliFlow integrates circular economy principles, promoting the continuous use of resources through sharing. This approach extends the lifecycle of products, reduces waste, and improves resource efficiency. By aligning with sustainable practices, SuppliFlow contributes to environmental stewardship and resilience in supply chain operations.
- **Flexibility and Adaptability:** SuppliFlow's customizable workflows allow users to tailor supply chain processes to their specific requirements, from procurement to delivery. This flexibility enables organizations to adapt to changing market conditions and specific customer needs, enhancing overall supply chain performance.
- **Transparency and Security:** The use of Beckn Protocol ensures that all transactions within the SuppliFlow platform are secure and transparent. The decentralized network

architecture enhances trust among stakeholders and reduces the risk of data breaches and fraud.

By offering these unique advantages, SuppliFlow stands out as a transformative solution in the field of supply chain management, providing organizations with the tools they need to optimize operations, reduce costs, and promote sustainability.

4. Discussion

4.1 Interpretation of results

The findings of this study underscore SuppliFlow's effectiveness in revolutionizing supply chain management through the integration of advanced technologies and circular economy principles. The successful implementation of the SuppliFlow prototype, particularly in the assembly service domain, highlights its potential to optimize supply chain processes, improve visibility, and reduce operational costs.

The literature review and related work provide a comprehensive understanding of the current advancements and challenges in SCM. Recent research has emphasized the integration of digital technologies and circular economy principles as a means to significantly enhance efficiency, transparency, and sustainability. Technologies such as IoT, blockchain, and AI have enabled real-time data sharing, improved transparency, and enhanced decision-making capabilities in supply chains (Bigliardia, et al., 2022), (Zhao, et al., 2023). Digital supply chains, characterized by greater agility, resilience, and efficiency, allow organizations to respond more effectively to dynamic market conditions and customer needs (Farajpour, et al., 2022). Furthermore, the adoption of circular economy principles promotes resource efficiency and sustainability, reducing waste and extending the product lifecycle (Simonetto, et al., 2022), (Montag, 2022). However, challenges such as coordinating with multiple service providers often result in delays, errors, and inefficiencies (Overcoming Fragmentation in Supply Chain Systems: A Comprehensive Guide, 2023), (GEP, 2022). Therefore, there is a pressing need for comprehensive solutions that streamline operations, enhance visibility, and maximize efficiency (Kalaiaresan, et al., 2022), (Alfaro & Chor, 2023). Compared to existing SCM platforms, SuppliFlow offers significant advancements. For a detailed comparison refer to section 2.2.

The successful implementation of the SuppliFlow prototype highlights its potential to revolutionize supply chain processes by enhancing efficiency, optimizing resource utilization, improving user satisfaction and providing accurate real-time tracking. Resource utilization is notably efficient, as order details such as configuration and confirmation are only processed after user approval, ensuring optimal use of resources and minimizing waste. Although external user feedback was not gathered, internal team feedback indicates that the application is user-friendly and provides clear steps, which results in a positive user experience. Real-time tracking is highly reliable, offering accurate status updates of the machine and detailing each step in the assembly process. This feature enhances transparency and allows users to monitor their orders effectively. By optimizing resource utilization and reducing the need for new machinery investments, SuppliFlow significantly lowers operational costs. Its ability to connect companies with surplus capacity to those in need further minimizes costs. SuppliFlow's streamlined workflows and real-time data sharing capabilities contribute to overall efficiency improvements in supply chain operations. The platform's integration with the Beckn Protocol ensures secure and innovative transactions, further enhancing operational efficiency. By following a structured development and testing approach, the SuppliFlow

prototype has demonstrated its capabilities and potential to revolutionize supply chain management, paving the way for future enhancements and broader implementation.

4.2 Implications

The findings of this study have significant implications for both future research and practical applications in the field of SCM.

For future research there is a need to explore the scalability and adaptability of SuppliFlow in different industries and geographical regions. This will help evaluate its effectiveness in diverse supply chain environments and identify areas for improvement. Further studies should also investigate the integration of additional advanced technologies, such as machine learning and predictive analytics, to enhance SuppliFlow's capabilities, particularly in demand forecasting and inventory management.

In terms of practical applications, the successful implementation of SuppliFlow in the assembly service domain indicates its potential for widespread adoption across various industries. Organizations can leverage SuppliFlow to streamline their supply chain processes, reduce operational costs, and promote sustainability. Additionally, policymakers and regulators can use the insights from this study to develop guidelines and standards for the adoption of decentralized networks and circular economy practices in SCM. Such measures will contribute to creating a more sustainable and resilient supply chain ecosystem.

4.3 Limitations

While this study provides valuable insights into the potential of SuppliFlow, several limitations should be acknowledged. Firstly, the study is based on the implementation of a prototype, which may not fully capture the complexities and challenges of real-world supply chain operations. Further testing and validation in diverse environments are needed to confirm the findings. Secondly, the study primarily focuses on the assembly service domain, which may limit the generalizability of the results to other supply chain tasks. Future research should explore the application of SuppliFlow in other areas of the supply chain. Lastly, the study does not include extensive user feedback, which is crucial for understanding the practical challenges and user experience of SuppliFlow. Future studies should incorporate user surveys and interviews to gather comprehensive feedback and improve the platform.

5. Conclusion

In conclusion, the research on SuppliFlow has yielded several key findings that highlight its potential to revolutionize SCM by integrating advanced technologies and circular economy principles. The successful implementation of the SuppliFlow prototype, particularly in the assembly service domain, demonstrates its capability to streamline supply chain processes, enhance visibility, and reduce operational costs. SuppliFlow provides highly customizable workflows that can be tailored to specific requirements from procurement to delivery. This flexibility enhances the adaptability of supply chain processes, allowing organizations to respond more effectively to changing market conditions and customer needs. The integration of the Beckn Protocol facilitates open, peer-to-peer decentralized networks, ensuring secure and innovative transactions within the supply chain. This integration enhances transparency, security, and trust in economic transactions, addressing the need for advanced technological solutions in SCM.

Additionally, SuppliFlow's emphasis on circular economy principles promotes continuous resource usage, extending product lifecycle, reducing waste, and promoting sustainability.

This aligns with the growing trend of incorporating sustainable practices in SCM to achieve environmental stewardship and resource efficiency. SuppliFlow's community-driven governance model fosters inclusive, transparent, and democratic decision-making processes. By leveraging collective intelligence, it creates a more collaborative and adaptive ecosystem, which is essential for modern supply chain operations. Furthermore, SuppliFlow provides real-time updates on order status and simplifies financial management by centralizing all payments. These features enhance transparency, improve monitoring capabilities, and reduce complexities in financial transactions. Overall, the findings from this research underscore the transformative potential of SuppliFlow in advancing supply chain management practices through technological innovation and sustainable principles. The potential impact of the approach includes

- **Industry Adoption:** The successful implementation of SuppliFlow in the assembly service domain demonstrates its potential for widespread adoption across various industries. Organizations can leverage SuppliFlow to streamline their supply chain processes, reduce operational costs, and promote sustainability.
- **Policy and Regulation:** Policymakers and regulators can use the insights from this research to develop guidelines and standards for the adoption of decentralized networks and circular economy practices in SCM. This will help create a more sustainable and resilient supply chain ecosystem.
- **Future Research:** The findings of this research provide a foundation for future studies to explore the scalability and adaptability of SuppliFlow in different industries and geographical regions. Further research can also investigate the integration of additional advanced technologies, such as machine learning and predictive analytics, to enhance SuppliFlow's capabilities.

In conclusion, SuppliFlow represents a significant advancement in supply chain management, offering a comprehensive solution that addresses the inefficiencies of traditional SCM methods. By leveraging advanced technologies and promoting sustainable practices, SuppliFlow has the potential to transform supply chain operations, enhance collaboration, and contribute to a more sustainable and interconnected business landscape.

Acknowledgment

I would like to express my deepest gratitude to Professor Heike Markus for her unwavering support and guidance, which have been instrumental in the development of the SuppliFlow project. Her insights and mentorship have been invaluable. I extend my gratitude to the Institute for Information Systems (iisys) research institute of Hof University for funding the research paper and the conference. My heartfelt thanks to Mrs. Shantall Cisneros Saldana for her significant contributions and innovative ideas, and to Ms. Rasika Danawade for her excellent software implementation of the front-end and creative input. Special thanks to the developers from FIDE Company for their invaluable assistance with the Beckn Protocol. I am also grateful to all team members and collaborators for their support.

References

- Alfaro, L., & Chor, D. (2023). *Global Supply Chains: The looming "Great Reallocation"*. Harvard Business School.
- Beckn For <Developers/>. (2021, September). Retrieved May 25, 2024, from <https://developers.becknprotocol.io/docs/introduction/introduction/>

- Beckn Protocol. (2023). Retrieved from <https://becknprotocol.io/enabling-trusted-commerce-using-beckn-protocol-and-blockchain/>
- Bigliardia, B., Filippelli, S., Petroni, A., & Tagliente, L. (2022). The digitalization of supply chain: a review. *ScienceDirect*.
- Descartes. (2024). Retrieved from <https://www.descartes.com/home>
- Ethirajan, M., & Kandasamy, J. (2019). An Analysis on Sustainable Supply Chain for Circular Economy. *16th Global Conference on Sustainable Manufacturing*.
- Evolving Supply Chain Management with Data. (2023). Retrieved May 22, 2024, from <https://www.snowflake.com/guides/evolving-supply-chain-management-data/>
- Farajpour, F., Hassanzadeh, A., Elahi, S., & Ghazanfari, M. (2022). Digital supply chain blueprint via a systematic literature review. *Technological Forecasting and Social Change*.
- Golicic, S., & Davis, D. (2012). Implementing mixed methods research in supply chain management. *International Journal of Physical Distribution & Logistics Management*.
- Grant, D., Shaw, S., Sweeney, E., Bahr, W., Chaisurayakarn, S., & Evangelista, P. (2023). Using mixed methods in logistics and supply chain management research: current state and future directions. *The International Journal of Logistics Management*.
- Gyllenskepp, M., & Martin, T. (n.d.). *Resilient Supply Chains Through Modularity*. Retrieved May 20, 2024, from <https://www.modularmanagement.com/blog/how-does-modularity-supports-resilient-supply-chains>
- He, Q., Yan, J., Yang, Y., Kowalczyk, R., & Jin, H. (2013). A Decentralized Service Discovery Approach on Peer-to-Peer Networks. *IEEE Transactions on Services Computing*.
- Hu, Q., Du, J., Li, R., & Leng, B. (2018). Study on the Model of Financial Centralized Management in the Large-scale Construction Enterprises. *IOP Conference Series: Materials Science and Engineering*.
- Infor. (2024). Retrieved from <https://www.infor.com/de-de/industries/industrial-manufacturing>
- Intelligent Agent-Based Supply Chain Management Using Service-Oriented Architecture. (2023). In R. Rajnala, P. Singh Nain, & A. Kumar, *Contemporary Studies of Risks in Emerging Technology, Part A*. Emerald Publishing Limited.
- Ivanov, D., Dolgui, A., & Sokolov, B. (2022). Cloud supply chain: Integrating Industry 4.0 and digital platforms in the "Supply Chain-as-a-Service". *Transportation Research Part E: Logistics and Transportation Review*.
- Kalaiarasan, R., Olhager, J., Agarwal, T., & Wiktorsson, M. (2022). The ABCDE of supply chain visibility: A systematic literature review and framework. *International Journal of Production Economics*.
- Liu, X., Zhang, Z., Lu, T., & Fan, W. (2007). Optimizing Supply Chains through Service-Oriented. *Research and Practical Issues of Enterprise Information Systems II*. Springer.

- MacArthur Foundation, E. (2023). *Designing supply chains for the circular economy*. Retrieved from Ellen MacArthur Foundation: <https://www.ellenmacarthurfoundation.org/circular-supply-chains>
- Montag, L. (2022). Circular Economy and Supply Chains: Definitions, Conceptualizations, and Research Agenda of the Circular Supply Chain Framework. *SpringerLink*.
- Oracle. (2024). Retrieved from <https://www.oracle.com/scm/>
- Overcoming Fragmentation in Supply Chain Systems: A Comprehensive Guide*. (2023, November 28). Retrieved May 20, 2024, from Cargologik: <https://www.cargologik.com/blog-post/overcoming-fragmentation-in-supply-chain-systems-a-comprehensive-guide>
- Predictive Analytics Today*. (2023). Retrieved from <https://www.predictiveanalyticstoday.com/top-supply-chain-management-software/>
- Redwood. (2023). Retrieved from <https://www.redwoodlogistics.com/insights/how-ibm-watson-can-support-your-supply-chain>
- Russo, I., Confente, I., & Pellathy, D. (2020). Supply chain management for circular economy: conceptual framework and research agenda. *The International Journal of Logistics Management*.
- SAP SCM. (2024). Retrieved from <https://www.sap.com/products/scm.html>
- Shopify. (2023, July 4). Retrieved May 22, 2024, from <https://www.shopify.com/blog/supply-chain-management-software>
- Simonetto, M., Sgarbossa, F., Battini, D., & Govindan, K. (2022). Closed loop supply chains 4.0: From risks to benefits through advanced technologies. A literature review and research agenda. *Elsevier*.
- Suleiman, Z., Shaikholla, S., Dikhanbayeva, D., Shehab, E., & Turkyilmaz, A. (2022). Industry 4.0: Clustering of concepts and characteristics. *Cogent Engineering*.
- Supply Chain Management How To Overcome Challenges*. (2022, October 18). Retrieved May 22, 2024, from <https://www.gep.com/blog/technology/supply-chain-management-how-to-overcome-challenges>
- SupplyChain Digital*. (2020). Retrieved from <https://supplychaindigital.com/technology/ibm-watson-how-ai-transforming-supply-chain>
- Tripathi, R. (2023, November 2023). *SupplyChainBrain*. Retrieved May 21, 2024, from <https://www.supplychainbrain.com/articles/38553-enhancing-supply-chain-resilience-a-modular-approach>
- Wilts, H. (2017). Key Challenges for Transformations Towards a Circular Economy – The Status Quo in Germany. *International Journal of Waste Resources*.
- Zhao, N., Hong, J., & Lau, K. (2023). Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model. *International Journal of Production Economics*.