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JOINØLOG

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Proceedings of the 1st Jordanian Conference Logistics in the Mashreq Region

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Foreword

The 1st Jordanian Conference on Logistics in the Mashreq Region was organized within the framework of the research project "JOINOLOG", funded by the German Ministry of Education and Science. The JOINOLOG network, which was built within the project, aims to breed collaboration and innovation in Jordan's logistical landscape. Theory of academia and practice of logistics businesses are continuously combined to further knowledge and capabilities of the sector.

This comprehensive approach to improve research conditions in logistics has been researched and implemented by a Jordanian and German team, in the publicly funded JOINOLOG project. As this project comes to an end, its results and further developments are handed over to German-Jordanian University (GJU). The project's conclusion and introduction to an audience of peers was the 1st Jordanian Conference on Logistics in the Mashreq Region, (JCLM1) conducted on November 14th and 15th, 2023. These are the proceedings of this final event.

The event combined scientific paper presentations, peer reviewed by an esteemed scientific committee, with spotlights from the logistics industry. The presentation of the JOINOLOG project and its transfer to GJU provided a fitting occasion for a scientific conference. An international audience and pool of presenters were to conduct the event at the Landmark Conference Hotel in Amman. Due to external factors, the event had to be moved to an online format, ensuring participation of speakers from Ghana, Belgium, UK, Croatia, Austria, Germany and - naturally - Jordan. The project team led through the two days, moderating and discussing the diverse contributions with an audience of peers, mainly consisting of academic and practical actors of the region's Supply Chain Management community.

These proceedings consolidate the shared efforts of all participants and speakers in JCLM1. The publication of these findings by a variety of researchers in SCM and related fields proves impressively the potential of the JOINOLOG network. The project team thanks all contributors, in particular the scientific committee of the conference and the project advisory board of JOINOLOG. The collection of these scientific results aims to promote logistical sciences and its transfer into application, which is reflected by their multidimensional presentation in this document. Future JOINOLOG events will build upon this base and grow the current network into an innovation center, establishing Jordan as the region's logistical heart, in theory and practice.

Empirical Research on Supply Chain Coordination and Cooperation Mechanisms in Jordan's Olive Oil Industry: *Insights from Small-Scale Farmers*

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ABSTRACT

The main objective of this research paper is to investigate and examine the coordination and cooperation within Jordan's olive oil sector, with a particular emphasis on gaining valuable insights from small-scale farmers. The olive oil industry in Jordan encounters substantial challenges attributed to a lack of coordination and cooperation among stake-holders, as a significant issue in Jordan's olive oil industry, which adversely affects small-scale farmers and the overall value chain. The study focuses specifically on exploring the potential of Contract Farming and Farmer Cooperatives as viable solutions for enhancing coordination and cooperation throughout the value chain. Furthermore, the research aims to analyze the potential for integration and vertical coordination in the industry, while also examining the pivotal role played by intermediaries, food processors, and retailers in the distribution channel of the olive oil industry. To achieve these objectives, a comprehensive mixed- methods approach will be employed, combining surveys and interviews with small- scale farmers, agribusiness firms, and other relevant stakeholders. The research seeks to comprehend the current situation faced by small-scale farmers in the olive oil industry, delving into their concerns, drivers, and motivations regarding Contract Farming and Farmer Cooperatives as potential solutions. Additionally, the study will investigate distribution channels and the transaction cost atributes associated with uncertainty as a crucial determinant of the industry's governance structure. By adopting this meticulous approach, the research endeavors to provide valuable insights into the opportunities and strategies for enhancing the overall functioning of Jordan's olive oil sector by exploring the potential for Supply Chain Coordination Tactics into improving the performance, quality, and coordination of Jordan's olive oil industry.

Key words: Supply chain coordination, Jordan's olive oil industry, Contract Farming, Vertical coordination and integration, Small-scale farmers

1. INTRODUCTION

Research approaches in agribusiness systems have shifted from individual market perspectives to chain, network, and systems perspectives, recognizing the importance of institutions (Malak-Rawlikowska, 2018; Mugwagwa et al., 2020; Pazaj and Kapaj, 2023). The olive oil industry has transitioned from individual markets to coordinated supply chains, emphasizing competition between supply chains rather than individual firms (Van der Meer, 2006; Pazaj and Kapaj, 2023).

Effective coordination and cooperation among stakeholders within the agri-food value chain are essential for smooth operations, productivity enhancement, and economic returns (ILO, 2014). Inadequate coordination and cooperation can have negative consequences for all participants in the value chain (Halalsheh et al., 2021). In Jordan, the olive industry has experienced significant growth, with olive trees covering 77% of the tree-planted area and accounting for 24% of the total cultivated area (Mercy Corps, 2017; Ayoub, 2017). Jordan is the eighth-largest exporter of olive oil globally and the second-largest exporter of fresh olives, with the northern region being the primary area for olive cultivation (Mercy Corps, 2017; Ayoub, 2017).

Smallholder farmers, who constitute a substantial segment of Jordan's agricultural workforce, face challenges in accessing export markets due to heightened consumer demands for high-quality products and stringent food safety regulations (Mercy Corps, 2017; Ayoub, 2017). They also encounter obstacles such as poor infrastructure, limited market information, and deficiencies in technical and marketing systems, advisory services, inputs, and post-harvest facilities (Al-Shdiefat, 2006; El Hanandeh Gharaibeh, 2016; Mercy Corps, 2017).

Contract farming is viewed as a solution to address the constraints faced by small- scale farmers, including limited credit, information, market risks, and weak market linkages (Mwambi et al., 2014). Coordination and cooperation deficiencies in Jordan's olive oil industry present significant challenges throughout the value chain (ILO, 2014; Halalsheh et al., 2021). Proposed remedies involve establishing coordination mechanisms involving stakeholders and strengthening partnerships between farmers, the private sector, and government institutions (ILO, 2014; Halalsheh et al., 2021).

The primary goal of this research paper is to comprehensively investigate the potential of Contract Farming and Farmer Cooperatives as effective mechanisms for enhancing coordination and cooperation within the value chain, with a specific focus on the olive oil sector in Jordan. This study adopts a rigorous empirical research approach, incorporating surveys and interviews to delve into the intricate dynamics of supply chain coordination within the context of agribusiness, thereby contributing valuable insights into strategies for enhancing the performance, quality and overall coordination of Jordan's olive oil industry.

The paper is organized as follows: In Chapter 2, we provide an overview of supply chain coordination, emphasizing its significance in the context of agribusiness. Chapter 3 delves into the theoretical background of Contract Farming, Vertical Coordination, and Farmer Cooperatives. In Chapter 4, we explore the dynamics of Contract Farming, including various models, participation factors, drivers, and transaction costs within agri-food chains. Chapter 5 examines the agricultural landscape of the olive oil industry for small-scale farmers in Jordan. Chapter 6 focuses on our data collection, methodology, and analysis. In Chapter 7, we present our recommendations, discussing the potential of Farmer Cooperatives and Contract Farming as a viable solution in the context of Jordan. Finally, in Chapter 8, we draw our conclusions based on the findings and insights gathered throughout the paper.

In line with the structure outlined above, this research paper endeavors to shed light on the potential of Contract Farming and Farmer Cooperatives in improving supply chain coordination, thereby facilitating the growth and development of Jordan's olive oil sector. By adopting a meticulous approach and rigorous empirical methods, this study aims to make a valuable contribution to the field of agribusiness and supply chain management.

2. SUPPLY CHAIN COORDINATION IN AGRIBUSINESS

In the realm of supply chain management, a supply chain is characterized as an intricate network of firms and entities that transform raw materials and components into end products, subsequently delivering them to consumers (Zhang, 2015). Various terms, such as cooperation, integration, and collaboration, are employed to address the management of interdependencies among activities. These terms are integral components of the concept of supply chain coordination (Handayati et al., 2015).

In a broader economic context, coordination and coordinated decision-making entail the alignment of separate entities to enhance overall performance. Historically, economic theory distinguished between firms, their hierarchies, and price mechanisms as modes of coordination (Handayati et al., 2015). When autonomous companies collaborate, it is termed combination or integration. Within supply chain management (SCM), the terms cooperation, coordination, and collaboration are often used interchangeably, leading to potential confusion (Moharana et al., 2010).

Cooperation is defined as the act of working together for a shared purpose, signifying a goal-oriented interaction with others. Some interpretations suggest a minimal level of interaction, while others underscore alignment toward shared objectives (Moharana et al., 2010 ; Mwambi et al., 2014). Coordination, on the other hand, refers to a more direct, active cooperation. It is defined as "the act of making arrangements for a purpose," the "harmony of various elements," "harmonious adjustment or interaction," and making separate things working together (Handayati, et al., 2015). Compared to cooperation, coordination involves an interactive, joint decision-making process where independent entities more directly influence each other's decisions (Moharana et al., 2010).

Collaboration is often more comprehensive than coordination, encompassing all coordination characteristics (Mwambi et al., 2014). Nonetheless, coordination maintains its significance by aiming for global optimization within a defined supply chain network. Collaboration denotes working together with a specific purpose, involving mutual interaction leading to joint decisions and activities, signifying a higher level of joint implementation (Moharana et al., 2010). Optimizing supply chain profitability necessitates close coordination at all stages (Chopra & Meindl, 2016). Empirical evidence underscores the importance of coordination, as it is recognized as a key factor in the success of manufacturing companies. A fully coordinated supply chain aligns all decisions with global system objectives (Moharana et al., 2010; Chopra & Meindl, 2016).

In the pursuit of enhancing the holistic performance of an agricultural supply chain, it is imperative that any entity within the supply chain possesses the capability to harmonize its individual actions (Zhang, 2015). The transformation of agribusiness systems toward high-value supply chains is crucial in developing countries (Schipmann & Qaim, 2011). Supermarkets are increasingly shifting from spot-market transactions to contractual agreements with farmers, facilitated by specialized intermediaries (Neven et al., 2009; Rao and Qaim, 2011). Challenges in small-holder farmers' participation in export markets stem from increased consumer demand for high-quality products, driven by supermarkets in developed countries and stricter food safety regulations (Mwambi et al., 2014).

Promoting smallholders' access to global export markets is essential for increasing their incomes and reducing poverty, particularly in developing countries heavily reliant on agriculture (Mwambi et al., 2014). However, smallholders face various challenges in producing and supplying high-quality products, including financial constraints, inadequate infrastructure, limited access to market information and technical advisory services, and difficulties in accessing post-harvest facilities (Mwambi et al., 2014).

Efforts have been made to improve smallholders' access to markets through globalization and Internet technologies. However, globalization tends to favor large- scale farmers seen as more reliable business partners with lower transaction costs (World Bank, 2008; Mwambi et al., 2014). Contract farming has emerged as a revolutionary approach to improving agricultural productivity in both developing and developed countries (Abbasi et al., 2021). It enables farmers to shift from subsistence to commercial production of higher-value crops, integrating them into the broader economy and increasing their income (Minot & Ronchi, 2014).

Contract farming, a transformative approach (Abbasi et al., 2021), has gained traction in Latin America, Asia, and Africa, particularly for export-oriented products (Ncube, 2020). Private firms‘ involvement has reduced government intervention in agricultural marketing (Minot & Ronchi, 2014). However, concerns about small-scale farmers‘ exclusion and rural income inequality persist due to power imbalances and information asymmetry, resulting in unfavourable contract terms, quality standards manipulation, and contract disputes (Minot & Ronchi, 2014).

3. THEORETICAL BACKGROUND OF CONTRACT FARMING, VERTICAL COORDINATION AND FARMER COOPERATIVES

3.1. Contract Farming

Contract farming has gained recognition as an effective approach, leading to recommendations from various stakeholders, including NGOs, policymakers, donors, and researchers, for governments, especially in developing countries, to promote and facilitate its implementation to enhance agricultural productivity (Mwambi et al., 2014). The objective of contract farming is to improve farmers' access to resources and support their integration into lucrative markets (Da Silva Rankin, 2013). Ton et al. (2017) highlight the role of contract farming in overcoming market constraints and promoting collaboration among various stakeholders for the benefit of small-scale farmers.

Arumugam et al. (2010) define contract farming as an agreement between a farmer and a firm, either oral or written, where the farmer produces an agricultural product and the firm commits to purchasing it under specific conditions. Contract farming establishes a commercial relationship between a firm and a group of farmers, with the firm pre-purchasing farm products in exchange for various services and benefits. It addresses the challenges faced by small farmers in accessing profitable markets and helps connect them to output markets while providing inputs, credit, and agricultural extension services. These services can be delivered by private firms or through multi- actor partnerships involving companies, governments, and NGOs (Mwambi et al., 2014).

Contract farming serves as a form of vertical integration in agricultural commodity chains, giving firms greater control over the production process, including quantity, quality, characteristics, and timing of goods (Prowse, 2012; Ton et al., 2017). It falls on a spectrum between fully vertically-integrated investments, where a firm controls every stage of the value chain, and spot markets (Ton et al., 2017). Contract farming provides a middle ground, allowing firms to exert some control over production and product without directly engaging in production activities (Prowse, 2012). See Figure 1 for visualization.

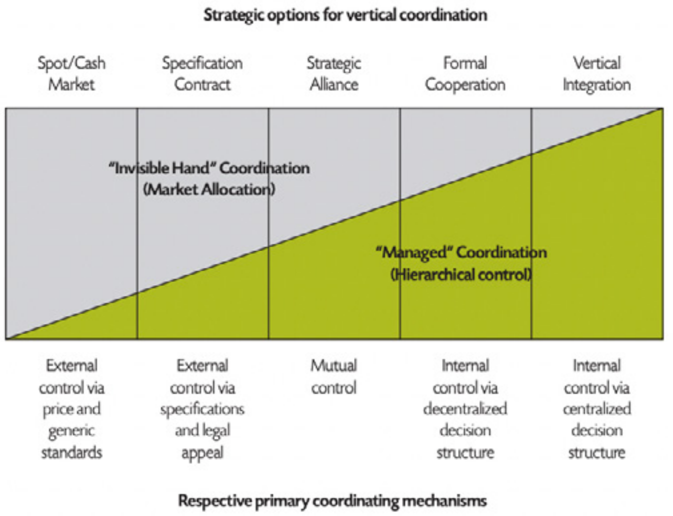

Figure 1: *Source: Prowse (2012), based on Peterson and Wysocki (1997)*

3.2. Contract Farming Mechanism

According to Barrett et al. (2012), the development of contract farming can be conceptualized as a game with the agribusiness firm as the first mover. The process involves several stages. Firstly, the firm strategically chooses a suitable location for sourcing agricultural commodities based on factors such as agroecological conditions, infrastructure availabilIty, and regional political stability. Secondly, the firm identifies and selects farmers to enter into contracts with, considering factors such as farm performance, farm size, and proximity to essential infrastructure like roads and irrigation. In the third stage, farmers have the choice to accept or reject the contract offered to them. If they reject the contract, both the firm and the farmers revert to engaging in spot market transactions. However, if farmers accept the contract, the fourth stage involves the firm and the farmers deciding whether to honor the terms of the contractual agreement by complying with its provisions (Barrett et al., 2012).

3.3. Integration And Vertical Coordination

The terms vertical coordination, vertical integration, and contract production are often used interchangeably (Rehber, 2000). Vertical coordination, as a broad term, encompasses all means of harmonizing vertically interdependent production and marketing activities, spanning from spot markets through various types of contracts to complete integration (Rehber, 2000). Subsistence farming involved families carrying out various tasks such as seed collection, crop cultivation, animal rearing, and self-consumption of the produce, with some reserved for future use. However, the shift towards market-oriented agriculture has led to a gradual disintegration of these functions (Bijman, 2013).

Integration refers to the consolidation of different parts into a unified entity (Rehber, 2000). There are three main types of integration. Vertical integration occurs when a firm combines activities that are different from its current operations but are related to them in the marketing and production sequence. For instance, a meat packer may engage in backward integration by operating livestock buying points and forward integration by running a meat wholesaling firm (Rehber, 2000).

Horizontal integration, on the other hand, involves a firm gaining control over other firms that perform similar activities at the same level of production and marketing. It is common for firms to expand both vertically and horizontally. Circular integration refers to the combination of vertical and horizontal operations, as seen in the case of local dairy cooperatives brought under a regional union (Rehber, 2000).

When assessing vertical coordination in an industry, one effective approach is to examine the extent of decision transfer and firm asset ownership. Ownership integration or merger occurs when a single firm controls all the decisions and assets, while vertical integration specifically refers to the technological consolidation of production and marketing stages under a single management (Minot Ronchi, 2014).

In contrast, quasi integration occurs when each firm retains its separate identity but delegates certain production and/or marketing decisions to another firm. This is sometimes referred to as vertical restrictions, wherein non-integrated firms establish long-term, binding contracts specifying price and other terms (Rehber, 2000). See Figure 2 for visualization.

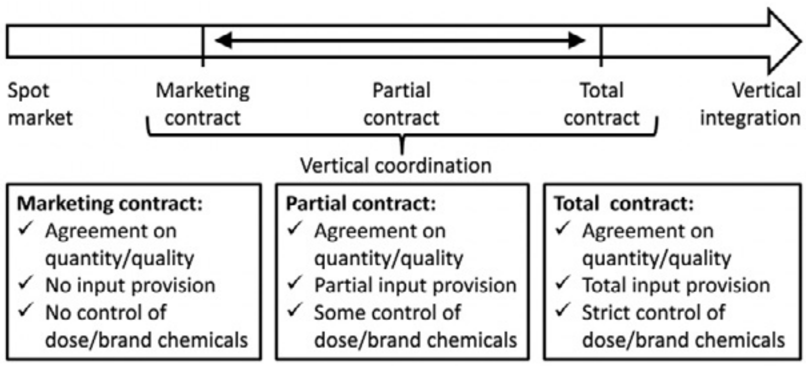

Figure 2: *Three types of contract farming along the vertical coordination continuum Source: Baa et al. (2019)*

3.4. Integration And Vertical Coordination

The term ‚vertical integration‘ is most appropriately reserved for scenarios of ownership integration where a single management effectively controls two or more stages in the production and marketing process. It is important to note that ‚vertical integration‘ also pertains to a technological rather than an institutional development. In other words, Vertical integration refers to a form of coordination where individual farms or businesses lose their independent identity and become part of a larger company-owned farm (Rehber, 2000).

In this arrangement, the parent company assumes ownership or leasing of the land, buildings, and equipment, and employs its own staff. A firm can be considered vertically integrated when it incorporates two production processes, where:

- Either the entire output of the first process serves as an input for the second process.

- Or the entire input for the second process is derived from the output of the first process.

This is sometimes referred to as full integration (Rehber, 2000).

A comprehensive way to assess vertical coordination within a specific industry involves examining the extent of the transfer of decision-making authority and ownership of firm assets. When all the decisions and assets of the firms come under the control of a single entity, this is referred to as ownership integration or merger (Rehber, 2000).

3.5. Farmer Cooperatives

Farmers' cooperatives play a significant role in vertical coordination within the agricultural industry (Mwambi et al., 2014) . These cooperatives are organizations owned and controlled by agricultural producers, operating for the mutual benefit of their members. By organizing under a cooperative structure, farmers can gain better control over their own destiny and enjoy benefits such as improved market access, higher net returns, and increased bargaining power against anti-competitive market forces (Rehber, 2000).

However, it is important to note that even within cooperatives, challenges and disputes can arise, particularly when alternative marketing opportunities exist. To address such issues, establishing contractual relationships with member farmers is advisable. Additionally, farmers can form bargaining cooperatives to strengthen their position during negotiations and determine the terms of contractual agreements (Mwambi et al., 2014). Managing supply and addressing non-member free riders are among the key challenges faced by these organizations. Despite the challenges, farmers' cooperatives have served as a balancing power and have contributed to enhancing competition in various agricultural commodity markets (Rehber, 2000).

3.6. Coordination Without Any Contract (Market Coordination):

Market coordination refers to the prevalence of spot market or open market transactions, which still dominate the global marketing system (Rehber, 2000). In this system, there is no formal contract between the firm and the farmer for buying or selling . Farmers have the freedom to choose their suppliers and sell their products to the highest bidder. However, this type of vertical relationship comes with uncertainties in both purchasing supplies and selling produce. The main drawback is the lack of certainty (Rehber, 2000).

Based on Rehber, (2000), in a competitive open market system, price signals dictate the market mechanism, with price information gradually reaching the processor from final supply points, farmers, and input suppliers. This traditional market organization relies on certain conditions, such as:

- Production being located near consumption points

- Control over short-term price variations through government or producer organizations

- Tolerance for imprecise grading by purchasers

- Effective agricultural extension and advisory services

Government price and income support programs have limited the presence of contract farming in grain, oilseeds, and cotton production. However, contracts for specific quantities, prices, times, and locations, such as forward and futures contracts, are considered part of market coordination (Rehber, 2000).

4. CONTRACT FARMING DYNAMICS: MODELS, PARTICIPATION, DRIVERS AND TRANSACTION COSTS IN AGRI-FOOD CHAINS

4.1. Contract Farming Arrangement Models/Schemes

Contract farming encompasses various models that differ in terms of the type of contractor, product type, vertical coordination intensity, and the involvement of key stakeholders (Eaton and Shepherd, 2001).

- The centralized model, which is a classic contract farming model, the centralized model involves a centralized processor and/or buyer procuring from a large number of small-scale farmers. The cooperation is vertically well integrated and most of the time several services such as pre-financing of inputs, extension, and transport are provided Processors typically favour larger farmers due to processing economies of scale (Mwambi et al., 2014).

- The nucleus estate model, which is a variation of the centralized model where the contractor not only sources from independent farmers but also has its own production facilities, such as an estate plantation. This model is commonly used for perennial crops and may involve varying levels of vertical coordination (Bijman, 2008).

- In the multipartite model, a joint venture between a statutory body and a private company can contract with farmers (Bijman, 2008). The multipartite model involves collaboration with other institutions or NGOs and is useful for establishing new ventures. Informal arrangements lack written contracts and vary from oral agreements to repeated marketing transactions (Mwambi et al., 2014). The level of vertical coordination in these models depends on the joint venture‘s control over transactions with farmers and may be influenced by political interests (Bijman, 2008).

- The informal model, involves individual entrepreneurs or small companies informally contracting with farmers on a seasonal basis, particularly for crops like fresh fruits and vegetables. Processing requirements for these crops are minimal, often limited to sorting, grading, and packaging. The success of the informal model relies on the availability of supporting services, typically provided by government agencies. Government extension services play a crucial role in supporting small traders who lack their own extension staff (Bijman, 2008).

• The intermediary model, This approach involves three key parties: a processor or major trader, a collector or middleman, and multiple farmers. It combines elements of the centralized and informal models and is common in Southeast Asia. However, it presents challenges in terms of vertical coordination and providing incentives due to the lack of a direct link between the contractor and farmers. Intermediaries oversee various aspects on behalf of the final buyer, including input supply, extension services, farmer payments, and product transportation (Bijman, 2008). The Avocado Growers Association of Kenya (AGAK) serves as an intermediary between farmer groups and contractors in the avocado marketing model in Murang'a (Mwambi et al., 2014).

These different contract farming models offer diverse approaches to vertical coordination, depending on the nature of the agricultural product, the involvement of stakeholders, and the level of formality in the contractual relationships.

4.2. Participation Of Smallholders In Contract Farming

Smallholders' participation in contract farming is affected by socio-economic and institutional factors. Limited access to productive resources like water and land, as well as a lack of access to production technologies, credit, extension services, and information on risks, discourages their involvement in contract farming (Mwambi et al., 2014).

However, depending on the contract nature, CF can improve smallholder welfare through several pathways (Mwambi et al., 2014).

• Firstly, contracts that provide interlinked services like training, credit, technical advice and market information aim to alleviate productivity constraints and increase marketed surplus.

• Secondly, CF serves as an institutional solution to market failures in credit, insurance, and information systems as well as it acts as a strategy for smallholder participation in restructured markets and value chains, leading to increased and stabilized incomes (Bellemare, 2012).

• Thirdly, contracts that determine output prices and terms in advance reduce price risks and provide incentive mechanisms for efficient resource allocation.

The efficacy of a contract scheme depends on the interaction between farmers, buyers, and other stakeholders involved. Poor coordination, unfavorable terms, and market-driven pricing have led to unsuccessful CF cases, including adverse selection, moral hazards, and contract violations (Arumugam et al., 2010; Ton et al., 2017). Effective management of CF can develop markets and transfer technical skills for the benefit of both contractors and farmers.(Mwambi et al., 2014). For instance, prior to the implementation of vertical integration, large dairy farms in Slovakia possessed cooling tanks and dairy specialists, while small Polish dairy farms did not have these resources (Dries et al., 2009).

4.3. A Typology Of Contracts

The level of control over the production process varies, without actual farm ownership or operation by the firm. Risk allocation depends on contract specifications, with farmers bearing most production risks and firms assuming processing and marketing risks. The choice of contract type depends on transaction costs, market uncertainty, asset specificity, transaction frequency, and monitoring costs (Bijman, 2008).

Mighell and Jones (1963) proposed three main types of agricultural contracts: market- specification contracts, production-management contracts, and resource-providing contracts. These types differ in objectives, transfer of decision-making authority, and risk allocation between farmers and contractors (Bijman, 2008).

• Market-specification Contracts: Specifies the quality, price, and timing of the product but does not provide inputs to farmers. Farmers are responsible for making production decisions and bearing most of the associated risks" (Bijman, 2008).This contract is a type of pre-harvest agreement, facilitate the exchange of market data and are commonly used in casual or unofficial contract farming models. In these contracts, farmers retain decision rights over their farming activities and assume the majority of the production risks" (Bijman, 2008; Ncube, 2020).

• Production-management Contracts: This type of contract involves higher buyer involvement and control over the production and harvest process. The buyer provides technical guidelines and instructions to the farmers. Clear and detailed con- tracts with enforcement mechanisms are necessary for maximizing the benefits of this arrangement. The farmer delegates decision- making authority over cultivation and harvesting practices to the contractor, who assumes most of the market risks (Bijman, 2008; Ncube, 2020).

• Resource-providing Agreements: These contracts involve the buyer providing inputs and extension services to farmers, which are considered in- kind credit and reimbursed upon product delivery. The contract specifies decision-making power and risk allocation. This type of contract reduces coordination risks for farmers by providing inputs, credit, and extension services. The buyer benefits from lower prices and reliable supplies. Resource-providing agreements are used in informal and centralized contract farming models. These contracts can involve production management or focus on providing inputs and an output market, leaving production decisions and risk with the farmer (Bijman, 2008; Ncube, 2020).

The selection of contract types depends on commodity, agent characteristics, and market conditions. Farmers choose contracts based on their risk attitude and market failures they encounter (Mwambi et al., 2014). Contracts reduce marketing risks and integrate small and low-income farmers into the market economy. However, concerns about market segmentation and exclusion exist. Despite this, contract farming offers benefits like reduced marketing risk, income stability, improved decision-making, and increased effectiveness for farmers, especially in thin markets where contracts ensure demand (Bijman, 2008; Mwambi et al., 2014).

4.4. Contract Farming Drivers

Based on the literature, there are various drivers that have led to a renewed interest in contract farming (CF), and these drivers encompass both economic and political factors. The state of the current world food system, characterized by contrasting trends of globalization and localism, has played a significant role in shaping these drivers (Ncube, 2020).

Several drivers have been identified for promoting commercialization in agriculture as shown below, these drivers highlight the need for SSFs to transition from subsistence-oriented farming practices to more commercialized and market-oriented approaches (Ncube, 2020) :

- Population Growth
- New technology
- Market Access
- Food staples intensification
- Asset accumulation

4.5. Transaction Costs Related To Uncertainty In Contract Farming

Transaction costs in modern agrifood chains are greatly influenced by uncertainty, which is considered a key factor in determining governance structures (Abebe et al. 2013). Uncertainty increases the likelihood of opportunistic behavior in transactions , leading to higher transaction costs (Mugwagwa et al., 2020). Two forms of uncertainty are commonly discussed: Environmental uncertainty and Behavioral uncertainty.

Environmental uncertainty arises from factors beyond control, such as weather conditions, pests, and market fluctuations. Agricultural transactions involve high environmental uncertainty due to the inherent biological nature of production, making it challenging to accurately predict the volume and quality of output (Mugwagwa et al., 2020). Additionally, perishability, seasonality, and evolving consumer preferences further contribute to uncertainty in agricultural transactions. Compliance with changing food safety and quality standards also adds coordination costs as failures in meeting these standards can have severe consequences for the agribusiness firm (Abebe et al. 2013).

Behavioral uncertainty arises from the potential for opportunistic behavior by contracting parties. This is particularly relevant in modern agrifood chains, where specific attributes and production practices of agricultural products are highly valued (Bijman et al. 2011). Difficulty in measuring and ensuring product performance creates transaction costs related to searching, screening, selection, and monitoring (Abebe et al. 2013). Sellers may have an informational advantage and could engage in quality cheating, posing challenges in maintaining trust and reducing transaction costs (Mugwagwa et al., 2020).

4.6. Summary Of Relevant Studies On Contract Farming, Vertical Integration, And Supply Chain Coordination

The below Table 1 summarizes the most relevant studies that investigated Contract Farming, Vertical Integration, and Supply Chain Coordination in Agricultural context with the key findings, methodologies employed, models utilized, and potential avenues for future research in the context of Jordan's Olive Oil industry.

Table 1. *Summary of Contract Farming, Vertical Integration, and Supply Chain Coordination in Agricultural Literature Review*

Author	Core Findings	Model	Methodology	Future Research Implications in Jordan	Country
Pazaj & Kapaj (2023)	CF can help to improve the efficiency and profitability of the olive oil industry	Value chain analysis/ Transaction cost economics	Case study	Opportunity to enhance competitiveness in Jordan's olive oil industry include improving production, distribution, marketing, and branding. Lessons can be learned from the Albanian case, especially in reducing transaction costs and improving efficiency.	Albania
Abbasi et al. (2021)	CF in enhancing agricultural productivity specifically focusing on key productivity indicators such as yield, input use, and profitability.	Vertical coordination/ Principal-agent theory	Empirical analysis	Identifying factors for contract design considerations in contract farming for smallscale farmers in Jordan	Pakistan
Ncube (2020)	CF's impact on agricultural production varies positive or negative based on contract design and implementation context.	Transaction cost economics/ Principal-agent theory	Review of literature	Addressing challenges such as information asymmetry, power imbalances, and market vulnerability, and proposing strategies for overcoming them with a comprehensive understanding of contract farming's potential benefits and pitfalls.	Sub-Saharan Africa
Baa et al. (2019)	Inclusive contract farming can help small-scale farmers in the Vietnamese rice sector to improve their productivity and income	Vertical-Horizontal Coordination / Transaction cost economic	Empirical analysis	Evaluates contract farming models' benefits and challenges in terms of inclusiveness and benefit distribution, providing insights for designing cooperative and fair arrangements for smallscale farmers in Jordan's olive oil Industry.	Vietnam

Author	Core Findings	Model	Methodology	Future Research Implications in Jordan	Country
Mwambi et al. (2016)	Contract farming and farmer cooperatives can improve the income of small-scale avocado farmers.	Impact evaluation	Case Study	Assesses income changes among olive oil farmers in contract farming, identifying factors like market access, inputs, and technology that enhance income. Provides insights into income benefits of contract farming.	Kenya
Rouse (2012)	CF enhances farm production and improves farm households' welfare by reducing transaction costs of small- scale fruit and vegetable farmers.	Transaction cost economics/ Principal-agent theory	Randomized control trial	Contract farming improves welfare of smallscale olive oil farmers in Jordan through market access, inputs, technology, and technical assistance.	Thailand
Bellemare (2012)	Contract farming's welfare impacts for small-scale farmers depend on contract design and implementation context.	Transaction cost economics/ Principal- agent theory	Quantitative study	CF improves efficiency, profitability, and welfare for small-scale olive oil farmers in Jordan through reduced transaction costs, improved access to inputs and markets, and guaranteed prices.	Madagascar
Dries et al. (2009)	Vertical coordination can lead to more equitable distribution of rents by reducing transaction costs and improving bargaining power of farmers in dairy clusters.	Vertical coordination/ Principal-agent theory	Empirical analysis	Vertical coordination enhances Jordan's olive oil industry by reducing transaction costs, empowering farmers, and promoting equitable rent distribution. This results in increased production, higher incomes, and improved welfare for small-scale olive oil farmers.	Central and Eastern Europe
Dries et al. (2009) Rehber (2000)	Vertical coordination can help to improve the efficiency of the olive oil industry.	Transaction cost economics/ Principal-agent theory	Case study/ Survey	Impact of Vertical coordination, integration and examining the transaction costs in various aspects of Jordan's olive oil sector (production, processing, marketing).	Turkey

5. AGRICULTURAL LANDSCAPE OF OLIVE OIL INDUSTRY FOR SMALL-SCALE FARMERS IN JORDAN

5.1. Jordan Olive Oil Market Weaknesses

This section provides an overview of the key characteristics a identified in the olive oil market structures in Jordan, based on research findings and reports:

• Lack of Coordination between Growers and Oil Mills: The absence of effective coordination between olive growers and olive oil processors results in issues related to oil quality, storage, and the absence of a commercial structure (Al Hiar, 2019). Additionally, poor quality and diminished bargaining power translate into lower than expected prices for fresh olives. (Al-Shdiefat, 2006; El Hanandeh Gharaibeh, 2016)

• Fragmentation of the Sector: The olive oil sector in Jordan is characterized by fragmentation, with small farms operating independently. This preference for self-standing activities results in a scarcity of joint farmers' initiatives such as producer groups or cooperatives (ILO, 2014; Halalsheh et al., 2021). The lack of cooperation and coordination between farmers hampers the logistics of harvesting and marketing, preventing small farms from achieving higher levels of efficiency (Mercy Corps, 2017).

• Insufficient Knowledge and Awareness: Producers in the olive oil sector lack sufficient knowledge and awareness about market quality criteria, product varieties, market potential, types of pesticides and fertilizers, and proper packaging. This lack of knowledge can impact the overall quality and marketability of their products (ILO, 2014).

• Low Local Prices Compared to Costs: Local prices for olive oil in Jordan are not sufficiently profitable for producers, impacting their income and financial viability (Mercy Corps, 2017). This can discourage investment and hinder the sector's growth and development (Halalsheh et al., 2021)

5.2. Distribution Channels And The Fragmentation In Jordan's Olive Oil Market:

The distribution channels in the sector generally follow three main routes as explained

Table 2. *Routes of Olive Product Distribution in Jordan*

Route	Route Description
Farmers to Wholesalers to Retailers to Consumers	Farmers directly sell their olive products to wholesalers who operate in wholesale markets. Wholesalers distribute the products to retailers who sell them directly to consumers.
Farmers to Intermediaries to Food Processors or Retailers	Farmers sell their olives or olive products to intermediaries who act as middlemen. Intermediaries then sell the products either to food processors for further processing and sale to exporters or domestic market retailers, or directly to retailers who sell the products to consumers.

Route	Route Description
Farmers to Food Processors to Exporters and/or Domestic Market Retailers	Farmers sell their olives or olive products directly to food processors. Food processors process the products and sell them either to exporters for international markets or to domestic market retailers for local consumption.

***Source:** adopted from El Hanandeh Gharaibeh,(2016)*

These routes highlight the different paths through which olive products flow from farmers to end consumers. Understanding these distribution channels is important for analyzing the role of intermediaries, wholesalers, food processors, and retailers in the olive oil market. However, it is less common that olive farmers engage in direct sales to consumers, allowing them to bypass intermediaries and establish a direct connection with end consumers. This direct sales approach provides farmers with the opportunity to have more control over their products and establish direct relationships with their customers.

The shortcomings observed in the distribution channels:

- Dependence on Local Markets with challenges in Distribution Channel: Small-scale olive farmers in Jordan primarily rely on local markets, which limits their access to larger distribution channels and hinders market expansion (El Hanandeh Gharaibeh, 2016). The existing distribution system poses significant challenges, preventing direct reach to retailers, exporters, and end consumers (Al Hiar, 2019).

- Coordination and Commercial Structure Challenges: Efficient coordination between olive growers and oil processors is crucial for improving extraction rates and overall productivity (ILO, 2014).

- Lack of Marketing Strategy and Export Challenges: Wholesalers and olive oil press owners often lack a medium or long-term marketing strategy, leading to insufficient investments in marketing efforts, production equipment, and proper storage facilities (El Hanandeh Gharaibeh, 2016).

6. DATA COLLECTION, METHODOLOGY AND RESULTS ANALYSIS

This study employed a systematic approach to collect and analyze data on contract farming in the context of the small-scale olive oil industry in Jordan. The empirical results and discussions are presented in the following subsections, focusing on descriptive analysis and an analysis of the motivating factors for contract farmers.

Data collection involved a survey conducted over a period of two months, specifically in May-June 2023. The target population for the survey was small-scale farmers involved in the olive oil industry, both landowners and leaseholders. A total of 39 participants responded and provided valuable insights into their experiences with contract farming. A semi-structured questionnaire was carefully designed to gather primary data from the respondents. The questionnaire covered various aspects related to their profiles, including demographic information, farm characteristics, and their participation in contractual arrangements. This allowed for a comprehensive understanding of the farmers' backgrounds and their involvement in contract farming.

To complement the primary data, four personal interviews were conducted with key stakeholders, including representatives from the Jordanian Agriculture Engineers Association and small-scale farmers. These interviews served as an additional source of qualitative data, providing in-depth insights into the motivations and perspectives of the contract farmers. Furthermore, the study delved into analyzing the motivating factors that drive small-scale farmers to engage in contractual arrangements. This analysis aimed to identify the key actors and incentives that influence farmers' decision-making processes, shedding light on the drivers of contract farming participation.

It is important to note that the study faced certain limitations due to the scarcity of available data on contract farming in Jordan. The sector lacks specific papers and documentation on contract farming practices, which posed challenges during the data collection process. Nevertheless, the study relied on a combination of primary data gathered through surveys and interviews, as well as secondary data from reputable sources such as the Department of Statistics, the Ministry of Agriculture, and relevant reports from organizations like USAID, Mercy Corps, and the International Labour Organization.

6.1 Results And Data Analysis

In this section, we will analyze the empirical data gathered from small-scale olive farmers in Jordan. The demographic profile and characteristics of the farmers, as shown in Table 3 below, will be interpreted and discussed.

Table 3. *The demographic profile and characteristics of the farmers in Jordan*

Variables	**Frequency (n=39)**	
	Values	**Percentage (%)**
Age	21-30	5.41
	31-40	54.05
	41-50	32.43
	51-60	8.11
Gender	Male	89.79
	Female	10.81
Education level	No education	N.A
	Primary	24.32
	Secondary	40.54
	University Degree	35.14
Farming status	Full time	45.95
	Part time	45.95
	Not working currently	8.11

Variables	**Frequency (n=39)**	
	Values	Percentage (%)
Olive Cultivated area (in dunums)	1-20	40.54
	21-100	48.65
	101-200	8.11
	More than 200	2.7
Marketing channel	Local market	27.03
	Friends and connections	24.32
	Relatives	18.92
	Wholesalers	8.11
	Mill processors	13.51
	Others	2.7
Ownership	Owned	64.86
	Lease production	35.14
Contract farming	Participating in CF	5.4
	Not participating in CF	96.6
Methods for olive harvesting	Hand Methods	85
	Manual Olive Rake	12
	Electric Beater	3

6.2 Farmers, Market Profile And Contract Farming Participation

The empirical findings provide valuable insights into the characteristics and practices of small-scale olive farmers in Jordan shown in Table 3 below, will be interpreted and discussed.

• The Size of Olive Cultivated Area: the majority of olive farms in Jordan are small to medium-sized, with 48.65% of farmers cultivating an area of 21 to 100 dunums. This reflects the fragmented nature of olive farming, which presents challenges in terms of economies of scale and efficiency.

• Marketing Channels: local markets, friends, and connections are the primary marketing channels for olive products, indicating a localized approach. While this may limit exposure to larger distribution channels, the presence of wholesalers and mill processors suggests some integration into the broader supply chain.

• Contract Farming: Participation in contract farming is low, with only 5.4% of farmers engaged in such arrangements. This points to limited engagement in formal contractual agreements, which may be influenced by factors like information asymmetry, lack of trust, or insufficient support mechanisms for contract farming initiatives.

• Ownership: A majority of farmers (64.86%) own the land they cultivate, providing greater control over decision-making. However, 35.14% lease the land, indicating potential limitations in access to land resources and the need for secure land tenure arrangements.

• Harvesting Methods: Traditional harvesting methods, such as hand methods and manual olive rakes, are predominant (85%). This highlights a reliance on labor-intensive practices and the need for technological advancements and modern farming techniques.

Overall, these findings underscore the challenges faced by small-scale olive farmers in Jordan, including limited market access, farm fragmentation, and the need for improved farming practices. Addressing these challenges will require a comprehensive approach that includes market development initiatives, knowledge transfer programs, and supportive policies to enhance the competitiveness and sustainability of the olive sector.

6.3 Contract Farming Drivers Analysis

Based on the literature provided earlier, the mentioned drivers were utilized and investigated in our research. Table 4 below presents the drivers influencing the small-scale olive farmers in Jordan, along with their corresponding percentages and Radar Chart in Figure 3 below shows their distribution per city.

Table 4. *Drivers influencing the small-scale olive farmers in Jordan.*

Drivers	Percentage
Market stability	53%
Transfer of technology to improve farming practices	3%
Resources/inputs	35%
Indirect benefits	9%

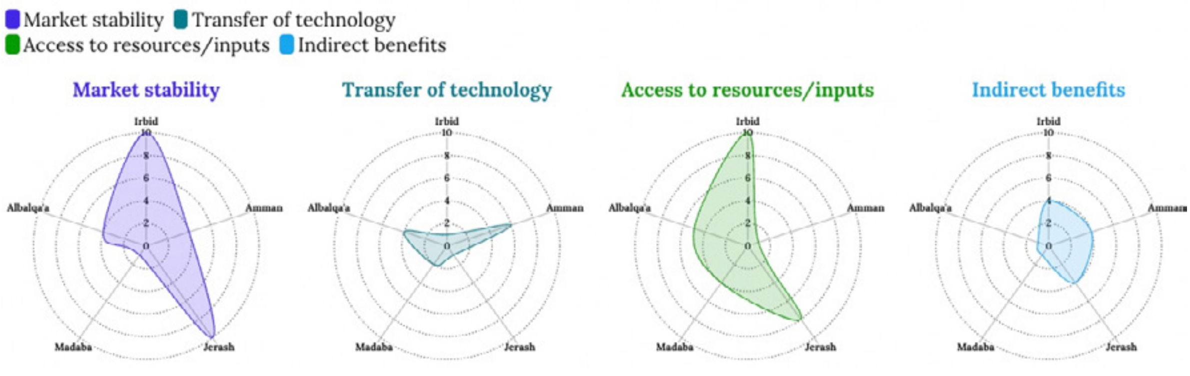

Figure 3: *Radar Chart Small Scale Farmers Drivers Distribution Per City*

Understanding these drivers is crucial for policymakers, agricultural organizations, and stakeholders involved in the development of the olive sector in Jordan. By addressing the identified drivers, interventions and policies can be tailored to support small-scale farmers, enhance market stability, promote technology transfer, improve access to resources, and foster sustainability. The findings provide valuable insights into the priorities and needs of small-scale olive farmers, guiding efforts to create a favorable environment for their success and the long-term growth of the sector.

6.4 Transaction Costs Related To Uncertainty In The Olive Oil Industry In Jordan

In our study, we focused on the impact of uncertainty on transaction costs in Olive Oil farmers and processors in the context of Jordan agrifood chains, as uncertainty is a crucial determinant of governance structure. Specifically, we examined the transaction attributes associated with uncertainty by experts in the field. The findings are presented in Table 5 below:

Table 5. *Impact of Uncertainty in Contract Farming the Olive Oil Industry in Jordan.*

Uncertainty Type	Transaction Costs (Source: Mugwagwa et al. 2020)	Expert' mean weight response
Behavioural	It is difficult to determine if farmers are complying with the contract.	2 out of 5
Environmental	- There is a risk of volumes being affected by agroecological factors such as drought and disease out-breaks. - It is difficult to forecast how much volume we need from farmers. Consumer tastes change quickly in this industry.	4.5 out of 5

7. RECOMMENDATIONS

This section presents a summary of the proposed solutions for addressing the challenges faced by the Olive Oil Industry in Jordan, particularly focusing on small-scale farmers. The suggested solutions are based on a thorough literature survey that was conducted.

7.1 Farmer Cooperatives As A Solution In Jordan

The presence of farmer cooperatives and associations is of utmost importance in the olive oil industry in Jordan. Their presence is critical as it directly impacts farmers' profitability. Moreover, in this section, I am going to highlight a noteworthy best practice and real-life case that exemplifies the successful application of farmer cooperatives as a solution for a national product. Drawing insights from this case can prove highly beneficial for the olive oil industry in Jordan, as it offers valuable lessons on the practical implementation, strategic considerations, and potential obstacles associated with adopting farmer cooperatives as a viable solution.

The avocado cluster in Kandara was formed to address challenges facing smallholders' participation in lucrative markets for high-value fruit tree value chains. Mwambi et al., (2014) emphasize the significance of such cooperatives and associations in addressing the challenges faced by smallholders and improving their participation in lucrative markets within high-value fruit tree value chains.

These challenges include a lack of market information, limited access to inputs and resources, weak incentives for upgrading, insufficient vertical and horizontal linkages within the value chain, and a lack of trust among producers, brokers, and exporters. Addition- ally, the introduction of stringent rules and market standards due to increasing consumer concerns about food safety has further complicated the situation (Mwambi et al., 2014). Donors, such as the United States Agency for International Development, have collab- orated with local business organizations to implement value chain upgrading strategies. These strategies involve improving the local variety, changing the governance structure of the value chain, and establishing closer relationships between buyers and suppliers (USAID, 2008).

In order to enhance the competitiveness of the avocado value chain in Kenya, the Kenya Business Development Services (KBDS) took proactive measures to improve relationships between lead firms (exporters) and avocado smallholders. In 2003, the KBDS mobilized farmers in the Kandara district and encouraged them to form groups consisting of 25-30 members. The primary objective of these groups was to facilitate the farmers' access to technical training and ensure compliance with the European global gap (EurepGap) standards, which are crucial for accessing export markets (Mwambi et al., 2014).

Additionally, the formation of these farmer groups aimed to enable smallholders to benefit from economies of scale. Since individual farms were relatively small and had a limited number of avocado trees, the formation of groups allowed farmers to aggregate their produce and collectively meet the requirements of contractors. This was particularly important because contractors often imposed a minimum threshold for purchasing fruits, such as not buying from farmers with fewer than 300 trees. Buying from individual farmers with small quantities would have resulted in high bulking costs for the contractors (Mwambi et al., 2014).

Several lead firms, including East Africa Growers and Kenya Horticultural Exporters, entered into contracts with the farmer groups. These contracts involved not only the purchase of produce but also the provision of interlinked services such as training, packaging, grading, transport, and spraying. The collaboration between lead firms and farmer groups aimed to improve overall value chain performance and ensure the delivery of high-quality products to the market (Mwambi et al., 2014).

In response to this situation, an intermediary body called the Agricultural Growers Association of Kandara (AGAK) was established in 2008. The primary purpose of AGAK was to organize the farmers and streamline coordination within the value chain (Mwambi et al., 2014). The farmer groups played a crucial role in coordinating smallholder farmers and achieving economies of scale, benefiting both the farmers and the contractor. By aggregating their produce, farmers could increase their bargaining power, improve efficiency, and reduce transaction costs. The coordination facilitated by the farmer groups also helped to address issues such as side-selling and enhance the overall performance of the value chain (Mwambi et al., 2014).

However, it is important to note that challenges still existed in the contractual arrangements. Information asymmetry, weak contract enforcement mechanisms, and the lack of prior agreement on prices and quantities exposed farmers to risks and uncertainties. The farmer groups, along with AGAK, worked to mitigate these challenges by building trust among group members and actively participating in contract enforcement and payment facilitation (Mwambi et al., 2014).

In the intermediary model observed in Kandara, subcontracting is a key feature. The lead firm delegates responsibilities to intermediaries who play a crucial role in the value chain. The contractor provides services like training, packaging materials, and transportation. However, unlike typical contracts, the current contractor does not offer credit or inputs to farmers, exposing them to price and production risks. The Agricultural Growers Association of Kandara (AGAK) addresses these challenges through informal arrangements. AGAK provides training, builds trust among farmers, and facilitates payments. Farmers must be part of a registered group affiliated with AGAK to market avocados through them, with a registration fee and deductions from sales contributing to AGAK's sustainability. These arrangements highlight the importance of trust, training, and efficient payment systems for farmers' market access and fair prices (Mwambi et al., 2014).

Overall, the case of the avocado farmers in Kenya highlights the significance of farmer groups and intermediary bodies in enhancing coordination, improving market access, and achieving economies of scale. The lessons learned from this experience can be valuable for the Jordanian olive oil industry, which can benefit from the establishment of similar cooperative structures to address the challenges faced by smallholders and enhance their competitiveness in the market.

7.2 Contract Farming As A Solution In Jordan

This fragmentation hinders the establishment of joint initiatives such as producer groups or cooperatives, impeding the logistics of harvesting and marketing and limiting the sector's overall efficiency. Understanding the dynamics of this fragmented system is crucial for comprehending the olive oil commodity chain, which involves multiple actors and decisions impacting the quality, distribution, and marketing of olive oil.

The weak mutual interaction between the actors within the sector further exacerbates the challenges. This is reflected in low export levels, primarily due to the instability of production from year to year, despite the presence of processors capable of producing high- quality oil. To address this issue, the signing of agricultural contracts between farmers and processors is seen as a potential solution. Such contracts can provide stability and create a framework for collaboration, thereby improving the sector's performance. Additionally, the creation of agricultural cooperatives, where plots planted with olives are merged to reduce fragmentation, can enhance production, facilitate access to a common market, and increase income. These measures would have a positive impact on export growth, addressing one of the main factors limiting olive oil exports. In the context of contract farming, different types of contracts can address specific transactional problems, offering advantages over spot market transactions and are suitable option for the olive oil sector in Jordan as explained below (Bijman, 2008):

- Market-specification contract reduces costs associated with gathering and exchanging information about demand, quality, timing, and price. By increasing information exchange, this contract type helps reduce uncertainty and market risks, particularly in the case of perishable products supplied for processing, exports, or supermarkets, as well as complex quality products and new niche markets where coordination costs are significant. Consequently, they can enhance the consistency and reliability of their olive oil supply, which is vital for meeting the requirements of export markets.

- Resource-providing contract can effectively decrease the costs of obtaining credit, inputs, and extension services. It is commonly utilized in crops where the output quality depends on the type and quality of inputs. This type of contract is advantageous when input provision reduces production costs for farmers and purchasing costs for the contractor.

• Production-management contract focuses on specifying cultivation practices to achieve desired quality, timing, and least-cost production. This contract type optimizes coordination costs and may support the skills development of producers, reducing future transaction costs.

By reducing information asymmetry and transaction costs, market-specification contracts promote better coordination and cooperation among farmers, processors, and other actors in the sector. They improve the sector's performance by enhancing the quality, distribution, and marketing of olive oil. Additionally, they contribute to export growth by addressing one of the main limiting factors in olive oil exports, which is the instability of production from year to year. Moreover, market specification contracts help address the weak mutual interaction between the actors in the sector. By specifying quality standards, packaging requirements, labelling guidelines, and delivery conditions, these contracts create a framework for collaboration and provide stability. They ensure that the olive oil meets the required standards, facilitate proper handling and storage, and enable traceability throughout the supply chain.

8. RECOMMENDATIONS

This research paper has provided valuable insights into the coordination and cooperation among small-scale farmers and other stakeholders in Jordan's olive oil sector. The study focused on agri-food coordination in the olive oil industry, with a specific emphasis on the perspectives of small-scale farmers. The findings shed light on the challenges faced by the industry, such as poor coordination, limited access to markets, and fragmented distribution channels.

The research highlighted the potential of contract farming as a solution to overcome the constraints faced by small-scale farmers, including limited credit, inadequate information, market risks, and weak market linkages. Different contract farming arrangement models were examined, including market-specification contracts, resource-providing contracts, and production-management contracts. These contract types offer advantages over spot market transactions and can enhance coordination, reduce uncertainty, and improve the consistency and reliability of olive oil supply.

Furthermore, the study emphasized the importance of vertical integration and the role of farmer cooperatives in improving coordination and cooperation within the olive oil sector. Vertical integration can optimize coordination costs and provide farmers with better access to resources and inputs, while farmer cooperatives can foster collaboration, enhance bargaining power, and facilitate collective marketing and distribution.

The research methodology employed a systematic and comprehensive approach, combining primary data from surveys and interviews with secondary data from reputable sources. Despite the limitations posed by the scarcity of available data on contract farming in Jordan, the study provided valuable insights into the profiles of contract farmers and the motivating factors driving their participation in contractual arrangements. The analysis of the data revealed that market stability, access to resources and inputs, and the transfer of technology were significant drivers for farmers' participation in contract farming. Market stability was particularly emphasized, highlighting the importance of stable and predictable markets for farmers to enhance profitability and ensure long-term sustainability. Access to resources and inputs played a crucial role in optimizing olive production processes, while technology transfer could improve productivity and overall farm performance. The study also examined the distribution channels in Jordan's olive oil market, revealing the influence of intermediaries and the limited bargaining power of farmers. The current distribution system impedes farmers' direct access to retailers, exporters, and end consumers, reinforcing the need for improved coordination and cooperation within the sector.

In conclusion, this research contributes to the understanding of supply chain coordination and sourcing in the context of the olive oil industry in Jordan. The findings provide valuable insights for policymakers, industry stakeholders, and farmers, highlighting the potential of contract farming, vertical integration, and farmer cooperatives to address the challenges faced by small-scale farmers and enhance the overall efficiency and competitiveness of the sector. Future research and interventions should focus on implementing effective coordination mechanisms and promoting sustainable practices that benefit all actors in the value chain.

9. REFERENCES

Abbasi, N., Vlachos, I., Vlontzos, G., & Papadopoulos, G. (2021). Contract farming as a tool for agricultural development in emerging economies. Journal of Rural Studies, 86, 32-42.

Abebe, G. K., Bijman, J., & Kemp, R. G. M. (2013). Transaction costs and governance structures in Ethiopian agricultural cooperatives. Journal of Cooperatives, 27(1),1-23.

Al-Hiary, H., Elayan, M. B., Alsukour, H., & Al-Ayyoub, M. (2019). The role of the agricultural and food sectors in the economic growth of Jordan. Journal of Food Products Marketing, 25(1), 37-57.

Abbasi, A., Hanif, I., Bashir, M. K., & Abbasi, M. (2021). Role of contract farming in enhancing agricultural productivity: Evidence from Pakistan. Management studies and Economic Systems, 3(1), 10-20.

Al-Shdiefat, A. A. (2006). Jordan's agriculture sector: competitiveness and role in economic development. Jordan Journal of Agricultural Sciences, 2(2), 145-152.

Arumugam, V., Balasubramanian, K. S., & Raju, S. S. (2010). Contract farming: A panacea for Indian agricultural sector. Asian Journal of Agricultural Extension, Economics & Sociology, 8(2), 85-90.

Arumugam. N. A., Fatimah, M. A., Chiew, E. F. C., & Zainalabidin, M. (2010). Supply chain analysis of fresh fruits and vegetables (FFV): Prospects of contract farming.Agric. Econ. – Czech, 56(9), 435–442.
Arumugam, V., Rajendran, K., & Chinnadurai, M. (2010). Role of contract farming in agriculture development: A review. Agricultural Economics Research Review, 23(1), 21-30.

Ayoub, A. (2017). Economic analysis of olive oil industry in Jordan. International Journal of Applied Agricultural Sciences, 3(10), 67-72.

Baa, H. A., de Mey, Y., Thoron, S., & Demont, M. (2019). Inclusiveness of contract farming along the vertical coordination continuum: Evidence from the Vietnamese rice sector. Land Use Policy. Advance online publication. https://doi.org/10.1016/j.landusepol.2019.104050.

Barrett, C. B., Bachke, M. E., Bellemare, M. F., Michelson, H. C., Narayanan, S., & Walker, T. F. (2012). Smallholder participation in contract farming: Comparative evidence from five countries. World Development, 40(4), 715-730.

Bellemare, M. F. (2012). As you sow, so shall you reap: The welfare impacts of contract farming. World Development, 40(7), 1418-1434.

Bijman, J. (2008). Contract farming in developing countries: An overview. Wageningen University.

Bijman, J. (2013). Producer organizations and market chains: Facilitating trajectories of change in developing countries. Journal of Agribusiness in Developing and Emerging Economies, 3(2), 89-108.

Da Silva Rankin, M. (2013). Contract farming, smallholders, and rural development in Latin America: The organization of agroprocessing firms and the scale of out-grower production. World Development, 41, 124-133.

Dries, L., Swinnen, J. F., & Noev, N. (2009). Vertical coordination, rent distribution,and development: The case of dairy clusters in Central and Eastern Europe. World Development, 37(11), 1742-1758.

Eaton, C., & Shepherd, A. (2001). Contract farming: Partnerships for growth. FAO Agricultural Services Bulletin, 145

El Hanandeh, A., & Gharaibeh, M. A. (2016). Environmental efficiency of olive oil production by small and micro-scale farmers in northern Jordan: Life cycle assessment. Agricultural Systems, 148, 169-177. http://dx.doi.org/10.1016/j.agsy.2016.08.003.

El Hanandeh, A., & Gharaibeh, M. (2016). Analysis of the Jordanian olive oil value chain: An application of the global value chain framework. Spanish Journal of Agricultural Research, 14(4), e1012.

Halalsheh, M., Al-Harahsheh, M., & Madanat, S. (2021). Factors affecting the com petitiveness of the Jordanian olive oil sector: A qualitative study. Journal of Food Products Marketing, 27(2), 136-151.

Handayati, Y., Simatupang, T. M., & Perdana, T. (2015). Agri-food supply chain coordination: the state-of-the-art and recent developments. Logistic Research Journal, Published online: 8 October 2015. Retrieved from Springerlink.com.

ILO. (2014). Market Study and Marketing Strategy of Olive Sector in Irbid (V2 ed.).International Labor Organisation (ILO).

Klein, B. (1996). Why hold-ups occur: The self-enforcing range of contractual relationships. Economic Inquiry, 34(3), 444-463.

Malak-Rawlikowska, A. (2018). Are Farmers Trapped in Hold-Up Relationships with their Contractors in the Supply Chain? The Case of Dairy Farmers and Feed Suppliers. Wieś i Rolnictwo, 4(181), 04. https://doi.org/10.7366/wir042018/04

Malak-Rawlikowska, A. (2018). Transaction costs in agricultural contracts: A literature review. Agricultural and Food Economics, 6(1), 1-20.

Mercy Corps. (2017). Jordan olive industry analysis: Opportunities and challenges. Mercy Corps Jordan.

Ministry of Agriculture and NCARE. (2015). 3rd Survey of Organic Agriculture in Jordan. pp. 2015.

Minot, N., & Ronchi, L. (2014). Contract farming in developing countries: Theory,practice, and policy implications. IFPRI Discussion Paper 01394.

Moharana, H., Murty, J. S., Senapati, S. K., & Khuntia, K. (2010). Coordination, Collaboration and Integration for Supply Chain Management. Interscience Management Review, 3(1), Article 4. Published in January 2010.

Mugwagwa, S., Chisango, F., & Ngwenya, T. (2020). Typology of contract farmingarrangements: a transaction cost perspective. Journal of Agricultural Economics Research, Policy and Practice in Southern Africa, 51(2), 1-14.

Mugwagwa, J., Gardebroek, C., & Perrot, C. (2020). Supply chain coordination: Theories, approaches, and implications for agri-food industry. Journal of Chain and Network Science, 20(3), 249-261.

Mwambi, M., Oduol, J., Mshenga, P., & Saidi, M. (2016). Does contract farming improve smallholder income? The case of avocado farmers in Kenya. Journal of Agribusiness in Developing and Emerging Economies, 6(1), 2-20. doi:10.1108/JADEE-05-2013-0019.

National Center for Agricultural Research (NCARE). (2015). Olive Research Department [Online]. NCARE, Amman, Jordan. Retrieved from http://www.ncare.gov.jo/body.aspx?id=145

Ncube, T. (2020). Contract farming in Sub-Saharan Africa: A literature review. Agrekon, 59(2), 153-166.

Ncube, S. (2020). Contract farming: Opportunities and challenges for smallholder farmers in developing countries. In Sustainable Agriculture Reviews (Vol. 42, pp. 37-61). Springer.
Ncube, A. (2020). The implications of contract farming on agricultural roduction:A review of empirical evidence. Sustainability, 12(12), 5063.

Pazaj, E., & Kapaj, I. (2023). The olive oil value chain in Albania and its implications for competitiveness. Economics of Agriculture, 70(1), 137-151.

Perry, M. (2008). A framework for understanding the implications of contract farming. Development Policy Review, 26(5), 555-571.

Prowse, M. (2012). Contract farming, farm production, and farm households' welfare: Evidence from small-scale fruit and vegetable farmers in Thailand. World Development, 40(6), 1184-1198.

Rao, E. J. O., & Qaim, M. (2011). Supermarkets, farm household income, and poverty: Insights from Kenya. World Development, 39(5), 784-796.

Rehber, E. (2000). Understanding vertical coordination and integration in agriculture.In Proceedings of the 13th International Farm Management Congress (pp. 23-31).Wageningen, Netherlands: International Farm Management Association.

Schipmann, C., & Qaim, M. (2011). Modern food retailers and traditional markets in developing countries: Comparing quality, prices, and competition strategies in Thailand. Agricultural Economics, 42(3), 281-298.

Ton, G., Vellema, S., & De Grip, K. (2017). Contract farming for improving smallholder incomes: What can we learn from effectiveness studies? World Development, 98, 283-296.

Van der Meer, M. (2006). Chain relations in the olive oil industry: Case studies in Greece and the Netherlands. Food Policy, 31(3), 227-239.

Williamson, O. E. (1998). Transaction cost economics: How it works; where it is headed. De Economist, 146(1), 23-58.

World Bank. (2008). World development report 2008: Agriculture for development.Washington, DC: World Bank.

Zhang, F. (2015). Supply Chain Coordination. In J. J. Cochran (Ed.), Encyclopedia of Operations Research and Management Science. Wiley

Quantitative Planning of Charging Infrastructure in Heterogenous Urban Environments in Germany: *A Multi-Period Greenfield Modulation*

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ABSTRACT

By 2050, two-thirds of the world's population will reside in cities. Combined with the continued electrification of fleets, these dynamic urban settings which quickly change over time require quantitative and multi-period charging infrastructure planning. To address this gap, this paper presents a greenfield approach that can be universally applied. In the first step, the target environment is classified by using vector-field analysis to identify central cities, inner suburbs, and outer suburbs as distinct areas. Next, the annual electric vehicle (EV) market is projected and afterward divided into charging need groups based on specific charging behavior. With this, the percentage share of total energy consumption per group can be determined. The energy is distributed across home, work, public, and long-distance charging and matched with three charging levels (level 1, level 2, and fast charging). This allocation, referred to as the charging mix, assigns a specific technology mix to each environment. To account for multi-periodically of the model, all metrics influencing the need for charging points over time (population, spatial dispersion, and modal split) are considered, allowing adjustments in growth scenarios to accommodate positive and negative changes. Ultimately, through the development of this greenfield modulation, it is aimed to close the identified research gap of a planning model that is adaptable across heterogeneous urban environments and over time. This paper provides a theoretical foundation whose practical application remains to be validated in real-world use cases.

Key words: Charging infrastructure, greenfield modulation, multi-periodical planning, electric vehicles

1. INTRODUCTION

Urbanization is a rapidly growing global phenomenon, with the United Nations estimating that by 2050, two-thirds of the world's population will reside in cities [1]. This trend has already gained significant momentum, resulting in a reversal of the rural-urban ratio, where urban areas now accommodate more people than rural regions [1]. Consequently, cities, despite occupying a mere two percent of the world's land area, consume a staggering 75 percent of the world's energy [2]. Anticipated growth in automobile sales, particularly in electric vehicles (EVs), will further contribute to the surge in energy demand, as urban centers become the primary sites for increased vehicle usage [2]. Considering the substantial population and wealth concentrated in urban regions, there will be a corresponding rise in vehicle miles traveled, as evidenced by historical trends in the United States over the past five decades [2]. Given the convergence of two influential factors, namely the global trend of urbanization and the electrification of vehicle fleets, charging infrastructure assumes significant macropolitical importance. Consequently, numerous attempts have been made to develop accurate models for planning charging infrastructure in urban environments.

1.1 Research Background

The pivotal role of charging infrastructure in the context of urbanization and the electrification of vehicle fleets has attracted significant attention in the academic community. Tamay [3] acknowledges the growing number of publications addressing charging stations (CS) and electric vehicles (EVs), as evidenced by a substantial volume of literature. For instance, a search using the keywords "electric vehicle charging station" yielded 5,719 articles from Scopus and 2,285 articles from the Web of Science for the period of 2001-2021 [3]. The core of most articles revolves around the evaluation of demand and the subsequent determination of the most efficient configuration and positioning of EV charging stations [4]. In the context of location planning, the siting of charging infrastructure has been comprehensively addressed [4]. Hence, the emphasis of this paper is placed on quantitative and especially multi-period planning. To determine optimal charging station sizing, which depends on charging demand, established transportation models are commonly used. The reviewed literature can be classified into three categories: node-based, flow-based, and agent-based. Node-based approaches represent charging demand as geographical points, often referring to zones or nodes in a directed graph [5]. In contrast, flow-based methods focus on traffic flows to position charging stations for maximizing traffic flow, requiring more data, such as origin-destination information [5]. Agent-based approaches differ by focusing on representative users, allowing for a heterogeneous user description but with potentially extensive data needs, including individual driving patterns and charging decision details [5].

In the context of multi-period planning, the fundamental principle involves adapting growth projections over time. Building upon the insights provided by Anastasiadis [6], the determination of the required number of charging points to meet the charging demand is presented as a function of both fleet size and population size. Anastasiadis' research findings reveal an initial rapid increase in the number of charging points required, followed by a more gradual ascent. By incorporating dynamic demand considerations into multi-period planning, potential insights into how station placement decisions impact future demand can be deduced [7].

Table 1 provides an overview of relevant literature in the field of quantitative analysis and multi-period planning. It also acknowledges limitations, thereby allowing this paper to build upon them and potentially eliminate existing limitations.

Table 1. *Selected literature on charging infrastructure planning.*

Author	Technology	Demand	Multi-Period	Limitations
Alhazmi et al. (2017)	Fast charging	Node-based	No	Randomness of driver's behaviors.
Anastasiadis et al. (2020)	Fast charging	Agent-based	Yes	No proportional correlation between number charging stations and fleet size.
Aryandoust et al. (2019)	Fast charging	Flow-based	No	Effectiveness of policies vary from city to city due to different patterns.
Chen et al. (2016)	Mixed	Agent-based	No	Charging station locations are a function of geography and travelers' patterns.
Huang et al. (2016)	Mixed	Node-based	No	Geometric segmentation can fully eliminate the partial coverage issue.
Luo & Huang (2017)	Mixed	Agent-based	No	Charging station placement is highly consistent with the traffic flow of Evs.
Zhang et al. (2017)	Fast charging	Path-based	Yes	–
Zhu et al. (2016)	Slow charging	Node-based	Yes	No adoption to other application scenarios (cities, urban environments, etc.)

It is evident that regardless of the urban or highway context, or the type of charging (fast or slow), there are consistent limitations. In the realm of quantitative planning, these limitations are closely tied to the flow of electric vehicles (EVs) [12]. This relationship is contingent on both the geographic coverage of the area and the travel patterns of the population [10]. Therefore, it is imperative to account for the differences in each urban environment. Huang et al. [11] have demonstrated that a geometric segmentation approach can effectively address this issue. In terms of multi-period planning, the number of charging stations required doesn't need to maintain a continuous proportional relationship with the fleet size [6]. These dynamics are rooted in the specific attributes and characteristics of urban environments [4]. Urban cores undergoing densification experience alterations in traffic flow and travel patterns over time, consequently exerting a notable influence on the planning of charging infrastructure [4].

To address this gap, this study proposes the adoption of a greenfield approach. Greenfield approaches have demonstrated success in various applications within the existing literature [15], [16]. For instance, Radanliev [15] employed a greenfield approach to investigate the relationship between multiple elements and factors influencing supply chain strategy formulation in the slate mining industry. Similarly, Kienzle & Andersson [16] applied a greenfield approach to design future multi-energy systems, including electricity and even developed a tool for long-term energy supply scenario studies.

1.2 Contribution To Current Discourse

Drawing upon these successful applications, this paper could address the identified research gap related to heterogeneity and the absence of multi-period charging infrastructure planning through the development of a greenfield modulation that is scalable across heterogeneous urban environments and over time. The proposed model could serve as a valuable tool for various stakeholders, including policymakers, urban planners, and researchers, facilitating effective communication and collaboration. Previous studies have highlighted the lack of communication and involvement among stakeholders in spatial planning policies. Priebs [17] observed that past German spatial planning policies often lacked coordination among public actors, private sector representatives, civil society, and academia, with a shift towards competitiveness, efficiency, and austerity. These communication and involvement issues extend to the European level as well. Ritter [18] emphasized the lack of coordination in spatial development policies between different bodies responsible for sectoral policies within the European Union, leading to opacity in procedures, substance, and impact. Consequently, there is a need for better alignment and understanding of the environmental and economic implications of spatial configurations [18]. By adopting and adapting this model, stakeholders could improve communication, overcome coordination challenges, and make informed decisions for the benefit of urban areas and their surroundings.

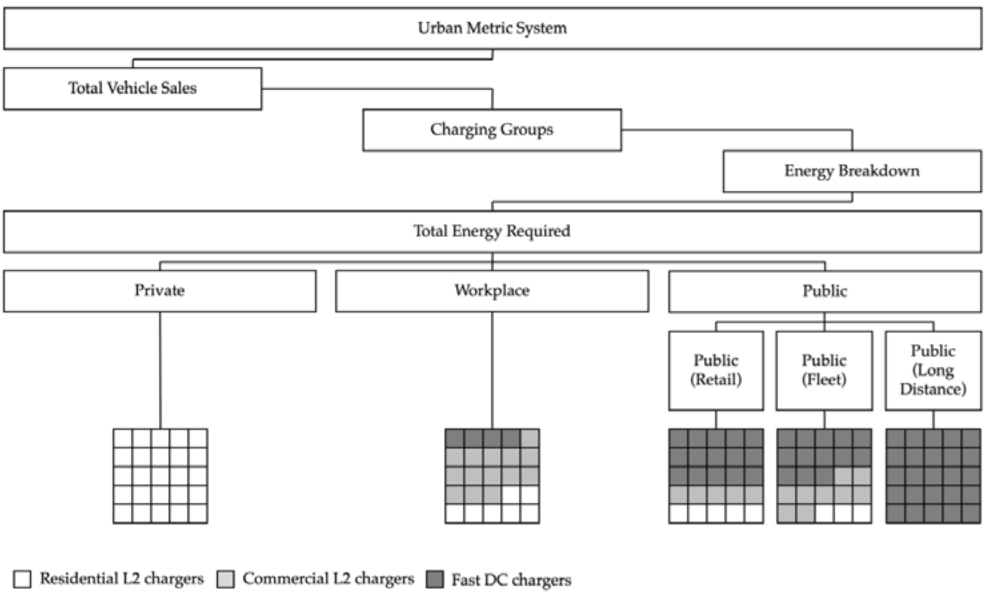
2. METHODOLOGY OF GREENFIELD MODULATION

The greenfield approach proposed in this study adheres to the methodological framework as outlined by existing literature [16, 19] and follows a systematic top-down process. The primary objective is to define absolute numerical requirements per predefined environment. Subsequently, through a series of iterative steps, it should be possible to allocate relative values to specific areas and use cases within the defined environment. Afterward, it is aimed to adjust projections based on changes arising from the evolving patterns of urban development over time. By implementing these steps, the identified research gaps related to heterogeneity and the absence of multi-period charging infrastructure planning can be effectively addressed.

2.1 Quantitative Estimation Of Required Charging Stations

The introductory stage of this greenfield module entails the calculation of absolute numerical values, which are subsequently converted into relative values tailored to specific areas and use cases within the designated environment. This process involves a series of sequential steps, which are illustrated in Figure 1.

Figure 1: *Greenfield modulation for estimating required charging stations and charging mix.*



To determine the required charging infrastructure for a specific environment, an initial classification is made, dividing the environment into central cities, inner suburbs, and outer suburbs. This classification provides a foundation for accurately estimating energy consumption within the given area. For this, the paper outlines a three-step process, starting with projecting annual electric vehicle (EV) sales and secondly dividing the electric vehicle market into charging need groups that exhibit distinct charging behavior. The third step focuses on determining the percentage share of total energy consumption for each previously defined charging need group. While the pre-defined percentage distribution per charging need group specifies where each group consumes its total energy demand, it does not specify how that energy is consumed. Consumers are EV drivers, encompassing both Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV). Hence, the energy allocation is matched with three different charging levels, specifically Level 1, Level 2, and DC fast charging. The ultimate objective is to align the calculated energy distribution with these three charging levels to effectively cater to the needs of each charging group during their journeys. Therefore, the technologies introduced (L1, L2, DC) are harmonized with the previously defined total energy consumption categories of home, work, and public charging. This results in relative distributions of needed charging type amounts per defined category in the environment. These can be combined with absolute defined numbers of total energy required and translated into numbers of required stalls of Level 1, Level 2, and DC fast charging posts.

2.2 Multi-Period Adaptations Of Required Charging Stations

Considering this paper's goal to potentially cater to multi-period aspects, it is aimed to adjust growth estimations over time based on the unique characteristics of specific urban environments. As previously recognized, the number of required charging points is intrinsically linked to fleet size [6]. However, as evidenced in the research background, it is important to acknowledge that in growth scenarios, the number of charging stations does not necessarily need to maintain a continuous proportionality with fleet size [6]. Hence, it is not the intention to assume static growth. Instead, it is aimed to account for the specific transformations occurring within urban environments over time. These influential factors can be categorized into four main categories. The first category is the correlation between population growth and increased activities in various domains, including commuting, shopping, and household demands [20-21]. The second category accounts for factors that induce changes in spatial distribution, such as the dispersion of industries, employment, and housing [22]. The third category pertains to centrality, in line with urban economic theory [23-24], which underscores the connection between city size, population density, and vehicle kilometers traveled. The fourth and final category considers shifts in the modal split, referring to the distribution of various transport modes within the total number of kilometers traveled [25-26].

3. RESULTS

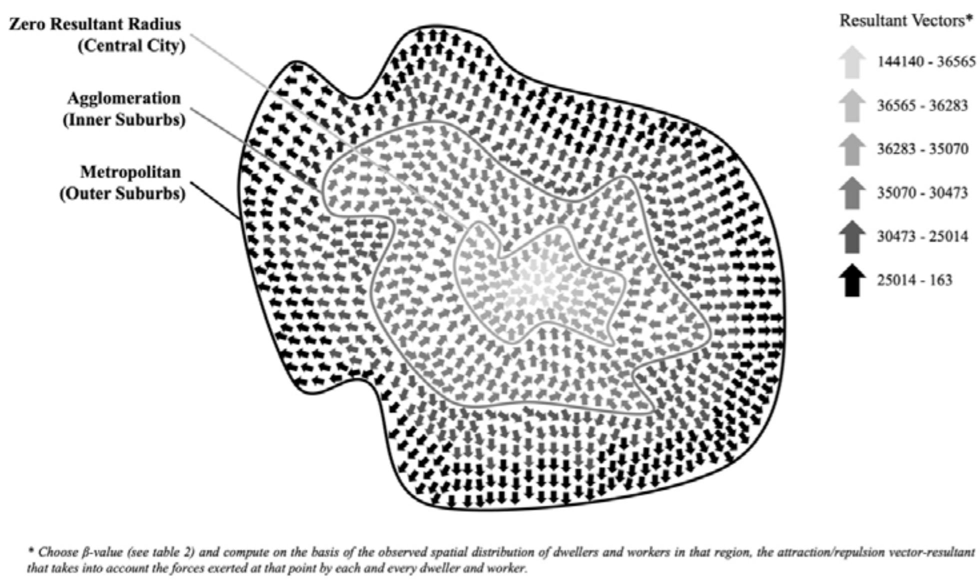
Following the presented methodology, it aims to define the relative required types of charging posts per predefined environment, before adjusting defined values over time.

3.1 Quantitative Estimation Of Requrired Charging Stations

3.1.1. Classification of urban environment

To define required charging posts for a certain environment, first, the environment needs to be classified into boundaries for central cities, inner suburbs, and outer suburbs. This allows later precisely determining the energy consumption for the given area. Oftentimes, the boundaries of urban areas are mainly arbitrary, in the sense that they are either based on administrative breakdowns, which are, most of the time, the result of multiple municipal subdivisions and mergers, or on some rules that vary from one period to the next, and from one state to the other [27]. Traditional literature has approached the examination of urban environments in a stepwise manner, using concentric ring-based analysis. Burgess [28] employed a series of three 8-km buffers to delineate fringe, periphery, and hinterland areas, based on the assumption of cities as concentric zones with distinct functions. This ring-based analysis is firmly rooted in classic urban theories and assumes a monocentric form of expansion, with growth radiating outward from a central core [29]. Expanding on this concept, Schneider and Woodcock [30] established that the core area ends where urban land densities drop below 50 percent. Beyond the core, urban expansion occurs within the urban-to-rural transition zone. Contrary to this established monocentric approach, it is acknowledged that urban environments are influenced by the movement of people and goods within and across the city [31]. Hence, this paper aims to clearly define the boundaries of urban environments. By employing vector-field analysis the Urban Metric System (UMS) method as introduced by Tellier [27] enables the computation of attraction/repulsion vector-resultants for any point within a given region. The vectors represent the combined influence of attractive forces on a point and denote the probable direction of movement for a population located at a particular point [27]. Since the attraction exerted by each attractor on the population of generators is determined using an attraction function considering the spatial arrangement of attractors at a specific moment, the concept is static, and each vector possesses a magnitude (or length) [27]. Aggregating these vectors allows the forming sectors to refer to a specific region within the vector field where all forces converge toward a central point. In the Urban Metric System, the delimited urban areas correspond to these vector-field sectors. Within these sectors, divergence points are surrounded by vectors pointing outward, marking clear sector boundaries. Consequently, the attraction/repulsion vector-resultants of neighboring points within these sectors point either toward the city center or the periphery, creating the Zero Resultant Radii [27]. Ultimately, this allows for the temporal assessment of the mathematically determined boundaries as exemplified in Figure 2.

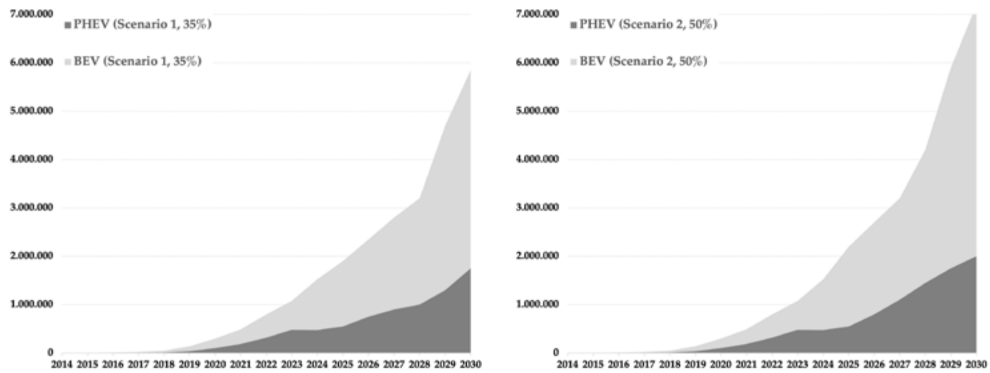
***Figure 2:** Exemplified computation of vector field illustrating boundaries of the central city, inner and outer suburbs. Note: adapted from [27].*



3.1.2. Estimation of required energy

The paper outlines a three-step process for determining the energy consumed in the model, first employed by Hall & Lutsey [32]. The first step involves projecting annual electric vehicle (EV) sales, which serves as the basis for determining the required charging infrastructure in Germany. The current electric vehicle market can be established using existing passenger electric vehicle stock data by metropolitan area [33]. Here, two distinct market scenarios are envisioned for the proportion of electric passenger car registrations by the year 2030. In Scenario 1, an electric car share of 35%, aligning with the zero- and low-emission vehicle target defined in the EU passenger car CO2 regulation, is assumed [34]. Scenario 2 anticipates an electric car share of 50%, reflecting the projections made by leading vehicle manufacturers [35]. These two scenarios are deemed conservative and indicative of the minimum number of charging points that will be requisite by the year 2030 [35]. Future EV sales can be estimated as a percentage of passenger vehicle registrations in Germany, increasing over time [36]. To reflect the redistribution of vehicles after the conclusion of a lease and to account for used vehicle sales, conventional and electric passenger vehicle registrations per capita can be compared to passenger vehicle stock per capita [37] and redistributed proportion- 234 ally after three years [35]. Overall electric vehicle stock operating on the road can be calculated based on cumulative vehicle sales minus vehicle retirement. Vehicle retirement can be calculated based on historical German passenger vehicle retirement [38] and modeled future. The outcomes are visually presented in Figure 3.

Figure 3: *Passenger electric vehicle stock in Germany for scenario 1 (35% of sales are EVs in 2030) and scenario 2 (50% of all sales are EVs in 2030). Note: Adopted from [35]*



In Figure 3 (left), a year-by-year representation of passenger electric vehicle stock estimates is presented for Scenario 1, depicting a 35% electric vehicle sales share in 2030. In Figure 3 (right), the corresponding stock estimates for Scenario 2, wherein a 50% electric vehicle sales share in 2030 is assumed, are shown. According to calculated estimates cumulative sales, without accounting for retirements, are projected to reach eight million by 2030 when the sales share is set at 50% [35]. The second step involves partitioning the electric vehicle market into charging need groups that show distinct charging behavior. Following Nicholas & Wappelhorst [35], these groups can be established alongside the dimensions of vehicle type (PHEV or BEV), commuting status (Commuter & Non-Commuter), and home charging access (home, no home). Table A3 provides relevant metrics for electric vehicles by housing type in 2018 and projected percentages for 2030 [35]. Although future home charging availability is unknown, the housing type can be used as a proxy for the likelihood that home charging will be available to those who purchase an electric vehicle [39]. The third step focuses on determining the percentage share of total energy consumption per the previously defined charging need group. The exact needs are primarily derived from a German survey of EV drivers [25], supported by data from other sources to disaggregate the results [26] and assembled in Table 4.

Table 4. *Energy breakdown by charging group, note: adopted from [35]*

Type	Commuting	Home Charging	Home Energy	Work Energy	Public Energy	DC Energy	Vehicle km p.a.	% electric km p.a.
BEV	Y	Y	70%	20%	5%	5%	15,100	100%
BEV	Y	N	0%	55%	20%	25%	15,100	100%
BEV	N	Y	80%	0%	10%	10%	12,354	100%
BEV	N	N	0%	0%	40%	60%	12,354	100%
PHEV	Y	Y	60%	30%	10%	0%	15,100	70%
PHEV	Y	N	0%	65%	35%	0%	15,100	40%
PHEV	N	Y	90%	0%	10%	0%	12,354	50%
PHEV	N	N	70%	0%	100%	0%	12,354	10%

3.1.3. Estimation of required charging mix

The prior defined percentual distribution per charging need group indicates where each group consumes its overall energy demand but has no indication of how that energy is consumed. Hence, in this step, the energy is matched to three different charging levels, namely level 1, level 2, and direct-current (DC) fast charging. This allocation is referred to as a charging mix. Level 1 chargers have lower power ratings (120 V / 15 A) and consequently require a longer time for charging [40]. As a result, these chargers are typically preferred in locations where EVs are parked for extended durations, such as homes and workplaces [41]. Level 2 chargers, on the other hand, utilize 19.2 kW of charging power and operate at 208 V or 240 V with currents up to 80 A [40]. Although the power ratings of level 2 chargers are higher than level 1 chargers, they still necessitate a significant amount of time for charging EVs [41]. Consequently, level 2 chargers are also well-suited for locations where EVs are parked for longer durations, including homes, workplaces, and public areas where EV drivers tend to spend a considerable amount of time. In contrast, DC fast chargers possess significantly higher power ratings and can rapidly recharge EVs within a limited timeframe [41]. Therefore, these chargers are primarily deployed for commercial use and in public areas where EV drivers tend to stay for shorter periods. As stated, the overall goal is to match the calculated energy distribution with the three charging levels to best cater charging needs of group customer journeys. Hence, the introduced technologies (L1, L2, DC) are matched with the already introduced total energy consumption categories home, work, and public charging. This is crucial since for instance, Fast DC charging technology is pivotal to relieving range anxiety. However, it isn't necessary for every charging application [42]. For this reason, below, as illustrated in Figure 4, this paper allocated a certain charging technology to a certain environment. Each environment is predominately characterized by certain use cases which demand different charging technologies.

Figure 4: *Estimation of required charging mix*

First, starting from left to right with the private space, which is exclusively for the use of the residents of the property [43], it is acknowledged that most electricity consumption takes place at home. By 2030, private use cases would still account for a large majority of all charging [42]. This is caused by the improvement of battery technology allowing ranges of more than 200 miles per charge, thus meeting the needs of most drivers who travel on average 30 miles a day by private vehicle [42]. These drivers will need fast chargers only when they are on long-distance trips and can't take the extra time to refuel at a slower public alternating-current Level 2 (AC L2) charger or when they forget to charge at home and can't make the round trip in the time available [31]. Consequently, for private areas, a distribution of 100% residential L2 chargers is allocated to meet customer demands now and in the future.

Secondly, for the workplace, Xi et al. [44] state that the hourly utilization greatly differs between weekdays and weekends, which can potentially be explained by the assumption that cars are used more often during working days, e.g., for the sake of commuting to work. Pevec et al. [45] analyzed the utilization of both charging stations and parking spots for each hour of the day for the year 2016. It can be observed that the charging utilization has 2 peaks during the day, mainly around 8 AM and 5 PM. These correspond 309 to times when drivers usually arrive at workplaces and home coming from work [45]. Thus, charging in the workplace has much longer dwell time than public charging and higher charging options are much less effective without vehicle swapping [46]. Following Li et al. [46], for all scenarios, Level 1 chargers are the most popular because of their low installation cost and relatively long charging duration for workplace charging. Level 2 chargers are recommended when the budget level is high and could help the system cover all charging demands. Consequently, this paper calculates 55% commercial L2 chargers and 30% residential L2 Chargers. However, due to higher parking spot utilization, a sufficient number of fast charging is needed. Thus, this paper also calculates with 15% fast DC chargers.

Third, public space, which is divided into easily accessible to the general public at any time of day or night [43], and fleets whose distribution is heavily dependent on the increase of shared concepts and the likely introduction of autonomous fleets and only accessible to those companies [42].

The third category public space defines locations as being easily accessible to the general public at any time of day or night [43] such as retail spaces and long-distance locations. It also features fleets where the distribution is heavily dependent on the increase of shared concepts and the likely introduction of autonomous fleets and only accessible to those companies [42]. As highlighted before, most EV charging is done at home or work, so public charging points are needed to serve drivers without access to private charging, and those traveling longer distances [42]. Paying off on this trend, Kampshoff et al. [42] estimated that charging will probably shift towards public options, and away from the home (accounting for around 75 % in 2020), as more people without access to home charging start to buy EVs. These drivers will choose either fast or slow public charging, depending on their daily trip plans, and want chargers to be placed where they need them. Hence, the mix of charging technologies must mirror the charging behavior of users. Davidov [47] analyzed this and acknowledged that the optimal charging technology mix stays unchanged after the average dwell reaches 450 min. In other words, if a longer charging time is required at a candidate location as a reflection of an EV driver's charging behavior, the optimal planning model must place a slower charging technology type at a location to address the charging convenience of the EV driver. Xi et al. [44] conclude that, due to the short parking time of vehicles at shopping locations (relative to workplaces), a greater proportion of the chargers installed in retail shopping locations should be DC to maximize the expected EVs charged. This is due to the short parking durations at these locations (relative to workplaces), which allows a single charger to be reused multiple times daily. At parking lots and other public destinations, for example, DC charging can be available as a premium service, but when a driver is parked for an hour or more, slower AC L2 charging usually works well enough [42]. Overall, this paper calculates a higher rate of 60% fast DC chargers and a comparably lower amount of 20% commercial L2 chargers and 20% residential L2 Chargers.

Regarding fleets, the distribution is heavily dependent on the increase of shared concepts and the likely introduction of autonomous fleets [48]. All future estimates of fleet size and the required charging infrastructure are extremely sensitive to battery recharge time and vehicle range. Following [49] each 80-mile range shared autonomous EV would replace 3.7 privately owned vehicles and each 200-mile range shared autonomous EV would replace 5.5 privately owned vehicles, under Level 2 charging. With DC fast-charging infrastructure in place, these ratios rise to 5.4 vehicles for the 80-mile range shared autonomous EV and 6.8 vehicles for the 200-mile range shared autonomous EV [49]. This highlights, that higher throughput is needed to serve more customers daily. Loeb & Kockelman [50] acknowledged, that fast charging allows for improving average response times, thus increasing potential cars that could charge per charging point. Additionally, Almutairi [41] estimated that by 2030 considerably less charging would be done at home, and the amount of charging in fleet depots would nearly double. Both papers underline the importance of a higher share of fast charging points in these environments. Ultimately, due to the shift to more and more shared concepts, this paper calculates a higher rate of 50% fast DC chargers and a comparably lower amount of 35% commercial L2 chargers and 15% residential L2 Chargers.

Lastly, for long-distance locations on highways, DC fast charging technology is pivotal to relieving range anxiety [42]. Hence, a distribution of 100% fast charging is allocated to meet customer demands now and in the future.

3.2 Adaption Of Growth Case Over Time

In light of this paper's aspiration to build a multi-period charging infrastructure module, it is now aimed to shape and adjust growth estimates according to the unique characteristics of a specific urban environment. As already acknowledged, the number of required charging points is a function of fleet size [6]. Thus, for stakeholders, it is necessary to adjust the assumed total numbers and modulate them based on the described growth case. However, this growth is currently static and does not account for specific changes occurring in urban environments over time. For example, the availability of home charging for all-electric vehicle sales in 2018 was at 80% but reduced to 72% of sales by 2030 estimates due to more customers living in apartments. This results in an increased need for workplace, public, and DC fast charging [36]. If significant enough, such factors can influence growth dynamics over time [51]. Consequently, to address this, the next step involves incorporating all metrics influencing the need for charging points and adjusting the growth case, considering both positive and negative changes. Featured are four main categories, all displayed with sources where data can be accessed to ensure replicability. The four categories are population growth, spatial distribution, centrality, and modal split (Table A5) as illustrated in the methodology.

The first category is well-established and includes the correlation between population growth and increased activity in various areas, including commuting, shopping, and households. The second category includes all factors causing changes in the spatial dispersion like the distribution of industries, employment, or as learned above housing. The third category captures centrality since urban economic theory [23-24] highlighted the relationship between city size, population density, and vehicle kilometers traveled. For example, in low-density areas, public transport is typically provided at lower service frequency rates due to large deficits resulting from low occupancy. Consequently, lower service frequency leads to a shift from public transport to private vehicles, particularly in less compact cities. As a result, not only are distances between points of interest greater in these cities, but the reliance on private modes of transport is also higher, ultimately necessitating more charging infrastructure [24]. The fourth influencing factor is changes in the modal split, which refers to the share of each transport mode in the total number of kilometers traveled [25-26]. This phenomenon is measured by analyzing national vehicle ownership and its development. This data provides insights into the increased or decreased adoption of fleets in the future and serves as an indicator of the extent to which daily activities, such as commuting and shopping, will be covered by public transport or private vehicles. Ultimately, by considering influencing metrics and their impact on charging infrastructure demand and traffic flows over time, it becomes possible to shape and adjust growth estimates according to the unique characteristics of a specific urban environment.

4. DISCUSSION

4.1 Contribution To Current Discourse And Practical Implications

Policymakers at the local, state, and municipal levels are confronted with a significant challenge when it comes to developing plans for electric vehicle charging infrastructure. The existing information ambiguity has caused considerable complexity and imposed substantial pressure on policymakers, who are already challenged by the rapidly evolving socio-economic problems [59]. By transferring the method of greenfield modulations into the context of charging infrastructure this paper tried to address the identified gap related to heterogeneity and the absence of multi-period charging infrastructure planning. As a result, this paper has the potential to be a valuable tool for a range of stakeholders, offering a means for more effective planning and communication. However, it is important to note that the practical utility of the model is contingent upon stakeholders clearly defining their specific environments, calculating the total demand as described, and employing the relative percentage distributions outlined in this paper. Only when these steps are diligently followed can such tools provide absolute numerical values, thus serving as decision-making aids for political decision-makers.

4.2 Limitations

This paper explores the effectiveness of greenfield approaches, which have shown success in various applications in existing literature. However, like other approaches, generalizations and assumptions are necessary to derive solutions that can be broadly applied. In this case, when developing total energy consumption for the eight charging need groups, it is essential to understand that these groups represent averages and are inherently heterogeneous. Individual-level vehicle specifications, driving patterns, and charging behavior vary significantly within each group. For instance, not all commuters have access to workplace charging, and not all home-charging users always plug in their vehicles. Nevertheless, the average charging behaviors of these groups are distinct and are sufficient for analysis and scenario purposes [37]. To ensure practical applicability, it is worth noting that some data (e.g., [20-21]) used in this paper may be outdated for specific purposes due to changes in the population. Stakeholders are encouraged to leverage more current and non-publicly available data they might have access to.

Secondly, as alluded to in the research background, extensive attention has been given to the placement of charging infrastructure in the context of location planning [4]. This paper notably omits the discussion of optimal location estimation and highlights Brenner's [60] recent work on a new method to locate EV charging infrastructures, based on the parallelism between mobility needs and heat equation implemented with Finite Element Method analysis (FEM). Heat density maps show the likely demand points to establish charging infrastructures for EVs. The analysis integrates heat density maps, electricity consumption patterns, and considerations of mains supply capacity. Together, these factors provide valuable insights for determining the optimal location of charging stations in future urban environments. This approach could serve as a valuable addition to our model for identifying suitable locations for charging posts in practical applications.

4.3 Future Research

As previously emphasized, this paper introduces a novel model for quantitative planning charging infrastructure within urban environments by employing a multi-period greenfield modulation approach. However, it's important to note that this is currently a theoretical framework, and its practical utility necessitates validation through real-world applications and the integration of realistic data."

5. CONCLUSION

Charging infrastructure plays a pivotal role in the context of urbanization and the electrification of vehicle fleets. With a substantial concentration of population and wealth in urban regions, there is a corresponding increase in vehicle miles traveled [2]. This underscores the significant macropolitical importance of charging infrastructure for various stakeholders. Policymakers at local, state, and municipal levels encounter formidable challenges when crafting plans for electric vehicle charging infrastructure. The existing information ambiguity has introduced a considerable degree of complexity and has added substantial pressure on policymakers, who are already grappling with rapidly evolving socio-economic issues [59]. Simultaneously, extensive efforts within the literature have been made to develop accurate models for planning charging infrastructure in urban environments. This paper addresses the identified research gap, which pertains to the diversity and the absence of multi-period planning for charging infrastructure. It does so through the development of a greenfield modulation approach that is adaptable across heterogeneous urban environments and over time. While this lays a theoretical foundation, its practical application remains to be validated in real-world use cases. It can be classified as a preliminary communication and an ongoing research effort aimed at aiding stakeholders. Considering the rapid acceleration of these changes due to significant trends, this model provides a robust foundation for future investigations.

5. REFERENCES

1. *Linden, E.; Wittmer, A. Urbaniniserung. In Zukunft Mobilität - Gigatrend Digitalisierung.* CFAC-HSG: St.Gallen, *Switzerland*, 2018. *https://cfac.unisg.ch/en/consulting-research-publications/publications/fachpublikationen-des-cfac*

2. *Mitchell, W. J.; Hainley B. E.; Burns, L. D. Personal Mobility in an Urbanizing World. In Reinventing the Automobile: Personal Urban Mobility for the 21st Century. MIT Press: Cambridge, Massachusetts, 2010. https://doi.org/10.7551/mitpress/8490.001.0001*

3. *Tamay, P.; Inga, E. Charging Infrastructure for Electric Vehicles Considering Their Integration into the Smart Grid. Sustainability 2022, 14, 8248. https://doi.org/10.3390/su14148248*

4. *Anonymous. Systematic literature review of charging infrastructure planning: Requirements for a universal Charging Infrastructure Model. Transport Geography 2023 (submitted).*

5. *Tim Unterluggauer, Jeppe Rich, Peter Bach Andersen, Seyedmostafa Hashemi, Electric vehicle charging infrastructure planning for integrated transportation and power distribution networks: A review, eTransportation,* Volume 12, 2022, 100163, ISSN 2590-1168, *https://doi.org/10.1016/j.* etran.2022.100163

6. **Anastasiadis, E.; Angeloudis, P.; Ainalis, D.; Ye, Q.; Hsu, P.-Y.; Karamanis, R.; Escribano Macias, J.; Stettler, M. On the Selection of Charging Facility Locations for EV-Based Ride-Hailing Services: A Computational Case Study. Sustainability 2021, 13, 168. https://doi.org/10.3390/* su13010168

7. *Zhang, A., Kang, J.E., Kwon, C. Incorporating demand dynamics in multi-period capacitated fast-charging location planning for electric vehicles. Transport. Res. Part B: Methodology 2017, 103, 5–29.*

8. **Alhazmi, Y.A., Mostafa, H.A., Salama, M.M. Optimal allocation for electric vehicle charging stations using trip success ratio. Int. J. Electr. Power Energy Syst. 2017, 91, 101–116.*

9. **Aryandoust, A., van Vliet, O. & Patt, A. City-scale car traffic and parking density maps from Uber Movement travel time data. 2019. https://doi.org/10.1038/s41597-019-0159-6*

10. *Chen, T. Donna, Kara M Kockelman, and Josiah P Hanna. "Operations of a Shared, Autonomous, Electric Vehicle Fleet: Implications of Vehicle & Charging Infrastructure Decisions." Transportation research. Part A, Policy and Practice 94, 2016, 243–254. Web.

11. *Huang Kai, Kanaroglou Pavlos, Zhang Xiaozhou. The design of electric vehicle charging network. Transportation Research D 2016, 49:1–17. 531

12. *Luo C, Huang Y-F, Gupta V. Placement of EV charging stations and balancing benefits among multiple entities. IEEE Trans Smart Grid 2017, 8(2):759e68

13. *Zhang, A., Kang, J.E., Kwon, C. Incorporating demand dynamics in multi-period capacitated fast-charging location planning for electric vehicles. Transport. Res. Part B: Methodology 2017, 103, 5–29.

14. *Zhu, Z.-H., Gao, Z.-Y., Zheng, J.-F., Du, H.-M. Charging station location problem of plug-in electric vehicles. J. Transp. Geography 2016, 52, 11–22.

15. Radanliev, P. Green-Field Architecture for Sustainable Supply Chain Strategy Formulation. International Journal of Supply Chain Management 2015, 2050-7399, Vol. 4, No. 2, pp. 62-67. https://ssrn.com/abstract=2998432

16. Kienzle, F; Andersson, G. A Greenfield Approach to the Future Supply of Multiple Energy Carriers. IEEE Power & Energy Society General Meeting 2009, 1–8. https://doi.org/10.1109/PES.2009.5275692

17. Knieling, J.; Priebs, A. Raumordnung in Deutschland. Braunschweig – Westermann. Spatial Research and Planning 2015, 73(3), pp. 239–240. https://doi.org/10.1007/s13147-015-0339-6

18. Ritter, E.-H.; Benz, A.; David. C.-H.; Schmidt-Aßmann, E.; Wahl, R. . Responsibilities for spatial development policy under the Treaty. In Spatial development policy in the European Constitutional Treaty: position paper from the ARL. Verl. d. ARL: Hannover, Germany, 2003; 3-88838-229-7

19. Zhou, Y., Held, H., Klein, W., Majewski, K., Speh, R., Stelzig, P. E., & Wincheringer, C. SoftGrid: A green field approach of future smart grid. In International Conference on Smart Grids and Green IT Systems 2013, Vol. 2, pp. 5-11. SCITEPRESS.

20. *European Commission - Eurostat/GISCO. The population on 1 January by broad age group, sex, and NUTS 3 region. 2019a. Retrieved from https://ec.europa.eu/eurostat/web/products-datasets/-/demo_r_pjanaggr3 (Accessed February 2023).

21. *European Commission - Eurostat/GISCO. Population on 1st January by age, sex, and type of projection. 2019b. Retrieved from https://data.europa.eu/euodp/en/data/dataset/g33Nsv6Vud3AmmX9EJeOw (Accessed January 2023).

22. *OECD. Rethinking Urban Sprawl: Moving Towards Sustainable Cities. OECD Publishing: Paris, France, 2018. https://doi.org/10.1787/9789264189881-en

23. *Alonso, W. Location and Land Use, Harvard University Press: Cambridge, US, 1964.

24. *Muth, R.-F. Cities and Housing. University of Chicago Press: Chicago, US, 1969.

26. Tal, G.; Lee, J.; Nicholas, M. Observed charging rates in California. UC Davis: Plug-In Hybrid & Electric Vehicle Research Center 2018. https://escholarship.org/uc/item/2038613r

27. Tellier, L.-N. Characterizing urban form by means of the Urban Metric System. Land Use Policy 2021, Volume 111, 104672. https://doi.org/10.1016/j.landusepol.2020.104672

28. Burgess, E. W. The growth of the city: an introduction to a research project. In The City Reader (pp. 212–220). Routledge. 2015. https://doi.org/10.4324/9781315748504-34

29. Blumenfeld, H. The tidal wave of metropolitan expansion. Journal of the American Planning Association 1954, 20(1), 3–14. https://doi.org/10.1080/01944365408979167

30. Schneider, A., & Woodcock, C. E. Compact, dispersed, fragmented, extensive? A comparison of urban growth in twenty-five global cities using remotely sensed data, pattern metrics, and census information. Urban Studies 2008, 45(3), 659–692. https://doi.org/10.1177/0042098007087340

31. Castells, M. Information age: Rise of the network society v.1: Economy, society and culture 1996, Blackwell.

32. *Nicholas, M., Hall, D., & Lutsey, N. Quantifying the electric vehicle charging infrastructure gap across U.S. markets. International Council on Clean Transportation 2019. https://www.theicct.org/publications/charging-gap-US

33. Kraftfahrt-Bundesamt. Bestand an Personenkraftwagen am 1. Januar 2019 nach Bundesländern und ausgewählten Kraftstoffarten absolut. 2019a. https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/b_jahresbilanz.html (Accessed January 2023).

34. Mock, P. CO2 emission standards for passenger cars and light-commercial vehicles in the European Union 2019. Retrieved from the International Council on Clean Transportation, https://www.theicct.org/publications/ldv-co2-stds-eu-2030-update-jan2019

35. Wappelhorst, S.; Nicholas, M. Regional charging infrastructure requirements in Germany through 2030. International Council on Clean Transportation 2020. https://theicct.org/sites/default/files/publications/germany-charging-infrastructure-20201021.pdf

36. European Commission - Eurostat/GISCO. Vehicle registrations by European NUTS 3 statistical areas. 2019. https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts (Accessed January 2023).

37. *European Commission - Eurostat/GISCO.Stock of vehicles by category and NUTS 2 regions. 2018. http://ec.europa.eu/eurostat/product?code=tran_r_vehst&language=en&mode=view (Accessed January 2023).

38. Kraftfahrt-Bundesamt. Kraftfahrzeuge und Kraftfahrzeuganhänger nach Fahrzeugalter 1. Januar 2019 [Inventory on January 1, 2019 by vehicle age]. 2019b. https://www.kba.de/ DE/Statistik/Fahrzeuge/Bestand/Fahrzeugalter/fahrzeugalter_node.html (Accessed January 2023).

39. Nicholas, M., Hall, D., & Lutsey, N. Charging Infrastructure in Cities: Metrics for Evaluating Future Needs. International Council on Clean Transportation 2020. https://doi.org/10.13140/RG.2.2.35006.51529

40. Alrubaie, A.J.; Salem, M.; Yahya, K.; Mohamed, M.; Kamarol, M. A Comprehensive Review of Electric Vehicle Charging Stations with Solar Photovoltaic System Considering Market, Technical Requirements, Network Implications, and Future Challenges. Sustainability 2023. 15, 8122. https://doi.org/10.3390/su15108122

41. Almutairi, A. Impact Assessment of Diverse EV Charging Infrastructures on Overall Service Reliability. Sustainability 2022, 14, 13295. https://doi.org/10.3390/su142013295

42. Kampshoff, P.; Kumar, A.; Peloquin, S.; Sahdev, S. Building the electric-vehicle charging infrastructure America needs. McKinsey & Company 2020. https://www.mckinsey.com/~/media/mckinsey/industries/public%20and%20social%20sector/our%20insights/building%20the%20electric%20vehicle%20charging%20infrastructure%20america%20needs/building%20the%20electric-vehicle-charging-infrastructure-america-needs-vf.pdf

43. Hesson, R. Types of Urban Space, Northern Architecture 2022. https://www.northernarchitecture.us/residential-areas/types-of-urban-space.html (Last Updated on Thu, 29 Jun 2022)

44. Xi, X.; Sioshansi, R.; Marano, V. Simulation-optimization model for the location of a public electric vehicle charging infrastructure. Transportation Research Part D: Transport and Environment 2013, 22, 60–69. https://doi.org/10.1016/j.trd.2013.02.014

45. Pevec, D.; Babic, J.; Kayser, M.-A.; Carvalho, A.; Ghiassi-Farrokhfal, Y.; Podobnik, V. A data-driven statistical approach for extending electric vehicle charging infrastructure. International Journal of Energy Research 2018, 42(9), 3102–3120. 602 https://doi.org/10.1002/er.3978

46. Li, S.; Xie, F.; Huang, Y.; Lin, Z.; Liu, C. Optimizing Workplace Charging Facility Deployment and Smart Charging Strategies. Transportation research. Part D, Transport and Environment 2020. 87. 0. 102481–. Web.

47. Davidov, S. Optimal charging infrastructure planning based on a charging convenience buffer. Energy 2020, 192, 116655. https://doi.org/10.1016/j.energy.2019.116655

48. Gurumurthy, K.-M. & Kockelman, K.; Loeb, B. Sharing vehicles and sharing rides in real-time: Opportunities for self-driving fleets. Advances in Transport Policy and Planning 2019. Volume 4, 2019, Pages 59-85. https://doi.org/10.1016/bs.atpp.2019.09.001

49. Chen, T.-D.; Kockelman, K.-M.; Hanna, J.-P. Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. Transportation Research Part A: Policy and Practice 2016, 94, 243–254. https://doi.org/10.1016/j.tra.2016.08.020 612

50. Loeb, B.; Kockelman, K.-M. Fleet performance and cost evaluation of a shared autonomous electric vehicle (SAEV) fleet: A case study for Austin, Texas. Transportation Research Part A: Policy and Practice 2019, 121, 374–385. https://doi.org/10.1016/j.tra.2019.01.025

51. Frenkel, A.; Ashkenazi, M. Measuring urban sprawl: how can we deal with it? Environment and Planning B: Planning and Design 2008, 35(1), 56–79. https://doi.org/10.1068/b32155

52. *European Commission - Eurostat/GISCO. Conventional dwellings by occupancy status, type of building, and NUTS 3 region. 2011. Retrieved from https://ec.europa.eu/eurostat/web/products-datasets/-/cens_11dwob_r3 (Accessed February 2023).

53. *Open Charge Map. The Open Charge Map API (n.d.). http://openchargemap.org/site/develop/api (Accessed January 2023).

54. *Bundesnetzagentur. Ladesäulenkarte (n.d.). https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ HandelundVertrieb/Ladesaeulenkarte/Ladesaeulenkarte_node.html (Accessed January 2019)

55. *Lemnet. Directory of charging stations for electric vehicles. (n.d.). https://www.lemnet.org/en/home (Accessed January 2023)

56. *Nicholas, M.; Hall, D. Lessons learned on early electric vehicle fast-charging deployments. International Council on Clean Transportation 2018, https://www.theicct.org/publications/fast-charging-lessons-learned

57. *Hall, D.; Lutsey, N. Emerging best practices for electric vehicle charging infrastructure. International Council on Clean Transportation 2017, http://theicct.org/emerging-electric-charging-practices

58. *Kraftfahrt-Bundesamt. Verkehr in Kilometern - Inländerfahrleistung. Kraftfahrt-Bundesamt 2019c. https://www.kba.de/DE/Statistik/Kraftverkehr/VerkehrKilometer/verkehr_in_kilometen_node.html

59. Rahimi, M.; Hafezalkotob, A.; Asian, S.; Martínez, L. Environmental Policy Making in Supply Chains under Ambiguity and Competition: A Fuzzy Stackelberg Game Approach. Sustainability 2021, 13(4):2367. https://doi.org/10.3390/su13042367

60. Brenna, M.; Lazaroiu, G.-C.; Roscia, M.; Saadatmandi, S. Dynamic model for the EV's charging infrastructure planning through finite element method. IEEE-Access 2020, 8, 102399–102408. https://doi.org/10.1109/access.2020.2998783

APPENDIX A

Table 3. *Distribution of housing for the general population in Germany. Note: adapted from [35]*

Category	Single-dwelling buildings	Two-dwelling buildings	Three or more dwelling buildings
Percentage of dwellings	30%	16%	55%
Conventional passenger vehicle stock by dwelling type in 2018	35%	19%	46%
Electric passenger vehicle stock by dwelling type in 2018	60%	16%	24%
Electric passenger vehicle stock by dwelling type in 2030	41%	18%	41%

Table 5. *Indicators influencing charging station growth case over time. Note. Adapted from [35]. 2 NUTS 3 = Nomenclature of territorial units for statistics, CI = Charging Infrastructure*

Category	Indicator	Variable	Source
Population	Population	Population by NUTS 3 statistical area	[20], [21]
Spatial Dispersion	Industry	And future projections	[22]
Spatial Dispersion	Employment	Enterprises by area and future projections	[22]
Spatial Dispersion	Housing	Employees by area and future projections	[52]
Centrality	Centrality	Number of dwellings in houses and apartments	[23], [24]
Modal Split	Vehicle stock	Av. Distance from land use to center.	[25], [26]
Modal Split	EV Registrations	Passenger vehicle stock by NUTS-2	[52], [54], [55]
Modal Split	Existing CI	Registrations EVs (BEVs & PHEVs) by NUTS 3 area	[53], [54], [55]
Modal Split	CI/EV	Counts of charging outlets in Germany	[32], [56], [57]
Modal Split	Charging Behavior	Ratios of electric vehicles to charge points.	[25], [26]
Modal Split	Travel behaviour	Observed charging rates (residential, workplace, public)	[58]

The impact of Supply Chain Management Practices on Organizational Performance and Environmental Sustainability among Export Jordanian Manufacturing Firms

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ABSTRACT

The significance of Supply Chain Management Practices (SCMP) has grown considerably as organizations seek to optimize their operations, maintain competitiveness, and address environmental sustainability concerns. Few studies were found on the impact of SCMP on both environmental sustainability, and organizational performance. This study investigates the comprehensive impact of various critical SCMP dimensions namely, strategic supplier partnership (SSP), customer relationship management (CRM) and lean Practices, on both organizational performance and environmental sustainability. In the dynamic global business landscape, SRM and CRM play vital roles as components of SCMP that influence how organizations manage relationships with their suppliers and customers. Lean practices, which focuses on efficiency and waste reduction, play an integral part in streamlining supply chain processes. Therefore, this study aims to answer two key questions: to what extent do these SCMP dimensions contribute to improved organizational performance? In addition, how do these SCMP dimensions influence environmental sustainability efforts? A conceptual framework has been developed encompassing the previously mentioned constructs and a well-designed questionnaire will be distributed to Jordanian manufacturing companies in order to collect data. Ultimately, this study will contribute to a better understanding of how organizations can balance the pursuit of economic goals with their responsibility towards environmental stewardship in the context of a well-managed supply chain.

Key words: supply chain management; environmental sustainability; supply chain management practices; organizational performance; manufacturing firms; Jordan

1. INTRODUCTION

Supply chain management (SCM) has become an emerging research area during the last decade. SCM is a business activity that has a strategic implication on any organization, therefore identifying the required performance measures is essential. Several definitions of supply chain management were proposed by researchers in literature (Stock and Boyer, 2009) defined SCM as “The management of a network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction". Similarly, Council of Supply Chain Management Professionals (CSCMP) outlines SCM as "a comprehensive process that includes the strategic planning and efficient oversight of all activities related to acquiring goods, transforming them, managing their movement, as well as coordination and collaboration with channel partners." Today`s dynamic global market forces organizations globally and locally not only to have high quality products and services, minimize waste and improve responsiveness but also to have an efficient supply chain management to remain competitive. The first key to achieving an efficient supply chain management practices and its impact on both organizational and environmental performances is recognition(Chesaro, 2016).

Organizational performance refers to how well an organization achieves its market-oriented goals as well as its financial goals (Yamin et al., 1999). A number of prior studies have measured organizational performance using both financial and market criteria, including return on investment (ROI), market share, profit margin on sales, the growth of ROI, the growth of sales, the growth of market share, and overall competitive position (Vickery et al., 1999). Many organizations continue to struggle to understand the complex issues associated with the coordinated planning and supply activities amongst the members of their supply networks despite the significant advances in research and practices (Mutuerandu and Iravo, 2014).One of the core challenges in supply chain management is coordinating the activities and processes among the different members of a supply network. This network typically includes suppliers, manufacturers, distributors, retailers, and other partners. Coordinated planning and execution are necessary to ensure smooth flow of materials, timely deliveries, and efficient use of resources.

According to (Tukamuhabwa et al., 2017) developing countries play an important role in the global supply chain as they are exposed to numerous risks and disruptions because of the political., economic, and cultural conditions. In Jordan, the manufacturing sector directly contributes to about 25% of GDP (Jordan Industry Chamber), therefore it is crucial to investigate the current SCMP and its impact on the overall organizational performance. For example, many previous studies which were conducted in Jordan provided a strong foundation and rationale for conducting further research on the impact of supply chain management practices on organizational performance in Jordanian manufacturing firms. In the context of sustainable development, SCMP should be implemented not just to boost business and supply chain efficiency but also to address environmental, economic, and social concerns. As a result, SCM practices should be used to achieve two goals: improving the performance of individual companies and ensuring that all members of the supply chain succeed in the competitive market. Additionally, companies should take responsibility for environmental matters in SCM and support other sustainable businesses in meeting environmental standards (Le, 2020).

In today`s dynamic business environment, SCMPs play a significant role in streamlining operations, reducing costs, enhancing customer satisfaction, and boosting profitability. Therefore, organizations started to recognize the importance of adopting SCMPs to achieve their goals and sustain their competitive advantage in

the market. Numerous numbers of studies were conducted to empirically investigate the impact of SCMPs on different types of performances like organisational performance, operational performance, and supply chain performance. Notably, the existing literature on this subject primarily focus on advanced nations, leaving a significant research gap in the context of developing countries. In addition to this, many businesses prioritize their financial interests, neglecting the consequences of their operations on environment (Chesaro, 2016).

In the context of Jordan, the German Agency for international cooperation conducted a study in support of ministries of environment, industry, trade, and supply addressing the growing concern about the "disposal of solid textile waste and numerous ready-made clothing items in Jordanian landfills". The study revealed that in the past year only, the textile waste generated by Al-Hassan Industrial City, Irbid amounted to nearly 11,000 tons. Additionally, the study highlighted that amount of waste generated in three phases namely, delivery, production, and storage. The generated waste during the delivery phase of textiles is almost negligible because when the defective imported materials are detected, they will be returned to suppliers for resolution immediately. On the other hand, the fabric waste generated from the cutting process accounts for about 70% of total waste production, generating approximately 23.5 tons of waste daily. As for the storage phase, the study found that waste is estimated at around five tons daily, and most of this waste consists of discarded packaging materials. Therefore, it was concluded that the waste generated from ready-made clothing factories consists of approximately 90% fabric, while packaging materials account for only about 10%. In the light of these findings, it becomes evident that the impact of Supply Chain Management Practices (SCMPs) on environmental sustainability performance is an area of study that holds great importance and emphasize the need to investigate the ways they can help minimize this environmental challenge and improve the sustainability of Jordanian textile industry (Jordan Zad, 2023).

This study aims to answer the following questions: to what extent do these SCMP contribute to improved organizational performance? and how do these SCMPs influence environmental sustainability?

The main objective of the research is to investigate the impact of supply chain management practices on organizational performance and environmental Sustainability among textile export manufacturing firms in Jordan. The sub- objectives include assessing different aspects including the level of supply chain management practices adopted among textile manufacturing firms in Jordan and their direct impact on organizational and environmental performances.

In this study a quantitative method will be employed as a research design, specifically a questionnaire method. The study will be carried out among textile export manufacturing firms in Jordan. Through the questionnaire that will be developed, the questions will focus on achieving research aim and objective.

2.LITERATURE REVIEW

2.1. Review Of SCMPs Dimensions In Previous Literatures

Supply chain (SC) is a complex system that encompasses many organizations and extends beyond the boundaries of an individual entity. It involves the flow of goods, information, and financials from the supplier`s supplier to the customer`s customer. In other words, it is the interconnected network of organizations and activities that contribute to the production and distribution of products (Coyle et al., 2015).

(Christopher, 1998) defined supply chain as "a network of organisations that are involved, through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hand of the ultimate consumer." The Council of Supply Chain Management Professionals (2010) defined supply chain as "the material and informational interchanges in the logistical process, stretching from acquisition of raw materials to delivery of finished products to the end user. All vendors, service providers, and customers are links in the supply chain" (Gibson et al., 2014). The supply chain includes suppliers, manufacturers, distributors, retailers, and customers. The customers are the main focus of the chain, since the primary purpose of the existence of any supply chain is to satisfy customer needs, in the process of generating profit for itself (Habib, 2011).

Scholars and practitioners have been interested in supply chain management (SCM), as an important management theory since the 1980s. SCM was developed and redefined throughout the previous decade from a management procedure to a management philosophy by most organisations as well as institutions (Asgari et al., 2016). The development of supply chain management (SCM) concept as we know it today has evolved through three phases. It started in the 1960s, with the development of physical distribution concept, which only focused on the outbound logistics of finished products. Subsequently, the concept of integrated logistics management which focused on both inbound and outbound logistics occurred in the 1980s. The last phase of development occurred in the 1990s, leading to the contemporary understanding of SCM concept (Coyle et al., 2015).

According to (Mentzer et al., 2001), supply chain management is defined as the "the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for improving the long-term performance of individual companies and the supply chain as a whole". Likewise, the Council of Supply Chain Management Professionals (CSCMP) outlines SCM as a comprehensive process that includes the strategic planning and efficient oversight of all activities related to acquiring goods, transforming them, managing their movement, as well as coordination and collaboration with channel partners.

SCM is seen as an opportunity to improve global competitiveness and increase market share. Many scholars perceive SCM as a significant business practice for improving competitiveness, profitability, and organisational performance (Al-

Shboul et al., 2017, Li et al., 2006). Similarly, (Attia and Salama, 2018) highlighted that Supply Chain Management has become a crucial instrument for enhancing performance and maintaining a competitive edge, as the world is witnessing the growing shift in business competition dynamics, moving away from traditional firm- to-firm rivalry towards a focus on competition within supply chains.

Supply chain management practices (SCMPs) are defined as the set of activities undertaken by an organization to promote effective management of its supply chain (Li et al., 2006). They are considered critical elements that must be met for successful supply chain management. It has been argued that among the latest global business practices, none compete the significance of Supply Chain Management Practices (SCMPs). For example, (Fredendall et al., 2016) see SCMPs as critical to modern organisation success as they can improve operations, supply chains, and company performance. Moreover, (Bayraktar et al., 2009) stated that when businesses collaborate with suppliers, consumers, and competitors while they respond to the changing business environment, they create a partnership that enables the exchange of information and knowledge with the goal of developing cooperative supply chains capable of competing, if not outperforming, others in their industries. These practises are a multidimensional concept that includes both upstream and downstream components of the supply chain. Evaluating and measuring the effectiveness of these dimensions comprehensively mandates the use of an assessment framework or instrument that combines all these dimensions into a structured evaluation tool.

2.2. Review Of SCMPs Dimensions In Previous Literatures

As stated in the above section, SCMPs is multidimensional and has been studied from various perspectives. Therefore, a rich number of literatures studied SCMPs dimensions and empirically validated them. (Li et al., 2006) laid the groundwork for shaping the dimensions and measures of SCMPs. Based on the thorough review of literatures, it was found that Strategic supplier partnership, customer relationship, information sharing, information quality, lean practices, and postponement are the top six dimensions that have been widely investigated in studies investigating the SCMPs-performance nexus in the context of developing and emerging economies. This study will focus on three key dimensions: Strategic Supplier Partnership (SSP), customer relationship management (CRM) and internal lean practice (ILP). A discussion of the three dimensions considered as part of the SCM practice construct is provided below:

2.2.1. Strategic Supplier Partnership (SSP)

Strategic supplier partnership (SSP) is defined by (Li et al., 2006) as “the long-term relationship between the organization and its suppliers”. This means that companies should move away from the transactional, "arm's length" relationships to “durable arm’s length” relationships, indicating a transition from purely transactional interactions to enduring, sustainable, and purposeful relationships, fostering trust, collaboration, and long-term cooperation for mutual benefit. In addition to this, the earlier supplier collaboration in operational activities the better. For instance, product development projects and sharing of product demand forecasts can lead to cost-effective design decisions, optimal component selection, streamlined production, improved product quality, and reduced lead times. The main goal is to enhance the operational and strategic competencies of organizations by forming strategic alliances with suppliers, enabling close collaboration and joint responsibility for product and firm success (Chong et al., 2009).

2.2.2 Customer Relationship Management (CRM)

Customer Relationship Management is defined as “The entire array of practices that are employed for the purpose of managing customer complaints, building long- term relationships with customers, and improving customer satisfaction”.The main activities CRM includes are sharing product information, receiving and processing customers’ orders, maintaining an order placement system , sharing order status updates with customers throughout the order scheduling process, and managing product deliveries (Li et al., 2006).

2.2.3. Internal Lean Practice (ILP)

Lean practices are defined as “the process of removing all the wasted time and resources in the production process. Lean can be considered a philosophy, a work culture, a technique, a management concept, a value or a methodology or an ethos" (Wilson and Roy, 2009). Similarly, (Boyle and Scherrer-Rathje, 2009) confirmed that the focus of lean practices is to identify and eliminate waste across the complete value stream of a product, encompassing not just the organization itself but also throughout its entire supply chain network.

2.3 Organizational Performance

No standardized definition has been accepted to define organizational performance by researchers (Ou et al., 2010). However, many studies defined organizational performance as the extent to which an organization achieves profit- driven goals (Yang et al., 2011). According to (Li et al., 2006) organizational performance is a broad concept that enables companies to assess their business performance by indicating how well their financial and market goals are achieved. Similarly, (Peng Wong and Yew Wong, 2011) defined firm`s performance as the degree of success an organization achieves in both market-oriented and financial goals. According to (Martin and Patterson, 2009), performance can be defined in terms of outcomes such as meeting quantitative goals or being profitable. High- performing firms can have a positive impact not only to the company but to the society, this includes wealth development, employment creation and resource attraction. Therefore, scholars have been increasingly drawn to further investigate the impact of Supply chain management related activities on firm`s performance acknowledging its growing significance as reflected in previous studies.

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Organizational performance is a complex and multi-dimensional concept, indicating that it encompasses numerous aspects and elements (Yang et al., 2011). According to the reviewed studies researchers used diverse indicators to measure a business performance but they can be mainly classified into financial measures and non-financial measures. Financial measures include profit before tax and turnover while non-financial measures focus on issues related to customer`s satisfaction and customers referral rates, delivery time, waiting time and employees' turnover. Recognizing the limitations of depending primarily on financial or non- financial measures, modern corporate executives decided to evaluate their company's performance using both financial and non-financial measures. (Prajapati et al., 2018), for example, evaluated organizational performance by taking operational customer satisfaction and financial factors into account. Similarly, (Vickery et al., 1999), examined organizational performance using a combination of financial and market measurements like Return on investment (ROI), market share, profit margin on sales, ROI growth, sales growth, market share growth, and overall competitive positioning.

This study will examine the impact of SCMP on organizational performance based on both market and financial performance indicators as proposed by previous researchers (Vickery et al., 1999).

2.4 Environmental Sustainability

The main goal of businesses has always been centered on economic reasons. However, the constant rapid changes of business circumstances forced companies to include additional objectives related to sustainability. Companies must engage in sustainable practices and acknowledge their environmental imprint to meet modern societal expectations (Svensson et al., 2016). Sustainable development is defined in the Brundtland Report of the World Commission on Environment and Development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. (Marshall et al., 2014) conducted a study in which they analyzed previous sustainability literatures. Their research findings revealed that sustainability performance is divided into three main dimensions: environmental, economic, and social holding a considerable importance and relevance for research in the fields of operations and supply chain management. Reinforcing this point, (Chardine-Baumann and Botta-Genoulaz, 2014) confirmed that the flow of materials within human society and the exchange of material and energy with the environment lies under SCM responsibility. Therefore, investigating the impact of SCM practices on suitability performance including its three main aspects (Economic, Environmental, and social) is noteworthy. In line with Marshall, (Bandehnezhad et al., 2012) conducted an empirical study on the contribution of lean practices to environmental performance of the manufacturing firms in northern region of Malaysia, affirming that environmental aspects have been the primary focus in earlier sustainability literature. This focus arises from the escalating global awareness on environmental issues and the diverse pressures on businesses to comply with environmental standards (Bandehnezhad et al.,2012).

(Jum'a et al., 2021) refers to environmental sustainability as the practices, actions, and methods that have an obvious positive effect on natural environment. The study stated that previous researchers on environmental sustainability, explored common issues like efforts to reduce air emissions, waste minimization, decreased solid waste generation, the reduction of hazardous materials usage, lower environmental accident rates, and overall enhancement of a company's environmental situation. Nonetheless, a research gap exists concerning the examination of the connections between traditional supply chain management (SCM) practices and environmental sustainability in the context of Jordan, a developing nation. To address this gap in the literature, this study seeks to investigate the relationship between SCM practices and environmental sustainability.

2.5 Hypotheses Development and Conceptual Framework

2.5.1. Effect of SCM Practices on Organizational Performance

(Al-Madi et al., 2021) conducted a study that examined the adoption of supply chain management practices in Jordanian medical devices and their impact on their organizational performance. The SCMPs used in this study include strategic supplier partnership (SSP), customer relationship management (CRM), level of information sharing (LIS), quality of information sharing (QIS), and postponement (POST). The methodology used in this study involves a questionnaire survey to collect data from managers in the top management of medical devices firms. The data collected was analysed using Structural Equation Modelling (SEM) with the help of the Statistical Package for Social Sciences (SPSS) and AMOS:21 software. The study revealed that “level of information sharing" stands out as the most influential, indicating that effective communication and information sharing have a profound effect on enhancing organizational performance. Following closely, "strategic supplier partnership" emerges as the second most influential SCMP, emphasizing the importance of fostering strong and enduring relationships with suppliers to reduce costs and improve product quality. "Customer relationship management" comes next, underlining the significance of prioritizing customer satisfaction and aligning products and services with customer needs. Finally, "postponement" is identified as having the lowest impact on organizational performance, with the belief that delaying operations in this specific context could lead to missed opportunities. The research was specifically focused on the medical devices firms in Jordan, which may constrain the extent to which its results can be extrapolated to different sectors. As a result, it is recommended that future research endeavours encompass a broader range of industries, including manufacturing and services, to enhance the generalizability of the study's findings.

Given the broad range of SC activities, SCM practices suggested by (Li et al., 2006) were adopted on basis of prior discussion. The development of hypotheses are as follows:

H1: SSP positively impact organizational performance.
H2: CRM positively impact organizational performance.
H3: Internal Lean Practices (ILP) positively impact organizational performance.

2.5.2. Effect of SCM Practices on Environmental Sustainability

(Dieste and Panizzolo, 2019) study analysed the transformation journey of three Italian manufacturing companies using lean practices over five years. The practices included flow layout, value stream mapping, kaizen events, spaghetti chart, 5S, Kanban, visual management, and PDCA. Data was collected through questionnaires and interviews, examining the use of lean methods, environmental performance indicators, and the relationship between lean practices and environmental outcomes. The study found that the implementation of lean practices positively impacts environmental performance, contributing to waste reduction, improved resource utilization, and enhanced sustainability. However, the findings may not be generalizable due to the lack of information on the companies' sizes, industries, and the confidentiality of their identities. Similarly, A research conducted by (Yang et al., 2011) made it evident that adopting lean practices yields significant and favourable results for overall organizational performance. These practices are shown to reduce set-up times and work-in-process inventory while improving responsiveness and lead times, consequently leading to improved market performance. Additionally, practices like Six Sigma have a positive influence on financial performance by enabling innovative problem-solving across various business processes, streamlining organizational procedures, and reducing costs. The study findings underscore the significance of implementing lean manufacturing techniques to enhance business performance in both market and financial aspects.

In the context of developing countries, like Jordan, (Abu Hajar et al., 2020) pointed out that the establishment of National Green Growth Plan in 2017, encouraged Jordan to move towards Environmental Sustainability. Reinforcing this point, an empirical study in 221 Jordanian manufacturing firms was conducted by (Al-Ghwayeen and Abdallah, 2018) to assess the impact of green supply chain management (GSCM) on environmental performance and export performance.

The research revealed that GSCM has a positive and significant impact on both environmental and export performance. Moreover, it was found that environmental performance positively mediates the relationship between GSCM and Export performance. In another study, (Abdallah and Al-Ghwayeen, 2019) investigated the impact of GSCM on environmental, operational, and business performances having environmental and operational performances as mediators. The findings indicate that green supply chain management has a positive and significant impact on both environmental performance (EP) and organizational performance (OP). The overall effect of green supply chain management on business performance is positive and significant,while the direct impact of green supply chain management on business performance is negligible and non-significant and the total positive effect is indirect and entirely mediated through EP and OP. (Jum'a et al., 2021), conducted a study to investigate the impact of SCMPs (strategic supplier partnership, customer relationship, level of information sharing, level of information quality and postponement) on environmental sustainability and financial performances. In addition to this, the role of environmental sustainability as a mediator between SCMPs and financial performance was also studied. The data was collected from Jordanian manufacturing firms using a survey questionnaire. The study examined 376 responses and used Structural Equation Modelling (SEM) to test the hypotheses. The results show that certain supply chain practices, such as customer relationship, level of information sharing, level of information quality and postponement, have a significant impact on environmental sustainability. Furthermore, environmental sustainability has a direct impact on financial performance. Eexcept for the strategic supplier partnership, environmental sustainability acts as a mediator between all supply chain management practices and financial performance.

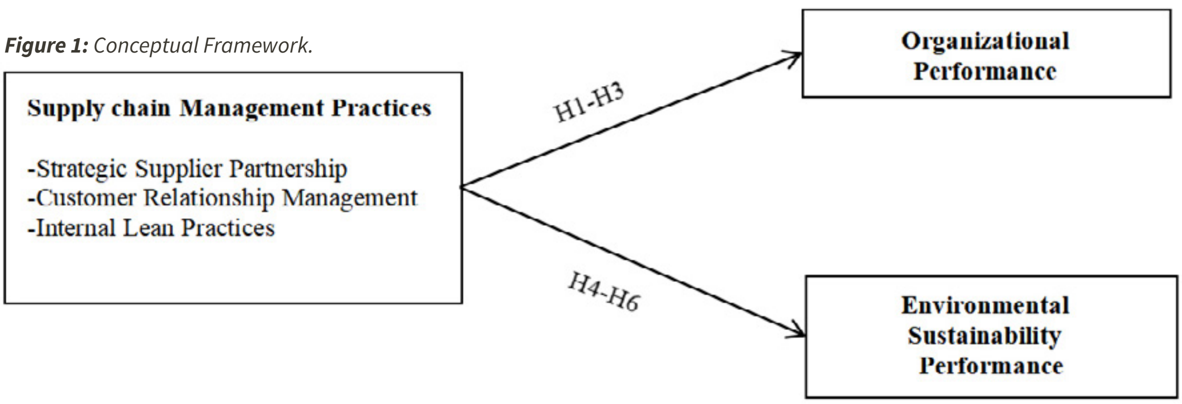
Based on the above literatures, the following hypotheses were developed:

H4: SSP positively impact Environmental Sustainability Performance.
H5: CRM positively impact Environmental Sustainability Performance.
H6: Internal Lean Practices (ILP) positively impact Environmental Sustainability Performance.

2.5.3. Conceptual Framework

As can be noticed from the thorough review of previous literatures, few studies explore the relationship between traditional supply chain management practices and environmental sustainability and according to best of authors knowledge, there is no study focused on exploring the nexus among SCMPs, environmental sustainability practices, and organizational performance in Jordan. Thus, the following conceptual framework has been developed to fill the gap exists in literatures (Figure 1).

Figure 1: *Conceptual Framework.*



3. CONCLUSION

In conclusion, the study`s main objective is to investigate the direct effect of three main SCM practices: strategic supplier partnerships (SSP), customer relationship management (CRM) and internal lean practices (ILP) on two dependent variables which are environmental sustainability and organizational performance in textile manufacturing firms in Jordan. Moreover, it will shed the light on the solid waste problem they are facing. Through the developed conceptual framework and well-structured questionnaire, the data will be collected. The findings of the study will seek to guide organizations in achieving a balance between economic success and environmental responsibility, providing valuable input for strategic decision- making and policy development in the ever-evolving business landscape.

4. REFERENCES

Al-Ghwayeen, W. S. & Abdallah, A. B. (2018). Green supply chain management and export performance. Journal of Manufacturing Technology Management, 29(7), p. 1233-1252.

Abdallah, A. B. & Al-Ghwayeen, W. S. (2019). Green supply chain management and business performance. Business Process Management Journal, 26(2), p. 489- 512.

Abu Hajar, H. A., Tweissi, A., Abu Hajar, Y. A., Al-Weshah, R., Shatanawi, K. M., Imam, R., Murad, Y. Z. & Abu Hajer, M. A. (2020). Assessment of the municipal solid waste management sector development in Jordan towards green growth by sustainability window analysis. Journal of Cleaner Production, 258

Al-Madi, F., Alfalah, T., Shraah, A. & Abu-Rumman, A. (2021). Supply chain practices and organizational performance: Evidence from Jordanian medical devices firms. Uncertain Supply Chain Management, 9(4), p. 831-840.

Al-Shboul, M. D. a. R., Barber, K. D., Garza-Reyes, J. A., Kumar, V. & Abdi, M. R. (2017). The effect of supply chain management practices on supply chain and manufacturing firms' performance. Journal of Manufacturing Technology Management, 28(5), p. 577-609.

Asgari, N., Nikbakhsh, E., Hill, A. & Farahani, R. Z. (2016). Supply chain management 1982–2015: a review. IMA Journal of Management Mathematics, 27(3), p. 353-379.

Attia, A. & Salama, I. (2018). Knowledge management capability and supply chain management practices in the Saudi food industry. Business Process Management Journal, 24(2), p. 459-477.

Bandehnezhad, M., Zailani, S. & Fernando, Y. (2012). An empirical study on the contribution of lean practices to environmental performance of the manufacturing firms in northern region of Malaysia. International Journal of Value Chain Management, 6(2), p. 144-168.

Bayraktar, E., Demirbag, M., Koh, S. C. L., Tatoglu, E. & Zaim, H. (2009). A causal analysis of the impact of information systems and supply chain management practices on operational performance: Evidence from manufacturing SMEs in Turkey. International Journal of Production Economics, 122(1), p. 133-149.

Boyle, T. A. & Scherrer- Rathje, M. (2009). An empirical examination of the best practices to ensure manufacturing flexibility: lean alignment. Journal of Manufacturing Technology Management, 20(3), p. 348-366.

Chardine-Baumann, E. & Botta-Genoulaz, V. (2014). A framework for sustainable performance assessment of supply chain management practices. Computers & Industrial Engineering, 76,p. 138-147.

Chesaro, R. C. 2016. Supply chain management practices and operational performance of multinational manufacturing firms in Kenya. Master`s Thesis.University of Nairobi.

Chong, A. Y.-L., Ooi, K.-B. & Sohal, A. (2009). The relationship between supply chain factors and adoption of e-collaboration tools: an empirical examination. International Journal of Production Economics, 122(1), p. 150-160.

Christopher, M.G. (1998), Logistics and supply chain management; strategies for reducing costs and improving services, London: Pitman Publishing
Coyle, J. J., Novack, R. A., Gibson, B. & Bardi, E. J. (2015). Transportation: a global supply chain perspective, 8th Edition, Boston: Cengage Learning

Dieste, M. & Panizzolo, R. 2019. The Effect of Lean Practices on Environmental Performance: An Empirical Study. Lean Engineering for Global Development.

Fredendall, L. D., Letmathe, P. & Uebe-Emden, N. (2016). Supply chain management practices and intellectual property protection in China. International Journal of Operations & Production Management, 36(2), p. 135-163.

Gibson, B.J., Hanna, J.B., Defee, C.C. & Chen. H. (2014). The Definitive Guide to Integrated Supply Chain Management:Optimize the Interaction Between Supply Chain Processes, Tools, and Technologies, New Jersey :Pearson Education

Habib, M. (2011). Supply Chain Management (SCM): Theory and evolution. In Habib, M. (Ed).Supply Chain Management-Applications and Simulations. Croatia: InTech, pp. 3-19.

Jordan Zad,(2023). Environmental concern from thousands of tons of waste from "Al Hassan Industrial" textiles [available at: https://www.jordanzad.com/index.php?page=article&id=533135, access October 15,

Jum'a, L., Zimon, D. & Ikram, M. (2021). A Relationship between Supply Chain Practices, Environmental Sustainability and Financial Performance: Evidence from Manufacturing Companies in Jordan. Sustainability, 13(4).

Le, T. (2020). The effect of green supply chain management practices on sustainability performance in Vietnamese construction materials manufacturing enterprises. Uncertain Supply Chain Management, 8(1), p. 43-54.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T. S. & Subba Rao, S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. Omega, 34(2), p. 107-124.

Marshall, D., Mccarthy, L., Heavey, C. & Mcgrath, P. (2014). Environmental and social supply chain management sustainability practices: construct development and measurement. Production Planning & Control, 26(8), p. 673-690.

Martin, P. R. & Patterson, J. W. (2009). On measuring company performance within a supply chain. International Journal of Production Research, 47(9), p. 2449-2460.

Mentzer, J. T., Dewitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D. & Zacharia, Z. G. (2001). Defining supply chain management. Journal of Business logistics, 22(2), p. 1-25.

Mutuerandu, M. N. & Iravo, M. (2014). Impact of supply chain management practices on organizational performance: A case study of Haco Industries Limited (Kenya). IOSR Journal of Business and Management, 16(4), p. 62-64.

Ou, C. S., Liu, F. C., Hung, Y. C. & Yen, D. C. (2010). A structural model of supply chain management on firm performance. International Journal of Operations & Production Management, 30(5), p. 526-545.

Peng Wong, W. & Yew Wong, K. (2011). Supply chain management, knowledge management capability, and their linkages towards firm performance. Business Process Management Journal, 17(6), p. 940-964.

Prajapati, H., Kant, R. & Gorane, S. (2018). Impact study of supply chain practices on organisational performance for Indian chemical industries. International Journal of Logistics Systems and Management, 31(1), p. 20-38.

Stock, J. R. & Boyer, S. L. (2009). Developing a consensus definition of supply chain management: a qualitative study. International Journal of Physical Distribution & Logistics Management, 39(8), p. 690-711.

Svensson, G., Høgevold, N. M., Petzer, D., Padin, C., Ferro, C., Klopper, H. B., Sosa Varela, J. C. & Wagner, B. (2016). Framing stakeholder considerations and business sustainability efforts: a construct, its dimensions and items. Journal of Business & Industrial Marketing, 31(2), p. 287-300.

Tukamuhabwa, B., Stevenson, M. & Busby, J. (2017). Supply chain resilience in a developing country context: a case study on the interconnectedness of threats, strategies and outcomes. Supply Chain Management: An International Journal, 22(6), p. 486-505.

Vickery, S. N., Calantone, R. & Dröge, C. (1999). Supply chain flexibility: an empirical study. Journal of supply chain management, 35(2), p. 16-24.

Wilson, M. M. & Roy, R. N. (2009). Enabling lean procurement: a consolidation model for small- and medium- sized enterprises. Journal of Manufacturing Technology Management, 20(6), p. 817-833.

Yamin, S., Gunasekaran, A. & Mavondo, F. T. (1999). Relationship between generic strategies, competitive advantage and organizational performance: an empirical analysis. Technovation, 19(8), p. 507–518.

Yang, M. G., Hong, P. & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. International Journal of Production Economics, 129(2), p. 251–261.

Human Factors and Ergonomics in Logistics Activities by Principles Of Industry 5.0

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ABSTRACT

Industry 5.0 is a concept that overcomes the barriers of its predecessor, Industry 4.0. The previous digitalization standards lacked a focus on a human in every segment of the manufacturing process, as well as the logistics activities. Therefore Industry 5.0 stands for a human-centred, resilient, and sustainable model that raises awareness of the importance of applicability of the principles of human factors and ergonomics. In this paper, the correlation between the implementation of novel and innovative technologies for logistics activities and its impact on human workers will be discussed. Based on the systematic literature review, key principles, methods and tools of human factors and ergonomics that can be applied to logistics activities and their impact on human health, safety, and well-being will be identified.

Key words: Industry 5.0, logistics, human factors, ergonomics, well-being

1. INTRODUCTION

The implementation of Industry 5.0 has nowadays become more optimistic than its predecessor, Industry 4.0. The 4.0 concept of the smart and digital factory with a very high level of process automatization has neglected the role of both existing and future human workers within the system and therefore created many barriers to its implementation. Similarly, to 80's when Computer Integrated Manufacturing was presented and couldn't be implemented due to the unavailability of needed technologies, Industry 4.0 over the past decade was facing similar challenges at a certain point. The technology was available, but in early stages of its development, therefore its price remained very high. Also, there was a significant shortage considering human skills and knowledge, operators who could implement, adapt, and later use the advanced technologies in the real manufacturing systems. At the same time, the high automatization and digitalization level has raised many concerns among the workers who were afraid of job loss but also refused to learn how to use new technologies due to their perceived high complexity. Therefore Industry 5.0 concept was presented to overcome all the barriers recognized over the years and enable the final implementation of flexible and modular systems, adaptive to all the sudden disruptions so the companies can remain competitive in the market. The new system aims towards resilience, sustainability, and human centricity and, just like the previous one, it should be applicable to every industrial sector and level, as well as in the logistics. Due to human-centricity the field of human factors and ergonomics has become very important and crucial not only for worker safety but also for their wellbeing which impacts productivity and efficiency. Therefore, the purpose of this research is to acknowledge the key principles, methods, and tools of human factors and ergonomics that can be applied to logistics activities based on the state-of-the-art findings in the present literature.

2. METHODOLOGY

To get an insight into the current literature findings, the most relevant database Web of Science was searched, in the timespan 2011 (the year Industry 4.0 was introduced) to 2023. Parallel with the introduction of Industry 4.0 the barriers were recognized and the possible solutions to overcome them were given which is why the works related to Industry 4.0 (not only 5.0) were included in this research. To get a complete overview of human factors and ergonomics in logistics activities, the following keywords were searched:

(1) Logistics AND Industry 5.0 – to get an insight into the specific technologies and principles used in Logistics 5.0 and to understand the context in which human factors and ergonomics should be included (147 records found)
(2) Logistics AND human-centered – to get an insight into what the human- centricity in logistics represents (90 records found)
(3) Logistics AND human factors and ergonomics – to get an overview of tools and methods of human factors and ergonomics in logistics activities and its impact on them (178 records found).

Among the 415 records found, 65 of them were chosen for the final review, based on their relevancy to the topic.

3. LOGISTICS AND INDUSTRY 5.0

The implications of smart logistics in Industry 5.0 are rarely discussed, according to (Jafari, Azarian and Yu, 2022) so the features of smart logistics in Industry 5.0 should be concerned with four areas: (1) intelligent automation, (2) intelligent devices, (3) intelligent systems and (4) intelligent materials. Smart logistics in Industry 5.0 is focused on the interaction between humans and technology and the increasing need for the adoption of collaborative systems.

Industry 5.0 is still in the conceptual stage and implementation can yet only be segmental. Literature related to supply chains in Industry 5.0 is limited, but Organizations' leadership, policymakers, and other practitioners involved in supply chains, and mainly those currently working with Industry 4.0 initiatives, need to have clear guidance regarding the dimensions needed to structurally design and implement an Industry 5.0 strategy (Frederico, 2021).

The novel concept of Logistics 5.0 should address the high complexities in logistics Cyber Physical Social Systems. It should accelerate the shift towards intelligent and sustainable logistics while human-oriented operating systems provide intelligent solutions. Logistics 5.0 serves as a critical catalyst in realizing 6S objectives, which are: (1) Safety, (2) Security, (3) Sustainability, (4) Sensitivity, (5) Service, and (6) Smartness (Li et al., 2019). The continuous development of technologies leads to significant progress in achieving sustainability, accessibility, and efficiency of logistics activities. Mobility 5.0 has the potential to shape a new era of intelligent logistics and transport and could bring benefits not only to the industry but also to individuals and society as a whole (Lin et al., 2023).

Digital twin drives Industry 4.0 and is also a crucial part of the supply chain. In the development stage, the importance of digital twins in Industry 4.0 was observed, as big data, machine learning, the Industrial Internet of Things, blockchain, edge computing, and cloud-based systems complemented digital twin models. Digital twin can be applied to improve sustainability in manufacturing and production logistics. Focus is set on the integration of deep learning, data models, and artificial intelligence for digitalization. COVID-19 pandemic drove the start of the prosperity stage of digital twin research in the supply chain while the researchers in this field are slowly moving towards applying digital twin for human-centric systems and mass personalization to prepare to transition to Industry 5.0 (Lam, Lam and Lee, 2023).

Physical Internet (PI) is an open global logistics system in which components are hyperconnected for increased efficiency and sustainability. Digital twin is well- perceived as a key driver in the development of PI-based Supply Chain Management (SCM). Due to the capabilities of real-time monitoring and evaluation of large-scale complex systems, significant research efforts have been made to exploit the values of PI/DT in SCM. Clustered into ten key research streams on PI/DT applications are: job shop scheduling, smart manufacturing design, PI-based SCM, manufacturing virtualization, information management, sustainability development, data analytics, manufacturing operations management, simulation, optimization and assembly process planning. Future potential emphasize on several PI/DT-related issues, including business ecosystem, sustainability development, SC downstream management, cognitive thinking in Industry 5.0, citizen twin in a digital society, and SC resilience (Nguyen Ngoc, Lasa and Iriarte, 2022). Cloud Computing has been part of the logistic processes that enable better supply chain integration, warehousing services, and transportation support. Also, it comes with certain risks, the lowest in customer service activities and the highest in procurement activities (Maniah and Milwandhari, 2020).

The cloud supply chain can be a business model based on cloud-enabled networking of some third-party physical and digital assets to design and manage a supply chain network. The main characteristics of the cloud supply chain are related to (1) multistructural dynamics; (2) platforms, digital supply chains, ecosystems, and visibility, (3) dynamic service composition with dynamically changing buyer/supplier roles, (4) resilience and viability, and (5) intertwined supply networks and circular economy (Ivanov, Dolgui and Sokolov, 2022).

There is a constant demand for a fast supply of logistics at the lowest cost which has brought pressure to the manufacturing industries. One of the possible methods to fulfil customer requirements is the development of the IIoT for smart manufacturing and logistics systems to minimize time and cost while maximizing customer satisfaction and organizational profit. IIoT can be a platform for optimal route identification, real- time monitoring of vehicles and their parameters such as fuel, wheel axel, and engine vibration, temperature monitoring, and customized design of maintenance schedules to improve efficiency in transport. In using the IIoT system, 77-98% in overall performance was found with an increase in customer satisfaction, process efficiency, decreasing cost of operation with energy efficiency and low latency performance of the new IIoT-based framework (Bhargava et al., 2022).

The Internet of Things enables the interconnection of physical objects, real-time monitoring, and decision support. Humans still play a significant role while XR technologies enable immersive visualization that can strengthen the connection between the human and cyber-physical systems. Therefore an important tool in human-centric supply chains are XR solutions (Tsang et al., 2022).

Data interoperability is one of the core principles of Industry 5.0 and the supply chain visibility must be aligned with socially, economically, and environmentally sustainable objectives. All the aspects of data sharing in SCs may be brought together in service of the paradigm of I5.0 (Khan and Abonyi, 2022). The existing mathematical models for supply chain planning can put an emphasis on lean manufacturing from the aspects of flexibility, resilience, and sustainability. The goal is to obtain a more autonomous supply chain (Reyes, Mula and Díaz-Madroñero, 2023).

The implementation of artificial intelligence and robotic technologies leads to many changes in logistics sectors. The past data such as the numbers of use and sales value of the service robots in the logistics sector, along with the environmental data (i.e. CO2 emission) allows the prediction of the different stages of robotic logistics technologies and its future benefits (Oran and Cezayirlioglu, 2021).

The human aspect of working with automated guided vehicles (AGV) has been neglected in Industry 4.0, while there are many challenges the companies face in this field. Human- and organisation-related challenges arise with the introduction of AGVs, i.e. supporting the AGVs with new work procedures for managing AGV errors, determining what different operators need to know about AGVs, and developing acceptance among employees (Thylén, Wänström and Hanson, 2023). (AI)-based logistics Unmanned Aerial Vehicles (UAVs) have been widely applied in intelligent transportation systems due to their advantages of faster speed, lower cost, more environment-friendly, and less manpower needed. Most of the existing UAV models have neglected energy consumption. To minimize the total energy cost a cooperative path planning problem via jointly optimizing the route of the logistics UAVs and the service allocation is developed by a Large Neighbourhood Search Algorithm (LNS) to accelerate the convergence rate of the Genetic Algorithm (GA), and then develop an improved GA based cooperative path planning algorithm (IGCPA). Simulation results have shown that the energy cost of IGCPA is reduced by 17.35%, 15.18% and 9.99% compared with GA, LNS and Particle Swarm Optimization (PSO). Sensitivity analysis of the maximum UAV load and battery capacity reveals that the distribution cost tends to decrease and then increase as the increase of maximum load and battery capacity (Du et al., 2023).

An efficient order-picking system is the core of a high-performing warehouse. Humans have specific skills and perceptions, which should be taken in mind in such models. A Toolset of five modeling constructs was proposed: (1) varying work rates,

(2) quantitative physical state indicators, (3) stochastic worker behavior and work execution, (4), subjective worker experience and judgment, and (5) socio- demographic worker differentiations (De Lombaert et al., 2023).

Speech recognition technology can be used in logistics picking systems. This is how walking time can be reduced while the workflow is simplified. It also improves data transmission accuracy and both picking and economic efficiency (Fu and Sun, 2018). New assistive technologies, such as exoskeletons, are perspective in use in logistics systems. The interest in its implementation is increasing, while the evaluation of efficiency and cost-effectiveness should be studied before its implementation (Ashta et al., 2023). The implementation of digital technologies in logistics activities should be strategically defined to maximize future benefits and shorten the ROI period. The strategy can be defined with the aid of a decision support system by the unique goals the company has set by calculating the readiness factor in which both operators and management should be included (Trstenjak et al., 2022).

Current megatrends, such as the aging population, growing urbanization, shifts in consumer demands, geopolitical shifts, depletion of natural resources, and climate change, influence the supply chain, while digitalization trends support such changes. Five supply chain capabilities as prevalent and mostly fitting the external contingencies, i.e., customer-driven, urban-centered, resource-efficient, fast reactive, and human-centered supply chains are recognized (Pessot et al., 2023).

Digital development of logistics activities goes hand in hand with sustainable and green solutions, but the research results that the awareness of this concept remains relatively low while the implementation of novel technologies is rather passive than active (Trstenjak et al., 2023). Logistics systems should be re-thinked from a human- centered perspective. The balance between automation and digital technologies and human work should be achieved due to several irreplaceable capabilities of operators. Human-machine integration, human-robot collaboration, worker assistance systems and work design 4.0 are the most common challenges during the transformative process. It is necessary to rethink the traditional workforce, taking care of human factors and therefore achieve a sustainable system of novel logistics solutions (Cimini et al., 2022). Industry 5.0 should provide resilient operator 5.0 with more intuitive, symbiotic, human-centered, and cognitive working computing environments to enhance human adaptation capabilities, productivity, and mental health. This is enabled through the combination of softbots and augmented reality, called augmented softbots. Such software prototype has been implemented for the purposes of preventive maintenance (Zambiasi et al., 2022). The skills of the worker remain the challenge inherited from the Industry 4.0 concept. Special competencies, such as lean thinking or data science skills are yet to be developed for educational purposes while academia must continuously follow and implement new trends. The competence profile of Industry 5.0 is related to education in logistics, but, surprisingly, the research has shown that there are no significant differences in job performance and job satisfaction related to the levels of competence of the worker (Pacher, Woschank and Zunk, 2023).

4. HUMAN FACTORS AND ERGONOMICS IN LOGISTICS ACTIVITIES

There are many activities machines cannot imitate which is why human work remains important. As the system gets more complex, the human factors must be considered for its performance to remain high. (Kumcu and Ozyoruk, 2022).

Analysis of the impact of technology on human work is part of the human-centered smart logistics processes due to the increased complexity of systems, which is why in-depth knowledge of each activity and related human aspects is needed (Lagorio et al., 2023). When designing in a human-centered manner there is a dilemma between technological feasibility and labour-politically desirability, under the constraint of an economically reasonable design of work and technology (Dregger et al., 2018). The role of human factors and ergonomics in logistics activities, based on the resources found in the literature, in the following chapters will be discussed by topics of implementation of novel technologies and managerial challenges it brings.

4.1. Implementation of novel technologies

The role of digital technologies in industrial logistics processes has become pivotal. Digitalization might increase the complexity of processes in terms of integration and management.

Wearable devices (Handheld Computers (picking order information), Voice-Direct Headsets (voice picking), Smart Glasses (pick-put to light), Activity Trackers (steps, heart-rate), Exoskeletons (lifting and moving), Wearable Scanners); AVS/RS (AGVs (picking and moving) Smart Fast Rotation Storage Systems Smart Trasloelevators Smart Mini-Loaders Smart Lifts and Forklifts); Drones (Drones (inventory, picking and moving) Collaborative Robots (picking)); and logistics robots (Collaborative Robots (load-n'-unload, inspection, kitting, and packing), Industrial Robots (inspection, kitting and packing), and Labelling Systems) are most common novel and digital technologies which demand certain point of human interaction which should be optimized to enable the proper utilization of the hardware.

Each activity can be enabled by certain assistive hardware for human operators. I.e. for picking those are Exoskeletons (lifting assistance), Automated Guided Vehicles- AGV, Drones, and Collaborative Robots; for packaging and delivering: Collaborative Robots (inspection, kitting, and packing); storage and stowage: Exoskeletons (moving), AGVs (moving), Drones (moving) and Collaborative Robots (load-n'- unload)); material handling: Exoskeletons (moving), AGVs (moving), drones (moving) and collaborative Robots (load-n'-unload)) (Lagorio et al., 2023).

With the use of smart devices, there is a need to provide the assessment of the cognitive ergonomics by of evaluation cognitive workload. Research results by (Kreutzfeldt, Renker and Rinkenauer, 2019) showed that the participants were slower in using smart glasses compared to a headset, however, with smart glasses, they were less distraction-prone and more flexible in their responses. They suggest that smart glasses may be more suitable for conveying information in rather complex tasks relying on visual information whereas headsets may be more suitable for simple tasks in uncluttered environments.

The human grasp investigation can also lead to further development of the robots equipped with an intelligent picking system and grasp planning algorithms from the viewpoint of the ergonomics (Li et al., 2019).

In the implementation of AGV-s the focus is mostly set on the machines, rather than their influence on humans. This has raised certain challenges in the interactions between the human, technology and organization such as supporting the AGVs with new work procedures for managing AGV errors, determining what different operators need to know about AGVs, and developing acceptance among employees (Thylén, Wänström and Hanson, 2023).

4.1.1. Exoskeletons

Exoskeletons have the potential to prevent the musculoskeletal disorders and improve the ergonomic principles of a workplace in demanding activities. They aren't adopted on the level to fulfill their full potential, which is often criticized by the experts. There are various support effects of both active and passive exoskeletons. Exoskeletons can cause different biomechanical effects on the human body concerning their level of support and the angle-dependent curve shape. Passive and active exoskeletons led to significantly reduced muscle activations in certain movement phases. Although exoskeletons can cause the desired muscular relief in the targeted body region, they can also lead to additional stress in other body parts (Ralfs et al., 2023). Passive exoskeletons appear more suitable for tasks requiring relatively light assistance and little dynamic movements, while heavier and more dynamic tasks will justify the use of more complex active exoskeletons. Most back-support exoskeletons are implemented using rigid articulated structures, which tend to be heavy and bulky, but generate more appropriate patterns of forces. Fewer soft exoskeletons have been developed to date, although they could be integrated with or worn underneath standard working attire and offer greater user comfort (Toxiri et al., 2018).

Work-related musculoskeletal disorders are considered nowadays the most serious issue in the Occupational Health and Safety field while industrial exoskeletons appear to be a new approach to addressing this challenge. Exoskeletons are not a complete solution technology, neither for workers nor for job tasks; but they show potential in static activities, while in dynamic tasks, they can obstacle regular job performance. Comfort and easiness of use are the key factors influencing the user's experience (Baldassarre et al., 2022).

4.1.2. AR and AI

Augmented reality (AR) can facilitate many tasks. It extends the user's perception and can improve their performance. Pervasive AR is developed by human-centered design principles which supports the training of logistics operators. It enables identification of operators' difficulties, and challenges and defines the requirements by using Head- Mounted Display (HMD) and Handheld Device (HHD). Operators consider the use of AR as more useful and efficient in supporting the operators' activities on the shop floor (Maio et al., 2023). Palletisation largely depends on the employee's performance and expertise. There are several advantages to the use of AR in palletization activities, while compared to the conventional paper-based pick list and tabled, AR provides a less strenuous method to assist participants in palletization, which makes it appropriate to use, but the useability should be improved considerably (Kretschmer et al., 2018). A number of errors can be reduced while at the same time, handling times can be prolonged when the AR device is used in palletization. In all experimental conditions of the research by (Plewan et al., 2021), performance improved in the course of the experiment. At the same time, the utility of the AR is limited when the task demands are low. AR technologies, such as smart glass allow workers to perform tasks hands-free while viewing real-time, task-relevant information within their visual field of view. Poorly designed interfaces for smart glasses may distract workers, yet the potential lays in using well-designed AR HWD technology to improve workplace safety and health. This and earlier studies suggest that smart glasses can have important implications for human/task performance as well as workplace safety and health (Kim, Nussbaum and Gabbard, 2016). Picking operation can also be improved using mounted display solutions for order picking task, but little research has been put on comfort of head mounted displays such as smart glasses and how to alter them to increase their product lifecycle (Smith et al., 2021). No significant difference in device preference regardless of task type is shown and despite the side-weighted arrangement being the most comfortable, the participants still were uncomfortable. Artificial intelligence (AI) technologies and learnable systems can transform logistics, but their use in collaboration between humans and machines remains a challenge. To overcome the challenges, special training of the workforce is needed, specifically work-based training. The concept of reciprocal learning has emerged and is seen as one of the possible paths toward the human-centered systems (Nixdorf et al., 2022) while the human characteristics must be included in various mathematical planning models (Grosse et al., 2017).

4.1.3. Digital twin

Digital twins can combine the strengths of humans and machines. In such a system, the operator uses cognitive advantage for specific support when the machine reaches its limits. This is an emerging topic, as an enabler of digital transformation toward smart factories. Less research focuses on the role of the digital twin in quantifying, evaluating, and providing ergonomics, mental or physical workload, posture feedback, or warnings to workers, aiming to improve their safety conditions in logistics systems (Berti and Finco, 2022). Digital Human Modelling is one of the essential parts of the smart factory which brings ergonomic aspects into focus. However, little attention was given to the macro-ergonomic analyses, using simulation methods. Micro-ergonomic human models primarily consider anthropometric and work-physiological aspects, but hardly any work-psychological or work-sociological issues. In addition, there is a lack of software procedures for evaluating the work environment in the Digital Factory, which was noticed by (Zülch, 2021).

4.2. Managerial challenges

The transformation towards Industry 5.0 remains a black box for many companies, while the new management approaches can help to successfully overcome the future challenges in logistics. The adoption of advanced control tools for real-time monitoring allows the development of accurate planning models and enables proactive decision-making. Human workers remain very important but less considered. The human-centric logistics system includes the consideration of the diversity of human workers and an in-depth integration of Industry 4.0 technologies in operations processes to support the development of smart and sustainable systems (Sgarbossa et al., 2020).

Decision support tools enable the definition of criteria to choose the best technology and adopt it according to the requirements of the company. It highlights the better understanding of human factors involved to avoid potential critical issues related to technological changes i.e. need for additional investment in training, or identification of required skills (Lagorio et al., 2023). A multi-criteria approach for choosing the optimal alternative to material handling should have taken into consideration the ergonomics aspects to satisfy the company's objectives related to both ergonomic criteria and production performance measures (Rossi et al., 2013).

Many studies that take human factors into consideration focus either on designing the workplace or on operation planning activities. Little has been published on production and logistics systems that incorporate human factors and that combine different levels of short-term operational policy decisions (e.g. job allocation) and long-term system characteristic decisions (e.g. layout design). The novel framework should incorporate human factors into production and logistics systems by combining different levels of decisions to improve performance, quality, and well-being (Vijayakumar and Sgarbossa, 2020).

4.2.1. Skills and competency of workers

Due to changes, logistics will need highly skilled workers. The change of roles reads to transfer from the executive work to computer systems. This leads to the need for acceptance of lifelong learning for Logistics 5.0 which would develop skills such as ICT Competency, critical thinking, innovative thinking, and self-learning. Critical thinking includes analytical competencies, understanding as the ability to analyze, evaluate, interpret, and infer information; the ability to synthesize information, and understanding as the ability to combine parts or elements. ICT competency can be defined as the ability to constantly identify and locate resources of required information, to acquire and transform information for specific needs. Innovative approach means as ability to rethink things and create them from the beginning without past models, forms, or styles. Self-learning competency is understood as the ability to acquire knowledge without interference with the teacher (Wrobel- Lachowska et al., 2018).

To cope with challenging tasks, companies should develop qualification strategies. Within the competency model, the future competencies for operational and planning activities should be included. It consists of professional, methodological, social, and personal competencies while considering the process for implementation and future adjustments of logistics processes. This can conduce to strategic personal planning (Kohl et al., 2020).

Technology acceptance increases when there is a good environment inside the company. These results suggest that workers were generally accepting of the digital procedures and that worker perceptions of perceived usefulness perceptions likely have an indirect effect on procedure deviation frequency (Hendricks et al., 2023).

The aging population at the workplace is becoming challenging, while raising several concerns of aging operators, such as their physical, cognitive, ergonomic, and well- being conditions (Alves, Lima and Gaspar, 2022).

4.2.2. Cognitive workload – cognitive ergonomics

The relationship between the 4.0 technologies and the implementation of human factors showed that technology tends to replace logistics operators, not only for dangerous physical tasks but also for cognitive tasks that are stressful and repetitive. Moreover, for some tasks in which many different human factors are involved, the evolution is towards operator assistance, rather than replacement (Cimini et al., 2022). Companies are more dependent on manual human work because of their cognitive ability and flexibility, but at the same time, many decision support models in logistics systems have neglected the characteristics of human workers which could lead to worsening of working conditions. Therefore, the workload evaluation is very important, while the aspects of physical, mental, and psychosocial influences must be included. Evaluation tools such as NMQ, NASA TLX, SWAT, and JCQ can be used in this case (Vijayakumar and Sgarbossa, 2020).

Picking operations can be studied from the cognitive perspective. The combination of the cognitive architecture of the operation can decrease the amount of human error and increase the service level. The model by (Caro, Quintana and Castillo, 2017) provided evidence for three logistic factors, namely, the picking zone type, the order difficulty level, and the experience level; furthermore, from the cognitive perspective, attention and memory. In complex manual assembly, cognitive and chronobiology aspects of work can contribute to fatigue and degrade worker performance. High fatigue is more common during evening shifts. Mental demands and frustration can be predictors of high fatigue. Therefore, in novel manufacturing systems cognitive workload of workers should be considered, in terms of work schedule planning, shift duration, task complexity, etc. Sleep duration can also be one of the predictions of fatigue, but this can be subjective. The most often used scales in cognitive workload evaluation is the NASA-TLX scale and Samn-Perelli Fatigue Scale (Torres, Nadeau and Landau, 2021). Monotony related fatigue, as an isolated case, by the increase of the automation level, might increase in the future more often (Bier et al., 2020).

5. CONCLUSION

As the barriers of Industry 4.0 are being resolved, implementation of Industry 5.0 seems more and more realistic. With the continuous technology development which increases its availability on the market, the concept of digital and smart factories is more common to the manufacturers, as well in the logistic sector. Industry 5.0 represents a human-centric, resilient, and sustainable system, which gives very high importance to human factors and ergonomics and all related methods and tools. The inherited technologies from Industry 4.0, according to the literature are segmentally implemented into logistics activities and at the same time, their potential to incorporate human factors and ergonomics has become clearer. Novel assistive hardware, such as exoskeletons, smart glasses, and other wearables, and related software (AR, AI) and their use in logistics activities have been proven to increase productivity, reduce the risk of injuries, and enable the human worker to deal with more complex tasks. The use of digital twins and digital human modelling enables the real-time monitoring of both the activities and condition of the human worker, but also the efficient process optimization by the ergonomic principles of the workplace. Implementation of a human-centred system raises also certain managerial challenges such as the improvement of workers' skills and knowledge through lifelong learning concepts but also the aspects of cognitive ergonomics which must be taken into consideration to avoid the potential threats of monotonous work and fatigue.

6. REFERENCES

Alves, J., Lima, T.M. and Gaspar, P.D. (2022) 'The sociodemographic challenge in human-centred production systems – a systematic literature review', Theoretical Issues in Ergonomics Science, 0(0), pp. 1–23. Available at: https://doi.org/10.1080/1463922X.2022.2148178.

Ashta, G. et al. (2023) 'Passive Exoskeletons to Enhance Workforce Sustainability: Literature Review and Future Research Agenda', Sustainability, 15(9), p. 7339. Available at: https://doi.org/10.3390/su15097339.

Baldassarre, A. et al. (2022) 'Industrial exoskeletons from bench to field: Human- machine interface and user experience in occupational settings and tasks', Frontiers in Public Health, 10. Available at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1039680 (Accessed: 19 October 2023).

Berti, N. and Finco, S. (2022) 'Digital Twin and Human Factors in Manufacturing and Logistics Systems: State of the Art and Future Research Directions', IFAC- PapersOnLine, 55(10), pp. 1893–1898. Available at: https://doi.org/10.1016/j.ifacol.2022.09.675.

Bhargava, A. et al. (2022) 'Industrial IoT and AI implementation in vehicular logistics and supply chain management for vehicle mediated transportation systems', International Journal of System Assurance Engineering and Management, 13(1), pp. 673–680. Available at: https://doi.org/10.1007/s13198-021-01581-2.

Bier, L. et al. (2020) 'How to measure monotony-related fatigue? A systematic review of fatigue measurement methods for use on driving tests', Theoretical Issues in Ergonomics Science, 21(1), pp. 22–55. Available at: https://doi.org/10.1080/1463922X.2018.1529204.

Caro, M., Quintana, L. and Castillo, J. (2017) 'Preliminary cognitive model of a semi- mechanized picking operation', IFAC-PapersOnLine, 50(1), pp. 13958–13963. Available at: https://doi.org/10.1016/j.ifacol.2017.08.2219.

Cimini, C. et al. (2022) 'Human-technology integration in smart manufacturing and logistics: current trends and future research directions', Computers & Industrial Engineering, 169, p. 108261. Available at: https://doi.org/10.1016/j.cie.2022.108261.

De Lombaert, T. et al. (2023) 'In pursuit of humanised order picking planning: methodological review, literature classification and input from practice',

International Journal of Production Research, 61(10), pp. 3300–3330. Available at: https://doi.org/10.1080/00207543.2022.2079437.

Dregger, J. et al. (2018) 'Challenges for the future of industrial labor in manufacturing and logistics using the example of order picking systems', Procedia CIRP, 67, pp. 140–143. Available at: https://doi.org/10.1016/j.procir.2017.12.190.

Du, P. et al. (2023) 'AI-based energy-efficient path planning of multiple logistics UAVs in intelligent transportation systems', Computer Communications, 207, pp. 46–55. Available at: https://doi.org/10.1016/j.comcom.2023.04.032.

Frederico, G.F. (2021) 'From Supply Chain 4.0 to Supply Chain 5.0: Findings from a Systematic Literature Review and Research Directions', Logistics, 5(3), p. 49. Available at: https://doi.org/10.3390/logistics5030049.

Fu, T. and Sun, B. (2018) 'Application of Speech Recognition Technology in Logistics Selection System', in Q. Zu and B. Hu (eds) Human Centered Computing. Cham: Springer Internatio-

nal Publishing (Lecture Notes in Computer Science), pp. 654–659. Available at: https://doi.org/10.1007/978-3-319-74521-3_68.

Grosse, E.H. et al. (2017) 'Incorporating human factors into decision support models for production and logistics: current state of research', IFAC-PapersOnLine, 50(1), pp. 6900–6905. Available at: https://doi.org/10.1016/j.ifacol.2017.08.1214.

Hendricks, J.W. et al. (2023) 'Workers' Acceptance of Digital Procedures: An Application of the Technology Acceptance Model', IISE Transactions on Occupational Ergonomics and Human Factors, 11(1–2), pp. 59–68. Available at: https://doi.org/10.1080/24725838.2023.2240342.

Ivanov, D., Dolgui, A. and 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, 160, p. 102676. Available at: https://doi.org/10.1016/j.tre.2022.102676.

Jafari, N., Azarian, M. and Yu, H. (2022) 'Moving from Industry 4.0 to Industry 5.0: What Are the Implications for Smart Logistics?', Logistics, 6(2), p. 26. Available at: https://doi.org/10.3390/logistics6020026.

Khan, A.A. and Abonyi, J. (2022) 'Information sharing in supply chains – Interoperability in an era of circular economy', Cleaner Logistics and Supply Chain, 5, p. 100074. Available at: https://doi.org/10.1016/j.clscn.2022.100074.

Kim, S., Nussbaum, M.A. and Gabbard, J.L. (2016) 'Augmented Reality "Smart Glasses" in the Workplace: Industry Perspectives and Challenges for Worker Safety and Health', IIE Transactions on Occupational Ergonomics and Human Factors, 4(4), pp. 253–258. Available at: https://doi.org/10.1080/21577323.2016.1214635.

Kohl, M. et al. (2020) 'Competency Model for Logistics Employees in Smart Factories', in W. Karwowski, S. Trzcielinski, and B. Mrugalska (eds) Advances in Manufacturing, Production Management and Process Control. Cham: Springer International Publishing (Advances in Intelligent Systems and Computing), pp. 133– 145. Available at: https://doi.org/10.1007/978-3-030-20494-5_13.

Kretschmer, V. et al. (2018) 'Smart Palletisation: Cognitive Ergonomics in Augmented Reality Based Palletising', in W. Karwowski and T. Ahram (eds) Intelligent Human Systems Integration. Cham: Springer International Publishing (Advances in Intelligent Systems and Computing), pp. 355–360. Available at: https://doi.org/10.1007/978-3-319-73888-8_55.

Kreutzfeldt, M., Renker, J. and Rinkenauer, G. (2019) 'The Attentional Perspective on Smart Devices: Empirical Evidence for Device-Specific Cognitive Ergonomics', in F. Rebelo and M.M. Soares (eds) Advances in Ergonomics in Design. Cham: Springer International Publishing (Advances in Intelligent Systems and Computing), pp. 3–13. Available at: https://doi.org/10.1007/978-3-319-94706-8_1.

Kumcu, S. and Ozyoruk, B. (2022) 'Bibliometric Analysis of Research on Human Factors in Logistics', in J. Xu et al. (eds) Proceedings of the Sixteenth International Conference on Management Science and Engineering Management – Volume 1. Cham: Springer International Publishing

(Lecture Notes on Data Engineering and Communications Technologies), pp. 643–657. Available at: https://doi.org/10.1007/978-3-031-10388-9_47.

Lagorio, A. et al. (2023) 'Operationalisation and validation of a human factors-based decision support framework for technology adoption in the logistics sector', International Journal of Logistics Research and Applications, 0(0), pp. 1–23. Available at: https://doi.org/10.1080/13675567.2023.2235298.

Lam, W.S., Lam, W.H. and Lee, P.F. (2023) 'A Bibliometric Analysis of Digital Twin in the Supply Chain', Mathematics, 11(15), p. 3350. Available at: https://doi.org/10.3390/math11153350.

Li, Z. et al. (2019) 'Factors affecting human hand grasp type in tomato fruit-picking: A statistical investigation for ergonomic development of harvesting robot', Computers and Electronics in Agriculture, 157, pp. 90–97. Available at: https://doi.org/10.1016/j.compag.2018.12.047.

Lin, Y. et al. (2023) 'Mobility 5.0: Smart Logistics and Transportation Services in Cyber-Physical-Social Systems', IEEE Transactions on Intelligent Vehicles, 8(6), pp. 3527–3532. Available at: https://doi.org/10.1109/TIV.2023.3286995.

Maio, R. et al. (2023) 'Pervasive Augmented Reality to support logistics operators in industrial scenarios: a shop floor user study on kit assembly', The International

Journal of Advanced Manufacturing Technology, 127. Available at: https://doi.org/10.1007/s00170-023-11289-1.

Maniah and Milwandhari, S. (2020) 'Risk Analysis of Cloud Computing in the Logistics Process', in 2020 Third International Conference on Vocational Education and Electrical Engineering (ICVEE). 2020 Third International Conference on Vocational Education and Electrical Engineering (ICVEE), pp. 1–5. Available at: https://doi.org/10.1109/ICVEE50212.2020.9243247.

Nguyen Ngoc, H., Lasa, G. and Iriarte, I. (2022) 'Human-centred design in industry 4.0: case study review and opportunities for future research', Journal of Intelligent Manufacturing, 33(1), pp. 35–76. Available at: https://doi.org/10.1007/s10845-021- 01796-x.

Nixdorf, S. et al. (2022) 'Reciprocal Learning in Production and Logistics', IFAC- PapersOnLine, 55(10), pp. 854–859. Available at: https://doi.org/10.1016/j.ifacol.2022.09.519.

Oran, İ. and Cezayirlioglu, H. (2021) 'AI - Robotic Applications in Logistics Industry and Savings Calculation', Journal Of Organizational Behavior Research, 6, pp. 148–165. Available at: https://doi.org/10.51847/jUXQmvCvqf.

Pacher, C., Woschank, M. and Zunk, B.M. (2023) 'The Role of Competence Profiles in Industry 5.0-Related Vocational Education and Training: Exemplary Development of a Competence Profile for Industrial Logistics Engineering Education', Applied Sciences, 13(5), p. 3280. Available at: https://doi.org/10.3390/app13053280.

Pessot, E. et al. (2023) 'Empowering supply chains with Industry 4.0 technologies to face megatrends',

Journal of Business Logistics, 44(4), pp. 609–640. Available at: https://doi.org/10.1111/jbl.12360.
Plewan, T. et al. (2021) 'Exploring the benefits and limitations of augmented reality for palletization', *Applied Ergonomics*, 90, p. 103250. Available at: https://doi.org/10.1016/j.apergo.2020.103250.

Ralfs, L. et al. (2023) 'Insights into evaluating and using industrial exoskeletons: Summary report, guideline, and lessons learned from the interdisciplinary project "Exo@Work"', *International Journal of Industrial Ergonomics*, 97, p. 103494. Available at: https://doi.org/10.1016/j.ergon.2023.103494.

Reyes, J., Mula, J. and Díaz-Madroñero, M. (2023) 'Optimisation Modeling for Lean, Resilient, Flexible and Sustainable Supply Chain Planning', in F.P. García Márquez et al. (eds) *IoT and Data Science in Engineering Management*. Cham: Springer International Publishing (Lecture Notes on Data Engineering and Communications Technologies), pp. 341–345. Available at: https://doi.org/10.1007/978-3-031-27915- 7_60.

Rossi, D. et al. (2013) 'A multi-criteria ergonomic and performance methodology for evaluating alternatives in "manuable" material handling', *International Journal of Industrial Ergonomics*, 43(4), pp. 314–327. Available at: https://doi.org/10.1016/j.ergon.2013.04.009.

Sgarbossa, F. et al. (2020) 'Human factors in production and logistics systems of the future', *Annual Reviews in Control*, 49, pp. 295–305. Available at: https://doi.org/10.1016/j.arcontrol.2020.04.007.

Smith, E. et al. (2021) 'A comfort analysis of using smart glasses during "picking" and "putting" tasks', *International Journal of Industrial Ergonomics*, 83, p. 103133. Available at: https://doi.org/10.1016/j.ergon.2021.103133.

Thylén, N., Wänström, C. and Hanson, R. (2023) 'Challenges in introducing automated guided vehicles in a production facility – interactions between human, technology, and organisation', *International Journal of Production Research*, 61(22), pp. 7809–7829. Available at: https://doi.org/10.1080/00207543.2023.2175310.

Torres, Y., Nadeau, S. and Landau, K. (2021) 'Evaluation of Fatigue and Workload among Workers Conducting Complex Manual Assembly in Manufacturing', *IISE Transactions on Occupational Ergonomics and Human Factors*, 9(1), pp. 49–63. Available at: https://doi.org/10.1080/24725838.2021.1997835.

Toxiri, S. et al. (2018) 'Rationale, Implementation and Evaluation of Assistive Strategies for an Active Back-Support Exoskeleton', *Frontiers in robotics and AI*, 5, p. 53. Available at: https://doi.org/10.3389/frobt.2018.00053.

Trstenjak, M. et al. (2022) 'Logistics 5.0 Implementation Model Based on Decision Support Systems', *Sustainability*, 14(11), p. 6514. Available at: https://doi.org/10.3390/su14116514.

Trstenjak, M. et al. (2023) 'Use of Green Industry 5.0 Technologies in Logistics Activities', *Tehnički glasnik*, 17(3), pp. 471–477. Available at: https://doi.org/10.31803/tg-20230518185836.

Tsang, Y.P. et al. (2022) 'How is extended reality bridging human and cyber-physical systems in the IoT-empowered logistics and supply chain management?', Internet of Things, 20, p. 100623. Available at: https://doi.org/10.1016/j.iot.2022.100623.

Vijayakumar, V. and Sgarbossa, F. (2020) 'Tools for Evaluating Human Factor Aspects in Production and Logistics System', in B. Lalic et al. (eds) Advances in Production Management Systems. The Path to Digital Transformation and Innovation of Production Management Systems. Cham: Springer International Publishing (IFIP Advances in Information and Communication Technology), pp. 591–598. Available at: https://doi.org/10.1007/978-3-030-57993-7_67.

Wrobel-Lachowska, M. et al. (2018) 'ICT in Logistics as a Challenge for Mature Workers. Knowledge Management Role in Information Society', in R.H.M. Goossens (ed.) Advances in Social & Occupational Ergonomics. Cham: Springer International Publishing (Advances in Intelligent Systems and Computing), pp. 171–178. Available at: https://doi.org/10.1007/978-3-319-60828-0_18.

Zambiasi, L.P. et al. (2022) 'Supporting Resilient Operator 5.0: An Augmented Softbot Approach', in D.Y. Kim, G. von Cieminski, and D. Romero (eds) Advances in Production Management Systems. Smart Manufacturing and Logistics Systems: Turning Ideas into Action. Cham: Springer Nature Switzerland (IFIP Advances in Information and Communication Technology), pp. 494–502. Available at: https://doi.org/10.1007/978-3-031-16411-8_57.

Zülch, G. (2021) 'Guidelines of the German Association of Engineers for Evaluating Human Work in the Digital Factory', IISE transactions on occupational ergonomics and human factors, 9 (3–4), pp. 223–232.

Factors affecting adoption of Enterprise Resource Planning Systems and their impact on Supply Chain Integration in Jordanian Manufacturing Organizations

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ABSTRACT

Enterprise Resource Planning (ERP) systems are gaining a lot of attention as a crucial tool for enhancing efficiency in operations and supply chain integration in industrial firms all around the world. This study focuses on the variables affecting the adoption of ERP systems and investigates their effects on supply chain integration in the context of Jordanian manufacturing enterprises. To investigate the mentioned objectives, this study will rely on a questionnaire distributed among a representative sample of employees in Jordanian Manufacturing Organizations. The study identifies various factors that influence the adoption of ERP systems, including Organizational Culture (OC), Technological Support Infrastructure, and Top Management Support (TMS). The impact of ERP adoption on supply chain integration including supplier integration, customer integration, and internal integration is also examined. Supply chain integration refers to the extent to which ERP systems enable seamless information flow and collaboration among supply chain partners. It encompasses both internal integration within the organization and external integration with suppliers, distributors, and customers. This study will provide valuable insights for manufacturing organizations in Jordan seeking to adopt ERP systems and achieve supply chain integration. Decision-makers can use the highlighted variables as a guide when determining if ERP adoption inside their organizations is ready and appropriate. The research will also emphasize the significance of taking proactive steps to promote smooth integration and optimize the advantages of ERP systems, including top management support, employee training, and alignment with organizational goals.

PROBLEM STATEMENT

The adoption of Enterprise Resource Planning (ERP) systems and their impact on supply chain integration are critical concerns for Jordanian manufacturing organizations. Understanding the factors that influence ERP adoption and their subsequent effects on supply chain integration is essential for organizations aiming to enhance operational efficiency and competitiveness. Therefore, this study aims to address this gap by investigating the factors influencing the adoption of ERP systems and assessing their impact on supply chain integration in Jordanian manufacturing organizations.

LITERATURE REVIEW

Hwang and Min (2015) conducted a research titled "Identifying the drivers of enterprise resource planning and assessing its impacts on supply chain performances ", the goal of the research was to list all of the factors that either help or hinder the implementation of ERP in commercial settings. This study also identified its function in supply chain operations and evaluated how it affects supply chain performance. In this study, the authors carried out three phases: a pre-pilot; a pilot; and a large-scale questionnaire survey. It was found that the decision of a firm to adopt and implement ERP is primarily influenced by its internal environment. Contrary to common belief, the firm's external environment has minimal impact on its decision regarding ERP adoption and implementation. However, the external environment can indirectly influence the decision through its mediating effect on the internal environment. Additionally, the authors discovered that ERP can enhance the organizational capability and supplier capability of firms that adopt it.

The research conducted by Abro et al. (2017) titled "Antecedents of Enterprise Resource Planning and its Impact on Firm Performance with Supply Chain Integration as mediating factor" aimed to examine the mediating role of supply chain integration in the association between ERP implementation and firm performance. The study focused on ten organizations located in the Kingdom of Saudi Arabia. The target population consisted of senior-level managers with knowledge about their respective organizations. The sample for the study included 70 managers from the ten selected organizations in Saudi Arabia. The research employed an analytical descriptive approach and utilized a questionnaire to gather data. After applying appropriate statistical methods, the study revealed several key findings, notably indicating that supply chain integration acts as a mediating factor in the relationship between ERP implementation and firm performance.

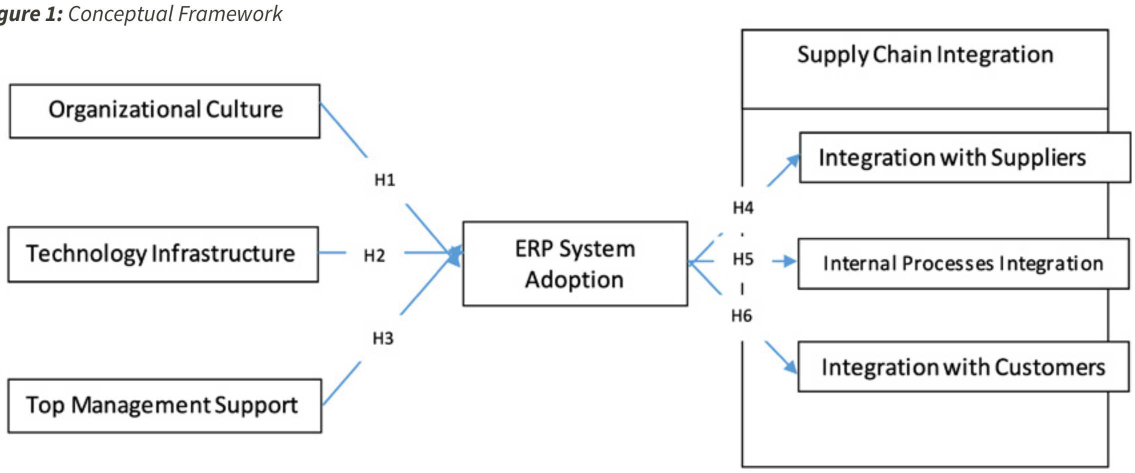
Aremu, Shahzad, and Hassan (2021) investigated the impact of ERP usage on the performance of medium enterprises (MEs). They developed a framework to examine the mediating role of ERP usage in the relationship between ME performance and eight factors: organizational culture, communication process, organizational structure, IT readiness, technological changes, information access, government policies, and support of technology infrastructure. The results of the study demonstrated that the adoption of ERP systems would enhance the performance of MEs.

Al-Qudah (2020) examined the impact of ERP System Usage on Supply Chain Integration at Jordanian Pharmaceutical Manufacturing firms. A total of 183 individuals were randomly selected from various departments (Human Resource, Financial, Production, Supply Chain, Operations & Quality) within Jordanian Pharmaceutical Manufacturing firms to form a representative sample for the study. The analysis was conducted using SPSS and Amos software. The study utilized a questionnaire and employed Structural Equation Modeling (SEM) to achieve its research objectives. The findings indicated a significant positive impact of Customer Relationship Management System, Inventory Management System, Financial Management System, and production and operation Management System on Integration with Supplier, Integration with Customer, and internal processes integration. The study concluded that there is a statistically significant relationship between the adoption of ERP system and Integration with Supplier, Integration with Customer, and internal processes integration in Jordanian Pharmaceutical Manufacturing firms. Additionally, the study highlighted the substantial contribution of ERP system in promoting supply chain integration within the context of Jordanian Pharmaceutical Manufacturing firms.

Alimohamadian and Abdi (2014) conducted a study titled "Exploring the impact of information technology on supply chain integration: The mediating role of ERP success." The aim of the study was to examine the mediating effect of ERP success in the relationship between information technology and supply chain integration. The research was conducted in Tehran, Iran, and involved companies operating in that region. The study population comprised three Iranian companies with a total of 325 employees. A sample of 163 employees was randomly selected for the study. An analytical descriptive approach was adopted, and data was collected through a questionnaire. The findings of the study revealed a positive relationship between ERP success and supply chain integration.

CONCEPTUAL MODEL

Figure 1: *Conceptual Framework*



EXPECTED OUTCOME

- Determine Key driving factors of ERP adoption.

- Identify the impact of ERP system on supply chain integration dimensions at Jordanian Manufacturing Organizations (JMOs), including integration with suppliers, internal processes integration, and integration with customers.

- To offer recommendations and guidance for manufacturing companies in Jordan to improve the use of ERP systems and assist supply chain integration, while taking organizational culture, technological infrastructure, and top management support into consideration.

CONTRIBUTIONS

This research aims to contribute to the existing body of knowledge by providing insights into the factors influencing ERP adoption and their impact on supply chain integration in Jordanian manufacturing organizations. The findings will help organizations in Jordan understand the importance of organizational culture, technological support infrastructure, and top management support in successful ERP adoption. Moreover, the research will shed light on the implications of ERP adoption on supplier integration, customer integration, and internal integration, providing practical recommendations for enhancing supply chain integration. The outcomes of this study will serve as a valuable resource for manufacturing organizations in Jordan and can potentially inform ERP adoption strategies and practices in other similar contexts.

By providing insights into these specific factors and their interrelationships, the research offers valuable knowledge to guide organizations in their efforts to adopt ERP systems successfully and enhance supply chain integration, ultimately contributing to improved operational efficiency and competitiveness.

REFERENCES

Abro, M., Memon, Z., Shah, A., and Naqvi, I. (2017). Antecedents of Enterprise Resource Planning and its Impact on Firm Performance with Supply Chain Integration as mediating factor. Mehran University Research Journal of Engineering and Technology, 36 (2), 407-418.

Agha, W. A., Ragheb, M. A., and Shawky, A. Y., (2019). Transformational leadership as a critical success factor for the enterprise resource planning system implementation. Open Access Library Journal, 6(2), 1–27. DOI: 10.4236/oalib.1105243.

Alimohamadian, S., and Abdi, F. (2014). Analyzing the effects of information technology on supply chain integration: The role of ERP success mediator. Management Science Letters, 4, 799-806.

Al-Qudah, H. S. S. (2020). Impact of ERP System Usage on Supply Chain Integration: A Structural Equation Modeling, Jordanian Pharmaceutical Manufacturing Case study. Journal of Economics and Business, 3(2). https://doi.org/10.31014/aior.1992.03.02.233

Annan, J., Boso, N., Mensah, J., and Nagbe Sulee, E. (2016). Antecedents and Consequences of Supply Chain Integration: Empirical Evidence from a Developing Economy. International Journal of Supply Chain Management, 5(1), 10-24.

Aremu, A.Y.; Shahzad, A.; Hassan, S., (2021). The empirical evidence of enterprise resource planning system adoption and implementation on firm's performance among medium-sized enterprises. Glob. Bus. Rev. 22, 1375–1404.

Brady, J.A., Monk, E.F. and Wagner, B.J. (2001), Concepts in Enterprise Resource Planning, Course Technology-Division of Thomson Learning, Boston, MA.

Cao, Z., Huo, B., Li, Y., and Zhao, X. (2015). The impact of organizational culture on supply chain integration: a contingency and configuration approach. Supply Chain Management: An International Journal, 20(1), 24-41.

Huo, B., Han, Z., Chen, H., and Zhao, X. (2015). The effect of high-involvement human resource management practices on supply chain integration. International Journal of Physical Distribution & Logistics Management, 45 (8), 716-746.

Hwang, D. M., & Min, H. (2015). Identifying the drivers of enterprise resource planning and asses-

sing its impacts on supply chain performances. Industrial Management and Data Systems, 115(3), 541–569. https://doi.org/10.1108/imds-10-2014-0284

Hwang, D., & Min, H. (2015). Identifying the drivers of enterprise resource planning and assessing its impacts on supply chain performances. Industrial Management & Data Systems, 115(3), 541-569.

Hwang, W., & Min, H. (2013). Assessing the impact of ERP on supplier performance. Industrial Management & Data Systems, 113(7), 1025-1047.

Mehrjerdi, Y. Z., (2010). Enterprise resource planning: Risk and benefit analysis. Business Strategy Series, 11(5), 308–324, https://doi.org/10.1108/ 17515631011080722.

Sukati, I., Hamid, A. B. A., Baharun, R., Alifiah, M. N., and Anuar, M., A. (2012). Competitive advantage through supply chain responsiveness and supply chain integration. International Journal of Business and Commerce, 1(7), 1-11.

Tarigan, Z. J. H., Siagian, H., and Bua, R.R., (2018). The impact of information system implementation to the integrated system for increasing the supply chain performance of manufacturing companies. IOP Conf. Series: Materials Science and Engineering, 473, 012050.

Tarigan, Z. J. H., Siagian, H., and Jie, F. (2020). The role of top management commitment to enhancing the competitive advantage through ERP integration and purchasing strategy, International Journal of Enterprise Information Systems, 16 (1), DOI: 10.4018/IJEIS.202001010.

Yu, W., Jacobs, M. A., Salisbury, W. D., and Enns, H. (2013). The effects of supply chain integration on customer satisfaction and financial performance: An organizational learning perspective. International Journal of Production Economics, 146 (1), 346-358

Zhao, L., Huo, B., Sun, L., and Zhao, X. (2013). The impact of supply chain risk on supply chain integration and company performance: a global investigation. Supply Chain Management: An International Journal, 18(2), 115-131

Assessment of Procuremenet Practices using Portfolio Analysis at a selected Company

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ABSTRACT

This research aims to assess procurement operations through a case study conducted at a Selected Company. By employing portfolio analysis techniques, data related to procurement activities is collected and analyzed to identify opportunities for improvement. Comparative analysis is performed to align the results with the company's data, evaluating the effectiveness of the analysis and providing actionable recommendations. The study contributes insights for strategic decision-making, supplier selection, risk management, and cost-reduction efforts in procurement.

Keywords: procurement, portfolio analysis, comparative analysis

RESEARCH PROBLEM

The research problem for the graduation project titled "Assessment of Procurement Practices: A Case Study Comparing Portfolio Analysis with Company Data" is to investigate and evaluate the effectiveness of portfolio analysis as a procurement strategy in a real-world business context. This study aims to address the question of whether portfolio analysis, when applied to supplier management, results in improved procurement practices, cost-efficiency, and overall supply chain performance.

OVERVIEW

Procurement practices play a critical role in the success and sustainability of organizations. Efficient supplier management is vital for achieving cost savings, ensuring quality and reliability, and mitigating risks in the supply chain. Portfolio analysis, which involves categorizing suppliers based on their strategic importance and performance, is a well-established approach used by companies to make informed decisions about their suppliers. This project seeks to assess the utility of portfolio analysis in the context of procurement and supply chain management by comparing its outcomes to actual company data.

PROBLEM STATEMENT (PORTFOLIO ANALYSIS FOR SUPPLIERS)

The specific problem addressed in this research is to evaluate whether the implementation of portfolio analysis for suppliers positively impacts a company's procurement practices. Portfolio analysis involves classifying suppliers into categories based on predefined criteria such as strategic importance, performance, and risk exposure. However, the extent to which this categorization effectively guides procurement decisions and contributes to overall supply chain success remains a topic of interest. The problem statement can be articulated as follows:

"To what extent does the application of portfolio analysis in supplier management lead to improved procurement practices, cost-efficiency, and supply chain performance in a real-world business environment, and how does this compare to the actual company data?"

This research problem is at the heart of the graduation project, and addressing it will provide valuable insights into the effectiveness of portfolio analysis as a procurement strategy, helping organizations make informed decisions in supplier management and procurement practices.

LITERATURE REVIEW

Efficient procurement practices play a crucial role in enhancing organizational performance and achieving sustainability goals. The use of portfolio analysis has emerged as a valuable approach for assessing and optimizing procurement practices. This literature review examines relevant studies that have applied portfolio analysis in the assessment of procurement practices and highlights their contributions.

Torres-Ruiz and Ravindran (2018) propose a multiple criteria framework for sustainability risk assessment in a supplier portfolio. Their study emphasizes the importance of considering sustainability factors in procurement decision-making, providing insights into the evaluation and selection of suppliers based on sustainability performance.

Aloini, Dulmin, Mininno, and Zerbino (2019) focus on leveraging procurement-related knowledge through a fuzzy-based decision support system (DSS). Their study contributes to refining purchasing portfolio models and offers a valuable tool for assessing and managing procurement portfolios more effectively.

Gelderman and Van Weele (2003) address measurement issues and strategic directions within Kraljic's purchasing portfolio model. Their research highlights the need for a comprehensive understanding of measurement aspects and aligning strategic objectives with procurement portfolio management.

Knight, Tu, and Preston (2014) explore the integration of skills profiling and purchasing portfolio management, emphasizing the opportunity to build purchasing capability. Their study showcases the importance of aligning procurement practices with the skills and competencies of the purchasing team.

Chowdhury, Paul, Sianaki, and Quaddus (2020) examine the dynamic sustainability requirements of stakeholders and their influence on the supply portfolio. Their research emphasizes the need to consider evolving sustainability demands in procurement decision-making processes, providing insights for managing procurement portfolios in a dynamic environment.

These studies collectively contribute to the understanding and application of portfolio analysis in the assessment of procurement practices. They highlight the significance of considering sustainability, refining models, addressing measurement issues, integrating skills profiling, and accommodating dynamic stakeholder requirements. By applying these insights to the assessment of procurement practices at a selected company, valuable recommendations can be developed to enhance procurement performance and sustainability outcomes.

EXPECTED OUTCOMES

The research on " Assessment of Procurement Practices: A Case Study Comparing Portfolio Analysis with Company Data" may lead to the identification of key performance indicators (KPIs) and metrics, providing recommendations for procurement processes. It can compare portfolio analysis techniques, offer insights into risk management, assess the business value generated, and provide implementation guidelines for leveraging data-driven approaches.

EXPECTED CONTRIBUTION

This research contributes to the field of procurement assessment by focusing on the application of portfolio analysis techniques within a specific case study context. The originality lies in the integration of portfolio analysis methods with company data, which provides a novel approach to assessing procurement operations. By combining theoretical concepts with real-world data, the research brings a unique perspective to the field.

The research makes several significant contributions to the field. Firstly, it extends the existing body of knowledge on procurement assessment by demonstrating the practical application of portfolio analysis techniques. This offers valuable insights into how companies can effectively manage their procurement activities using data-driven approaches.

Secondly, the research provides a comprehensive case study that showcases the implementation and outcomes of portfolio analysis within a specific company. The findings and recommendations derived from this case study can serve as a practical guide for other organizations facing similar challenges in procurement assessment.

Additionally, the research contributes to the understanding of risk management in procurement. By exploring the role of portfolio analysis in identifying and mitigating risks, it offers valuable insights into how companies can proactively manage uncertainties and improve decision-making in these domains.

Overall, the research not only advances theoretical knowledge but also offers practical implications for managers and practitioners in the field of procurement. It provides a valuable resource for organizations seeking to assess their operations and enhance performance through portfolio analysis techniques.

REFERENCES

Torres-Ruiz, A., & Ravindran, A. R. (2018). Multiple criteria framework for the sustainability risk assessment of a supplier portfolio. Journal of Cleaner Production, 172, 4478-4493.

Aloini, D., Dulmin, R., Mininno, V., & Zerbino, P. (2019). Leveraging procurement-related knowledge through a fuzzy-based DSS: a refinement of purchasing portfolio models. Journal of Knowledge Management.

Gelderman, C. J., & Van Weele, A. J. (2003). Handling measurement issues and strategic directions in Kraljic's purchasing portfolio model. Journal of purchasing and supply management, 9(5-6), 207-216.

Knight, L., Tu, Y. H., & Preston, J. (2014). Integrating skills profiling and purchasing portfolio management: An opportunity for building purchasing capability. International Journal of Production Economics, 147, 271-283.

Chowdhury, M. M. H., Paul, S. K., Sianaki, O. A., & Quaddus, M. A. (2020). Dynamic sustainability requirements of stakeholders and the supply portfolio. Journal of Cleaner Production, 255, 120148.

Leadership Behaviours for the effective use of Lean Six Sigma: *Jordan*

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ABSTRACT

This research project aims to explore the leadership behaviours that facilitate the effective use of Lean Six Sigma, whereby organisations and leaders can realise the required behaviours to use the Lean Six Sigma successfully. This research studies leadership from a behavioural lens. This mitigation is needed to enable organisations to improve their journey to reach elevated Lean Six Sigma performance levels in the workplace.

This research asks: how can leadership behaviours facilitate the use of Lean Six Sigma? In order to answer this question, a grounded theory methodology was used to collect and analyse the qualitative data. From that, the framework developed was grounded on the data. In other words, identifying the required leadership behaviours was based and grounded on the themes that emerged from the data analysis. Twenty-seven interviews were conducted and, through analysing these interviews, thirty-six aspects of leadership behaviours emerged. The researcher made a constant comparison to let the aspects emerge during data analysis. These aspects were given to the participants in the focus group workshop to group them into core categories (themes). The researcher adopted and relied on three sources to identify the possible leadership behaviours to develop the proposed framework. These sources are a focus group workshop, interviews analysis, and the literature. The framework is a series of leadership behaviours that target specific themes. These leadership behaviours can positively support themes that influence Lean Six Sigma, which enables the effective use of Lean Six Sigma in the manufacturing sector. Eight themes emerged that influence the successful use of Lean Six Sigma emerged: (1) Training and development; (2) Continuous improvement and development; (3) Communication; (4) Empowering employees; (5) Motivating employees; (6) Managing qualities and operations; (7) Employees engagement and involvement; and (8) Supporting culture.

The framework was validated through experts' judgment from industry. The experts' feedback was this framework is comprehensive and covers all topics. They believe that adopting these behaviours can lead to achieving the desired goal, which enhances operations efficiency.

This research has contributed to facilitating the effective use of Lean Six Sigma by identifying the leadership behaviours required for the successful use of the Lean Six Sigma. This identification would be helpful for organisations practising or about to use Lean Six Sigma to understand what leaders should do and how they should behave to address the challenges of using Lean Six Sigma. In addition, the list of leadership behaviours would be a base for developing formal Lean Six Sigma leadership development programmes. They can be used to evaluate leaders' effectiveness and provide training programmes about appropriate leadership behaviours for Lean Six Sigma.

How does the Prosthetic Industry benefit from Additive Manufacturing Technologies? A Supply Chain Perspective

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PURPOSE

The study evaluates how additive manufacturing technologies improve prosthetic supply chain capabilities in terms of customization level, innovativeness, production flexibility and responsiveness, sustainability and efficiency, by developing a literature-based theoretical model of the main areas that have changed after using the 3D-printing technologies in the prosthetic supply chain. Additionally, it explores the impact of adopting these technologies in the Jordanian prosthetic industry, which prompted structuring an empirical model.

DESIGN METHODOLOGY / APPROACH

A qualitative approach was employed in this study, where data were collected based on field observations and 21 in-depth interviews conducted in several Jordanian organizations related to the prosthetic industry and the 3D-printing technologies. The methodological triangulation technique was adopted, by gathering information from literature, field observations and interviews. The interviews sample was selected by following two strategies; the convenience sampling strategy and the snowballing strategy.

FINDINGS

Adopting the 3D-printing technologies has improved the capabilities of the prosthetic supply chain in terms of customization, efficiency, innovativeness, production flexibility responsiveness, sustainability and production quality. This research provides clarification on what are the affected areas in the prosthetic supply chain after adopting the 3D-printing technologies. Furthermore, it shows that adopting the 3D-printing technologies in the Jordanian prosthetic industry improved the capabilities of the supply chain, where the Jordanian prosthetic industry is utilizing 3D-printing technologies to improve patient customization. The ultra-postponement strategy is deployed with 3D-printing technologies adoption, which has impacted inventory and production strategies, leading to changes in raw material composition and volume reduction. Also, it was concluded that, 3D-printing technologies eliminate finished products and prosthetic components inventory and production approaches become design-to-order and/or engineer-to-order, depending on organizational capabilities and policies. Additionally, adopting 3D-printing technologies in the Jordanian prosthetic industry enhances the provided level of customization to patients and the innovativeness in the prosthetic supply chain, due to enhancement in factors like, types of 3D-prinitng inputs, labor backgrounds and skills, digital

tools usage (digital data files, supportive technological tools and online ordering systems). Furthermore, the prosthetic supply chain has shown improved flexibility and responsiveness across all partners, with 3D-printing technologies adoption. Also, this phenomena leads to changes in supply base composition, assembly line rationalization, delivery approaches, warehousing optimization, and emergence of new supply chain parties (3D-printing service providers, local resellers of the 3D-printable raw materials and 3D-printers, 3D-printers suppliers, 3D-printing technical advisors, 3D-design advisors, 3D-prosthetic designers, NGOs and 3D-printing manufacturing hubs). The Jordanian prosthetic industry has successfully adopted 3D-printing technologies, resulting in reducing waste generation, reducing external and internal environmental impacts, improving production cleanliness, reducing power consumption, and improving degradability of 3D-printable wastes. This adoption has improved the quality of prosthetic production processes and devices, with improvements in design, scanning, measuring, and ordering accuracy. However, local 3D-printing manufacturing quality depends on experience and quality control practices. As well, the adopting of 3D-printing technologies leads to enhance prosthetic supply chain capabilities, leading to increase patient empowerment, accessibility and availability to designs and devices. On-site 3D-printing and simplicity of learning and applying 3D-printing technologies have made 3D-printed prosthetics more accessible. This has improved after-sale services and competitiveness in the Jordanian market. Patient satisfaction is a key objective, and various tools are used to evaluate this satisfaction, including direct feedback, social media ratings, recommendations and surveys. Finally, this research provides recommendations to the government and different prosthetic organizations, to improve the benefits gained from 3D-printing technologies.

ORIGINALITY/VALUE

This research addresses how understanding three vital issues; the prosthetic industry, the additive manufacturing technologies and the supply chain, which can improve the knowledge since this study creates a base for comparative research between Jordan and other similar contexts. Comparative research can enrich and enhance knowledge greatly. Also, it is considered as the first study that explores the phenomenon of adopting the 3D-printing technologies in the Jordanian prosthetic industry, by defining the impacts of this adoption in the supply chain and the challenges that may face Jordanian decision-makers.

Keywords: AM supply chain, Customization, Prostheses, Prosthetic industry, Jordan, 3D-printing technologies.

The impact of Industry 5.0 on Global Supply Chain: *A Systematic Literature Review*

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ABSTRACT

Industry 5.0 is the new era of industrialization focusing on sustainability, resilience, and humans. During the last few years, research studies on Industry 5.0 have significantly grown and engaged in various topics in supply chain management.

This study addresses the developing perception of Industry 5.0, which aims to grasp the environmental and social sustainable concerns associated with the ongoing human-centric digital transformation. However, the definition, capability, and applications of Industry 5.0 in the supply chain still need to be clarified, as well as an inadequate understanding of its sustainability-oriented innovation components and projected regenerative values.

The primary purpose of this study is to investigate the literature systematically to highlight and identify I5.0 enablers and the challenges the global supply chain faces while deciding on implementing I5.0 value-oriented technologies.

A systematic literature review was conducted using a set of 481 publications, including journal papers, conference papers, reviews, and book chapters, selected from the well-known database Scopus for the last eight years. The SLR highlights the impact of Industry 5.0 and its applications affecting the global supply chain.

The findings highlight that the future of industrial transformation must be more human-value-oriented, agile, and sustainable, with the pillars Industry 5.0 is based on, offering potential solutions to socioeconomic and environmental problems that were ignored and worsened by previous industrial revolutions.

The study gives governments, organizations, and decision-makers a holistic overview of Industry 5.0 opportunities and challenges, stressing the importance of all supply chain stakeholders' integration for value-added effective industrial transformation

Keywords: Industry 5.0, global supply chain, innovation, sustainability, systematic review

Enhancing Sustainability: *Identifying Supply Chain Challenges for Jordanian Companies*

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ABSTRACT

The significance of sustainable business practices has grown significantly in the contemporary globalized context, wherein corporate objectives are increasingly prioritizing environmental and social considerations. This abstract examines the different challenges encountered by enterprises operating in Jordan while endeavoring to incorporate sustainable practices into their supply chains. These issues can be classified into three primary domains: sourcing, manufacturing, and distribution.

In the domain of procurement, businesses in Jordan face many sustainability challenges. One primary issue frequently encountered is the restricted accessibility of sustainably derived materials and products within the local market. This trend compels firms to depend on imported items, hence exacerbating the carbon emissions linked to transportation. Furthermore, the absence of standardized sustainability certifications and a well-defined legislative framework presents additional challenges in the realm of sustainable buying.

Additionally, manufacturing processes entail a distinct array of sustainability challenges. Jordan is characterized by the prevalence of energy-intensive manufacturing processes, which consequently contribute to a substantial carbon footprint. The adoption of cleaner and more sustainable production methods is impeded by the need for significant initial capital investment and the limited availability of specialized labor.

As for the distribution function, businesses operating in Jordan encounter multiple challenges pertaining to transportation and logistics. The geographical location of the country as a landlocked country causes the dependence on road transportation, which is generally considered to have a lower level of environmental sustainability compared to alternative forms of transportation. The issues are further compounded by inefficient routing, limited access to innovative logistics technologies, and poor infrastructure.

In summary, the implementation of sustainable business practices in the supply chain encounters a range of complex challenges throughout the domains of procurement, manufacturing, and distribution. By effectively tackling these stated challenges, businesses in Jordan have the potential to transition towards supply chains that are more environmentally and socially responsible.

Keywords: Sustainable distribution practices, Sustainable manufacturing practices, Sustainable procurement practices, Supply chain management, Jordan

Powering Jordanian Manufacturers: *How the Synergy of Supply Chain Integration and Innovation drive success*

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ABSTRACT

The purpose of this study is to examine the effect of supply chain integration (SCI) in terms of internal integration, supplier integration, and customer integration on business performance (BP) directly, and indirectly through the mediating effect of innovation in terms of product innovation, process innovation, marketing innovation, and management innovation in the context of Jordanian manufacturing firms. Based on the resource-based view (RBV) and relational view (RV), a research model was developed representing the proposed hypotheses about SCI dimensions, innovation dimensions, and BP. To test this model, survey data were gathered from 292 Jordanian manufacturing firms belonging to different industry types. SmartPLS 4 software was used to test the validity and reliability of the research constructs, and to conduct partial least squares structural equation modeling (PLS-SEM) to test the proposed research hypotheses.

Regarding the direct relationships between SCI and BP, the results indicated that internal integration and supplier integration directly and positively affect BP, while customer integration does not. For the innovation-BP relationships, the results indicated that only product innovation and management innovation directly and positively affect BP. For the SCI-innovation relationships, the results indicated that internal integration positively affects all innovation dimensions. However, supplier integration positively affects all innovation dimensions except process innovation, and customer integration positively affects all innovation dimensions except management innovation. Regarding the indirect relationships, the results showed that internal integration indirectly affects BP through both product innovation and management innovation, and customer integration indirectly affects BP through product innovation only, while supplier integration does not have an indirect effect on BP through any one of the innovation dimensions.

This study addresses an evident gap in the available literature regarding the effects of SCI dimensions on innovation dimensions and BP. This study extends the current literature by contributing the discussion of a comprehensive model underlining the different mediating roles of innovation dimensions on the relationships between SCI dimensions and BP. This study also acquires additional value as a result of conducting it in a developing country, Jordan. In general, manufacturing firms in developing countries face more difficulties related to the supply chain than those in developed ones; these challenges can limit the innovation and subsequently BP of manufacturers in developing countries. This study informs manufacturers interested in improving their BP to focus on establishing both internal and supplier integrations. This study also

provides theory-driven and empirically proven explanations for manufacturers to differentiate the effects of internal and external integration efforts on different innovation dimensions and subsequently BP. In developing countries in particular, manufacturers need to pay substantial attention to internal integration, as it is the key antecedent of product and management innovations and subsequently BP. Moreover, manufacturers should be aware of the essential role of customer integration in improving product innovation and subsequently BP. Thus, they should make long-term plans to integrate their internal units and functions, incorporate their key external customers, and reconsider their current relationships with their suppliers.

Achieving Supply Chain Sustainability through Traceability

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ABSTRACT

The primary objective of this conference paper is to provide insights into the important connection between supply chain sustainability and traceability. It seeks to address the growing need for environmentally friendly and socially responsible practices within modern global supply chains.

This study aims to explore the effects of supply chain traceability on sustainability performance indicators across various industries. To achieve this, a mixed-methods approach will be utilized, which includes conducting qualitative interviews, analyzing quantitative data, and conducting an extensive literature review. By employing this comprehensive methodology, the study seeks to gain a deeper understanding of how supply chain traceability influences sustainability performance in diverse industries. The primary results indicate a noteworthy and positive connection between the implementation of traceability measures and improvements in sustainability. This emphasizes the important part that traceability plays in reducing the environmental impact, ensuring ethical sourcing, and strengthening the overall resilience of the supply chain. Nonetheless, this study recognizes specific constraints, such as the requirement for additional data over an extended period and the potential obstacles that may hinder the implementation of traceability measures in smaller businesses. Based on these discoveries, potential areas for future research could focus on the creation of affordable methods for tracking products in small and medium-sized businesses. Additionally, further investigation could be conducted to better understand the societal consequences of implementing traceability measures in supply chains. The study highlights the importance for businesses to prioritize traceability technologies and transparent supply chain practices in order to promote sustainability, ethical sourcing, and consumer trust. By doing so, businesses can align their operations with the changing expectations of society. This paper offers valuable insights into how supply chain traceability can drive sustainability. It also highlights areas for future research and practical implications for businesses operating in a socially and environmentally conscious supply chain management landscape.

Keywords: Supply Chain Sustainability, Traceability, Sustainable Practices, Global Supply Chains

Assessment of the eligibility of Jordanian processed food export to the German market

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ABSTRACT

According to the International Standard of Industrial Classification (ISIC Rev. 4), the food processing sub-sectors are outlined as 11 sub-sectors and hundreds of products; 1: Processed and preserved meat; 2: Dairy products; 3: Processed and preserved fruits and vegetables; 4: Bakery and Arabic sweets; 5: Animal and vegetable fats and oils; 6: Products from the milling industry; 7: Cocoa, chocolate and sugar confectionery; 8: Processed fish and crustaceans; 9: Macaroni and pasta products; 10: Other food products; 11: Animal feed.

The sensitivity of food processing in specific has a direct impact on human health whether in terms of nutrition or safety. This creates challenges for food producers, seeking export growth to assess and ensure the eligibility of their products to international markets.

This paper focuses on evaluating the eligibility of Jordanian processed food, specifically, the sub-category of processed and preserved meat and/or processed and preserved fruits and vegetables to export for the German market. The German market is known for its strict food safety standards. The paper employs a comprehensive approach that combines regulatory compliance and quality control, and prequalification to provide recommendations into the export eligibility of Jordanian food producers to Germany.

The assessment examines the regulatory framework, including the EU import requirements, rules on food hygiene, and on official food controls requirements for Jordanian processed food products as stated for the third countries (non-EU countries). The objective is to capture the gap between the Jordanian producers and the German market. The methodology followed a multi-method approach, which involved analyzing quantitative and qualitative data by applying the following tools: Desk review was conducted to gain an understanding of the current situation, key informant interviews were performed face-to-face using a semi-structured questionnaire. This paper offers valuable insights into how current barriers could be identified and resolved. It also highlights areas for future research and practical implications for targeted businesses.

Keywords: Food Processing, Export Eligibility, Regulatory Compliance

Intermodal Freight Transport Multi Objectives

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ABSTRACT

Intermodal freight transportation is defined as a system that carries freight from origin to destination using two or more modes of transportation (Anichkul and Ferreira, 2005). The strategic objectives related to intermodal freight differ for each stakeholder, and conflicts of interest between stakeholders reflect various polices and decisions that serve one or multiple parties, but not the interests of the whole chain of intermodal freight transport parties. Many decisions might be taken that are useful for one or multiple parties, but which may affect other stakeholders or the whole cycle negatively. The objective of the research is to develop an intermodal sea freight strategy in the mode of maritime roads, and explore a holistic approach wherein operators, beneficiaries, and all actors/players working with unified combined objectives manifest in an integrated business model, comprising a tool to integrate the multiple objectives/criteria of diverse stakeholders. This is intended to support stakeholders achieving compliance with the same objectives, eliminating conflicts of interest, and providing guidelines for strategic, tactical, and operational decisions and action plans. This can increase the competitiveness of intermodal sea freight transport, with positive and sustainable long-term impacts on national economies, trade, socio-economic development, and communities.

The research examines intermodal sea freight transportation multiple actors and objectives by selecting the parameters that reflect the main interest and objectives of each stakeholder acting in various phases of the maritime road mode. It seeks to integrate the actors' objectives into one holistic, integrated business model (a multi-actor, multi-objective paradigm), to meet the needs of each actor, including investigation of the competitiveness of intermodal freight transportation components.

Agenda of the Conference

Day 1 November 14

Time 09:00 – 17:00 AST

OPENING		
09:00	Opening	
09:15	**Key Note Speech:** Developing capacity for next generation transport and logistics practitioners and applied research through leadership and strategic networks – story of Centre of Excellence in Transport and Logistics (TRECK)	Charles Adams *(Kwame Nkrumah University of Science and Technology, Ghana)*
BREAK	**10:00 – 10:30**	
Science	**Session 1**	
10:30	Examining Supply Chain Coordination and Cooperation Mechanisms in Jordan's Olive Oil Industry: Insights from Small-scale Farmers	Muath Basheer *(KU Leuven & UC Louvain, Belgium)*
11:00	Quantitative planning of charging infrastructure in hetero-genous urban environments: A multi-period greenfield modulation	Niklas Hildebrand, Sebastian Kummer *(Vienna University of Economics and Business, Austria)*
Industry	**Session 1**	
11:30	Aqaba Logistics Village role in supporting the vision of Aqaba as a logistics hub	Hakam Abul Feilat *(Aqaba Logistics Village, Jordan)*
12:00	Building research & innovation ecosystems: Networking, funding and structural aspects	Mahmoud Abu Hussein *(Higher Council for Science and Technology, Jordan)*
LUNCH BREAK	**12:30 – 13:30**	
15:30	The Impact of Supply Chain Management Practices on Organizational Performance and Environmental Sustainability Among Export Jordanian Manufacturing Firms	Yasmeen Baddar *(German Jordanian University, Jordan)*
16:00	Assessment of procurement practices using portfolio analysis at a selected company	Rand Hassan Abu-Musallam *(German Jordanian University, Jordan)*
16:30	Assessment of the eligibility of Jordanian processed food export to the German market	Ahmad Hanaktah, Khaldoun Tahboub, Saja Alkhasawneh *(German Jordanian University, Jordan)*
END OF DAY 1	**17:00**	

Day 2 November 15
Time 09:00 – 17:00 AST

OPENING		
09:00	Opening	
09:15	Presentation of the JOINOLOG project	Jakob Grubmüller *(Hochschule Fulda, Germany)*
BREAK	**10:00 – 10:30**	
Science	**Session 4**	
10:30	Leadership behaviours for the effective use of Lean Six Sigma: Jordan	Mohammad Alnadi *(Philadelphia University, Jordan)* Ismail Abushaikha *(Cranfield University, UK)*
11:00	Identifying Supply Chain Challenges for Jordanian Companies	Luay Jum'a *(German Jordanian University, Jordan)*
11:30	Intermodal Freight Transport Multi Objectives	Fares Abudayyeh *(University of Antwerp, Belgium)*
LUNCH BREAK	**12:00 – 13:00**	
Industry	**Talks 2**	
13:00	Transformation and Technology in the Shipping Industry	Rafiq Alotti *(Hapag & Lloyd, Jordan)*
Science	**Session 5**	
13:30	Factors Affecting Adoption of Enterprise Resource Planning Systems and their Impact on Supply Chain Integration in Jordanian Manufacturing Organizations	Fatima Al-Badareen *(German Jordanian University, Jordan)*
14:00	Achieving Supply Chain Sustainability through Traceability	Khaldoun Tahboub, Saja Khasawneh, Ahmad Hanakta *(German Jordanian University, Jordan)*
BREAK	**14:30 – 15:00**	
Science	**Session 6**	
15:00	Powering Jordanian Manufacturers: How Synergy of Supply Chain Integration and Innovation Drive Success	Omar Bwaliez *(German Jordanian University, Jordan)*
15:30	Human factors and ergonomics in Logistics activities by principles of Industry 5.0	Maja Trstenjak, Goran Đukić, Tihomir Opetuk *(University of Zagreb, Croatia)*
CLOSURE		
16:00	Hand-Over of JOINOLOG	Jakob Grubmüller *(Hochschule Fulda, Germany)*, Rana Badran *(German Jordanian University, Jordan)*
16:30	Wrap-Up	Ismail Abushaikha *(German Jordanian University, Jordan)*
END OF DAY 2	**17:00**	