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Digitalising Sustainable Supply Chains: A case study approach

*Neville Rowney
Manchester Metropolitan University*

*Dr Iain Reid
Manchester Metropolitan University*

*Dr Marina Papalexi (m.papalexi@mmu.ac.uk)
Manchester Metropolitan University*

*Jamie Laird
Manchester Metropolitan University*

Abstract

Supply chain pressures have increased significantly in recent years, promoting business to adopt sustainable supply chain management (SSCM), whilst the growth of digitalisation presents business with the opportunity to transform performance. This study addresses the opportunities for SSCM from a footwear manufacturer perspective. We demonstrate how the sector is significantly challenged by factors of SSCM through digitalisation. We present how digitalisation supports SSCM through systematic literature review and concentrate on specific challenges for digitalisation. We present the challenges of digitalised SSCM through a longitudinal study, describing the critical success factors (CSFs) that accompany successful footwear design and manufacture.

Keywords: Digitalisation, Sustainable Supply Chains, Case Study

Introduction

Due to the complex nature of supply chains and supplier relationships, and the wide range of potential sustainability impacts, achieving supply chain sustainability is seen as a major challenge (Seuring and Muller, 2008; Grimm et al., 2014; Weiss et al., 2017; M. Xu et al., 2019). To address this, the establishment of SSCM is advocated, built around supplier collaboration to identify sustainability impacts and implement improvement initiatives (Villena and Gioia, 2018; Hedstrom, 2019; Mc Loughlin et al., 2021). The increased urgency to commit to supply chain sustainability with the additional pressure to advance social equality and justice, requires businesses to embed environmental and social sustainability objectives alongside economic sustainability objectives within integrated governance programmes (Jaenglom et al., 2013; Meixell and Luoma, 2015; Winston, 2021; Bowcott et al., 2022). Research has shown that most environmental and social impacts of a business occur within its supply network (Bove and Swartz, 2016), reflecting on the premise posed by Krause et al. (2009), “a company is no more sustainable than its supply chain”.

Building on SSCM thinking, scholars have turned to Industry 4.0 technology to transform all aspects of business performance (Lu, 2017; L. D. Xu et al., 2018; Horvath and Szabo, 2019; Gartner, 2022). For example, cloud-based platforms for mapping of sustainability impacts (Papetti et al., 2019), use of Internet of Things (IOT) devices for monitoring of impacts such as energy consumption (Marconi et al., 2017), and blockchain to aid traceability and transparency of sustainability throughout supply networks (Park and Li, 2021).). However, studies also highlight the unproven nature of technologies still in their infancy, proposing future research examines the implementation challenges and correlation between digitalisation and improved SSCM, with the use of case studies to inform the development of frameworks to guide digital technology adoption (Luthra and Mangla, 2018; Ardito et al., 2019; Jabbour et al., 2018; Mc Loughlin et al., 2021; Ben-Daya et al., 2019. These conclusions lead to the identification of a research gap, raising the question, can digitalisation support SSCM? If so, what technologies can help, how are they implemented, and to what extent is SSCM supported? To address the identified research gap, this research aims to answer the research question: *How does digitalisation enhance footwear SSCM operations?*

The research is split into two phases. First, we carried out a systematic literature review to determine the impact of digitalisation on SSCM and identify the role of digital technologies within footwear design and manufacture. The second phase consisted of a longitudinal study collaboration with Vivobarefoot (Vivo). Our research contribution created a sustainable business model supported by the adoption of digital technology for footwear supply chains. This enabled the development of a digitalisation framework supporting Vivo in the fulfilment of its vision, whilst acting as a guide for businesses within similar industries who share objectives to develop sustainable supply chains.

Literature review: Supply Chain Sustainability

Carter and Rogers (2008) identified how businesses who engage in sustainability activities can deliver economic benefits and competitive advantage, highlighting cost savings from reduced waste, increased productivity and improved quality. Alongside these benefits, McLoughlin et al. (2021) highlight how businesses are increasingly held to account for their sustainable performance from a multitude of stakeholders. Additionally, Jaenglom et al. (2013) identify how consumer demand for ethical products is leading businesses to embrace sustainability, whereas Krause et al. (2009) highlight the opportunity to increase competitiveness by publicising sustainability goals. However, achieving supply chain sustainability faces many challenges and barriers. Seuring and Müller (2008) recognise the impact of reputation loss with consumers through publicity of sustainability infringements as a key driver for adoption, as well as the obligation to comply with environmental and social legislation. Grimm et al. (2014) emphasise supplier resistance and their lack of knowledge and resource as key inhibitors, also suggesting a lack of executive support and resistance to change as major factors, resulting in an absence of strategic sustainability goals and unwillingness to invest. Linked to this, Giunipero et al. (2012) highlight the lack of trust and commitment between stakeholders and supply network partners, resulting in a lack of cooperation and transparency regarding sustainability performance.

Addressing these challenges forms the foundation for the establishment of effective SSCM. Villena and Gioia (2018) identified common themes leading to the establishment of a SSCM model, where SSCM is an integrated set of practices, with a primary requirement for leadership, commitment and strategy, and highly dependent on integration with suppliers to measure sustainability risks and cooperate on building sustainability through improved policies and practices.

The role of Supply Chain Sustainability within Footwear Manufacturing

The globalised fashion and textile industry has a long history of sustainability impacts stretching back to the Nike child labour scandal in 1996 which motivated the industry to become one of the first to prioritise supply chain sustainability (Khurana and Richetite, 2016). However, Ciasullo et al. (2017) highlight the continued deep impact of fashion activities on the global environment and dependence on use of natural resources. Furthermore, Mckinsey (2021), reflect on how the industry remains one of the least sustainable, accounting for 4% of global CO₂ emissions (2.1 billion tonnes/year), highlighting its intensive use of water, land and wood in the farming of raw materials contributing significantly to biodiversity loss, with 23% of global pesticide use in cotton agriculture and 25% of water pollution resulting from textile dyeing. Substantial impact from solid waste is also identified where 17.5m³ of textiles is sent to landfill or burned every second. As a major sector within the fashion industry, footwear contributes significantly to these global impacts, with annual global footwear sales of \$365 billion accounting for 25% of the global fashion sales total in 2021 (Statista, 2022).

Ciasullo et al. (2017) studied the factors influencing sustainability in footwear, highlighting internal drivers including top management values that support corporate social responsibility combined with objectives to improve business process efficiency and the effectiveness of generating sustainable products and processes. External drivers include compliance with regulations and pressure from non-governmental organisations (NGOs) and consumers. With improvements in communication technologies, consumer awareness and pressure has increased, driving business to offer environmentally certified products that are tracked to their origins (Weiss et al., 2017; Papetti et al., 2019).

However, Ciasullo et al. (2017) emphasise the deeply fragmented and complex nature of footwear supply chains with multiple layers of sub-contractors as a major challenge, requiring a high level of commitment and resource to reach each supplier and initiate action, and highlight the use of software platforms to educate and inform suppliers. Papetti et al. (2019) also recognise the complexity of shoe manufacturing supply chains and point out the challenge for businesses in coalescing around establishing common systems and standards needed for effective data sharing and collaboration and advocate the use of cloud-based systems to facilitate supply chain mapping and sustainability data collection. The use of digital platforms is supported by Mc Loughlin et al. (2021), who identify technology as a key enabler, emphasising its importance as a major factor in optimising SSCM performance.

Digital Supply Chain Design

Horvath and Szabo (2019) define how digitalisation, stretches beyond technological development and affects the nature of business models, organisational structure and external value chains and requires businesses to create a digital strategy, a view supported by Queiroz et al. (2021) and Khan et al. (2022). Shahi and Sinha (2021) concur and emphasise the need for a clear vision with prioritised short and long-term goals, founded on an innovative and adaptive culture and engagement of all key stakeholders. Loonam et al. (2018) argue that successful digitalisation requires transformation to be seen from a business context and not simply as a technological solution, with focus on organisational factors of leadership, change management and business wide communication, to ensure that business structure and processes are aligned, enabling an integrated approach to systems development across the organisation. Once organisational and strategic factors have been addressed, Andriole (2020) emphasises how the simplification, standardisation and modelling of all business

processes is a critical pre-stage to digitalisation followed by prioritisation of opportunities based on those that will deliver the greatest impact. Based on the conclusions from research, it is possible to summarise the CSFs that underpin successful digital transformations as show in Table 1.

Table 1: CSFs for Digitalisation

Critical Success Factors
Ensure leadership commitment with appropriate digital skills and experience
Establish clear digital vision and prioritised goals and embed into overall business strategy
Simplify, standardise and model all business processes as prerequisite to digitalisation
Communicate with and engage whole organisation and key stakeholders in strategic vision
Ensure organisational structure is aligned to support digitalisation with digital talent
Develop values and employee capability based on innovation and agile methodologies
Develop and integrate IT resources across the structure of the business

Summary of the Literature Review

In this study, numerous studies have compared sustainability within footwear manufacturers, with studies including sustainability impacts, drivers for adoption and implementation challenges. With its complex supply chains and significant environmental and social impacts, achieving supply chain sustainability is of critical importance to the shoe manufacturing industry and therefore adopting SSCM is paramount to success.

Studies have also identified the role of digitalisation in achieving SSCM, a point emphasised by Mckinsey (2021) who report on how fashion industry executives recognise the major opportunity that digital technology presents to achieving sustainability. From academic literature review there are two factors for achieving digital transformation: (1) business change and (2) the multiple internal and external challenges. Queiroz et al. (2021), Ben-Daya et al. (2019), and Jabbour et al. (2018) all identify a lack of available frameworks due to the relative immaturity of digital technology. The limitation of SSCM frameworks for digitalisation would benefit from understanding how organisations champion their implementation on successful supply chain digitalisation and provide guidance from both business change, and how internal and external factors cope with digital acceptance and adoption, Given the complexity of footwear design and manufacture, this study bridges the gap of digital implementations and generic CSFs.

Research Design

A case study methodology with interpretivist approach was adopted to address the research question: *How does digitalisation enhance footwear SSCM operations?* Interviews carried out at Vivo were carefully designed and conducted (Gioia et al., 2013). It was not intended to generalise SSCM digitisation in footwear design, but to understand the CSFs that facilitate implementation. Our empirical evidence draws on a number of sources including: 9 semi-structured interviews with key participants (see Table 2), 42 hours of observation, company artefacts and collaborative workshops, as a basis for triangulation of the relationships (Ligthart et al., 2016).

A thematic analysis was conducted to analyse the data. The aim of the data analysis process was to establish a narrative account demonstrating the status of supply chain sustainability within Vivo and how this can be improved through digitalisation.

Table 2 - Summary of Participants

Code	Role	Company
P1	Digital Supply Chain Analyst	Vivo
P2	Head of Sourcing & Value Chain	Vivo
P3	Head of Sustainability Regenerative Impact	Vivo
P4	Head of Sustainability Integration	Vivo
P8	Head of Circular Business	Vivo
P6	Head of Technology	Vivo
P5	Regenerative Materials Analyst	Vivo
P7	Regeneration (Product & Value Chain)	Vivo
P9	Chief Product Officer	External

Findings: SSCM and Digitalisation Factors

In considering the status of SSCM at Vivo, the following key factors are identified:

Strategy Planning and Leadership - Vivo's current strategy to SSCM includes goals to establish regenerative products designed from sustainable materials, produced from a transparent sustainable supply chain and facilitating a circular business model (Vivo, 2022b: Online; 2022c: Online). As stated by P3, Vivo replaces the term "*supply chain*" with "*value chain*", signifying the regenerative strategy of adding value to the entire network from raw material to end of life with objectives to reduce social and environmental impacts, whilst P2 adds to this, highlighting how "*it's not just about being net zero*", explaining how Vivo works proactively with suppliers and stakeholders to encourage positive sustainability initiatives.

Governance and Policies - As identified by P3 and P4, Vivo's B-Corp certification serves as a foundation for the management of its activities, helping to drive strategic focus and positive business change. A key aspect of the certification is the self-assessment of the business with supporting evidence every 3 years against 5 core pillars including governance, workers, community, environment and customers. The governance pillar evaluates a company's mission relating to sustainability, ethics and transparency and how this is formally supported through business structure and governance mechanisms. P2 highlighted how the B-Corp framework (<https://www.bcorporation.net/en-us/>) shapes how the business interacts and manages its suppliers including expectations for sustainability.

Sustainability Goals - Based on its regenerative philosophy, Vivo has established goals within its current business strategy, with numerical targets set to drive the business towards improved performance (Vivo, 2022g). In relation to sustainability, targets have been set to increase Vivo's B-Corp results, driving strategic focus throughout the business. Other targets include improvements to V-Matrix scores (a system providing a score for each shoe design based on use of sustainable materials and facilitation of recycling) and increases to the percentage level of value chain transparency and environmental impact monitoring. P1 focused on one such initiative called 'Vivo Biome', a project aimed at establishing customised footwear based on localised digital manufacturing units built predominantly around 3D printing (3DP) technology (Vivo, 2021:Online). As identified by P1, the key benefits will include: "*a value chain with improved speed, quality, and efficiency providing economic benefit whilst delivering positive sustainability impact through reduced waste and consumption of materials and energy throughout the manufacturing, logistics and distribution cycle*". The Biome business model removes the need for inventory, negating the risk of stock obsolescence and wastage, further supporting circular value chain principles.

Stakeholder Management – Vivo is committed to stakeholder engagement focussed on areas such as regenerative sourcing, transparency, sustainable materials, waste,

energy and emissions (Vivo, 2021:Online). The importance of consumer engagement regarding sustainability is highlighted by P3 and P4 whilst P8 comments on how many consumers “*want to wear their sustainability*”. P3 and P4 both emphasise how consumer engagement is a key driver for the business, with P3 stating how the business is “*built from a customer perspective*” with the business keen to gain more feedback on how they operate. P4 adds how consumers are “*very engaged and ask tough questions*” and how this brings an element of pressure. P2 confirmed “*engagement with other organisations helps Vivo shape its sustainability initiatives within the supply chain such as taking guidance for its supplier policies from the International Labour Organisation, whilst also encouraging suppliers to join the BetterWork programme focussed on improving working conditions and employment rights in the apparel industry*” (BetterWork, 2022:Online). P3 and P5 state how collaboration with other brands is imperative in addressing key industry challenges, a point illustrated by P2 who explained how collaboration with Timberland on initiatives within a shared supplier enables more effective consolidated action. P5 and P8 highlight the benefit of Vivo’s involvement with Fashion for Good, a coalition of brands and innovators (FashionforGood, 2022:Online), with focus on sustainability and circularity with P8 explaining how this initiated Vivo’s partnership with a platform provider specialising in fashion supply chain impact measurement.

Supplier Management - Vivo has established a code of conduct and associated policies that form the basis for supplier management with 100% of tier 1 suppliers signed up (Vivo, 2021:Online). P2 explains how managing the suppliers involves making sure they have the capability, capacity and are right for us as a business from an ethical standpoint and adds to this, stressing “*the importance of transparency in developing a sustainable supply chain*”, a view also expressed by P3, P4, P7 and P8. To achieve this, P2 defines Vivo’s approach is based on collaboration and trust and how this leads Vivo to consolidate its network towards having less suppliers where long-term partnerships can be developed. However, relative to other brands, P2 comments how “*Vivo is a small fish in a big pond*” affecting their influence with suppliers from tier 2 and below, but to address this, focusses on supplier engagement. P2 explains how suppliers at all tiers are invited to annual conferences “*to tell them what we're doing and how we're doing it*” with the objective to “*get them invested in our business*”.

Impact Assessment - Vivo has established targets to work towards full transparency of social and environmental impacts in the supply chain. However, as stated by P2, supply chain visibility below tier 2 is a significant issue that Vivo is focussed on addressing, expressing how “*it's the biggest unknown for us*”, with P4 commenting that “*transparency is a huge challenge*”. P3 comments how “*you can only be a regenerative business if you know what your impacts are and that is impact down to tier five*” and emphasises how “*it takes one slight issue to bring down everything you build*”. Both P2 and P4 highlight the difficulty of identifying impacts due to the complex nature of Vivo’s supply chain, in terms of the multi-tier network, the number of suppliers, and the range of materials, components and processes used in manufacture of the shoes. Alongside supplier mapping, P3 and P8 explain how Vivo is focussing on gathering impact data from the supply base, initially by sending an environmental impact questionnaire to all tier 1 suppliers. P8 explains how suppliers are required to reply with data and supporting evidence from which scorecards will be created including red flags for areas that need action.

Performance Monitoring - P2 highlights the importance of monitoring suppliers to ensure products being produced are compliant with legislation (relating to use of chemicals, product labelling and product safety) and from a sustainability perspective

ensuring that *“if we say that a product is 95% recycled materials, we've got the certification to be able to back up that claim”*. P2 explains the need to back up certification by conducting on site audits with suppliers to verify compliance with legislation and Vivo’s policies. P4 adds how this is *“based on highest volume, highest risk suppliers”* as a means of *“taking precautionary steps to act now on certain things that we know are the right things to do whilst we work to gain full visibility and transparency”*. Focussing on improving supplier performance, P8 explains how suppliers are *“encouraged to take a proactive approach to improving sustainability within their own operations and lower tier suppliers”*.

Digitalisation - P6 explains how *“the architecture of the systems comprises many different cloud-based platforms supporting the various functions of the business, including core systems such as ERP, PLM, CRM and E-Commerce”*, but identifies how *“not all systems are integrated and a number of functions rely upon spreadsheet systems with manual uploading of data such as purchasing and inbound shipment management”* (Vivo, 20221). P6 also defines how the IT function supports system maintenance and development with a primary focus on Healthy Digital, a strategic initiative to develop consumer based digital platforms, whilst also aiming to automate and integrate many of the manual processes. P3 explains how a new cloud-based platform will integrate impact analysis with the V-Matrix system enabling Vivo to gain more accurate measurement of product sustainability. P3 and P8 add how integration of social impact analysis into the platform is a future objective, however P9 explains the platform can only collect social data, not validate it, illustrating the difficulty with social impacts, citing an example of *“how do you validate that the salary was really paid?”*.

Future State Digitalised SSCM

A framework showing a potential future state digitalised SSCM (Figure 1) has been developed. It is recognised that many digital technologies remain in their infancy and as stated by P9, adoption within suppliers is likely to vary greatly dependant on digital maturity. It is proposed that Vivo survey their suppliers to understand their capabilities, however, it is likely that any systems Vivo adopts will require flexibility to accommodate a range of supplier modes of interaction. The framework comprises the following digital technology components:

- IOT enabled digital ID (Identification) footwear aiding traceability along the supply chain, whilst enabling circular business and automation within customised footwear units. This is the key foundation technology in the overall functionality of the SSCM system.
- Cloud-based platforms to aid SSCM including Artificial Intelligence (AI) and Big Data Analytics (BDA) enabled impact mapping, supplier management, and facilitation of circular business processes.
- Customised footwear incorporating 3DP, robotics and IOT interconnectivity to create a Cyber Physical System (CPS), integrated with Augmented Reality (AR) driven customisation and scanning platforms.
- Blockchain to enable secure transfer of data along the value chain.
- AI/BDA to aid design of new products including circular materials selection, whilst also driving business intelligence linked to a central data warehouse.
- Virtual Reality (VR) to enhance design visualisation and remove the need for physical samples.

The purpose of this framework is to provide a vision for Vivo, portraying what is possible by the application of digital technology and how this integrates to other systems within the business.

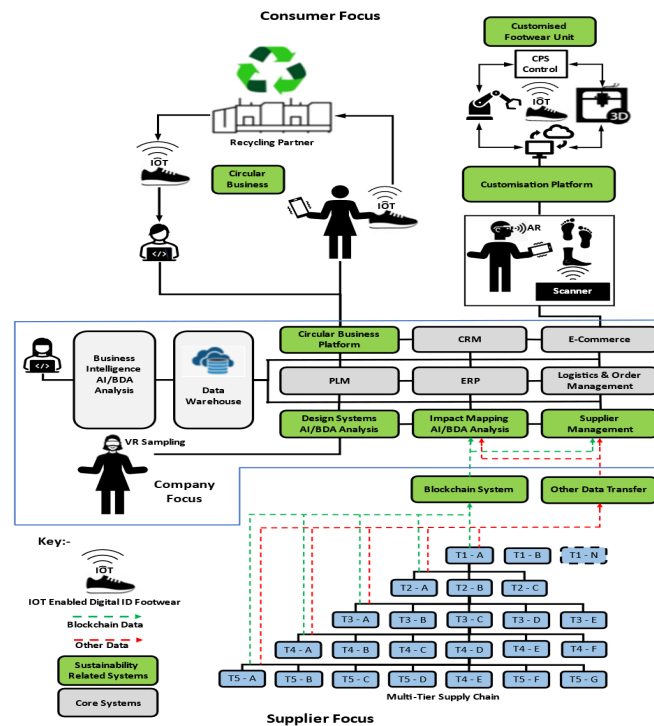


Figure 1: Future State Digitalised SSCM

Conclusion

The aim of this research was to determine the contribution of digitalisation in enhancing SSCM, enabling the establishment of a digital technology implementation framework. The findings provided a rich source of evidence as to the SSCM practices and digital applications within Vivo relative to the CSFs and also highlighted additional organisational and technological underlying themes.

Our Study has shown that Vivo fully embraces SSCM, driven by its regenerative philosophy to achieve a positive impact for people and planet. Strong governance is demonstrated with its supplier policies, whilst Vivo recognises the need to create trust and transparency within a complex, multi-tier supply chain, with the objective of generating sustainability improvements. Although Vivo is at the start of its journey towards SSCM digitalisation, its intent is clear with its investment in impact mapping platforms and the major 3DP manufacturing project, providing sufficient evidence to support the benefits of SSCM based digital applications. However, the key fundamental in driving improvements in supply chain sustainability is the development of long-term collaborative partnerships with suppliers sharing common values, with the objective of fostering joint sustainability initiatives. Digital technology can only enhance the SSCM process, confirming its supporting role as an enabler in delivering sustainability. Based on the status of SSCM and digitalisation at Vivo, and considering applications identified in literature, it was possible to propose the development of digitalised SSCM solutions, leading to a future state digitalised system. The importance of this research can be demonstrated by considering its contribution from both business and academic contexts.

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