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Driving Competitive Edge in Sarawak's Manufacturing Industry: Leveraging Supply Chain Management, Smart Integration, and Circular Economy Practices

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Abstract

Sarawak's manufacturing industry is vital to the state's economy, contributing to employment, GDP, and overall development. The industry must enhance supply chain management, integrate smart solutions, and adopt circular economy principles to stay globally competitive. Effective flow control of materials, information, and finances is essential for operational excellence and market adaptability. Key technologies like AI, blockchain, and IoT should be adopted to create faster, cost-efficient, customer-centric processes and products. Emphasizing resource, material, and waste reduction aligns with circular economy goals, reducing costs and fostering long-term growth. This review merges academic research with practical insights, offering actionable strategies for policymakers, industry players, and scholars to drive sustainable innovation in Sarawak's industrial landscape.

Keywords

Sarawak, manufacturing companies, supply chain management capability, smart supply chain integration, circular economy, competitive performance

INTRODUCTION

Manufacturing is one of the crucial sectors of Sarawak's economy. It is under pressure from globalization, technological innovation, and environmental imperatives. The industry's competitive performance is important for growth, development, and resilience (Lim, 2023). The following sections review three related elements: supply chain management (SCM) capability, smart supply chain integration, and circle economy implementation, which provide insight into the manufacturing industry in Sarawak.

SCM capability derives operational efficiency and agility in manufacturing (Christopher, 2022; Chin et al., 2014; Duoming & Chin, 2022; Idris et al., 2023; Zheng et al., 2024). According to the statement, effective SCM ensures coordination of resources, timely goods delivery, and response to market changes. Thus, for the Sarawak manufacturing industry, the focus has to be on SCM practices and their relationship with competitive performance (Salam, 2021; Singhry, 2015; Thoo et al., 2011). On March 30, 2022, the Deputy Premier of Sarawak, Datuk Amar Awang Tengah Ali Hasan, said that Sarawak would be one of the most attractive destinations for investments in manufacturing locally. Sustainable growth with a competitive advantage in the manufacturing sectors in Sarawak is inseparably linked to SCM capability, as has already been proven in the literature.

The integration of smart technologies in SCM represents a crucial change. These technologies foster optimization and innovation of business processes, such as IoT, AI, and Blockchain. According to the Sarawak Digital Economy Strategy 2018–2022 (SDES), the areas where smart supply chain technologies are critical include real-time visibility, predictive analytics, and autonomous decision-making over traditional supply chain practices (Sarawak Government, n.d.). Best practices and emerging trends will explain how these companies can utilize smart technologies to outperform their competitors (Zhao et al., 2020).

A transition to a circular economy is important to achieving sustainable development. The shift from the traditional linear model focused on "take, make, and dispose" to a circular model improves resource efficiency, reduces generated wastes, and reduces environmental impacts (Ghisellini et al., 2016; Van Berkel, 2023). Principles of reduction, reuse, and recycling drive businesses towards a low ecological footprint and open new avenues for innovation and cost savings. Sarawak is promoting a green energy agenda as part of efforts to support sustainable development.

SCM, smart integration, and circular economy practices are decisive factors in the competitiveness and sustainability of the manufacturing sector in Sarawak. SCM enhances operational efficiency and agility to address logistic inefficiencies and regulatory challenges. Smart technologies like AI and blockchain would help improve supply chain visibility and decision-making for informed business decisions that support the SDES. Circular economy practices enhance sustainability through resource efficiency, waste reduction, and environmental care; they align with global efforts on sustainability and local initiatives. These practices foster innovation, cost savings, and market differentiation.

In 2021, Sarawak established the Ministry of Energy and Environmental Sustainability with the Sarawak Premier, YAB Datuk Patinggi Tan Sri (Dr.) Abang Haji Abdul Rahman Zohari Tun Abang Haji Openg, as its chairman. This ministry handled green and renewable energy development related to global climate change. The 12th Malaysian Plan outlines the strategies to increase the share of recycled materials, increase sustainable consumption and production patterns, and increase awareness about the concept of a circular economy. Sarawak Energy Bhd., the state's power producer, emphasizes the dominant role that low-emission coal technology and renewable resources such as hydropower will play.

The paper intends to record an integrated understanding of the various factors improving the competitive performance of Sarawak manufacturing companies. In particular, it helps policymakers, industrial stakeholders, and researchers improve innovation, sustainability, and resilience. This review will help position the industrial sector in Sarawak at the global forefront by borrowing elements of good practice from scholarly articles, industrial reports, and empirical evidence.

METHODS

This review is based on an approach where the synthesis of secondary sources, such as academic literature and industry reports with relevant statistical data, is combined with primary data collection through interviews with industry experts. Such methodological integration allows for an in-depth exploration of challenges and opportunities faced by the manufacturing industry in Sarawak. At the same time, the findings will be contextually based but informed by expert insights. It underlines the key trends and patterns and captures subtle perspectives, further contributing to a well-rounded understanding of the industry landscape.

Supply Chain Management Capability

SCM promotes efficient and responsive manufacturing processes. To Sarawak, it is important to understand SCM's current capability. Some achievements have been mentioned in literature studies, but there are also challenges, such as the insufficiency in technological infrastructure, lack of skilled workforce,

and non-conformity with regulatory requirements (Birou & Hoek, 2022; Salam, 2021; Tamam et al., 2021). These challenges must be resolved to make Sarawak's SCM capability superior in manufacturing.

Automation and digitization are the aspects of the development of SCM capability that most especially need attention. As the article published by McKinsey & Company (2016), entitled "Supply Chain 4.0 – the next-generation digital supply chain" states, "the underlying fact of digital supply chains is their strong usage of top digital technologies such as blockchain and Radio-Frequency Identification (RFID) to improve traceability and visibility of the supply chains." This process reduces lead times and optimizes the management of inventories. Investments in developing talents and training would also be crucial to developing a skilled workforce that can apply advanced SCM procedures (van Hoek et al., 2020; Wehrle et al., 2020). Furthermore, cooperative projects must be promoted between academics, the government, and industry partners to enhance knowledge transfer and skill-building activities. These will thus enhance the SCM skills of Sarawak's manufacturing companies, as indicated in the Sarawak Digital Strategy of 2018 to 2022 by the Sarawak Digital Economy Corporation.

Recent interviews with industry experts revealed that some regional manufacturers had adopted high-end logistics practices. However, gaps remain in technology and labor expertise, as evidenced in the MIDF Thematic Report (Yusof et al., 2023), which mentioned that logistics inefficiency makes operating costs higher in Sarawak. In addition, based on a Tive survey in April 2023 involving over 260 supply chain professionals in another country, 77% of respondents stated that real-time shipment visibility is a must-have feature. However, only 25% currently use the necessary technologies. Success stories like those in Malaysia's electrical and electronics sector, using predictive analytics and just-in-time inventories, indicate cost reduction and efficiency. Sarawak can be equally competitive and better coordinated between industry players and government agencies.

Smart Supply Chain Integration

The integration of smart technologies across the supply chains has been an important strategy for the manufacturing industries due to rapid technological advancement. Yanamandra (2019), Lee et al. (2023) and Zhang et al. (2023), who spotted the importance of emerging information and communication technologies in enhancing performance across supply chains, identified the trend.

In Sarawak, adopting such smart supply chain practices has attracted much attention. The companies have increasingly adopted novel solutions, including the installation of IoT sensors for real-time monitoring and the adoption of advanced techniques in data analytics to optimize various supply chain operations (Ali et al.,2023; Gisbrecht, 2018; Taj et al., 2023)

Most of the research justified the revolutionary potential of supply chain management when integrated with smart technology (Agarwal et al., 2024; Bouti & El Khoukhi, 2023; Lorenz et al., 2020; Nasiri et al., 2020; Wu et al., 2016; Zhang et al., 2023;). Most of the research suggested that technology-based interventions can change and improve how the normal work of the supply chain is carried out, enhancing some of the key performance metrics. For example, machine learning and predictive analytics have improved demand forecasting accuracy, enabling companies to make better judgments, hold inventory efficiently, and offer better customer services using large datasets and complex algorithms (Hassini et al., 2023).

Advice or a reference may also come from experience from other successful smart supply chain projects. Technology providers and industry stakeholders must collaborate to realize these through partnerships and knowledge-sharing efforts. These efforts enabled the joint development of creative solutions designed to resolve the unique problems Sarawakian industries face.

Smart technologies implemented in the supply chain are strategic steps toward technological advancement and the future of Sarawak's manufacturing industry. If adopted, such innovations help

businesses become more resilient, agile, and competitive in today's innovating and digitally connected world economy. Examples from Singapore and Germany give an idea of the impact brought about by smart technologies: in Singapore, IoT-enabled sensors reduce transit time by 25% and increase customer satisfaction (Bhatt, 2023), whereas in Germany, blockchain integration boosts visibility and cuts counterfeiting (Lypskyi, 2023). If the same were to occur in Sarawak regarding IoT and blockchain pilot project public-private partnerships, a similar impact could be found to prove feasibility for its wider industrial adoption, observes the MIDF Thematic Report (Yusof et al., 2023).

Circular Economy Implementation

With the global community's increased emphasis on sustainable practices, the circular economy is an important paradigm shift in manufacturing (Singh, 2023). The Sarawak manufacturing industry resonates with the idealistic goals of these principles. This section will discuss how circular economy practices are being implemented in Sarawak while examining initiatives, policies, and success stories.

One initiative in Sarawak is industrial symbiosis, whereby companies cooperate to share wastes and by-products to mutual advantage (Shi, 2022). For example, a paper mill can supply waste paper to a nearby packaging company to reduce the demand for virgin materials and reduce the waste produced, thereby conserving resources and fostering innovation and cost savings in the Sarawak local industrial system.

Government policies play a huge role in promoting a culture of circular economy practices in Sarawak. The State Government has devised various incentives and regulations encouraging businesses to go green. This was revealed through the Sarawak State Budget 2024 (Office of the Premier of Sarawak, 2023), which includes tax incentives for companies investing in eco-friendly technologies or reducing waste, as announced through the tabling of the annual national budget. Such policy interventions create an enabling environment where businesses appreciate circular economy principles as the main drivers of economic growth and environmental stewardship.

Adopting the circular economy in Sarawak's manufacturing industry promotes environmental sustainability and long-term competitiveness. As such, the circular economy has the added benefit of cost savings by reducing resource inputs and waste disposal. Secondly, consumers and investors increasingly invest in companies with sustainability concerns. Hence, adopting the circular economy will inherently ensure companies' brand reputation and positioning in the market. The two-day Malaysia SDG Summit 2023: Sarawak Region finally came to a close in Kuching with the commitment to a sustainable future rededicated by Premier of Sarawak Datuk Patinggi Tan Sri Dr. Abang Haji Abdul Rahman Zohari Tun Datuk Abang Haji Openg, citing proactive and bold steps to that effect, which are part of the 2015 Paris Agreement (Kementerian Ekonomi Malaysia, 2023).

Circular economy practices in Scandinavia provide valuable insights. Sweden's forestry sector has implemented closed-loop recycling, turning waste into raw materials, reducing waste by 40%, and generating new revenue (Ghisellini et al., 2016; Nascimento et al., 2019; Yu et al., 2021). The Netherlands' construction industry uses industrial symbiosis, where waste from one process becomes input for another (Schut et al., 2016). Sarawak can adopt similar initiatives by fostering symbiotic relationships among industries, such as timber and furniture sectors, that recycle wood waste. Promoting incentives for green technologies and facilitating business-waste management institution partnerships will further enhance circular economy practices at lower costs with heightened sustainability.

Transitioning to a circular economy will take time, resources, and effort. According to the "New Sarawak Tribune" (Singh, 2023), most companies still lack knowledge of its benefits and implementation. These challenges, which involve resource-efficient technologies, operational restructuring, and regulatory and logistical barriers, require strong and concerted efforts from the government, industry, and civic stakeholders. In conclusion, although shifting to a circular economy is challenging, this process benefits Sarawak's business, environment, and society industries enormously.

Challenges Faced By Manufacturing Companies In Sarawak In Supply Chain Management, Smart Integration, And Circular Economy Practices

Lack of Technological Infrastructure

The challenges involving the adoption of advanced supply chain management systems and the low-technology infrastructure of the manufacturing industry in Sarawak are expected to be addressed. Strong technology frameworks are needed to embed innovative solutions, hence competitiveness and efficient operation in the supply chain ecosystem (Taieb & Affes, 2013), as stipulated in the SDES.

Poor supply chain data management is a significant outcome of low technology infrastructure. Businesses with advanced digital systems can collect, analyze, and apply data perfectly, leading to efficient decision-making and the loss of optimization possibilities (Vlachopoulou & Manthou, 2005). Additionally, the current problem requires more technology integration in terms of communication and coordination in the supply chain (Vlachopoulou & Manthou, 2005). The ineffective communication and outdated communication methods will result in delays, miscommunication, and misalignments in production, distribution, and logistics processes.

Improved technological infrastructure can only be achieved by implementing advanced supply chain management systems like automated inventory tracking, predictive analytics, and forecasting of demands. These technologies will strengthen the supply chain's agility, elasticity, and responsiveness to changes in the market environment and customers' demand (Haji et al., 2020).

Finally, to effectively address these challenges, the technological capacity for the Sarawak manufacturing industry must be developed. This can be done through investment in physical infrastructure improvement, whereby telecommunications networks, digital platforms, and information systems facilitate proper data and information flow within the supply chain.

Notably, apart from increasing the industry's physical infrastructure, there must be digital literacy and capacity-building programs among industry players to enable them to exploit advanced technologies to improve the efficiency of the supply chain. Training can be done within an organization through workshops and knowledge-sharing platforms to implement digital tools and systems operations in any business along the supply chain.

Therefore, tackling the problems caused by inadequate technological infrastructure is significant to the Sarawak manufacturing industry if it successfully achieves the many benefits that can be reaped from more advanced supply chain management systems. Advanced technological investment in technology upgrades and digital readiness helps enterprises build competitiveness, resilience, and sustainability in an increasingly digitalized and interlinked global marketplace. In addition, the Sarawak Digital Economy Strategy (2018-2022) (47 strategies) set out the direction Sarawak can take to be at the forefront of the digital world. In the recent Sarawak budget 2025 presented by the Premier, RM15.8 billion has been allocated for development and operating expenditure, significantly be used for technological advancement in Sarawak (Sarawak Government, n.d.).

Skill Gaps and Workforce Training

Challenges abound in Sarawak's manufacturing industry. Modern supply chain management requires a much more highly skilled workforce than is currently available (Cao, 2022; Idris, 2023; Lim et al., 2024; Sani et al., 2022), which has been confirmed based on recent interviews with industry players. A workforce that can only operate at high-level supply chain management systems and technologies is in an inferior position to compete or adapt well in the international market.

It is thus incumbent to fill these gaps by having a skilled workforce to handle the supply chain management process. Extensive industry-oriented training programs would only then play a cardinal role in mitigating the stated gaps and arming the workforce with the skills to handle intricate supply chains, as corroborated by "Business Today" (Idris, 2023).

Companies must also be committed to continuous professional development so that their employees keep on learning and innovating about emerging trends, technologies, and best-practice supply chain management. In this initiative-taking approach, the workforce acquires capabilities that foster innovation and a culture of continuous improvement in the industry. Companies operating in Malaysia have to pay their share in the Human Resource Development Funds Croporation (n.d.), which are then utilized in training their employees .

The design and implementation of workforce training programs should be collaboratively done by stakeholders from the industry, learning institutions, and government agencies. Such a category of stakeholders can pool their resources, experience, and insight to formulate and implement relevant training programs with attributes, among others, a curriculum consistent with the industrial requirement and help in knowledge and skill flow from the university to the industry. According to the official portal of the Ministry of Education, Innovation and Talent Development Sarawak (2023), Sarawak will target 30 percent of its skilled workforce by 2030.

Companies ought to, therefore, adopt policies for talent attraction and retention in SCM. Such policies are essential in ensuring that future skill shortages are adequately addressed through competitive remuneration packages, promotion opportunities, and incentives for professional development. These policies encourage people to pursue careers in supply chain management and foster industry growth and sustainability.

Therefore, the issue of an available and able workforce to practice current supply chains is relevant to the capacity building and competitiveness of the Sarawak manufacturing industry. With strategies for training and development, stakeholder collaboration, and productive talent attraction and retention, this sector will evolve resilient supply chain systems to thrash out emerging challenges ahead.

Regulatory Compliance

Of the major challenges for cross-border supply chain activities, one is the regulatory framework. Many laws govern several jurisdictions, covering the environment and trade regulations. With the dynamic changes in the regulatory environment, given that the world keeps changing in the spheres of globalization, rapid technological advancement, and increasing awareness of the need to protect the environment, this scenario demands constant re-adjustment of the businesses to change compliance needs. Failure to adjust in time means bearing the penalty and sometimes tainting the firm's reputation (Bariyah et al., 2012).

Companies must comply with international standards, such as ISO 9001 and ISO 14001, to remain competitive. These standards improve performance in their operations, brand reputation, and consumers' confidence. Compliance will mainly require a significant resource base, specialized personnel, technology, and investment in training. The manufacturing companies in Sarawak need guidance in terms of understanding and meeting complex regulatory frameworks since, in most instances, resources and expertise are less available. Compliance management advisory and technology solutions help lighten the administrative overload that manufacturing faces today regarding compliance management and uniformity. These solutions include advisory services on compliance management and state-of-the-art technologies, such as regulatory compliance management software for monitoring, documentation, and reporting.

Collaboration with companies, government agencies, and trade groups would help share information and develop compliance procedures that reduce the burden on each business. The collaboration outlined above enables the stakeholders to drive regulatory reform, spearhead the adoption of industry best practices, and influence the regulatory interpretation as an enabling environment creation drive for growing businesses and industries.

Monitoring and dealing with the inherent supply chain complexity under the relevant and applicable regulatory framework is critical for Sarawak's manufacturing industry. It would put operations at the forefront of compliance issues through necessary investments in resources and technologies and collaboration with stakeholders. This measure would reduce risks, build resilience into operations, and help capture the winds of global market opportunities.

Data Security and Privacy Concerns

In this regard, the implication of smart technologies for efficiency and innovativeness in Sarawak's manufacturing industry is undeniable. However, at the same time, it also ushers in several effects of the technological revolution associated with many risks to the security and privacy of sensitive information. This comes with an equally rapid rise in the threat of cyberspace exposure to data breaches and cybersecurity threats with every advancement in connectivity across businesses, unlimited cross-interoperable systems, and digital platforms (Jamwal et al., 2021; Settembre-Blundo et al., 2021). For example, a cybersecurity breach could trigger several serious unfavorable consequences relating to financial losses, reputation damage, legal issues, and regulatory actions that attract sanctions. This implements robust cybersecurity and strict privacy protocols to mitigate risks (Murphy & Murphy, 2013).

One of the major issues related to securing sensitive data in modern times is its heterogeneity and interconnection across modern supply chain ecosystems. Enterprises should implement multi-layered security mechanisms that keenly monitor, detect, and respond to threats in case digital information moves through multiple interfaces and touchpoints: advanced encryption techniques, intrusion detection systems, and access controls to safeguard digital assets from unauthorized access.

Another challenge comes from compliance with data protection laws, such as GDPR and PDPA. To comply with these regulatory frameworks, organizations should closely monitor the legal environment and conduct regular audits while implementing good data governance practices. They must also develop consortia with industry partners, government agencies, and cybersecurity experts to address the above challenges collaboratively.

Intelligence, best practices, resources to pool collective strength in counter-cyber threats, and a culture of awareness and vigilance in the industry should be shared among companies. Workers need to be trained and capacity-built to identify and mitigate cyber threats. Their training programs must be oriented to phishing awareness, password hygiene, and incident response procedures to have a human firewall in place to reduce the possibility of security breach risk (Cayetano et al., 2018). Smart technologies can vastly transform the industry for better efficiency and improved competitiveness. Such potential is, however, coupled with new challenges to cybersecurity and data privacy. Therefore, the Sarawak manufacturing industry can overcome the challenges. At the same time, it reaps the transformative benefits of smart technologies through proactivity towards cybersecurity, enhanced protection measures that can be taken, and collaboration among stakeholders (Tao et al., 2021).

High Implementation Costs

While implementing smart technologies in supply chain systems entails a significant financial investment, it is a crucial step towards enhancing the competitiveness of small and medium-sized enterprises in the manufacturing industry in Sarawak. The initial setup cost, ongoing maintenance, upgrading, and staff training are substantial. However, the potential for increased competitiveness in today's digitized marketplace is a compelling reason to consider this investment (Raman et al., 2023).

Costs of set-up

The set-up cost of implementing smart supply chains is also high. Costs involve implementing hardware and software solutions, interfacing new technologies with existing infrastructures, and

customizing solutions to meet specific business requirements (Chen et al., 2020). For Sarawak manufacturing companies, committing to these specific investments would demand an adequate disaggregation of the financial components to allocate enough amounts for specific expenses (Chen et al., 2020).

Other costs

Other expenditures include long-term operational and maintenance costs for smart technologies. In this case, companies must allocate amounts for software update costs, cybersecurity measures, technical support services, and staff training programs (Beshai et al., 2020; Chen et al., 2020).

Financing the investments

Companies may need support in identifying financing options for smart technology investments. Traditional lenders consider these projects high risks for the business, especially in cases where the business's financial history is shorter or if no collateral assets exist. To finance their digital transformation implementation, companies must investigate other financing sources, such as government grants, venture capital, or strategic partnerships, to be more confident about their investment.

A detailed approach to the financial challenges is crucial. Strategic planning, cost-benefit analysis, and engagement with industry players are important for planning the financial commitments of implementing smart technologies. By actively participating in the industry, companies can gain valuable insights, form strategic alliances, and feel more connected to the larger community of businesses undergoing digital transformation (Chen et al., 2020; Majeed & Rupasinghe, 2017; Raman et al., 2023).

Government incentives and support programs that motivate company digitalization provide resources and guidelines for digital transformation. Companies can also control costs by adopting scalable and modular smart technology solutions, which can have phased adoption and improvements. Such a business scenario would enable manufacturing companies in Sarawak to have measurable returns on investment in smart technologies and generate momentum in further digital initiatives (Chen et al., 2020).

While adopting smart technologies presents a significant financial challenge for manufacturing companies, it also enhances competitiveness, efficiency, and resilience. By strategically and collaboratively approaching the financing and implementation of these technologies, manufacturing companies in Sarawak not only overcome these challenges but also leverage the transformational benefits of digitalization in their SCM.

Resistance to Change

Adopting new technology is the only way organizations can be competitive digitally; hence, it requires a strong commitment from the organization's stakeholders. Fiorentino et al. (2020) talked about organizational inertia and those accepted habits that do not make way for innovation, significantly hindering the adoption of new technology. Resistance to change, existence, and a firm belief in the old ways of work must be surpassed to integrate smart technologies into supply chain operations. Fiorentino et al. (2020) described the change as so difficult that a shared commitment toward adopting technological change would affect its effectiveness.

The significant issues are organizational inertia, resistance to change, and a strong liking for conventional working methods that inhibit technological adoption. Fiorentino et al. (2020) explained that organizations must have effective change management to ensure the staff members can innovate. The employees must be trained on the benefits of new technology adoption, opportunities for skills development, and incentives to participate actively in transformation activities. Fiorentino et al. (2020) elaborated on how smart technologies have been instrumental in organizations for spanning the

design–implementation gap of sustainable business models. This means that organizations need to be able to communicate to the readers the benefits of technology adoption, provide opportunities for skills development to make them digitally literate, and provide incentives for active participation in transformation activities.

Another innovative strategy that may be vital is the development of a culture that allows for innovation to take root, an environment that fosters experimentation, creativity, and learning. Organizations have to encourage curiosity, risk-taking, and learning from failures. Fiorentino et al. (2020) explained how new enabling technologies promote an innovative environment.

Leadership is considered to be the foundation upon which organizational culture is built and on which technological change is guided. Leaders should personify the innovation desired, leading the charge for new projects and reinforcing creative efforts. The fixtures of this—deemed necessary for effective leadership in technological change—as verified by Fiorentino et al. (2020), include integrating sustainability strategies, smart technologies, and change management studies.

Partnering with external agents, such as technology providers, industry associations, and academic institutions, provides specialized knowledge, resources, and network access. Such strategic alliances often integrate smart supply chain systems and co-develop customized solutions to meet organizational needs.

Integrating smart technologies in supply chains is a complex undertaking, requiring them to break away from the status quo and establish a dynamic culture of innovation. Companies can leverage technology to achieve greater efficiency, agility, and competitiveness in the ever-evolving, digitalized global market, provided that resistance is overcome, the workforce is engaged, and external partnerships are formed.

Lack of Circular Economy Awareness

The manufacturing sector is essential in realizing sustainability within Sarawak. In this view, there is an impending requirement to increase awareness and perception of the principles of the circular economy among industries. According to Ekins et al. (2019), principles such as these are related to enhancing resource efficiency, waste reduction, and closed-loop systems that enable material recycling and re-usage. Whereas these principles can be good for business, most manufacturing businesses in Sarawak need to be made aware of them and how to use them appropriately.

The literature identifies the pressing need to sensitize and educate manufacturing companies in Sarawak on the concept of the circular economy. With information on such principles, a business owner may comprehend how the shift towards more circular business modes could benefit the firms. According to Nikolaou et al. (2021), these modes attain cost efficiency, contribute to competitiveness, and have reduced environmental impacts, all based on the shelf-life of products, conservation of resources, and waste reduction.

A lack of understanding of the principles of the circular economy will likely have certain impacts. Like most parts of the world, the manufacturing industry is experiencing a series of environmental issues linked to unsustainable modes of production and consumption. The less efficient management of waste and non-renewable use of resources has degraded the environment, channeled negatively into the health of ecosystems, and caused negative effects on human well-being (Chennak et al., 2023).

Stakeholder engagement is important in bridging the knowledge gap and fostering a culture of sustainability within the Sarawak manufacturing sector through government agencies, industry associations, educational institutions, and other stakeholders. It drives training, information sharing, and knowledge exchange on the principles.

Circular economy principles hold great promise for the Sarawak manufacturing sector. Associated education and awareness activities could realize that potential through investment. Circularity ensures economic benefits, conservation of the environment, and well-being for all; it is tied to the imperatives

of sustainable development (Kandpal et al., 2024). With circularity, Sarawak enterprises can take leading positions in a sustainable manufacturing industry, driving change for good throughout this region and beyond.

Infrastructure for Recycling and Reuse

Setting up the infrastructure to sort, recycle, and reuse products is important in driving circular economy practices toward a shift to a more circular economy. The research reinforces the need for such infrastructure to enable this shift. However, problems like the absence of more recycling facilities and little cooperation between businesses and waste management entities are still hindering successful implementation.

The circulation of materials depends upon the efficient collection, separation, and processing of materials to reintegrate them into production cycles. Much of the region needs more support in its recycling infrastructure, which can fail to close the circle of resource consumption (Yang et al., 2023). To ensure proper facilities, businesses can find sustainable replacements for traditional linear production models.

Collaborating with waste management entities is equally important in optimizing resource recovery and reducing waste generation. The cooperation leads to the research and development of innovative material reuse and recycling solutions and the establishment of effective collection and transportation systems. However, even with collaboration, some valuable resources still go to waste, thus further damaging the environment.

These challenges need strong stakes from all sectors. Governments invest in and develop recycling and waste management infrastructure to facilitate the implementation of the circular economy, as suggested in the article published by Global Infrastructure Hub (2021) titled "Roadmap for Enabling Circular Economy Potential in Infrastructure." Policies and regulations can encourage businesses to engage in sustainable practices and cooperation with waste management entities.

Companies are responsible for making resource efficiency and sustainability a priority. Investments in recycling and reuse technologies reduce a business's reliance on virgin resources and reduce the generation of waste (Akomea-Frimpong et al., 2024). Businesses may facilitate material flows and improvement of resource recovery in partnerships with waste management entities.

Collaboration platforms and networks help the free flow of knowledge and best practices between businesses, waste management, and other interested parties. Such collaborations based on common capacities and resources could spur innovation and speed up the transition to the circular economy.

Despite the need for an enabling infrastructure in recycling and reusing materials while implementing circular economy practices, addressing the challenges of inadequate facilities and lack of collaboration is also significant. By leveraging efforts at all levels and using already available resources, stakeholders can clear the path towards a more sustainable future.

Possible Solutions and Future Directions

Research and Innovation

This study encourages research initiatives and innovation to grow the Sarawak manufacturing industry. It is also key to overcoming contemporary challenges and developing new solutions. Cooperation between academia, industry, and government is imperative to advance various domains—from supply chain management to technology integration and circular economy implementation. (Chokshi et al., 2023; Chukwuebuka, 2023; Ferraz & Pyka, 2023; Rejeb et al., 2023).

Knowledge sharing and cooperation in the supply chain management process helped identify the importance of academia-industry collaborations in encouraging innovation (Ferraz & Pyka, 2023). By applying high-end academic research, businesses can access the latest insights and methodologies to enhance their operation and sustainability (Ferraz & Pyka, 2023).

Following the research cooperation, advanced technologies are acquired and implemented in the business's manufacturing processes. It helps by using such technologies to optimize resource usage, minimize waste, and increase productivity (Rejeb et al., 2023). The government accelerates technological innovation and adopts the same at an industry-wide level (Chukwuebuka, 2023)

Apart from the above, research cooperation is also required to drive the circular economy practice. By contributing equal expertise, the stakeholders develop innovative and new recycling, remanufacturing, and waste reduction strategies to increase sustainability and resilience in the manufacturing industry (Ferraz & Pyka, 2023).

Promoting research cooperation can help businesses stay competitive in a dynamically changing market. By staying updated with technology and methodology trends, they can adapt to changing consumer demands, regulatory landscapes, and market dynamics (Rejeb et al., 2023).

In conclusion, research initiatives and cooperation between academia, industry, and government help overcome challenges and drive innovation in Sarawak manufacturing. Such collective efforts will unlock new growth opportunities, enhance sustainability, and add to the cause of economic development (Chokshi et al., 2023; Chukwuebuka, 2023).

Stakeholder Collaboration

Industrial players, government agencies, and research institutions must collaborate to create a conducive environment for transformative change in the Sarawak manufacturing industry. Such collaboration will drive sustainability and innovation, as some collaborations between players and educational institutions demonstrate regarding research and activities.

Ensuring Knowledge Exchange and Best Practice Sharing

Such collaboration will utilize expertise and resources to enable stakeholders to share knowledge easily through learning and best practices through cooperation. Industry players bring in practical experience and on-ground experience, while government agencies provide regulatory guidance and support. Research institutions bring in scientific expertise and the provision of innovative solutions.

Resource Pooling for Collective Action

Indeed, such collaboration can also bring together resources for action. This, in turn, would lead to stakeholders seeking efficient solutions to the same problem. Research projects, pilot schemes, and capacity-building activities could overcome the three sustainability barriers while accomplishing significant movement toward common ends.

Fostering Continuous Learning and Improvement

Such collaboration has also strengthened the culture of continuous learning and improvement. This would make partners respond to the ever-changing environmental, social, and economic conditions. In this way, stakeholders could, through constant dialogue and engagement, understand emerging trends, anticipate future challenges, and adjust the pathways accordingly.

In other words, industry players, government agencies, and research institutions in Sarawak collaborate in the manufacturing sector to achieve holistic sustainability. In such collaboration, stakeholders are better placed to harness collective action power to drive positive change, enhance resilience, and create long-term value for society and the environment.

Education and Training Programs

There is a specific need for investments in education and training to fill these skill gaps and maintain a competent workforce by continuously upgrading their skills in the present supply chain practices and infusing present technology. This is very important for an industry like Bangladesh's RMG sector, which requires investment to develop skills and remain competitive in world markets (Swazan & Das, 2022).

Improved literacy levels and education programs allow workers to be more competent in the complexity of today's supply chain, sustainability practices, and modern technologies, boosting an individual's competency levels to make organizations more resilient and competitive in this dynamic world market (Swazan & Das, 2022).

* Education and training programs may include data analysis, supply chain concepts, and sustainability practices.
* Businesses can lower risks, innovate along the supply chain, and optimize operational performance by providing necessary training and support to employees.

Furthermore, investment in education and training fosters a culture of lifelong learning and adaptability among workers. Employees are quick to master new technologies and adapt to the changes in customers' demands. They ensure long-term success as they navigate this rapidly changing business environment (Swazan & Das, 2022). Education and training efforts are extended to broader societal implications because they promote an individual's employability and well-being.

CONCLUSION

This paper synthesizes research on the circular economy, smart supply chain integration, and SCM capabilities in Sarawak's manufacturing industry. Effective SCM strengthens logistics, inventory, and supplier relations, improving responsiveness, efficiency, and competitiveness while reducing costs and boosting customer satisfaction.

Blockchain, AI, and IoT are smart technologies that optimize supply chains through automation, data-driven decisions, and real-time coordination. The circular economy enhances resource efficiency, reduces waste, and prolongs the life of products, increasing profitability and sustainability.

The paper has emphasized the need for SCM improvements, smart technology integration, and circular economy adoption to enhance competitiveness and sustainability in Sarawak's manufacturing sector. The main recommendations include infrastructural investments, incentives toward technology adoption, academia-industry collaboration, and demonstration projects. KPIs such as inventory turnover, waste reduction, and workforce upskilling should be measured for effectiveness.

Future research could also examine the long-term impacts of emerging technologies and challenges like regulatory barriers and resource constraints in Sarawak. A holistic approach will help the sector become a leader in sustainable industrial practices.

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