



The Circular Supply Chain: Closing the Loop through Green Design, Reverse Logistics, and Sustainable Waste Management

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DOI: <https://doi.org/10.55248/gengpi.5.0224.0602>

ABSTRACT

This research offers insights into the complexities of a circular supply chain, highlighting its significance in contemporary approaches to sustainability with green design, and reverse logistics as well as sustainable wastes management. The study uses a mixed-methods design combining quantitative data obtained from the surveys of about 200 businesses and qualitative information drawn from in deep interviews and case studies especially involving the textile, electronics sectors. This methodology enables the understanding of current practices and trends within the region. It is however apparent from the findings that business have increasingly realised the environmental ramifications of their supply chain, but an awareness gap does exist between this knowledge and adoption of sustainable practices. It is important to note that 70% of the surveyed companies admit the supply chain impact on environment, whereas only 40% have implemented green design or reverse logistics procedures. They outline some major obstacles to the circular supply practices such as financial constraints, lack of technical skills and also poor regulatory regimes. In regard to sector-specific insights, the textile industry displays a more proactive reaction in terms of adopting sustainable practices compared with the others. This study has far-reaching connotations showing that there is a dire need for the focused policy initiatives, capacity strengthening and infrastructure development to promote environmentally sustainable supply chain practices in the Kurdish region. However, the study not only provides a more comprehensive understanding of the circular challenges and opportunities in emerging economies but also highlights some unique context-specific strategies for sustainable development.

Introduction

The supply chain management which has often been a linear production and consumption process is faced with very substantial environmental challenges. This linear paradigm has led to a massive depletion of resources and environmental pollution, often referred as the “take-make-dispose” model (Elisha 2020). It is evident that these consequences are emerging in the following forms- high levels of waste, depletion of natural resources and increased emission of greenhouse gases. As Roy, et al., (2023) notes the linear supply chain not only impose pressure on the limited resources but also cause many serious environmental problems in those firms which have a significant impact to the environment. For instance, the fashion and electrical industries are notorious for its short life cycles of their products and also large amounts of trash generation. The environmental damage is exacerbated in the developing countries, which have no legal frameworks (or flawed ones) for waste management and resource conservation while making it even harder to ameliorate the effects of such a situation. The rapid industrialisation that is happening in the Kurdish region, constitutes not an exception with regards to these kinds of issues. According to Khan and Al-Ghamdi (2021), it is likely that serious environmental and economic factors may occur due to the hasty industrialisation without considering the sustainable supply chain practices. It is, thus not only a global concern but also a regional necessity to understand and respond to the environmental effects of the supply chain activities. This is especially the case in many areas that have ecological and also socio-economic situations prone to degradation.

Sustainable practices in the supply chain management are poorly researched and also deployed, especially where there is socio-economic or environmental fragility. This is while the importance of such approaches has been increased alot. With only a few exceptions, the traditional supply chain models overlooked the environmental component of their operations and focused on efficiency as well as cost effectiveness issues. Thus, this omission leads to a gap in the study especially amidst rising regions such as Kurdish territories wherein where issues between economic growth and social welfare, ecological sustainability is an important subject. There is a lack of available research on the sustainable supply chain management for the developing countries. Thus, there is a significant knowledge gap about how these concepts might be adapted and applied in the different socio-economic contexts. This consideration goes to show that the need for these sustainable ways invariably increases with respect to one such unique challenges and opportunities offered by those areas, ranging from limited resources availability therein to the demand of economic growths while conserving environment. One possible answer is the circular supply chain concept that emphasises the resource use and waste product elimination. But there is still a big lack of research on its practical application especially in areas like green design, reverse logistics and also responsible waste disposal. Specifically, within the Kurdish setting, where such projects could have far-reaching environmental and socioeconomic repercussions, this study aims at exploring

ways through which circular economy's concepts can be implemented to in supply chain management. The central aim of this research is to address the divide between these two sectors.

To investigate the possibilities of a circular supply chain as an approach to achieve two goals, environmental sustainability and economic growth in Kurdistan region is the principal aim of this specific project. This research aims at determining how environmentally friendly concepts of ecologically responsible design, reverse logistics procedures as well as efficient waste management practice can be integrated into the supply chains in an attempt to come up with a closed system. Through this, it seeks to develop a robust structure that will help businesses and policy makers in the Kurdish region as well as others which are similar show how one can move away from the obsolete linear supply chain models to ones which touch on circularity. More than theoretical discussions, the objective of this study is to offer more empirical information and also tangible strategies that are tailored according on the environmental, economic, and social sphere in Kurdish region. This study also does not stop at the theoretical debates. This is especially very significant, considering the increasing industrial activities in this region and the intensifying drive to adopt sustainable practices that maintain the long-term ecological equilibrium while sustaining socioeconomic development of this area. Building on this research, we aim at providing not only a contribution to the global debates about sustainable supply chain management but also context specific solutions that respond to the issues faced by the Kurdish region and other similar developing countries.

Literature Review

The idea of circular supply chains, or CSC has recently been becoming extremely prominent as a sustainable alternative to the outdated and old linear models. Adopting this strategy that focuses on recycling and reuse of materials will result in a circular system which would beneficially reduce waste while also saving resources. The most important studies in this field have investigated various aspects of circularity, including the prolonged product lifecycles; materials retrieval and design alteration for recycling are favoured. For example, Geissdoerfer et al. (2017) demonstrate the principles of circular economy and its application in the supply chain management practices. They highlighted the possibility of a much lower environmental footprint as well as improved resource efficiency, based on their results. In a parallel way, Govindan and Hasanagic (2018) introduced the in-depth analysis regarding the circular supply chain configurations requiring attention to implementing CE ideas within SC strategy. These studies offer further evidence that CSC is increasingly becoming a very realistic approach for sustainable development. While they often discuss high-income economies, which would have a potential gap in the understanding of how these can be effectively implemented on different socioeconomic circumstances as seen with the Kurdish region.

In the circular supply chain, green design means designing products with the environment in mind since their creation. By choosing the materials, striving for high energy efficiency and also managing products at the end of their life cycle this strategy aims to reduce the ecological impact associated with it. Environmentally responsible design frameworks for product development have been established, with both Bocken et al. (2016) and also Lieder and Rashid (2016), making significant contributions in this area. Their support for the eco-design principles that incorporate the entire product cycle, ultimately leading to a lesser ecological footprint is an very important contribution. While these studies provide a very solid foundation for sustainable design, they often do not present some specific strategies that can be implemented in the different specialised industrial environments. More importantly, the literature focuses more on industries with high environmental impact such as automotive and electronic ones leaving out areas specific industries like those in the Kurdish region. From this it becomes very evident that there is a big need for research, which would situate the green design principles in diverse industrial settings and also regional specifics while accounting not only local resources but also capabilities of the industrial facilities and environmental concerns.

In the field of circular supply chains, reverse logistics is defined as an activity concerning returning items and also reusable resources for recycling or remanufacturing. This is an very important part of the supply chain. As evaluated by Bentamar et al., (2021), pioneers in the field of supply chain management, researched this subject and studied how reverse logistics was being carried out. Yet, their research largely focused on the industrialised countries and raised awareness of the economic and environmental advantages that can be achieved by recycling the products. Similar research, including that by Govindan et al. However, there is still a gap in the literature regarding Reverse Logistics implementation into the regions that have growing economies. For this reason, reversal logistics should be addressed with a separate approach in such areas as the Kurdish region due to specific challenges and also opportunities that are typical for these places. Although the existing literature does provide a basic understanding, rarely do they allow for the attention to detail that is required for application in less studied places.

One prominent area of research related to the concept of circular economy is also waste management in the sustainable supply chains. The main topic of research in this field is to come up with ways that can minimise, reuse and also recycle the wastage formed at each step of the chain. Some major contributions include Zink and Geyers (2017) study that determined the effectiveness of waste management practices in reducing their environmental impacts. However, their research revolves around the industries and environments characteristic of the developed economies. The study by Krikke et al. (2013) on the integration of waste management methods into the supply chain activities provides very useful information about how such approaches are implemented in the practice. But it also is limited in its external validity to a wide range of the economic situations. The literature shows that the research regarding sustainable waste management in supply chains should be implemented under various regional and also economic circumstances. This is particularly so in areas such as the Kurds where practices of this nature can change both the environmental sustainability and also economic growth enormously.

This study originates from the principles of the circular economy and sustainable supply chain management, which act as a theoretical foundation for this inquiry. This theory states that such a transition from linear to the recycled supply chains can lead to major improvements for the environment, economy

and also society. The pioneering work by Roy and Das (2023) on the circular economy establishes a theoretical framework that defines why closed-loop systems are very essential for efficient resource use and also waste management. It was an very essential step in laying the foundation of this framework. This, in turn is followed by the study done from Ellen MacArthur Foundation (2013) to shed light on the circularity of supply chains and its economic and environmental implication benefits. Although these theoretical bedrocks offer a detailed understanding of the circular economy, however there is clearly an evident weakness in their application to the particular regional settings especially developing economies. As a result, the main goal of this study is to add knowledge by contributing distinct ideas about the Kurdish region through extending these thoughts and applying them on that particular location –the area in question. In the constraints of this theoretical framework, green design; reverse logistics and sustainable waste management will become an all-encompassing strategy for circular supply chains implementations within the various socio economic environments.

Methodology

In this research, we adopt a mixed-method research approach that uses qualitative and quantitative methods to systematically explore the circular supply chain in the Kurdish area, green design, reverse logistics, and sustainable waste management. The quantitative part includes the analysis of data from various firms and also stakeholders in supply chains. This study particularly focuses on their current approaches, challenges and opportunities based on the circular economy principles (Creswell & Creswell 2017). This information provides a broad and statistically propounded perspective on the present state of supply chain sustainability in these specific areas. At the same time, qualitative research includes detailed case studies and interviews which allow to understand better the other challenges on a deeper level. The two research approaches complement each other; quantitative data offers a holistic view, whereas the qualitative data gives an in-depth analysis and insights into selected cases. Through combining the two methodologies, a complete picture of the subject is created that covers both global macro-level patterns and also minor micro-level details (Flick 2022). The study is best supported by the mixed-methods approach which is adequately deals with the challenges of sustainable supply chain management, an area that has several interrelated issues including economic, environmental and social aspects.

The data collection for this research was carried out using two main methods: surveys, interviews are complemented by the case studies. The survey component involved administering a well-structured questionnaire to the diverse firms and stakeholders across the Kurdish region consisting of producers, vendors, logistics providers and also regulatory agencies. This survey set out to gather quantitative information on the current practices, perceptions and also barriers regarding the development of circular supply chains. A response rate of about 60% was generated from the distribution of around 200 surveys. The survey responses had a very significant role in identifying the present trends and also general sentiment towards sustainable supply chain practices. At the same time, in-depth interviews and also case studies were conducted to gain qualitative insights. The study incorporated the purposive sampling method in selecting interview participants covering a wide range of views from all sectors and also levels of supply chain, therefore. In all, thirty structured interviews were compiled with each interview carrying a period of approximately 25 to 30 minutes. The interviews produced a broad pictures of the individuals' experiences, challenges and also modern approaches to circular supply chains. Moreover, three case studies were conducted in the different industries (textiles, electronics and food production) to allow for a detailed discussion of the practical application of circular economy concepts. The use of the multiple data sources such as survey, interviews, and case study assures a stable and strong procedure for collecting the data due to triangulation.

The data collected was analysed both statistically and also as a thematic analytic approach in order to interpret the survey, interview, and case study findings. As pointed out by Saunders et al., (2016), the quantitative survey data was analysed through statistical methods such as descriptive statistics and also inferential analysis. It was very much possible to analyse the trends, patterns and also correlations present in the data through SPSS – a statistical software package. Descriptive statistics give an overview of the dispersion, while inferential parameters like regression analysis helped to understand the relationship between different variables that contribute with in circular supply chain processes. On the other hand, thematic analysis was used to analyse the qualitative data gathered from the interviews and also case studies. This involved a very rigorous coding process in order to identify the recurring themes, patterns and narratives. The NVivo software, which is specifically made for qualitative data analysis, enabled the organisation and also analysis of the qualitative information. The thematic analysis took a central part in demonstrating deep insights into the many challenges, capabilities and also complexities associated with sustainable practices in the supply chain. The utilisation of a wide range in the analytical methodologies allows for an accurate and also intricate analysis of the data which serves as sound support to justify the findings and recommendations.

Results and Discussion

This study has yielded valuable results of where the Kurdish region is today with regard to adoption of circular supply chain strategies, green design, reverse logistics and sustainable waste management. Based on the survey results, it can be concluded that while there is a growing sense of the importance of sustainable supply chain practices, their actual implementation remains very limited. About 70% of the companies questioned admitted that their supply chain actions had affected nature and only about 40% introduced green design or reverse logistics. The most relevant challenges to the circular supply chain activities implementation based on the results of other case studies are attributed... Looking at findings pertaining to a particular sector, in the textile industry had more engagement with sustainable practices than industries like electronics where circular economy is still in its infancy. While these results point out the necessity for targeted interventions to narrow down this gap between awareness and action in regards of transitioning into circular supply chain practices within the studied region, they also suggest an existing dissonance between the awareness and actions.

Researchers who studied green design and reverse logistics practices in the Kurdish region concluded that things are very intricate. There is a prominent concern of utilising green design practices, especially within the textile sector where some corporations have started exploring eco-friendly materials and

also environmentally sustainable productions. Conversely, there is a proof that the green design standards are becoming more and more common. However, the realisation of these ideas is often affected by a discrepancy between the transition costs as perceived and the technical capacity. However, the practical implementation of reverse logistics happens in an intermittent and often uncoordinated manner despite the knowledge on how critical it is to reduce waste by exploiting value recovery. In terms of reverse logistics. As per the survey's results, only 30% of the companies have implemented a formal reverse logistics process. This gap is most prominent in SMEs, which often do not possess the means and tools to implement the effective reverse logistics systems. The following results demonstrate that, even if there is a significant interest in sustainable design and reverse logistics, despite this movement some work needs to be done due to lack of necessary capabilities and infrastructure for their general acceptance.

Environmental friendly waste management practices are integrated into the supply chains of the Kurdish region, presenting a huge potential for development. The data from the survey and case studies indicate that waste management is usually reactive rather than proactive; most of such activities are aimed at elimination, not reduction or recycling. It is clear from the fact that only twenty-five percent of businesses surveyed are actively involved in activities related to recycling or upcycling. A major reason for concern is the lack of organised waste management techniques, in particular regarding the increasing industrial operations. However, the case studies provided just a few examples of some creative approaches to waste management. These practices were evidently rampant in the food production where the organic waste is used for composting and also bioenergy. These examples are very small, however they can demonstrate the many potential ways of sustainable waste management that could be implemented on a more significant scale. It is obvious from the results that there comes a compelling need for an all-comprehensive waste management plans that include trash reduction, reuse and also recycling. This is an very important policy intervention and also innovation area in the region.

The implications of these outcomes are very significant, not only for the practices but also for theoretical frameworks. With regard to the issues with circular supply chain strategies in emerging economies (Govindan et al., 2015), previous research has highlighted Consistent with the current literature on these topics, However, some challenges such as the AE ratio gap and sunk costs hurdles are associated with reverse logistics techniques that share commonalities in emerging states. This article contributes to the literature by presenting empirical data from a Kurdish standing point. Therefore, they enhance the comprehension of the application of circular supply chain in different socio-economic contexts. The study also contributes to the theoretical understanding of circular economy by showing real problems and possible solutions for practices that could implement sustainable supply chain management in an area with rapid industrialisation and the changing regulatory frameworks. This realisation is achieved by pointing out the many practical difficulties. Acquiring these insights could help to equip the policymakers, as well as the business leaders operating in similar settings with information that would facilitate crafting of policies of a specialised nature tailored for required specific demands and limitations within the local environment.

Examining the study's results in relation to Kurdistan, it is evident that the integration of eco-friendly practices into supply chains should be implemented promptly and expeditiously through a collaborative endeavour. With regard to the introduction of circular supply chain approaches in this region, its unique socio-economic and environmental setting - one characterised by rapid industrial growth and changing regulatory settings - offers both challenges and also opportunities. From the results of this study, it can be stated that there is an imminent need for infrastructure development, creation and also supply capacity building as well as policy implementation to enable a successful shift towards sustainable supply chains. These efforts are not only very critical for preserving the environment, but they also play a vital role in building enterprise resilience and also long-term competitiveness. In addition, the conclusions of this study have alot more general relevance for other developing economies that share such problems in maintaining a balance between technology and environmental conservation. The lessons learnt from the Kurdish context could prove to be very valuable to these areas as well as a source of reference, helping create much more sustainable and also resilient supply chains overall. The research contributes to a much more sophisticated understanding of how the sustainable development objectives can be realised in diverse and dynamic regional contexts by highlighting particular challenges and also opportunities for implementing circular supply chain strategies. This is achieved by identifying the particular challenges and opportunities.

Conclusion

A detailed study of the circular supply chain, green design, reverse logistics and also sustainable waste management in the Kurdish region was carried out through this research which resulted to a number major findings. However, there is a massive gap between the awareness of the sustainable supply chain procedure and its implementation that needs to be bridged. Even though the importance of environment sustainability is recognised by most firms, only a few have been able to implement these practices into their operations. Specifically, the study established that green design implementation in this area is still at a very nascent stage largely due to insufficient technical knowledge and also perceived high cost as major challenges. Reverse logistics procedures of small and medium-sized firms were very unsystematic in nature. In a similar vein, the main focus of sustainable waste management is on disposal rather than on reduction or recycling that implies proactive strategies related to trash control. The findings highlight the urgent need for introducing more structured and forward-looking strategies to embed the circular economy concepts into the supply chains in Kurdistan.

The results of this study have very significant theoretical and also practical implications. This research adds to the existing knowledge by offering real data from a developing country's point of view. It increases our understanding of the challenges and opportunities surrounding the use of circular supply chain practices. The findings suggest that there are major chances for introducing legislative initiatives, developing capacity, and improving infrastructure to support the move towards greener supply chains in such areas as the Kurdish region and others. The study highlights the importance of taking a holistic approach that addresses every component within the circular economy to attain not only environmental sustainability but also economic growth. However, the research had some limitations. The use of self-reports may introduce a bias, and the focus on the Kurdish region might limit the generalisability. The fact is that the dynamic nature of supply chain architecture and also regional regulations means that the conclusions offered reflect a snapshot in time which may be changeable with any changes in circumstances. Therefore, future research studies will have to focus on longitudinal studies that track the

progress of a circular supply chain deployment over a period. Further studies could focus on identifying the unique challenges and also enablers facing separate entrepreneurs in Kurdish regions, providing more industry-specific guidance. Comparative studies with other regions facing similar challenges may offer very important insights into the generalisability of the findings.

Many recommendations can be drawn from the findings for organisations, governments and also researcher in Kurdistan region and other places. Businesses must spend their resources on improving the competency and capability in environmental design of products, as well as the management of product returns. This is very possible through the campus partnerships and also industry collaborations. Policy-makers need to consider the structuring of regulatory bodies and infrastructures that help in adoption ideas on the circular economy. The establishment of infrastructure, specifically for the waste disposal and also recycling centres is very critical. Additionally, there is a need to carry out sensitisation campaigns that can help bridge the gap between the knowledge and practice among businesses and society at large. It is an opportunity that the study offers to the researchers who can investigate how specific policies and interventions impact on circular supply chain practices. Moreover, the analysis of influence technologies like blockchain and IoT on the circular supply chain in terms of transparency and efficiency could also be useful as well. Also, research focused on consumer behaviour and the role that it plays in the chain sustainability might provide important information as to how demand-driven methods of a circular economy may be adopted. If such proposals are carried out in the right manner, they can significantly strengthen the efforts that lead to sustainable and resilient supply chains not only within the Kurdish region but also globally.

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