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The Adoption of Robotic Process Automation Considering Financial Aspects in Beef Supply Chains: An Approach towards Sustainability

Khushboo E-Fatima [1,*], Rasoul Khandan [2,*], Amin Hosseinian-Far [1] and Dilshad Sarwar [1]

1 Department of Business Systems and Operations, University of Northampton, Northampton NN1 5PH, UK; amin.hosseinianfar@northampton.ac.uk (A.H.-F.); dilshad.sarwar@northampton.ac.uk (D.S.)
2 Aston Professional Engineering Centre, Aston University, Birmingham B4 7ET, UK
* Correspondence: fatima.e-khushboo@northampton.ac.uk (K.E.-F.); r.khandan@aston.ac.uk (R.K.)

Abstract: Sustainable beef production is a global challenge in present times. This research paper aims to investigate the financial risks and barriers in the adoption of robotic process automation (RPA), which has emerged as a strategic catalyst for achieving sustainability in the beef sector. Beef manufacturers constantly strive to achieve sustainability and a competitive advantage in order to gain enhanced beef productivity at low operational costs. There is a gap in the research, as there is a lack of knowledge about the financial aspects, barriers, and challenges influencing the RPA adoption process in the beef supply chain. To bridge this gap, secondary research is used to extract statistical data and information relevant to the RPA adoption process in beef supply chains, considering financial aspects. This study utilises a simulation method adopting a process model created in previous research and analyses different scenarios based on financial parameters using values or variables in Simul8 software. The scenario analysis allows for the identification of financial risks in the adoption of RPA and evaluates the simulation results from a sustainability perspective. The scenario analysis highlights the financial risks and barriers in the adoption of RPA in beef supply chains through process simulation, using financial parameters as a basis. KPI values, income statements, and carbon emission reports are generated to evaluate the main bottlenecks at various beef supply chain stages, thus allowing business users to conduct a thorough cost analysis. Successful adoption of RPA can lead to reduced supply chain complexity, thus improving financial and operational efficiency, which results in increased beef productivity, quality, and shelf life. This study is extremely important as it assesses scenarios from a sustainability perspective and contributes to academic knowledge and professional practice. It provides a process model to support the financial and ethical decision-making of managers or stakeholders, while helping the beef sector adopt RPA with greater ease. The process model can be adopted or modified according to the financial circumstances and individual requirements of business users. Furthermore, it provides decision-makers with the knowledge to eliminate or prevent financial barriers, thus advancing and accelerating the adoption of RPA. Robust adoption of RPA assists beef supply chains in gaining higher productivity at reduced costs, thus creating sustainable value.

Keywords: robotic process automation; beef supply chains; sustainability; simulation; scenario analysis; financial aspects

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Citation: E-Fatima, K.; Khandan, R.; Hosseinian-Far, A.; Sarwar, D. The Adoption of Robotic Process Automation Considering Financial Aspects in Beef Supply Chains: An Approach towards Sustainability. *Sustainability* **2023**, *15*, 7236. https://doi.org/10.3390/su15097236

Academic Editor: Wen-Hsien Tsai

Received: 22 March 2023
Revised: 21 April 2023
Accepted: 24 April 2023
Published: 26 April 2023

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1. Introduction

The supply chain system plays a vital role in the effective functioning of business processes. The term "supply chain", defined as a network of information, goods, resources, and business activities, emerged and developed from logistics, marketing, production, and distribution [1]. The coordination of materials, resources, information, and financial flows is an important aspect of a supply chain system. In a broader sense, a supply chain is also known as an inter-organisational flow of services with important units to consider, such as production, marketing, procurement, and finances. Businesses aim to govern and monitor supply chain processes with enhanced efficiency and accuracy in order to perform effectively. Gayialis et al. [2] highlighted that high production levels, lower operational costs, fast-paced production systems, and enhanced sustainability strategies are currently some of the main objectives of organisations. As businesses have become more competitive than before, as a result of technological advancements and innovative implementations and adoptions, it is crucial to manage supply chain processes with more attentiveness and diligence [2].

According to Popkova et al. [3], technological innovations have improved process delivery and enabled organisations to meet sustainability criteria by streamlining business operations and increasing profit margins. Emerging technological solutions such as robotic process automation (RPA) have greatly improved and enhanced food processing and manufacturing and have helped supply chains achieve sustainability and a competitive advantage, as well as create value in business processes. Sustainable food production, which is safer, healthier, and more secure for human consumption, is currently one of the prominent and growing concerns for food supply chains. RPA helps food manufacturers to improve and speed up their business procedures to ensure the production of high-quality, healthy, and safe food with reduced operational and functional costs. In food production, it is extremely important to consider the economic growth and financial health of businesses as organisations are expected to cater to wider masses and a growing food demand, which is quite challenging, especially in a competitive business world [4].

RPA is seen as an emerging technology that can accelerate business processes through the automation of repetitive, strenuous, and rule-based tasks in supply chain systems. RPA is often referred to as software robotics or "bots", and follows instructions defined by the end-users to automate repetitive processes or activities in business organisations. RPA technology uses software bots in place of the human workforce to perform tedious tasks. The implementation of RPA technology not only facilities business processes by making them less complex, but also reduces human error to make supply chains more well synchronized, integrated, and systematic. Digital transformation, such as RPA, has attracted corporate attention as a result of several supply chain complexities, uncertainties, risks, and barriers due to increased globalization and wide-spread supply chains. Technological advancements such as RPA have gained popularity as they accelerate supply chain processes, and reduce the time, cost, and energy required to enhance supply chain operations. RPA's promising benefits include value addition and a competitive advantage for supply chains, thus creating sustainability. Achieving sustainable value is the main concern of supply chains; RPA automates tasks and makes businesses less reliant on the human workforce, thus enhancing production levels, improving supply chain processes, and reducing operational costs, which create sustainability in supply chain processes [5–7].

The beef supply chain is highly fragmented, which makes its management system complex and challenging. Sustainable beef manufacturing and processing has attracted attention globally and is a cause of concern for beef manufacturers. The beef sector involves various stages that include complex procedures in beef production and involve system uncertainties and disruptions. The beef manufacturing supply chains constantly face supply chain risks and challenges related to high operational costs, beef productivity, quality, safety, and shelf life. The beef sector, a representative of the food industry, has social, environmental, and economic challenges. Growing awareness towards beef quality and safety raises concerns for beef manufacturers, who constantly strive to achieve sustainable value and produce nutritious, healthy beef at low operational costs. Process automation within beef supply chains facilitates work-flow management systems, eases complex and tedious tasks through process excellence, and reduces human error to speed up processes. Moreover, automation in the beef sector serves as a process facilitator that enhances supply chain performance and boosts task delivery, resulting in a higher output to satisfy the growing demand for beef. Sustainability-oriented innovations and solutions such as

RPA could reduce supply chain risks through process acceleration and support the beef sector to reduce operational costs and meet sustainability goals. RPA further enhances employee-level efficiency as bots are able to work 24/7, unlike humans, on processing lines to manufacture high-quality, sustainable beef at a low cost. Technological breakthroughs such as RPA have the potential to enhance supply chain operations and satisfy customers by maintaining quality standards. Automation acts as a sustainability driver in beef supply chains to add value in business processes. Innovative approaches such as automation within the beef sector improve production levels, increase supply chain resilience, and make businesses more competitive [8–10].

Sustainability in beef supply chains is a constant concern and challenge for the beef industry [11]. Beef supply chains are complex and large in order to cater to their dynamic structure and business system. Beef supply chains struggle to produce high-quality, nutritious beef due to the high financial costs and overhead expenses of production systems that companies install and implement for efficient beef production. The beef sector strives to achieve sustainable beef production to add value to their supply chains and satisfy the high customer demand due to growing consumer needs and requirements. Beef supply chains are fragmented and very complex across the world as well as in the UK with respect to their functioning, monitoring, and management. High production costs including labour work, machinery usage, technological adoptions, and organizational set-up are some of the financial aspects that are concerning for beef manufacturers. Manufacturing supply chains are seeking sustainable procedures and methods to ensure reduced financial burden and lower operational costs while aiming for higher production levels [12]. This promising RPA technology allows beef supply chains to achieve sustainable production systems.

This research aims to investigate the financials aspects that are important to consider in the RPA adoption process. The study further analyses the financial barriers or risks that may potentially exist in the adoption process of RPA within the beef supply chain system. This study adopts the process model developed in previous research to conduct a 'what-if' scenario analysis based on financial parameters for the identification of financial barriers or risks in the adoption process of RPA that could potentially impact supply chain production levels, costs, and efficiency. Beef supply chain characteristics and features are critically analysed to understand the implementation process of RPA in the beef sector in an enhanced manner, considering the financial aspects. By simulating the business process model and considering the cost-related parameters, this study allows for the assessment and evaluation of the socio-economic benefits of RPA adoption, as well as how RPA can be adopted in a successful manner by eliminating financial barriers to create sustainability within beef supply chains.

This research rationale and its significance is crucial to discuss in order to further understand the aims and objectives of this work. The research supports that beef supply chains struggle to adopt the RPA adoption process because of cost analysis or financial reasons. Although RPA is a popular and widely used process for excellence and efficient supply chain functioning, there are no thorough evaluations related to the financial factors that influence its adoption and previous research lacks information related to the financial barriers or risks present in its implementation. The identification of the financial risks and barriers in the adoption of the RPA process requires critical research and investigation to fill the gap. The process models provided by authors in previous studies examined and investigated the beef supply chain from the perspective of operational efficiency, shelf life, and quality. This study is significant as it uses a simulation approach along with the previously formed process model, and analyses different scenarios based on financial or economic parameters to evaluate the best approach for adopting RPA in beef supply chains. This research uses the process model to analyse the scenarios using the financial parameters or factors that impact the RPA adoption process. Therefore, this study critically examines the process model using financial factors or parameters that are important to consider for effective adoption using a simulation-based approach. The model, depicting crucial beef supply chain stages, is tested and run to observe the production levels and costs at various stages of the supply chain. The simulation uses SIMUL8 software and the scenarios are analysed to observe the bottlenecks or barriers at various stages using a virtual simulation environment. The study considers cost-related factors that contribute to the successful adoption of RPA in beef supply chains to ensure sustainable beef production. It further depicts the financial barriers that could potentially hinder the successful adoption of RPA. Hence, to use RPA to its full potential, it is crucial to identify the potential barriers related to financial aspects in order to obtain sustainable value and gain a competitive advantage. The study has both academic and practical contributions as it allows managers or beef manufacturers to consider the financial risks when adopting RPA, and encourages improved financial decision-making when implementing RPA for process delivery. It further allows beef supply chains to conduct a critical and thorough cost analysis at different stages of the beef supply chain in order to alleviate or avoid any potential risks in the RPA adoption process and to achieve the sustainability goals. This will help organisations successfully adopt RPA in their supply chains and gain high productivity levels with low operational costs, thus creating sustainable value. The base of the research parameters used for the scenario analysis are costs associated with infrastructure/implementation expenses, and expenditures associated with different stages of beef supply chains. Two scenarios are analysed to observe the socio-economic impact of RPA implementation in beef supply chains and to investigate it from a sustainability perspective. The research parameters based on financial aspects are further examined in the results section.

The simulation and optimization of supply chain systems allows for analysing business processes using a virtual environment [13]. The simulation approach is widely used in beef supply chains to assess the behaviours of processes at different stages of the supply chain. The assessment of behaviour of different events at various stages of the beef supply chain enables users to analyse and adopt the best strategy for conducting business activities. Furthermore, food manufacturers use simulation-based methods as a testing technique to analyse different events, processes, or activities at various stages across the supply chain. Food manufacturing supply chains are constantly under pressure due to perishable food items, which have a short life cycle and high production costs. Simulation techniques help to relieve the stress and pressure that food manufacturers face by identifying the bottlenecks and risks present in supply chain processes. This is of great help to the food manufacturing industry as the simulation approach ultimately helps to relieve financial tension and in aids smarter financial decision-making, thus reducing operational costs and increasing supply chain production or output [14].

In supply chains, simulations imitate the operations of real-life scenarios or business systems with the utilization of models. The simulation method involves testing and analysing the business process model. The model represents the characteristics and key behaviours of a supply chain process or system procedure involving a chain of activities. Simulation-based optimization has its strengths and weaknesses in terms of process modelling and experimentation. While simulation has advantages, such as the behavioural assessment of business activities at different supply chain stages and the identification of potential risks in supply chain processes, the simulation method also has some limitations. Some of the prevailing limitations observed in simulation method are that it uses process modelling in a virtual environment, which can at times differ from real-world scenarios. Real-world situations involve humans; the human workforce behaves differently during times of disruption or panic in business situations or vulnerable environments. This is seen as a weakness or limitation in the simulation method, which can only assess or identify business or activity-bound risks, but it cannot evaluate human behaviour or reactions in difficult practical scenarios. Another simulation limitation could be associated with the cost of simulations, which could be high depending on the frequency of testing of the model. At times, due to data unavailability or the high cost of data accessibility, using the simulation method could become challenging. Simulations provide ways of evaluating and assessing solutions; however, simulations do not generate solutions themselves. Hence, the simulation method has no interference with real-world business systems. It allows business managers to visualize the long-term impacts in a quick and systematic manner [15]. On the other hand, the simulation-based approach supports decision-makers by evaluating the potential risks and assessing business procedures and activities, which greatly helps managers or business users plan and schedule accordingly, as well as minimize or prevent the threshold of any risk events in real-life scenarios. In addition, with the wide use of virtual modelling and simulation techniques in manufacturing supply chains, people are also becoming familiar with virtual processes to prevent any risk events in the real world, combat aftershocks, and improve work-flow management systems. The simulation method and model optimization allow managers to understand and identify the impact of every action on the business process and to develop strategies to prevent any prevailing issues in advance [16,17].

There are various types of simulations present in supply chain management, such as system dynamics, business games, discrete-event simulation, and spreadsheet simulation [18]. This study uses the discrete-event simulation technique as a simulation to map out different stages of the beef supply chain. The discrete-event simulation method is used to simulate the performance and behaviour of real-world processes, systems, or facilities. This simulation technique represents a discrete sequence or chain of events, or stages of a business system [19,20]. DES is a popular modelling method that is suitable for manufacturing systems as it provides insight into different processes or stages of a supply chain. The DES simulation method maps the different stages to observe the performance levels and behaviours of events or activities conducted through progressing time. The DES simulation technique has many advantages, such as providing a level of flexibility to the process by detailing and observing the dynamic behaviour of the supply chain at various stages. It is beneficial to use the DES modelling technique in manufacturing supply chains to analyse the performance levels of activities and to evaluate the operational efficiency of the supply chain. DES simulation also helps to identify the risks or uncertainties at various stages of the supply chain with respect to quality, logistics, efficiency, time taken, and interaction levels. This simulation technique is widely used within the food industry for quality assurance and productivity levels, but financial and operational efficiency remains challenging for food supply chains. The DES technique is used in practical aspects within food supply chains to determine the process performance and improve the standard of quality in food production [21].

Other key advantages of the DES simulation include a thorough analysis of the operational efficiency levels within manufacturing supply chains, helping businesses save time, cost, and energy by determining risks and uncertainties. The operational efficiency can be evaluated by providing various resource inputs and parameters for robust results. The DES simulation technique, when used in practice, helps manufacturing supply chains understand and evaluate key risks that can be eliminated in real-life scenarios in order to boost process delivery and to lower operational costs to achieve sustainability. It further supports businesses with effective decision-making to enhance supply chain performance by reducing supply chain complexity and incorporating sustainable practices [22].

As discussed above, in this study, the discrete-event simulation technique is used for modelling and staging beef supply chain processes. A model adopted from a previous study is used to simulate and analyse different scenarios, considering the financial aspects of the adoption process. Financial or cost-related parameters are the basis for developing the scenarios used for process simulation and examination in this study. The discrete-event simulation tool is widely used by food supply chains as it helps map supply chain processes for an enhanced understanding of the business system and how processes are carried out. It is a streamlined process for mapping different supply chain stages that can provide insight into the business activities or events [23]. The discrete-event modelling technique also provides insight into the cost analysis, which greatly helps in assessing the sustainability of supply chains [24]. Therefore, it is beneficial to use the modelling technique to assess the beef supply chain from financial or economic aspects, and to evaluate cost reductions and profitability by implementing RPA technology. The simulation model helps to further evaluate the time taken for tasks at various stages of the beef supply chain and how the chosen RPA technology save costs while improving efficiency. The technique could potentially investigate the economic and social value from the perspective of sustainability. The RPA model could also be adopted by managers or business decision-makers considering the financial or cost-related aspects. It also helps with effective financial decision-making in real-life scenarios, where the beef sector can alleviate or avoid financial barriers or risks beforehand and adopt a better approach for RPA implementation.

Section 2 discusses the literature review and provides an in-depth explanation and insight into the following aspects of the beef supply chain: dynamics and challenges, the significance of achieving sustainability through adopting RPA, different dimensions for a more sustainable approach through RPA adoption, and a simulation-based using RPA integration considering the financial aspects. Section 3 highlights the methodological choice of research. Section 4 discusses the results related to the simulation and analysis of the process model using different scenarios based on financial parameters. It further illustrates the KPI values, income statements, and carbon emission reports by simulating scenarios using Simul8 simulation software. Section 5 is the discussion section where the simulation results of the scenarios are critically discussed with respect to the three dimensions of sustainability: social, economic, and environmental. Section 6 discusses the conclusion, limitations, and future scope for research.

2. Literature Review

2.1. The Dynamics and Challenges of the Beef Supply Chain

Singh et al. [25] described beef supply chains as a challenging business system involving complex processes and stages. It is imperative to consider the dynamics and features of the beef supply chain system in order to understand its unique characteristics and procedures that are different from other food supply chains. The beef supply chain has various stages and phases that demand high vigilance, monitoring, and handling due to the complexity of the execution process and beef production. In previous years, the beef sector has mainly been manual-centric because of procedures requiring human handling and intervention. However, as a result of the growing demand for beef, technological advancements, fast-paced competitive markets, and unprecedented events such as the pandemic, the industry has started to consider adopting innovative technology. Technological innovations such as RPA have simplified beef processing tasks and relieved employees from performing strenuous and repetitive tasks. The beef industry involves complicated procedures as the animal must be disassembled into different products for human consumption or sale in the market. The products are marketed to different industries, such as retailers, export, and food service. The beef industry was also impacted by COVID-19 as the business processes were mostly manual-centric in the past. The beef sector was impacted economically as a result of the pandemic, and producers, manufacturers, and consumers were significantly impacted [26]. The beef supply chain involves different stages in which the carcass is processed for the produced and manufactured into beef products that ultimately reach the consumer for the purpose of consumption. The first stage of the beef supply chain is the farming or breeding stage, after which the cattle progress to the next stage of logistics or reaching the abattoir, as depicted in Figure 1. The third stage is the beef manufacturing or processing stage, where the carcass is processed further for boning, fat trimming, cutting, etc. Then, the processed beef reaches the retailer or distribution centre, after which it reaches its last stage of the supply chain—the customer. The Figure 1 depicts all the significant beef supply chain stages that are crucial to highlight for firmer understanding.

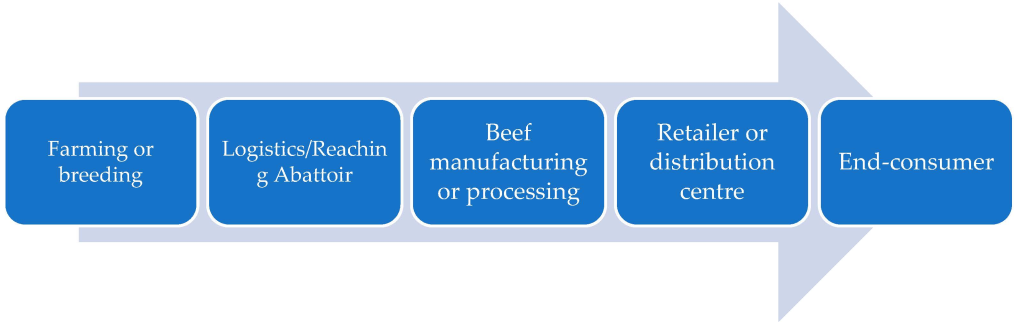


Figure 1. Beef supply chain phases (adapted from [27]).

The beef manufacturers constantly face sustainability challenges, as the supply chain system is typically complex and difficult to manage. The beef supply chain is sensitive to manage as it involves environment, financial, and food-related concerns and challenges, which increase its complexity [28]. Considerations regarding beef shelf life, quality, human consumption, and financial aspects makes the beef supply chain challenging. Because of the constant social and financial pressure faced by beef manufacturers, they are constantly seeking sustainable strategies that could be implemented to address these concerns. According to Cox et al. [29], the supply and demand of beef is highly uncertain due to the nature and distinctive features of the beef supply chain. Beef manufacturers are seeking sustainable approaches and autonomous production systems in order to meet the growing demand for beef, achieve customer satisfaction, and maintain a high level of production. Some central problems related to beef production are quality concerns, shelf life, environmental challenges, and high costs. Globalization and technological advancements have the potential to enhance production systems, cut-down labour costs, and increase operational and employee-level efficiency to achieve sustainability and a competitive advantage [30].

The demand for beef is growing as a result of the increasing population, which has introduced challenges within the beef sector. The dynamics of the beef supply chain are unique and complex due to the presence of various actors in the stages of the supply chain. These actors involve breeders, butchers, slaughterhouses, producers, manufacturers, retailers, end consumers, etc., which increase its managerial and processing complexities in task delivery. The beef industry is competitive and faces issues such as cultural and managerial challenges, economic difficulties, supply chain disruptions, and unprecedented events, which make the processes in the supply chain complicated and risky to handle. To address these issues and prevent any discrepancies that could cause supply chain disruptions, it is crucial to assess the risks in advance and to develop an efficient management system by adopting systematic, innovative tools and techniques [31].

The beef supply chain is also considered to be risky as it consists of its complex production and manufacturing stages involving strenuous processes that could be harmful to the environment and employees working on the processing lines. Widespread stages and procedures in the supply chain result in coordination, synchronization, and managerial issues. The beef industry faces unprecedented events that raise concerns about its manual-centric processes; the adoption of innovative and sustainable strategies that could create supply chain resilience is thus encouraged. Resilience in beef supply chains is important as the consumption of beef is directly related to human health concerns that impact both society and the environment. Sustainable solutions and innovative procedures in the supply chain could help these procedures, thus making the supply chain resilient to any risks or disruptive events such as COVID-19. Other than disruptions caused by the COVID-19 pandemic, other risks such as animal diseases and agricultural disturbances also impact the production and manufacture of beef. The beef industry is focussed on addressing labour shortages, supply and demand uncertainties, high operational costs, and environmental issues; to achieve resilience in these issues, sustainable and long-term strategies should be adopted to avoid any losses or failures in the respective supply chains. As a result of these prevailing sustainability challenges, the beef sector should endeavour to adopt efficient techniques and systems to deal with environmental and social concerns, such as labour scarcity and the transmission of diseases, in order to create financial and operational resilience and enhance management practices [32,33].

2.2. RPA Technology—An Essential Sustainability Tool in the Beef Sector

The beef industry has been a late adopter of technology due to the unique structure of the supply chain system and its individual characteristics and features; hence, most of its procedures are manual-centric. Producing nutritious beef is challenging for manufacturers as a result of variables in the weight, height, and colour of the carcass; intensive beef cutting procedures; maintaining standards of quality; and health concerns. RPA allows for process excellence by using software bots to perform rule-based, repetitive tasks that were manually conducted in the past. The adoption of RPA enhances the operational and financial efficiency of the beef supply chain and ensures that high-quality, healthy beef that is safe for human consumption can be manufactured. The promising benefits of RPA also include a high level of productivity and faster manufacturing lines, as well as being time saving, energy efficient, and cost effective; these are currently concerns of the beef industry and supply chains due to the increasing demand for beef. RPA provides autonomous solutions to complex systems and its implementation could reduce the costs and energy use of organisations, thus achieving maximized output levels and satisfying consumers [34].

Lynch et al. [35] shed lights on sustainability-focused innovation, which has been a topic of debate within the beef sector due to the complex management and attributes of its supply chains. Recently, the beef supply chain has faced many challenges related to human health, animal welfare, biodiversity, greenhouse gas emissions, quality, and shelf life. The beef industry seeks to implement sustainable approaches and solutions to cater to all of these problems and to gain sustainable beef production for human consumption. Achieving sustainability remains a multi-dimensional issue within the beef supply chain and it requires attention and focus. This is because the structure of the beef supply chain is broad and wide-spread, and its procedures are not fully automated due to their individual complexities. Therefore, the supply chain still requires human involvement and handling. The use of RPA in the beef sector will allow tasks to be automated, less complex, and improve beef quality and safety. RPA also enables organisations to enjoy long-term financial and social gains by reducing operational costs, minimizing beef wastage during processing, and preventing any accidents or environmental hazards. Innovative efforts such as RPA could bring socio-economic gains and help business owners gain a sustainable competitive advantage in beef production and processing.

Sustainability-oriented innovations such as RPA will pave the way for green production, as automated tasks produce less waste along the processing line with lower chances of disease and viral transmissions. Developing sustainable beef production systems through by implementing and adopting technological innovations such as RPA enables the production of low-cost, high-quality beef with social, economic, and environmental benefits. Food safety and quality in beef has encouraged decision-makers to pursue and implement sustainable technological solutions in order to enhance the performance, maximize financial benefits by lowering the associated operational costs, and meet health and safety requirements [36,37]. Achieving sustainability has created awareness within business setups, encouraging the adoption of sustainable business approaches so that long-term advantages can be achieved. The awareness and recognition of sustainable supply chains incorporating modern technology such as RPA has attracted many businesses [38]. The different approaches and perspectives of sustainable supply chains are explained in Table 1.

Table 1. Definitions of sustainable supply chains.

Definition of Sustainable Supply Chains	Reference
A sustainable supply chain is described as the management of business processes including social, environmental, and financial aspects.	[39]
The term sustainable supply chain is focussed on considering and implementing sustainable business ideas, innovations, and approaches for long-term benefits.	[40]
Sustainable supply chains employ and incorporate methods of green production and operations management to ensure social, environmental, and economic gains.	[41]
Sustainable supply chains strive to achieve adding value and competitive advantage by engaging in sustainable business activities.	[42]
A sustainable supply chain is a business system concentrating on competitive opportunity, public interests, and green production systems.	[43]
Sustainable supply chains possess an enhanced understanding of digitally enabled processes and innovative business approaches to minimize supply chain complexities and risks.	[44]
Sustainable supply chains concern the identification of potential barriers and implement technology to enhance operational and employee-level efficiency.	[45]
Sustainable supply chains aim towards process excellence, innovative solutions, and greater business efficiency while reducing any negative impacts on the environment and society.	[46]

Sustainability has gained a lot of attention and has become a primary goal of beef supply chains to add value and achieve corporate social responsibility [47]. Sustainable beef processing and manufacturing brings considerable benefits to organisations as they could achieve long-term viability, profit, and cost reduction. Sustainable business strategies and procedures such as the use of technology could prevent risks and hazards and achieve a positive social, economic, and environmental impact. The use of RPA tools can maximize profits and enhance task efficiency in processes such as beef cutting, deboning, and packaging. The implementation of RPA can also reduce environmental or social hazards such as accidents on the processing line or the transmission of diseases by replacing humans with software bots to complete tasks. The bots are also able to work 24/7 and do not require any breaks, which increases beef production levels; this also ensures the quality of beef produced as the chances of meat contamination are reduced. RPA not only provides technological support to beef supply chains, but also enables decision-makers and managers to achieve sustainability criteria in the fast-paced market. RPA is a valuable addition to beef supply chains as it assists and improves system processes and allows firms to achieve sustainable value and achieve a competitive advantage [48].

Modern technological advancements in simulation and process automation have been widely adapted for use within businesses and industry. Incorporating sustainable technologies in organisations has gained value as automation can relieve employees who perform strenuous, repetitive tasks, as well as provide sustainable solutions to complex and disruptive business environments. RPA is a leading and widely adopted technology that has the potential to improve business process management through task automation and it is considered a sustainable practice to enhance supply chain operations. RPA technology facilitates, improves, and optimizes business processes considering the addition of value and sustainability criteria. For instance, RPA acts as a helpful sustainability tool to enhance workforce efficiency by replacing tough and repetitive tasks with automation, allowing humans to use their potential and expertise in judgement-based tasks or managerial areas. Moreover, RPA also simulates different process systems and analyses the data to develop a more cost-effective and sustainable method of organising. It is crucial for business users to decide which processes would be most suitable for automation in order for successful adoption of the process. Digital transformation, such as RPA, continuously improves supply chain operations and process efficiency, and helps organisations meet their sustainability agendas and goals [49].

RPA serves as a process efficiency tool to create sustainable value in beef supply chains. Automation solutions such as RPA accelerate production processes by speeding up the processing line and reducing errors by replacing the human workforce with software bots. New sustainability demands are linked to beef quality, safety, and cost and are associated with supply chain processes in the beef industry. The integration and adoption of RPA assists by adding value to supply chain processes and producing high quality beef that is sae for human consumption. RPA also allows for an eco-friendly beef production environment as tasks are automated, resulting is less human error; reduced chances of accidents on the processing line; lower transmission of diseases; and less time, cost, and energy consumed when conducting strenuous tasks. It also improves supply chain synchronization and coordination through the removal or reduction of human error and through efficient process delivery at different stages of the beef supply chain [50]. RPA is now perceived as an asset as it eases employee-level pressure by improving processes, thus allowing the human workforce to concentrate on meaningful and skilled-based activities. RPA provides business organizations with various advantages for achieving effectiveness and competitiveness. RPA increases productivity levels, improves the quality of production, and ensures enhanced consumer satisfaction. The value provided by RPA technology improves accuracy levels, increases profitability margins, and boosts the financial conditions of the business organization [51].

2.3. RPA Adding Value and Dimensions to Sustainability in the Beef Sector

RPA automates tasks to make business processes simpler, easier, and faster. Among others, some of the promising benefits of adopting RPA include scalable business solutions and gains, as well as financial stability. The positive role of RPA includes adding value by optimizing and simplifying supply chain processes. Value-added opportunities such as performance management, scalable production, and reduced human error or risks also enhance supply chain processes. According to Langmann and Turi [52], the adoption of RPA by business owners allows organisations to rely less on the human workforce by deploying software bots to complete mundane, routine-based tasks. The process of hiring, training, and accommodating the human workforce is costly. In times of unprecedented events such as COVID-19, the human workforce might be unable to carry out their roles and responsibilities. To deal with such issues, the adoption and implementation of RPA ensures the delivery of tasks in a robust manner, with greater control. This allows the human workforce or employees to focus on more judgement-based and skilled job roles and creates newer opportunities. Employees can focus on value-added tasks rather than performing repetitive tasks that are strenuous. Moreover, RPA is seen as a valuable addition to business processes due to its potential benefits, and is perceived as a sustainable business solution in complex supply chains such as the beef industry [53].

Digitalization has created new possibilities and opportunities for businesses to develop and progress [54]. Digital transformations such as RPA technology has redefined and optimized supply chain systems by recognizing the role and impact of automation in process delivery and excellence. New business models concentrate on adopting innovation-based technology that create sustainability and provide long-term benefits and higher levels of output. Internal and external pressure and unprecedented events such as COVID-19 have urged and stressed business organisations to transform their ideas about business and automate processes in order to reduce dependence on the human workforce. The traditional workforce has also transformed and re-organized into a good blend of humans working alongside software bots. The largest and most dominant concerns of businesses at present is achieving sustainability and business viability. Technological innovations such as robotic process automation (RPA) change and transform the nature of and strategy taken to complete tasks. RPA serves to ease business functions, reduce any human error by replacing humans with software bots, and gain competitive opportunities within business organisations. This emerging and innovative technology reduces process complexity and enhances operational efficiency, thus allowing beef supply chains to be more productive and efficient in nature. RPA allows process excellence and adds value at different stages of the supply chain in order to gain a competitive advantage in beef processing and manufacturing [55].

The beef supply chain is a complex management system where achieving sustainability is a challenge as the supply chain is highly fragmented. Optimising beef production systems to fulfil social and economic objectives remains a challenge. However, technology such as RPA contributes to automating complex and repetitive tasks, such as carcass cutting or splitting, beef cutting, and packaging, and helps to reduce human error [56]. RPA has been widely adopted in food supply chains to execute many repetitive tasks for business processes in order to be more cost-effective, scalable, and viable. The availability and accessibility of innovations has allowed beef supply chains to adopt sustainable business practices and approaches that reduce beef waste during processing, and to increase production levels while being cost-effective. The adoption of technology such as RPA enables more sustainable production systems as rule-based tasks are automated and performed by software bots. RPA allows for valuable additions within business processes at different stages of the beef supply chain, and increases the shelf life and quality of beef. The integration of innovative opportunities such as RPA facilitates beef supply chains in being more economically sound and robust, and helps businesses to improve in social and environmental dimensions. This also greatly benefits beef supply chains as sustainable approaches such as RPA help improve supply chain management and achieve corporate social responsibility within the beef sector [57,58].

2.4. Simulation-Based Approach to Create Sustainability in the Beef Sector through RPA Adoption

Magalhães et al. [59] pointed out that the beef supply chain has highly fragmented, broad, and unique characteristics. The beef sector faces constant pressure and challenges when attempting to achieve sustainability and gain added value. As the beef supply chain has complex procedures and activities, increasing production levels and enhancing operational efficiency is complicated. Emerging technological solutions such as RPA help improve business process delivery and reduce task complexity. Value-based beef supply chains help the beef sector to maintain quality and safety standards in production, while allowing for higher levels of output. Value-based supply chain systems are prioritized nowadays due to the awareness and need to build sustainable business systems. To enhance consumer satisfaction and maintain high food quality standards, innovative strategies are implemented within organisational structures to serve business purposes and gain sustainable value. Organisations in beef supply chains are responsible for the health and safety concerns of humans; hence, producing high-quality, nutritious beef is one of the main aims. To satisfy the demand for beef and ensure the production and processing of healthy, safe beef, valuable additions such as RPA could reduce human error and minimize the cost to perform these processes [60,61].

The simulation and optimization of food supply chains help to identify barriers so as to enhance business operations and prevent any risk factors present [62]. It is imperative that comprehensive and precise sustainable evaluation and assessment of business processes are conducted within the food industry. This is because the food industry, comprising of meat supply chains, includes the production and manufacture of perishable food items and thus it is essential that organisations meet the quality and safety standards. As the demand for beef has grown within recent years, it has become important for the beef sector to adopt and implement technological innovations such as RPA that could potentially help save money, time, and energy, as well as the lower cost of manufacturing beef [63]. Simulation-based approaches help business organisations to improve efficiency, lower waste due to processing, and increase business productivity and viability. Simulations also aid in identifying risk factors that are present in the business environment and help supply chains achieve sustainable value by ensuring social, economic, and environmental gains. Simulation-based approaches guide organisations in calculating and assessing the best approach for adopting technological and innovative strategies. Supply chains can gain long-term success through simulation and optimization, as risk events can be predetermined in a virtual environment and the best approach for conducting processes or business activities can be discovered and then implemented [64].

It is difficult to eliminate or prevent risks and assess supply chain performance in real-world processes; therefore, simulation-based approaches could be used to determine and investigate supply chain risks using a virtual environment, and thus be used to plan accordingly for the future. The beef industry is highly seasonable due to the cycle of calving, which raises issues regarding the supply and demand of beef, making supply chain processes inconsistent. Issues such as seasonality increase the risks of fulfilling the demands of consumers and manufacturers. Implementing innovative machinery and equipment, as well as employees working on the processing lines could be costly due to tension between the producers and manufacturers. Another concerning challenge is that supply chain procedures are cost-intensive, making the profit margins narrow. This is because supply chain processes are intensive due to the large supply chain system. The beef supply chain strives to achieve sustainable business development strategies that could facilitate supply chain processes, reduce operational costs, and improve production levels. A simulation-based approach could help address such concerns as it has the potential to provide a well-coordinated supply chain system with the integration of technology such as RPA, which could minimize costs and enhance financial and functional efficiency to create sustainable value at different stages of the supply chain. Simulations could potentially help evaluate supply chain activities and observe behaviour at various stages, thus identifying any inconsistencies or risks during task delivery. Process simulation and optimization allows beef supply chains to mitigate slaughtering, processing, and manufacturing bottlenecks while reducing operational costs, time, and energy. Simulation-based techniques use a virtual environment to develop models that accelerate supply chain performance and determine any handling issues to ensure smooth and systematic beef processing and distribution. The simulation and optimization of the beef supply chain also allows for the smooth adoption of technology such as RPA, allowing for automating labour-intensive tasks and replacing human workers with robots for process excellence. Simulation allows for minimization of the total production or system costs, and enables business organisations to enjoy socio-economic benefits and create sustainable value within beef supply chains [65].

Sustainability is the main goal of beef supply chains due to its complicated business structure and fragmentation; the simulation of beef supply chains can facilitate decision-makers or stakeholders to follow the best approach for technological adoption, and remove or prevent any risk events in real-life scenarios and create supply chain resilience [66]. The adoption of RPA could create sustainable value within supply chain systems and enhance business profitability and sustainability.

This study is aimed at mangers, shareholders, and decision-makers within the beef sector and provides them the opportunity to adopt RPA in a robust manner, considering the financial aspects sustainable value gained. The simulation-based approach in this study analyses and assesses the process model formed in previous research; the assessment is based on financial parameters or factors that influence the adoption process of RPA. This paper helps in the identification of the financial barriers or risks that could hinder the adoption of RPA using the simulation and optimization of a previously formed process model. The simulation allows RPA to be adopted to its full potential, and considers the sustainable value gained in the social, economic, and environmental aspects. Section 3 describes the materials and methods used in the study to generate financial KPI values, income statements, and carbon emission reports through scenario analysis based on financial parameters using Simul8 simulation software.

3. Material and Methods

The Research Background and Present Directions

This study uses secondary data for the simulation and analysis of the process model. The secondary data were available and sufficient to conduct the study, which used a simulation-based approach to analyse "what-if" scenarios considering financial aspects for the adoption of RPA. The secondary data were obtained from existing literature, organisational records, online published journals, government websites or sources, historical records, etc. The data derived for the study were related to beef supply chain management, sustainability in the beef sector, the impact of RPA adoption within the beef supply chain system, and sustainability dimensions with RPA implementation in the beef industry. Two scenarios were designed and formed based on financial parameters, and an analysis of the scenarios was achieved using a business process model. The process model was tested using the two scenarios in Simul8 simulation software.

The simulation and analysis of the beef supply chain help business users to eliminate financial risks in advance through the identification of barriers beforehand. It further allows organisations to adopt RPA more systematically and strategically to enjoy its full benefits and opportunities and to enhance supply chain performance. The study was conducted using a simulation method and followed certain steps to reach the final analysis through scenario testing and running. This simulation-based study involved the initial step of problem identification for effective planning ahead. After the identification of the problem, the study approached its next step of understanding the objectives for robust results. Then, the process model was conceptualized, and different events or stages were set following discrete-event modelling technique using Simul8 software. Moving forward, secondary data were collected for a simulation-based study, which extracted existing knowledge and information using published journals or articles, organisational and government websites, statistical data, and information, etc., related to beef supply chains, sustainability-oriented innovations such as RPA technology, integration of RPA in the beef industry, and sustainability dimensions and approaches. The process model in this simulation study used a model previously formed by other authors and evaluated the adoption process of RPA using financial aspects. The adopted process model was then analysed using the simulation and optimization of the beef supply chain and it evaluated the financial and operational performance of scenarios from the perspective of sustainability. The end stage involved reporting and documentation through scenario testing generated by Simul8 software. The simulation analysis generated KPI values, income statement reports, and carbon emission reports to evaluate the main bottlenecks and assess scenarios from the perspective of sustainability based on three significant dimensions—social, economic, and environmental. Figure 2 illustrates the research framework and the steps involved for the simulation-based study.

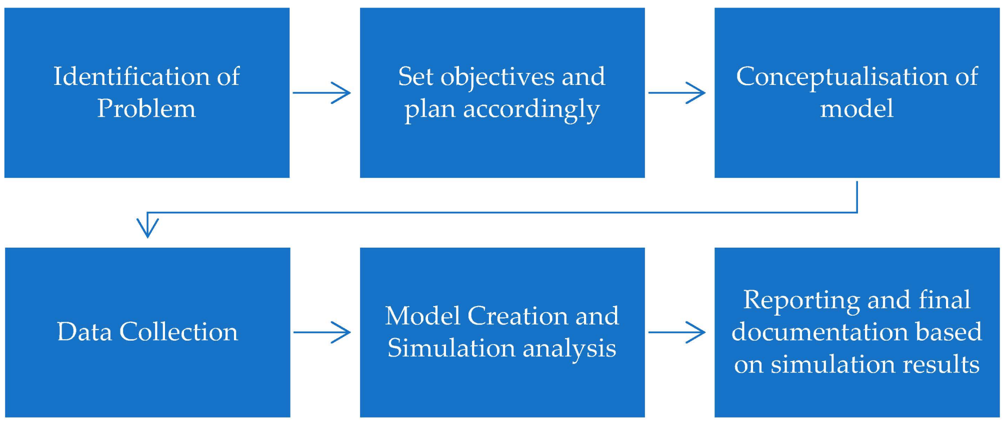


Figure 2. The steps involved in the simulation study (adapted from [67]).

The study used a simulation method as the research approach to conduct the simulation analysis of two assumed scenarios using financial parameters as the basis to conduct the study. As explained before, the research used a process model formed by authors from a previous study, and extracted secondary data relevant to the beef supply chain and RPA adoption in the beef sector for the simulation analysis. The study is unique as it developed scenarios based on the financial or cost-related aspects influencing the adoption of RPA in beef supply chains. Figure 2 shows several of the steps taken to conduct the study, and showcases the research approach and design to perform scenario analysis and assess the results from the lens of sustainability. The scenarios were tested and run to identify the financial barriers or uncertainties in the supply chain process along with determining the operational and financial performance of the beef supply chain. The simulation results will support practitioners and decision-makers in conducting robust cost analysis for the successful adoption of RPA and for reducing the high operational costs at different stages of the supply chain.

The process model for the simulation was derived and adopted from previous research [68] focused on potential barriers of RPA adoption in beef supply chains, based on parameters such as quality, safety, and security. This study is primarily and significantly focused on a simulation-based approach to analyse and test the business process model based on financial parameters or aspects that are important to consider for the effective adoption of RPA in beef supply chains. The cost-related aspects or financial parameters are also important to consider as reducing operational costs and gaining high levels of beef productivity are some of the current prevailing concerns in the beef sector. Eliminating the financial barriers or risks in beef manufacturing and processing allows RPA to work to its maximum capacity and potential. The successful adoption of RPA considering financial aspects result in adding value and achieving sustainability in beef supply chains, making them more viable, resilient, scalable, profitable, and efficient.

The present direction of the study focused on the analysis of "what-if" scenarios based on financial aspects or parameters. A simulation-based approach was used in this study to evaluate the financial risks or barriers at different stages of the beef supply chain and to identify the main bottlenecks that hinder the business activities being performed at various manufacturing and beef processing stages. Moreover, Simul8 software was used in this study to test two scenarios. The simulation improved the adoption process of robotic process automation (RPA) in beef supply chains and allowed users to implement the technology to its full potential and services. Financial parameters were the basis for developing the two scenarios for testing so as to analyse the stages facing major bottlenecks. The two scenarios were tested and analysed in a virtual environment using the discrete event model that was adopted from a previous study [68], and staged different phases that were important to map in the beef supply chain system. The process model was tested to analyse and evaluate the operational efficiency of the beef supply chain; also, the adoption of RPA was observed from the perspective of creating sustainable value within the various stages of the beef supply chain.

Three dimensions of sustainability were assessed to observe the benefits that adopting RPA could potentially provide with regard to social, economic, and environmental aspects. The process model was simulated and tested several times and generated the results in the form of financial KPI's, income statements, and carbon emission reports depicting the environmental impact of business processes. The report generated in the form of income statements depicted the profits gained with and without the adoption of RPA in the two scenarios. KPI were also generated in the form of a report to observe the financial and operational performance of the scenarios and to evaluate the business activities' efficiency, capacity, and working level. Sustainability assessment was crucially used to evaluate the socio-economic benefits that the adoption of RPA could provide within the beef supply chain. Sustainable value was also determined and assessed through simulating a process model where RPA is not adopted and the business activities are only performed by the human workforce. This allowed decision-makers to evaluate the potential financial risks or barriers in the adoption process and to observe the benefits of RPA adoption to create sustainable value in beef supply chains. The successful adoption of RPA allows the technology to serve as an essential sustainability tool and to create added value, which enhances the financial decision-making of business users and improves the economic growth and productivity levels in a practical or real-world environment.

Figure 3 illustrates the sustainability model used in the study to conduct the sustainability assessment through testing and process simulation of the two assumed scenarios based on financial parameters. The results were based on these sustainability dimensions and criteria depicted in the model. Figure 3 depicts three sustainability dimensions, namely social, environmental, and financial. The two scenarios were tested to identify the potential financial barriers or risks in the adoption of RPA; the testing and simulation of scenarios was also completed to assess it from the aspect of sustainability in order to observe the added value and sustainable value that RPA adoption could provide in order to enhance business operations. The sustainability evaluation for scenarios included economic value focusing on areas such as business stability and viability, cost reduction, and profit. Another dimension was social value, which comprised observations related to employee-level efficiency, human error, health and safety, and quality standards, as depicted in Figure 3. The third dimension to sustainability evaluation was environmental value concentrating on beef waste, pollution prevention, transmission of diseases, and hygienic beef production. The two scenarios assumed human workforce as a resource input and RPA working alongside humans as another resource input, which were analysed based on three sustainable value dimensions for sustainability assessment, as depicted in Figure 3.

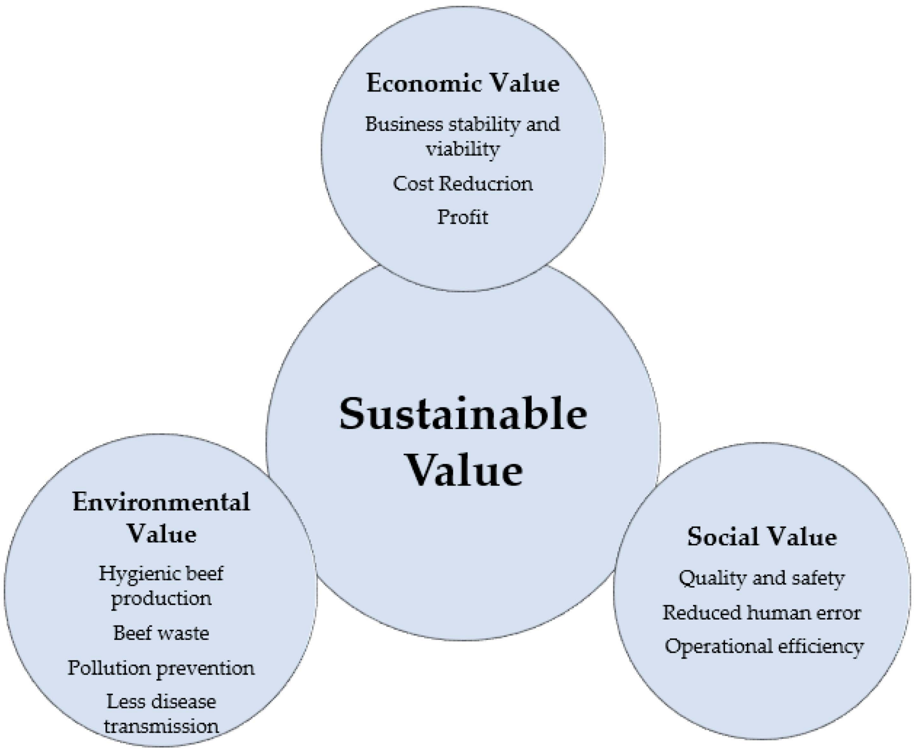


Figure 3. Sustainability assessment model for the simulation analysis.

Scenarios 1 and 2 were simulated using the previously formed business process model in Simul8 software. Simul8 software analyses scenarios in a virtual environment and depicts all of the bottlenecks at different stages of the supply chain. The software also generates a carbon emission report, which provides insight about carbon emissions at every phase of the supply chain and evaluates the environmental impact in statistical form through measuring it at all levels. The KPI values, income statement, and carbon emission report in each scenario support business owners in their financial and ethical decision-making and help them to prevent any risks in real-life events. A comparison was drawn through the simulation of Scenarios 1 and 2 in order to evaluate the financial and operational performance of beef supply chains, both when RPA works alongside the human workforce and when the human workforce works alone to complete tasks as the only resource input. This comparison helped assess the advantages of RPA or software bots working on the processing line and how the technology could prove as an addition of value and to provide economic, social, and environmental benefits. The results for these are discussed in the following section. Table **??** provides an overview of the two scenarios for the process simulation using a business process model developed in a previous study. The idea for sustainability assessment based on three dimensions was also tested through process model simulation using the scenarios developed based on financial parameters.

Table 2. An overview of the scenarios to assess sustainability through simulation.

Human Workforce at Workstations—Scenario 1	RPA and Human Workforce at Workstations—Scenario 2
▪ Scenario 1 has human workforce as the only resource input to assess the financial and operational performance. Supply chain is manual-centric.	▪ Scenario 2 has two resource inputs: RPA and human workforce. Financial efficiency and operational performance are analysed through task automation.
▪ Scenario 1 is tested and run to conduct sustainability assessment based on social, environmental, and financial value.	▪ Scenario 2 is simulated to observe sustainable value based on three dimensions: social, economic, and environmental.
▪ Scenario 1 observes the human workforce to work at different stations of the beef supply chain and assesses time-taken, beef productivity, capacity, and financial performance.	▪ Scenario 2 observes RPA technology working alongside the human workforce at different stages of the supply chain to evaluate the financial performance, time-consumed for task delivery, and beef production levels and capacity.
▪ Beef quality, safety, and shelf life are assessed in Scenario 1.	▪ Beef quality, shelf life, and safety are assessed through task automation in Scenario 2.
▪ Income statements, KPI values, and carbon emission reports are observed for business performance in three dimensions of sustainability.	▪ Income statements, KPI reports, and carbon emission reports are generated to depict business performance in all three dimensions of sustainability.

4. Results Based on Process Simulation

To obtain results regarding the adoption process, it is necessary to derive statistics and information related to financial aspects of the beef supply chain and RPA technology. This study used the available secondary data using online published sources, relevant literature, organisational websites, etc., focussed on adopting RPA technology as a sustainable tool for value creation in the beef supply chain, as well as the significance of RPA in beef supply chain management to create sustainable value. Several parameters influencing the adoption process of RPA technology were considered. This study focused on specific financial aspects concerning the adoption of RPA. We adopted existing financial statistical data and cost-related information regarding beef supply chain procedures and stages, beef supply chain management, RPA adoption criteria, installation costs, and other financial aspects of the beef supply chain that influence the implementation and facilitation of RPA. The financial parameters considered were significant for determining and investigating the role of RPA in order to enhance the financial performance and business operations within the beef sector, and to allow for the identification of any financial risks or barriers that could hinder its adoption. Moreover, financial parameters are vital to consider for the robust and successful adoption of RPA in order to add sustainable value within beef supply chains. RPA, as an important sustainability tool and innovative strategy, facilitates beef supply chains by reducing operational costs at different stages and enhances productivity, efficiency, and the capacity to satisfy the growing demand for beef. Reducing the processing costs of beef with the goal of achieving higher output levels remains a focus for business owners. The consideration of financial parameters not only assists in the smooth and robust adoption of RPA, but also allows the technology to become a game changer and act as a tool to add sustainability.

A simulation-based approach was chosen to assess the previously formed process model; it was tested using two scenarios based on financial parameters. The simulation using scenarios based on financial parameters was conducted using Simul8 simulation software. The simulation software used resource inputs and different stages of the beef supply chain were mapped using the DES modelling technique. The simulation tested the process model in order to generate income statements and financial KPIs, which determined the financial and operational performance of the beef supply chain. Variations in the resource input and costs were considered to ensure a thorough simulation test and run trial. Two resource inputs, namely labour and humans or RPA technology, were used in the process model.

The next stage of analysis assessed and evaluated the contextual relationship of the financial factors or parameters when adopting RPA in the beef supply chain. It is important to analyse the relationship between the financial factors that influence and impact the adoption of RPA in the beef supply chain. Hence, cost-related information and aspects at various stages of beef manufacturing and processing were a significant part of the analysis. Literature focusing on beef supply chain characteristics, manufacturing stages, financial aspects, and sustainability challenges were used to form a relationship model. Figure 4 depicts the financial factors that play a vital role in the successful adoption of RPA technology in the beef supply chain. These factors are important to evaluate as they impact the implementation of RPA, as well as its potential advantages by easing process delivery, reducing operational costs, enhancing beef quality, and improving productivity to gain sustainable value. Figure 4 shows the relationship between the financial factors that help create value and sustainability in the beef supply chain processes and impact the financial performance, business viability, and scalability in beef production. The financial factors or parameters depicted in the relationship model in Figure 4 are fixed costs, direct or in-direct costs, and variable costs when implementing RPA in beef supply chains.

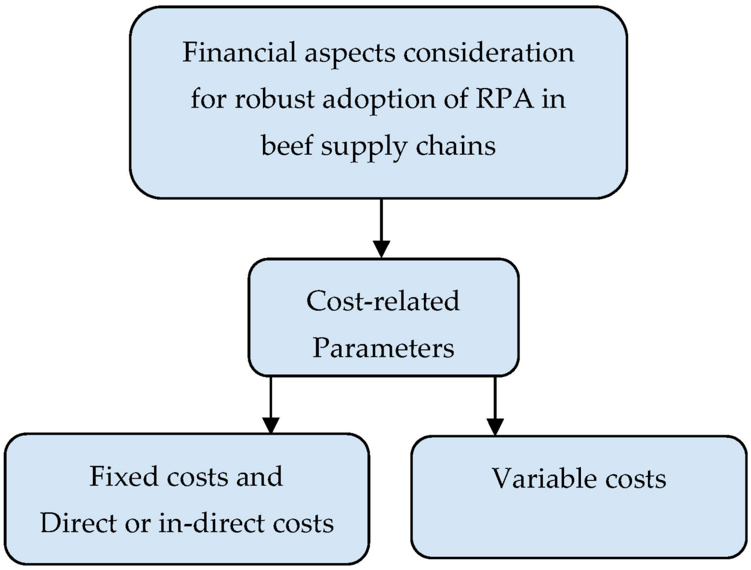


Figure 4. The link between financial parameters or factors in RPA adoption.

4.1. Process Model and Simulation Analysis—Financial Parameters as a Basis

A business process model formed in a previous study [68] was used in this paper for the simulation. The present study focused on a specific direction for the scenario analysis based on financial aspects or parameters that has not been discussed in previous research; this is an important dimension to consider when adopting RPA in beef supply chains. The process model is comprised of different stages of the beef supply chain, providing insight into the supply chain processes. The process model shows the overall important stages of the beef manufacturing supply chain, from the processing and production of beef to the consumption by the customer. Financial aspects and cost-related statistics were considered for all stages of the business processes in order to investigate the economic status and financial health of the supply chain with and without the implementation of RPA technology. The economic performance of the supply chain is an important part of the analysis as it depends on beef productivity, profits, and business scalability and viability. Other aspects such as beef quality, safety, and capacity were also investigated using Simul8 simulation software. Figure 5 shows the process model adopted in this study considering different cost-related parameters; three dimensions, social, economic, and environmental, were observed from a sustainability perspective.

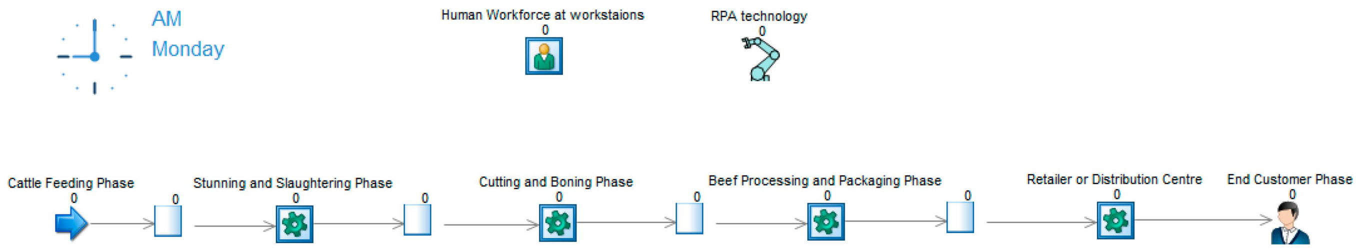


Figure 5. Business process model for scenario analysis (adopted from [68]).

The formed previously process model was simulated and analysed here using two different scenarios, where different resource inputs were used for testing. The two resource inputs were human workforce, which was used alone in Scenario 1. Scenario 2 analysed the human workforce working alongside RPA technology. The process model was tested, simulated, and run for 1 week in order to achieve more accurate results. The simulation was run at several frequencies to ensure robust results. The simulation was run several times using different financial parameters; these were the basis for the scenarios developed.

This discrete event simulation model used a simulation-based approach to investigate the changes in the financial and operational performance of the supply chain by providing various cost-related parameters. The simulation used resource inputs and other data based on financial aspects to observe the business performance at different stages of the supply chain [69]. A simulation-based approach imitates a situation, circumstance, process, or operation so as to evaluate the risks or barriers in a supply chain system [70]. The simulation technique helps stakeholders and business users test the supply chain activities and performance level in a virtual environment and provides organisations an opportunity to avoid these barriers in real-life situations. It also helps food manufacturers enhance their financial performance and produce food products of a high value and quality. By considering financial aspects using the simulation technique, food manufacturers can enhance their financial decision-making and increase productivity levels [71].

4.1.1. Scenario 1—Financial Considerations Using the Human Workforce as a Resource

The process model simulated in Scenario 1 used a manual-centric supply chain and only the human workforce was throughout the various stages of the beef supply chain. The model was tested and run for 1 week (7 days (12 h per day)); it was replicated several times to record and evaluate the results with increased accuracy. The repeated runs in Simul8 used financial data and information to assess and evaluate the financial performance and operational efficiency of the business activities. The average time taken for the carcass to reach the end customer phase was also analysed using the simulation model. Based on the assumed scenario, the results showed the performance of humans in the manufacturing line and evaluated the queuing time for the carcass to reach the next phase in the supply chain. Figure 6 shows the simulated process model that used labour or human workforce as the only resource input to perform the tasks. It was observed that beef capacity decreased as the stages progressed over time. It took longer for the carcass to reach to the progressing stage and the supply chain became slower. The overall productivity of beef production was also reduced at every stage of the supply chain; this means there was high human-error and wastage of beef along the processing line. The initial capacity seen at the start of the stunning and slaughtering stage was 40; this was reduced to 36 in the cutting and boning stage. The beef capacity was further reduced in the beef processing and packaging phase, with a value of 34. It dropped to 10 upon reaching the retailer or distribution centre, after which far less beef was produced for the final phase when reaching the customer. In this scenario, human efficiency was seen to be low and the operational efficiency was also evidently very low, with a low beef production capacity at the end. To further analyse the simulated model, as more time was taken when humans performed and conducted business activities at different stages of the supply chain, the costs for performing the activities on the processing line also increased, thus reducing the financial performance of the supply chain (Figure 6). As depicted in Figure 6, the main bottlenecks and risks were seen in the following phases: cutting and boning, beef processing and packaging, and retail.

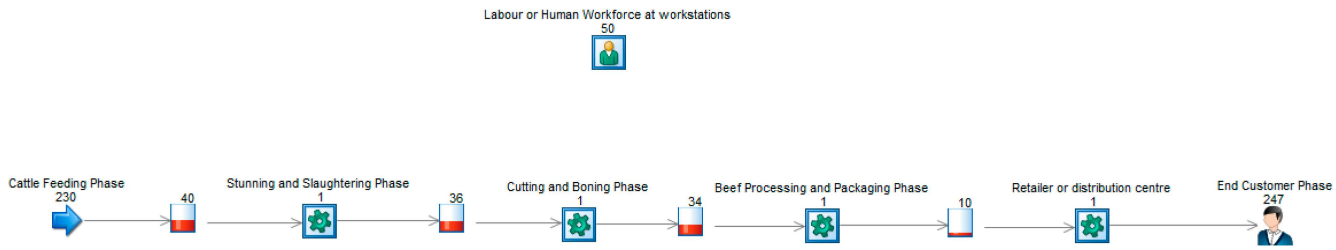


Figure 6. Process modelling using financial parameters in Simul8.

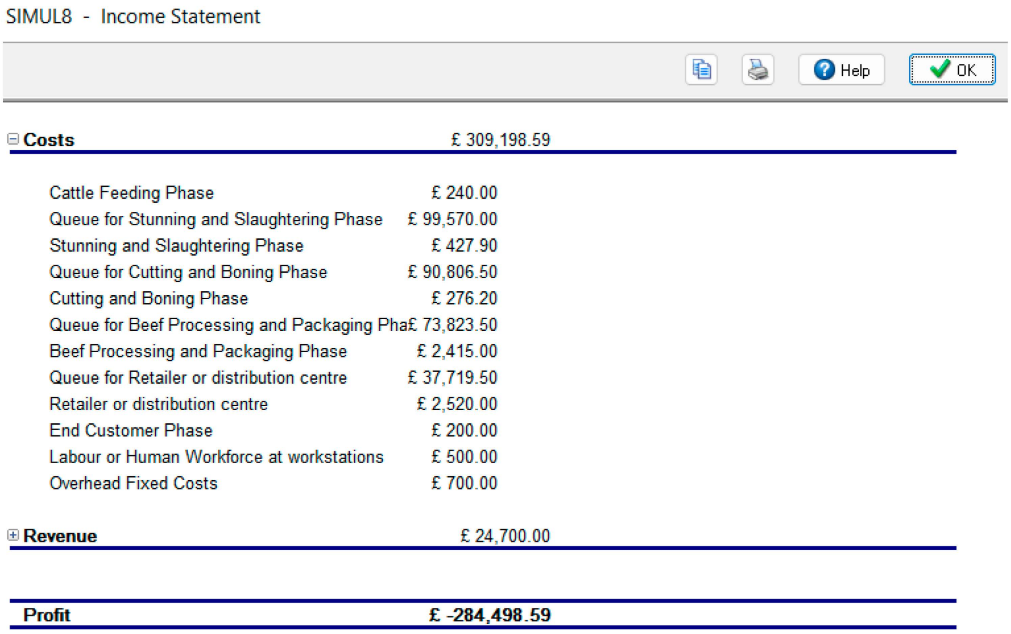
The simulated process model also generated financial KPIs to provide insight regarding the working performance of the beef supply chain. Financial KPIs are key performance indicators that summarise the overall performance level; this is assessed by testing and running the process model in the software. Table 3 depicts the analysis of the simulation process and the financial KPIs generated in Simul8. The average waiting time for carcass processing from the first stage to the last one was approximately 1428.76 min–23.81 h. The working% of the beef processing and packaging phase was 37.15; this appears to be low. The queue for the beef processing and packaging phase was an average size of 20.40. The average queuing time in this was noted to 253.50 min–4.2 h in the processing phase and the maximum queue time was observed to be 295.04–4.9 h, as illustrated in Table 3. The simulation analysis showed an increase in the average time taken for the carcass to reach the end customer stage; the queuing size and time were also high, which decreased the processing line and increased the cost of production. The increase in time taken reduced the financial and operational efficiency of the supply chain and increased the likelihood of beef wastage and the production of low-quality beef due to increased human error. We further considered the challenges in the supply chain relating to social, economic, and environmental hazards from a sustainability perspective through values generated in Table 3. These results indicate an increase in supply chain risks and disruptions and an increase in queuing size and time throughout the different stages.

Table 3. KPI values generated in Simul8 based on financial parameters.

Phases	KPI % System Results	Low 95% Range	Average Result	High 95% Range
End Customer Phase	Average Time in System	1308.84	1428.76	1548.67
Beef Processing and Packaging Phase	Waiting%	0.00	0.00	0.00
	Working%	38.19	37.15	39.11
	Maximum Use	1.00	1.00	1.00
	Average Use	1.00	1.00	1.00
	Current Content	1.00	1.00	1.00
Queue for Beef Processing and Packaging	Average Queue Size	13.24	20.40	27.56
	Average Queuing Time	184.21	253.30	322.40
	Maximum Queuing Time	252.10	295.04	337.98

To assess the overall financial performance of Scenario 1 for the manual-centric supply chain using the human workforce as a resource to complete task delivery, the software generated an income statement for the simulation. Simul8 provides an income statement, which helps business decision-makers decide whether the supply chain performance will generate profits or losses by assessing the costs and revenues at different stages of the supply chain. The secondary data and statistical information helped to assess the scenario using the human workforce to perform complex business procedures in the supply chain. Figure 7 shows the income statement, which had a poor financial and operational performance (as also seen in Table 3) as the costs were excessive due to increased human error as a result of the supply chain being manually driven for task completion. The income statement shows that the profit reached a negative value, indicating that the financial performance was low and the business activity costs were high, resulting in financial loss in the beef production. The average time taken from beef production until reaching the final customer was long and the supply chain lagged in efficiency and productivity. This was because of the higher average queuing size of 20.40 and increased average time in the beef processing and packaging stage, which was 253.30 min (4.3 h). Beef possessing cost 309,198.59 GBP and the revenue was only 24,700 GBP; this resulted in a negative number with a loss of −284,498.59 GBP. The generated income statement shows that because of the low financial and operational performance, Scenario 1 was unable to make a profit due to the slow processing line and high human error, and it did not achieve sustainable social, economic, and environmental value. Figure 6 shows the low beef productivity and capacity at each progressing stage. Figure 7 shows the high operational costs and increased energy and time consumption, which resulted in low production in the final stage; hence, the high demand for beef was not satisfied in this scenario. The supply chain costs exceeded the revenue, resulting in a poor financial performance and loss for the business in the assumed scenario analysis, as shown in the income statement report in Figure 7.

Furthermore, Simul8 also generated a carbon emission report for Scenario 1. As shown in Figure 8, the carbon emission report depicted the values related to emissions for each phase and activity of the supply chain. The carbon features from this report were broken down in order to analyse the values for emissions from each level. The carbon emissions for each stage of the beef life cycle in the supply chain were as a result of the energy use, fuel, packaging, extraction and use of raw materials, distribution, etc. The carbon emission report depicted the environmental impact caused during beef processing and manufacturing. As shown in the report in Figure 8, the environmental impact through carbon emissions was 278,961.49 CO2e in Scenario 1, which was very high as the supply chain was manual-centric. The increased amount of carbon emissions at different phases of the supply chain and the lower value of carbon offset resulted in a high environmental impact, showing a high risk of air pollution, low quality beef production, and health threats to workers. There was also increased risk of beef contamination due to poor air quality and other environmental hazards. The carbon offset refers to removal or reduction of carbon emissions or other gases, and was observed to be 24,700.00 CO2e (Figure 8), which was low.

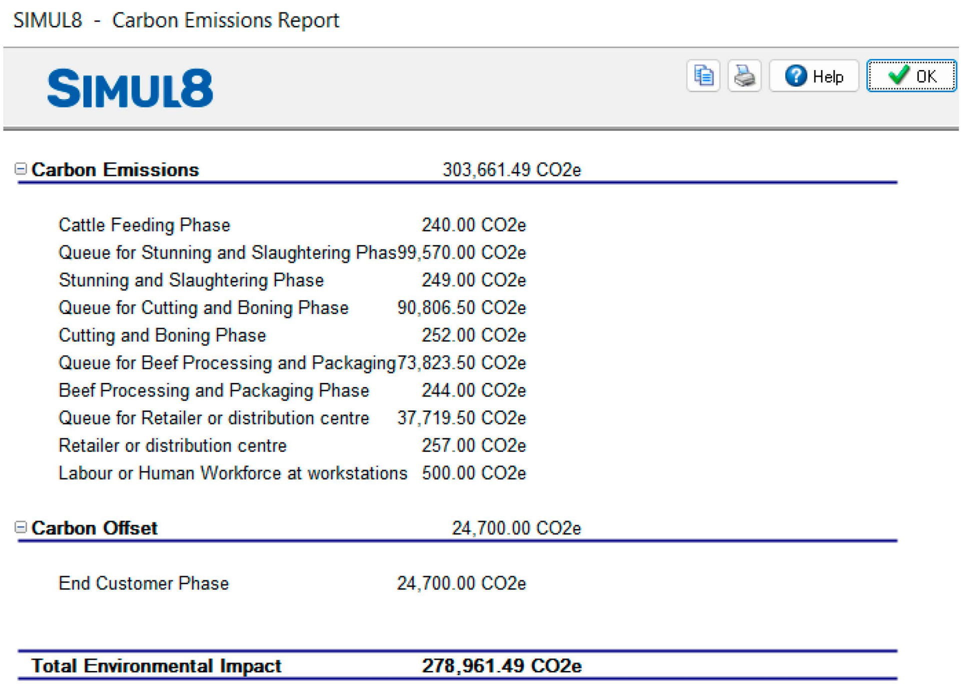


SIMUL8 - Income Statement

Help OK

Costs	£ 309,198.59
Cattle Feeding Phase	£ 240.00
Queue for Stunning and Slaughtering Phase	£ 99,570.00
Stunning and Slaughtering Phase	£ 427.90
Queue for Cutting and Boning Phase	£ 90,806.50
Cutting and Boning Phase	£ 276.20
Queue for Beef Processing and Packaging Pha	£ 73,823.50
Beef Processing and Packaging Phase	£ 2,415.00
Queue for Retailer or distribution centre	£ 37,719.50
Retailer or distribution centre	£ 2,520.00
End Customer Phase	£ 200.00
Labour or Human Workforce at workstations	£ 500.00
Overhead Fixed Costs	£ 700.00
Revenue	£ 24,700.00
Profit	**£ -284,498.59**

Figure 7. Income statement generated from the scenario analysis in Simul8.



SIMUL8 - Carbon Emissions Report

SIMUL8

Help OK

Carbon Emissions	303,661.49 CO2e
Cattle Feeding Phase	240.00 CO2e
Queue for Stunning and Slaughtering Phas	99,570.00 CO2e
Stunning and Slaughtering Phase	249.00 CO2e
Queue for Cutting and Boning Phase	90,806.50 CO2e
Cutting and Boning Phase	252.00 CO2e
Queue for Beef Processing and Packaging	73,823.50 CO2e
Beef Processing and Packaging Phase	244.00 CO2e
Queue for Retailer or distribution centre	37,719.50 CO2e
Retailer or distribution centre	257.00 CO2e
Labour or Human Workforce at workstations	500.00 CO2e
Carbon Offset	24,700.00 CO2e
End Customer Phase	24,700.00 CO2e
Total Environmental Impact	**278,961.49 CO2e**

Figure 8. Carbon emission report generated in Simul8.

4.1.2. Scenario 2—Financial Parameters as a Basis using RPA Integration with Humans as a Resource

Scenario 2 used two resource inputs at different workstations where RPA functioned alongside the human workforce to ease supply chain processes and automate tasks where RPA performed best. Scenario 2 considered the adoption of RPA technology to accelerate time taken, reduce human error, and increase throughput. This scenario integrated RPA along with humans to automate rule-based, repetitive tasks, and to provide autonomous solutions to create supply chain resilience. As seen in Figure 9, the simulation was conducted over 1 week (7 days) and testing was conducted through several replications in order to achieve the appropriate simulation results. The scenario showed that the implementation of RPA to automate tasks was productive and efficient. The beef capacity remained more consistent in this scenario and was observed to increase at each progressing phase. The beef capacity in the stunning and slaughtering stage was 15 and reached 18 in the cutting and boning phase and 19 in the beef processing phase. The beef capacity increased to 35 in the retailer and distribution stage, where it was observed to be at its maximum. As time increased, the capacity of beef produced also increased in every stage, which resulted in higher beef production and availability at the end customer phase. This scenario took less time to produce high-quality beef with reduced human error and wastage along the processing line, as seen in Figure 9. It also indicated a better financial performance as a result of the fast-paced processing line and greater beef production capacity.

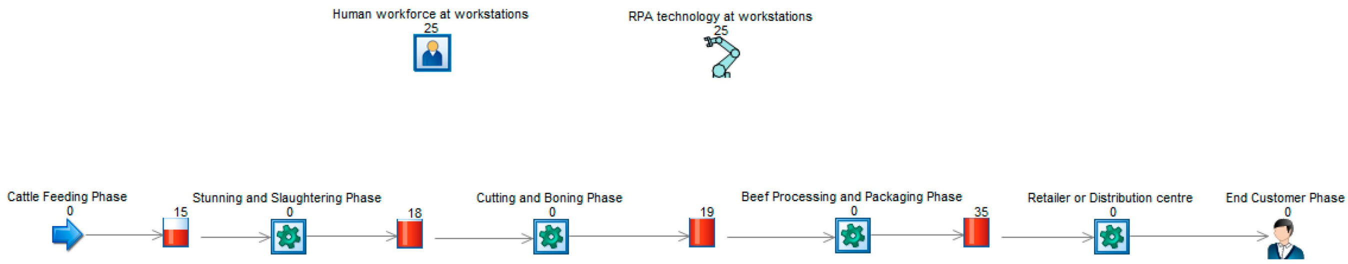


Figure 9. Process modelling considering financial parameters from the simulation.

Simul8 software also generated KPI values based on process simulation and provided a report to analyse the functional performance of the beef supply chain. Table 4 shows the KPI values, which were used to evaluate the operational and financial performance of business activities using financial parameters that influence the adoption process of RPA in the beef supply chain. The average time for the final customer phase was 705.91 min–11.7 h, which was much less than the results for Scenario 1. This means that the carcass took 11.7 h to reach to the end customer phase. The working percentage of the beef processing and packaging was 90.87%, which was double the working% in Scenario 1. The average queue size was 17.75 at the beef processing and packaging stage, and the average queuing time was 181.84 min to 3 h. The maximum queuing time as per the KPI values was 370.13 min to 6 h. The KPI report indicates that the average time taken for the carcass to reach the end customer was much less than for Scenario 1; also, the working% was almost double in this case, meaning that the processing line was more efficient and faster. The average queuing time was also observed to be less than for Scenario 1. The KPI values indicated that automation enhanced business processes, resulting in increased beef production in decreased time and cost.

Table 4. KPI values generated in Simul8 software based on financial parameters in scenario 2.

Phases	KPI % System Results	Low 95% Range	Average Result	High 95% Range
End Customer Phase	Average Time in System	679.91	705.91	731.91
Beef Processing and Packaging Phase	Waiting%	0.00	0.00	0.00
	Working%	88.23	90.87	93.51
	Maximum Use	1.00	1.00	1.00
	Average Use	1.00	1.00	1.00
	Current Content	1.00	1.00	1.00
Queue for Beef Processing and Packaging Phase	Average Queue Size	15.61	17.75	19.88
	Average Queuing Time	156.71	181.84	206.96
	Maximum Queuing Time	331.55	370.13	408.71

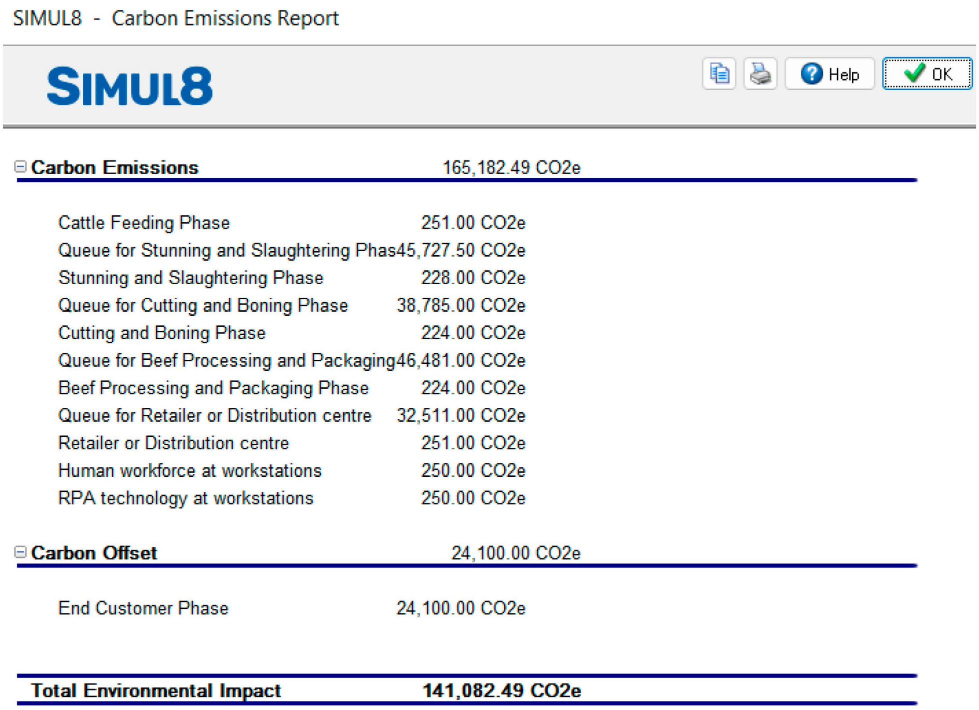
Furthermore, the simulation software also generated an income statement based on the simulation runs conducted. Figure 10 displays the income statement showing the financial performance of the beef supply chain. The income statement from Simul8 was used to better analyse and evaluate the supply chain costs and revenue according to the resource inputs and cost-related parameters from the simulation runs. This scenario used RPA integration to automate tasks where possible and used suitable and manual workforce to aid through monitory purposes or for support with tasks that could not be fully automated due to the complexity of the beef supply chain. The income statement showed a good financial performance and effective function of the business activities as it indicated profits earned through the adoption of RPA, which served to facilitate strenuous tasks by reducing human error, thus reducing operational costs (as seen in Figure 10). The revenue in the final customer phase was greater than the costs of performing business activities throughout all phases; therefore, the supply chain provided profits of 221, 300.39 GBP. The costs of beef production was 2,198,699.61 GBP in total and the revenue in the final stage was 2,420,000 GBP. Here, RPA showed promising cost-reduction benefits for supply chain processes by providing autonomous solutions and enhancing operational efficiency in the processing line. Less time was taken due to the reduced queue size and average time for carcass processing, which helped by reducing expenses and energy and provided an effective financial performance by earning profit, as displayed in the income statement generated by Simul8 in Figure 10.

SIMUL8 - Income Statement

Costs		£ 2,198,699.61
Cattle Feeding Phase	£ 167.00	
Queue for Stunning and Slaughtering Phase	£ 500,646.48	
Stunning and Slaughtering Phase	£ 148.00	
Queue for Cutting and Boning Phase	£ 512,438.98	
Cutting and Boning Phase	£ 99.20	
Queue for Beef Processing and Packaging Ph	£ 523,293.98	
Beef Processing and Packaging Phase	£ 738.00	
Queue for Retailer or Distribution centre	£ 534,701.98	
Retailer or Distribution centre	£ 741.00	
End Customer Phase	£ 75.00	
Human workforce at workstations	£ 250.00	
RPA technology at workstations	£ 125,000.00	
Overhead Fixed Costs	£ 400.00	
Revenue		£ 2,420,000.00
End Customer Phase	£ 2,420,000.00	
Profit		**£ 221,300.39**

Figure 10. Income statement generated in Simul8.

The simulation-based approach in Scenario 2 also provided an opportunity to assess the environmental impact of business activities during beef processing and manufacturing. Simul8 also produced a carbon emission report, as depicted in Figure 11, to analyse the impact of RPA and humans working together in the processing line to perform various tasks. The carbon emission report generated by Simul8 software through the simulation indicated that the environmental impact of Scenario 2 was 141,082.49 CO2e. The carbon emissions was 165,182.49 CO2e and the carbon offset was 24,100.00 CO2e. As assessed from the report in Figure 11, Scenario 2 had a much lower environmental impact than Scenario 1. The environmental impact of Scenario 2 was lower; however, it still had an impact on the environment because the supply chain was not yet fully automated as there were some complex procedures that still required human presence. As the environmental impact was not high and was measured as low, there were lower risks to human health and the environment in this scenario. In addition, these was a higher chance of high-quality beef production as the processing line was fast-paced due to the adoption of RPA and process excellence. Furthermore, the risk of disease transmission, beef contamination, and beef wastage along the processing line were minimal due to the lower environmental impact as evaluated and revealed in the report. Therefore, through the simulation assessment and carbon emission report in Figure 11, Scenario 2 showed a lower environmental impact and safer, high-quality beef production.


SIMUL8 - Carbon Emissions Report

SIMUL8

Carbon Emissions	165,182.49 CO2e
Cattle Feeding Phase	251.00 CO2e
Queue for Stunning and Slaughtering Phas	45,727.50 CO2e
Stunning and Slaughtering Phase	228.00 CO2e
Queue for Cutting and Boning Phase	38,785.00 CO2e
Cutting and Boning Phase	224.00 CO2e
Queue for Beef Processing and Packaging	46,481.00 CO2e
Beef Processing and Packaging Phase	224.00 CO2e
Queue for Retailer or Distribution centre	32,511.00 CO2e
Retailer or Distribution centre	251.00 CO2e
Human workforce at workstations	250.00 CO2e
RPA technology at workstations	250.00 CO2e
Carbon Offset	24,100.00 CO2e
End Customer Phase	24,100.00 CO2e
Total Environmental Impact	**141,082.49 CO2e**

Figure 11. The carbon emission report for Scenario 2.

5. Discussion on Findings—Sustainability Assessment from the Results

The simulation-based approach plays a vital role for achieving sustainability goals within business organisations. Simulation software is widely utilized by firms to identify supply chain risks or disruptions and to conduct sustainability assessments to enhance decision-making [72]. Manufacturing supply chains use simulation-based approaches to simulate dynamic models and decrease any negative impact they might have on the wider community and environment because of their business practices. The simulation and optimization of supply chains can evidently result in numerous benefits to supply chains by helping to adopt technological innovations, improving organisational structure, and analysing supply chain risks and challenges using a virtual environment. The simulation approach also helps supply chains enhance process delivery by allowing for testing small changes in the early stages. This helps organisations analyse and identify any discrepancies and barriers, thus adopting sustainable business strategies to gain higher efficiency levels [73]. One of the main benefits of the simulation technique is that it enables organisations to achieve long-term sustainability goals and gain competitive advantages by identifying risks in the earlier stages in advance. Simulation-based testing is a powerful technique to assess and evaluate the operational and financial performance of supply chains and helps firms to increase profit margins and evaluate costs beforehand. Thus, a scenario analysis using a simulation allows business users and stakeholders to conduct sustainability assessments and adopt better approaches to create sustainable value [74].

The results from Scenarios 1 and 2 were analysed from the perspective of sustainability in three dimensions, namely social, economic, and environmental. The simulation results from Scenarios 1 and 2 were compared from the lens of sustainability in the beef supply chain. The findings were considered from a sustainability perspective by assessing the scenario analysis in Simul8 and considering financial aspects. The simulation is a robust sustainability assessment tool that can observe the sustainable value created in each level of the supply chain by testing different scenarios and evaluating the results.

5.1. Comparison of the Simulation Results from Scenarios 1 and 2 from a Sustainability Perspective

5.1.1. Social Value

Scenario 1 uses the human workforce as labour to perform tasks at different stations or phases of the beef supply chain. The results from the simulation show that Scenario 1 is unable to create social value within the beef supply chain. Scenario 1 is manual-centric, and results in a low beef production capacity as time passes through different phases of the supply chain. The simulated model shows a result of for 40 beef capacity or shelf life at the initial phase of the supply chain, and it constantly reduces at every level; it is observed to be 10 when processed beef reaches the retailer or distribution centre. As shown in Table 3, the working% of the beef processing and packaging stage is 37.15 and the average time taken for the carcass to reach the final customer is 1428.76 min–23.81 h, which extensive in comparison with Scenario 2. Increased time taken to produce beef, higher queue size, and increased human error due to manual handling of the processes result in low-quality beef production with a reduced shelf life. As the working% of beef processing is also lower and is half the value observed in Scenario 2, this indicates lower operational and employee-level efficiency.

Scenario 2 uses RPA technology and the human workforce as a resource input. Beef supply chain tasks are automated and human workers work together to process beef for production. The integration of RPA enhances supply chain operations, and the supply chain observes a consistent and higher beef capacity throughout the supply chain workstations. The initial beef capacity or shelf life observed during the stunning and slaughtering stage is 15, and as the carcass progresses, the capacity increases to 18 and then reaches 19 in the beef processing and packaging phase. Finally, it increases to 35 when it reaches the retailer or distribution centre. The average time taken for the carcass to be processed is 705.91 min–11.76 h, which is much less than Scenario 1. The simulation analyses show high-quality beef production and safer beef for consumption due to the automation of tasks, which saves energy, time, and money. The working% is 90.87, as depicted in Table 4, for Scenario 2, which is almost double the percentage seen in Scenario 1; hence, a higher operational and employee-level efficiency is observed.

The simulation analysis shows that Scenario 2 has a greater shelf life and higher quality of beef production. The working% during the beef processing and packaging stage is also double, and so a greater employee-level efficiency and operational performance is observed in Scenario 2. Scenario 2 also demonstrates social value and improvement in terms of sustainability due to the profitable supply chain system and reduction in costs in comparison with Scenario 1.

5.1.2. Environmental Value

Scenario 1, from the perspective of environmental value, has a high environmental impact, as shown in the carbon emission report in Simul8. The carbon emissions in Scenario 1, which is manually handled, are very high due to higher amount of fuel, energy, resources, raw materials, costs, packaging, and distribution used during beef processing and manufacturing. The carbon emissions are also higher, resulting in a high environmental impact due to the presence of human labour, which increases human error, costs, supply chain risks, and supply chain disruptions. Reduced operational and employee-level efficiency contributes to increased time and energy consumption, thus leading to high carbon emissions and less carbon offset. The supply chain in this scenario is considered to have more environmental risks, health and hygiene challenges, environmental pollution, and threats to beef contamination and the transmission of diseases due to human handling and intervention. There is an increased risk of beef waste in the processing line due to human error. The environmental impact is 278, 961.49 CO2e, indicating greater environmental threats, as depicted in Figure 6.

Scenario 2 shows a lower environmental impact of 141,082.49 CO2e, as displayed in Figure 9, compared with Scenario 1, which is almost double this amount. The carbon emission report in the scenario shows less carbon emissions throughout different stages of the supply chain. Lower carbon emissions contribute to a decreased environmental impact, as the supply chain uses RPA technology alongside humans on the processing line. The tasks are automated, thus reducing the time, energy, and costs needed, which leads to lower carbon emissions. RPA integration with humans allows for better utilization of resources, fuel, and financial performance, as well as enhanced production and distribution systems. This leads to less environmental threats and increases the likelihood of high-quality and hygienic beef production. A lower environmental impact also indicates the prevention of pollution and reduces beef waste. Automation also reduces the risk of disease transmission.

Beef production involves industrial processes that contribute to air pollution due to carbon dioxide emissions at different supply chain stages, thus resulting in an environmental impact that could be threating and hazardous to the atmosphere and to humans. Scenarios 1 and 2 are investigated through process simulation and scenario testing, and are considered from the perspective of environmental impact. To further emphasize this concept, Scenario 2 has a lower environmental impact on the atmosphere and environment according to the carbon emission report, as observed in Figure 11. Scenario 2 has two resource inputs, namely RPA technology and human workforce, which are used for support and for handling complex tasks in different workstations of the supply chain. The carbon emission report in Scenario 2 shows a lower environmental impact on the atmosphere from beef processing in comparison with Scenario 1, where the environmental impact is double. Beef processing and production result in significant greenhouse gas emissions due to the complex nature of the supply chain processes. Beef supply chains emit carbon dioxide emissions during beef processing and manufacturing due to the complex procedures involved, such as slaughtering, cutting, deboning, and packaging, which cause environmental hazards and threaten the environment and atmosphere. Scenario 2 includes process automation through RPA adoption and less human handling, thus using less fuel and energy during beef production. As less energy, time, and fuel are used for beef processing at each progressing stage of the supply chain, less operational costs are involved, as seen in Scenario 2. Automating tasks reduces human error and speeds up supply chain operations, thus reducing carbon dioxide emissions at different stages of the supply chain, as observed in the carbon emission report in Figure 11, which shows 141,082.49 CO2e. This reduces environmental concerns and pollution related to the atmosphere, and shows Scenario 2 as a safer and eco-friendlier alternative beef processing in comparison with Scenario 1, where the emissions are equal to 278,961.49 CO2e. The carbon emission report shows the statistical data for both scenarios, as observed in Figures 8 and 11, and illustrates the emissions at each phase of the beef supply chain. The comparison of the two scenarios indicates that Scenario 2 has increased environmental value as there are more chances for high quality quality and nutritious beef production than Scenario 1, which has a high environmental impact. The supply chain in Scenario 2 is also considered to be safer and more environmentally friendly as the sustainability goals are met.

5.1.3. Economic Value

The simulation analysis in Scenario 1 displays the income statement, where the costs of production and manufacturing surpass the revenue at the final stage, resulting in supply chain losses. The loss experienced in Scenario 1 is −284,498.59 GBP as a result of the high operational costs, and thus the supply chain experiences a poor financial performance and lack of efficiency regarding business activities during the different stages of the beef supply chain (depicted in Figure 5). The revenue in Scenario 1 is less than the costs because the supply chain activities are manually completed and delivered, which increases the time, energy, and human error. The supply chain is manually driven, which results in time consuming tasks, miscommunication, poor resource utilization, and a lack of security, leading to costly procedures throughout all levels of beef manufacturing. Thus, Scenario 1 has a low and poor financial efficiency, which reduces business viability and stability, increases costs, and minimizes profit margins.

Scenario 2 adopts RPA to automate strenuous, repetitive tasks and uses labour for performing complex procedures. The combination of RPA and humans helps improve supply chain processes and reduces costs at different phases of the supply chain. Scenario 2 displays a good financial performance as the cost of beef processing and manufacturing is reduced throughout all phases and the revenue at the end customer phase is increased, resulting in a profitable supply chain that amounts to 221,300.39 GBP, as seen in Figure 8. The lower consumption of time and energy, as well as improved business viability and stability, helps to reduce operational costs, thus ensuring an efficient financial performance for the supply chain.

Scenario 2 delivers enhanced financial efficiency and increased performance by generating profits and reducing functional costs, as shown by the income statement report in Simul8. On the contrary, Scenario 1 suffers losses and increased operational costs, which negatively impact business stability and viability. Hence, according to the simulation assessment, Scenario 2 increases economic value as the processing line is fast-paced and successfully produces good quality, hygienic beef.

The study is important in the domain of RPA adoption within beef supply chains and the results investigate and identify the potential financial risks and barriers in its adoption process. Previous studies have assessed and evaluated the process model of RPA considering various parameters such as beef quality, safety, and security; however, previous research lacks consideration of the cost-related aspects or financial factors that influence the adoption of RPA in beef supply chains. It is significant to highlight and assess the financial aspects that influence the adoption of RPA technology within the beef sector, thus fulfilling the gap in the research. Two scenarios have been analysed to observe the impact of RPA within beef supply chains, and the levels of supply chain efficiency and financial performance with and without the implementation of RPA as a resource input have been evaluated using Simul8 software. The results obtained through testing and running the process model in two scenarios is unique; they are observed from the aspect of sustainability in the three dimensions, namely social, environmental, and economic. To test the sustainability and evaluate the benefits of RPA in the beef supply chain, simulations considering the two assumed scenarios are tested and run. In broader sense, the results show that Scenario 2 produces healthier, safer, and more nutritious beef than Scenario 1. Scenario 2 uses RPA technology along with a human workforce to assist in different workstations within the beef supply chain. Scenario 2 shows a greater production beef capacity, productivity, and efficiency during each progressing stage of the supply chain, as the initial capacity at the start of the supply chain is observed to be 15 and it reaches 35 in its final stage, i.e., the retailer and final consumer. The financial and operational performance of Scenario 2 is also evaluated through process testing, and is seen to be better than Scenario 1. This is because Scenario 2 obtains profit due to task automation and reduced human error, thus facilitating the beef supply chain and resulting in lower operational costs and generating higher revenue, as depicted in Figure 10 in the income statement report. As a result of the low operational costs due to less reliance on the human workforce, better productivity levels, and efficient or speedy supply chains, Scenario 2 results in profitable business processes in comparison with Scenario 1, which shows a low financial performance and profit loss as the supply chain is human-centric with increased human error, resulting in increased operational costs and low revenue in the final stage. Therefore, Scenario 2 has a profitable supply chain system and shows a good financial and operational performance. On the contrary, Scenario 1 experiences a loss due to high operational costs and lower revenue generation over time, as well as the high amount of energy and cost utilized. Moreover, the results from the scenario analysis in the Simul8 software also depict that Scenario 2 that uses process automation along with the human workforce, and experiences less environmental threats and impacts than Scenario 1, as observed through the carbon emission report in Figure 11. Scenario 2 has is eco-friendly as a result of the autonomous processes and decreased human workforce throughout the different supply chain stages, thus reducing the time taken, as well as the fuel and energy consumption. The environmental impact is high in Scenario 1 as the carbon emission report shown in Figure 8 is double that for Scenario 2. To summarize the results, Scenario 2 uses process automation along with the human workforce to perform tasks, whereas Scenario 1 only uses the human workforce as labour for process delivery. Scenario 2 exhibits efficient financial and operational efficiency and high productivity levels with low processing costs, and creates social, economic, and environmental value in the beef supply chain. Scenario 1, being manual-centric, experiences poor financial and operational efficiency as greater time, money, and energy is used for task completion, resulting in a risky beef supply chain. Scenario 1 is more prone to risks as a result of high human error, longer queuing times for beef processing, and greater chances of low-quality beef production at higher costs, as shown in the analysis of the results. Therefore, because of the challenging work environment in Scenario 1, the beef supply chain does not achieve sustainable value.

The results obtained through the simulation analysis in this specific domain are new and have not been explored in previous studies. This is the first study focusing on the financial aspects in the adoption of RPA, and it explores the move towards sustainability through implementing RPA. The results of the study provide an improved approach for adopting RPA by considering the financial parameters. This emerging technology is not only considered in terms of its adoption, but also from the perspective of sustainability in beef supply chains. RPA acts as a sustainability tool to enhance supply chain business operations and improve financial performance through cost reduction.

The study evaluates the process model using a scenario analysis. Additionally, it provides an opportunity to businesses and beef supply chains to decrease financial risks and barriers in the adoption of RPA. It also introduces sustainability assessment criteria to analyse the scenarios from social, economic, and environmental aspects, considering all of the cost-related factors that play an important role when adopting of RPA. The study also encourages decision-makers to pay attention to the financial procedures of their business activities and helps improve their decision-making capabilities by providing insight into cost-analysis through the results from the simulation of the process model. This process model can be used as a basis to understand and observe the financial aspects of adopting RPA in beef supply chains and can be utilized by business owners as per their individual financial requirements or circumstances. The successful and robust adoption of RPA could assist organisations with sustainable beef production at reduced operational costs and help attain higher productivity levels [75].

6. Conclusions, Limitations, and Future Scope for Research

RPA can assist by streamlining business processes and providing sustainable business solutions by automating tasks and identifying risks [76]. This study uses a simulation-based approach to conduct a sustainability assessment using the Simul8 software. The testing scenarios provide insight at important supply chain phases related to the cost analysis, along with a critical evaluation of the processes impacting on the environment, society, and economy. With various financial factors affecting the implementation and introductory process of RPA in beef supply chains, this study serves as a contribution towards the financial considerations for the adoption of RPA. No formal financial evaluation criteria have been explored for RPA adoption within the beef sector before. Beef supply chains are highly fragmented, making the adoption process of RPA more strategic and challenging; hence, it is crucial to consider the financial aspects of its application.

This study analyses the best approach for the RPA adoption process considering the significant financial factors in its implementation. The findings of the study are beneficial in both theoretical and practical aspects. It contributes to theoretical knowledge in academia by identifying potential financial risks and challenges faced by beef supply chains in the adoption of RPA. Moreover, it serves in practical aspects by providing a critical analysis on the cost-related factors that influence RPA application in beef supply chains. It also improves the RPA adoption process by considering financial aspects and provides a process model that can be utilized to enhance the financial decision-making of business owners. Additionally, the analysis of the results provides an opportunity to conduct a sustainability assessment based on the three dimensions, namely, social, economic, and environmental aspects. The sustainability assessment is achieved through the development, simulation, and testing of the assumed scenarios, offering new scientific knowledge that is beneficial for both academia and the beef industry. The sustainable value of both scenarios is evaluated through process simulation to establish which scenario experiences greater financial and operational efficiency. As discussed in the results and depicted in the KPI values, income statements, and carbon emission reports, Scenario 2 achieved sustainable value in the social, economic, and environmental aspects. Scenario 2 displayed process excellence, hygienic beef production, high productivity and capacity, reduced operational costs, and long-term business profits and viability in comparison with Scenario 1, which showed a poor financial and operational performance. The impact and influence of RPA is found to act as a cost-saver and sustainability driver in Scenario 2. RPA integration reduces human error, energy, and time, resulting in less risk of beef contamination, wastage, or pollution, thus making it environmentally friendly. The cost−benefit analysis in Scenario 2 shows that automation reduces costs, and resources are utilized better to enhance the supply chain production and financial performance.

The paper is original in its contribution to both theoretical and practical aspects through the provision of the process model as a business solution for robust RPA adoption in beef supply chains. It further adds to scientific knowledge through the identification of financial risks and barriers at different beef supply chain stages. The study benefits and supports mangers and stakeholders in the beef industry by providing a business process model that could be adopted and modified according to the needs and financial circumstances of business users. Moreover, it encourages business professionals in the beef industry to adopt RPA through the successful removal of financial risks by conducting a thorough cost analysis. The process model supports professional practice as utilizing RPA eliminates any potential barriers beforehand. Moreover, the study adds to the research by identifying the main bottlenecks in different and complex stages throughout the beef supply chain and highlights the socio-economic benefits of adopting RPA. Additionally, the paper supports academia as it assesses various scenarios and shows that the successful integration of RPA helps to reduce operational costs, time, and energy, while improving beef quality, efficiency, and business viability, and creates sustainable value through automated business processes. The successful adoption of RPA will allow beef manufacturing supply chains to improve work-flow business systems and enhance financial efficiency. This innovative technology acts as a tool for sustainability by boosting beef productivity and quality, as well as saving on high processing costs.

As explained above, this research paper contributions academically and practically to the beef sector, as well as assisting managers and practitioners in the beef industry. The study identifies the financial risks, bottlenecks, and barriers in the adoption of RPA, which has emerged as an important tool for sustainability tool and as driver within beef supply chains, thus contributing to scientific knowledge. The research paper focuses on the financial aspects that influence the adoption of RPA in order to enhance supply chain operations and increase business viability. The study is unique as it considers the importance of the financial parameters that contribute to the successful adoption of RPA in beef supply chains, something that has not been given attention in previous studies. The study also observes two scenarios through process simulation to evaluate the potential risks throughout different workstations within the beef supply chain system. The simulation-based approach tests and evaluates "what-if" scenarios, using financial parameters as a basis for the simulation analysis. In addition, it not only focuses on the identification of financial risks or barriers using values or variables, but also analyses the process model from the perspective of sustainability. The findings of the study are important for evaluating the sustainability of adopting RPA in beef supply chains, and further observe the impact of integrating RPA in terms of social, economic, and environmental aspects. The findings of the study generate KPI values, income statement reports, and carbon emission reports by assessing the scenario simulations using Simul8 software. The scenarios are assessed from the perspective of sustainability and added value to observe supply chain operational and financial performance with and without the adoption of RPA. The study contributes practically as it provides a business process model for managers and practitioners within the beef industry, and the model could be adopted and modified according to the financial conditions, requirements, and individual circumstances of the beef supply chains. The simulation analysis and process model provide the opportunity for beef manufacturers to perform a thorough cost analysis to adopt RPA technology using the best approach. Using scenario testing, the findings of the study further facilitate managers by enhancing their financial and ethical decision-making, as well as by gaining maximized benefits and opportunities through the successful implementation of RPA within beef supply chains.

This study is in a specific domain and has some limitations. The study is limited to RPA application in beef supply chains; other food supply chains need to be investigated separately to analyse the use of RPA as a tool for sustainability. Another possible limitation of the project is the limited availability of data related to beef supply chains as well as the integration of RPA; however, this can be addressed through by developing different scenarios in the simulation process, as explained and discussed before. The research is limited to using the discrete-event modelling technique as the simulation approach for the scenario assessment. Other modelling techniques can be explored in future works in this specific domain. This study uses Simul8 software for simulation analysis and scenario testing, and this could be seen as another limitation of the study.

The findings of the study highlight that adopting RPA reduces operational costs, lessens environmental impact, and enhances beef productivity and quality through task automation, which increases sustainability in beef supply chains. Future works in the field could potentially focus on the development of other simulation models based on other factors or parameters, such as logistics, RPA assistance, technical expertise, and RPA design, that influence the adoption of RPA. This study contributes to a specific field and focuses on beef supply chains, and advancements in work could also consider other meat supply chains that could also benefit from sustainability-oriented innovations such as RPA technology for process acceleration. Future studies could also potentially evaluate other socio-economic benefits through advanced simulation testing and analysation considering the organisational factors impacting the adoption of RPA. Future studies could concentrate on simulation models to provide further insight and additional methods to tackle the environmental hazards and emissions resulting from beef production using RPA facilitations and opportunities. Other modelling techniques and simulation software such as AnyLogic, MATLAB, and SimScale could be used for model development and sustainability assessment in order to observe different approaches to RPA adoption and to create sustainable value. Currently, there are no thorough evaluations on the integration of RPA with AI assessing intelligent process automation in beef supply chains, and future works could focus on this domain. Moreover, future approaches in this field could explore contextual factors, such as managerial, individual, and organisational parameters, in the adoption of RPA. There are also no extensive studies on suitable processes for automation; hence, future works could critically analyse automation suitability according to organisational set up and explore ways to achieve sustainable value and a competitive advantage.

Author Contributions: Conceptualization, K.E.-F., R.K., A.H.-F. and D.S.; methodology, K.E.-F., R.K. and A.H.-F.; software, K.E.-F. and R.K.; validation, K.E.-F., R.K. and A.H.-F.; formal analysis, K.E.-F. and R.K.; investigation, K.E.-F.; writing—review and editing, K.E.-F., R.K., A.H.-F. and D.S.; supervision, A.H.-F., R.K. and D.S.; project administration, D.S. and A.H.-F.; funding acquisition, A.H.-F. and D.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The presented data in the study can be made available upon request from the corresponding author.

Acknowledgments: The authors would like to thank the University of Northampton's Department of Business Systems and Operations for providing access and license of the Simul8 simulation software, which greatly helped in conducting this research project.

Conflicts of Interest: The authors declare no conflict of interest.

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