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Adoption and Influence of Robotic Process Automation in Beef Supply Chains

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

[1] Department of Business Systems and Operations, University of Northampton, Northampton NN1 5PH, UK; fatima.e-khushboo@northampton.ac.uk (K.E.-F.); amin.hosseinianfar@northampton.ac.uk (A.H.-F.); dilshad.sarwar@northampton.ac.uk (D.S.); hareer.ahmed@northampton.ac.uk (H.F.A.)

[2] Aston Professional Engineering Centre, Aston University, Birmingham B4 7ET, UK

* Correspondence: r.khandan@aston.ac.uk

Abstract: *Background:* This paper aims to critically examine the potential barriers to the implementation and adoption of Robotic Process Automation (RPA) in the beef supply chain. The beef supply chain has been challenging due to its complex processes, activities, and management. The beef industry has relied heavily on the human workforce in the past; however, RPA adoption allows automating tasks that are repetitive and strenuous in nature to enhance beef quality, safety and security. There are considerable potential barriers to RPA adoption as organisations have not focused on trying to eliminate them due to various reasons. Previous studies lack knowledge related to potential barriers to RPA adoption, so this creates a research gap and requires attention. *Methods:* Statistical data and information are extracted using secondary data relevant to RPA adoption in the beef supply chain. A business process model is formed which uses values or variables using existing statistical data and information. Simulation of the process model is carried out using Simul8 software and analyses of different scenarios help in choosing the best approach for RPA adoption. *Results:* The results have identified the potential barriers in RPA adoption through the simulation process thus ensuring RPA performs with more potential. Analysis of 'what-if' scenarios allow organisational and employee-level improvements along with enhancing RPA's accuracy. *Conclusion:* The process model is a generic model for use in real-life scenarios and can be modified by organisations according to their own business needs and requirements. The study contributes in theoretical and practical aspects as it allows decision-makers to adopt RPA in a robust manner and adds to scientific knowledge by identification of potential barriers to RPA adoption.

Keywords: beef supply chain; beef supply chain management; robotic process automation; simulation; Simul8

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1. Introduction

"Supply chain" is a broad term from the perspective of the business world. It is described as a network of goods and services in accordance with supply and demand [1]. The food business produces products and services to meet the needs of people and their activities. Food supply chain management operates and assures food safety and quality through effective methods of production, distribution, and consumption. Because of its complexity and difficulties in administration, the food supply chain differs from other supply chains. Food safety, food quality, traceability, and freshness of food products all contribute to the complexity, which makes it difficult. Technological breakthroughs such as Robotic Process Automation have ushered in significant improvements and developments in the FSC by automating operations in food processing and packaging, ensuring food freshness and quality for greater customer satisfaction. There are so many manufacturing processes or procedures in the FSC; as such, it demands careful control [2–4].

The beef supply chain is large and expanded and has a complex supply chain system which makes it challenging. Technological adoptions such as Robotic Process Automation allow beef supply chains to enhance their operational efficiency and speed up the production line to meet consumer demands. This research aims to critically evaluate and investigates the role and impact of Robotic Process Automation in beef supply chains. It further inspects the associated barriers or risks to the adoption of RPA in the beef industry. The features and characteristics of the beef supply chain are critically analysed to understand the overall business process for successful RPA adoption within it.

The rationale for conducting this study is to support the beef industry by offering a generic process model which can be used by managers, decision-makers, and stakeholders for the effective adoption of RPA. The process model is generic and can be modified by organisations according to their individual needs and circumstances. Over recent years, a lot of interest has been given to the adoption of Robotic Process Automation in the beef supply chains. However, there is no thorough assessment of the potential barriers to RPA adoption within beef supply chains, which creates a research gap. An in-depth study and scenario analysis are assessed in Simul8 to investigate the potential barriers to allowing the successful adoption of RPA and overcoming the possible risks. The significance of the study is to assess the role and impact of RPA in beef supply chains and identify the potential barriers to the efficient adoption of RPA technology. The study contributes to both practical and theoretical aspects as it examines and identifies the barriers to RPA adoption in the beef supply chain and allows managers to utilise the process model for effective RPA adoption. Enhanced RPA potential allows beef supply chains to achieve strategic, financial, and operational goals and alleviate risks in terms of beef quality, safety, and security. The process model projects the various stages of the beef supply chain and is analysed using scenarios in Simul8 software. The research parameters which are beef capacity, shelf-life, and safety, are the base for developing the scenarios in the process model. Two scenarios are analysed and assessed in the Simul8 software to evaluate RPA accuracy and benefits in the beef supply chain. It also helps in the identification of any risk factors involved in beef production stages, in a virtual environment. The research parameters are further discussed in the results section below.

There are four simulation types used in supply chain management, i.e., discrete event simulation (DES), system dynamics (SD), spreadsheet simulation and business games. Discrete event simulation is used in this study to form the process model which maps the beef supply chain stages in a process. The DES is one of the popular and desired modelling methods used to model real-world systems in supply chain systems. The DES maps the processes or events separately that progress with time. The DES simulation model has many benefits including a variable and flexible level of detail along with the possibility to model dynamic behaviour and uncertainties of a real system [5,6]. It is advantageous to use such a model in manufacturing supply chains to map and integrate individual stages of a supply chain. The DES model also supports the supply chain network design and evaluates it analytically. However, on the contrary, the DES tools focus on logistical trends in a supply chain more than sustainability or quality. The key capabilities of DES modelling involve pointing out supply chain uncertainties related to product quality and logistics, along with their interaction. The DES tool is implemented extensively in food supply chains to improve food supply chain design in terms of speed and quality production. The DES simulation model also helps in effective decision-making and helps save operational costs whilst speeding up the process by identifying any supply chain risks [7].

The discrete event simulation model also provides key benefits related to the operational efficiency of meat processing supply chains. Operational efficiency remains one of the biggest concerns for the meat processing industry and organisations constantly strive to enhance it. The DES simulation tool analyses the current operational efficiency and tests it by providing variations in the parameters to give results. This further allows us to evaluate the efficiency of the meat supply chain at various stages and identify any uncertainties or risks associated with it. The DES tool allows stakeholders and managers to improve the meat supply chain efficiency in real-life environments and enhance meat quality, safety, and security. It also further enables them to better understand the factors that increase operational efficiency and production levels and allows them to improve managerial practices to alleviate potential barriers. The DES simulation used in the meat processing supply chains allows critical evaluation of the supply chain stages in a virtual environment and helps in understanding the key factors that can lower production costs and enhance operational efficiency in real-life scenarios [8].

This study uses the DES modelling method to map the beef supply chain's stages in a well-integrated manner. The process model is formed based on the research parameters and scenarios are analysed using the Simul8 software. A simulation approach to the process model and analysis of 'what-if' scenarios allow identification of risk factors or potential barriers in Robotic Process Automation adoption within the beef supply chain in a virtual environment. This will help managers or stakeholders to eliminate risks or barriers in real-life scenarios and enhance beef supply chains by maximizing the benefits that RPA can provide and lead to an effective adoption process.

The following section discusses the literature review which provides an in-depth study regarding the beef supply chain trends, forecasts, business procedures and supply chain concerns and challenges. It further highlights the role and impact of RPA in beef supply chains. It also discusses the factors that influence RPA adoption in the beef sector. Moreover, the distinctive features and attributes of the beef supply chain and its complexities are discussed. RPA functionality and adoption benefits are explained in the literature review section. The materials and methods are discussed along with the results, discussion, and conclusions in the further sections.

2. Literature Review

The long forecasts for the beef industry are progressive and good due to the constant increase in population. The consumer demand for beef has enhanced which increases its demand and supply in the market. The beef industry constantly strives to maintain beef quality and safety to add value to its supply chain systems. The beef supply chain constantly faces socio-economic pressures due to escalating environmental and health concerns. The major concern and challenges for the beef supply chain are to produce quality and hygienic meat and maintain beef quality standards [9,10]. Innovation and technological advancements play a vital role in effective beef supply chain management to respond actively to the growing beef market and meet consumer demand promptly. The introduction of advanced technological systems such as Robotic Process Automation (RPA) automates manual and repetitive tasks that were previously performed by humans. This improves business procedures and activities in the beef industry and offers task completion through automation, thus making it simpler and more efficient. The implementation and adoption of Robotic Process Automation create the opportunity to lower hygiene risks in beef production, cater to a scalable beef market, produce quality beef, and improve consumer satisfaction [11,12].

The food supply chains are challenging and complex and so require improvements in business performance. It is important to acknowledge performance improvements in business processes related to quality, delivery, flexibility, and costs. Organisations seek supply chain management capabilities that enable and allow them to achieve value creation, customer satisfaction, competitive advantage, and exceptional returns. It is significant for organisations to gain a competitive advantage and achieve market-oriented goals to enhance their performance level. Effective management of materials, control of supply chain operations and active coordination between internal activities also help decrease supply chain complexity. Hence, many factors can influence the performance level of food supply chains [13]. The meat crisis and growing demand in recent times have increased the attention on the meat industry. Meat quality, safety and customer satisfaction are among the greatest prevailing concerns in the meat market. Technological requirements, business and customer needs and identification of regulatory guidelines are important aspects to consider in a productive meat supply chain. Transparency is a crucial factor to consider in meat supply chains to ensure quality, safety, and security in meat production. Efficient collaboration between networks for the purpose of forming supply chain transparency systems leads to lower management costs and enhanced food safety. Meat supply chains need to stress internal engagement and efficient information-sharing systems to address safety concerns related to meat production [14].

The beef supply chain is crucial to understand due to its complexities and difficulty in management as the overall supply chain phases are complex [15]. The characteristics and dynamics of the beef supply chain are unique and have distinctive features. The demand for this sector and its mechanism has experienced increased focus and attention within organisations and its supply chain process. The main challenge in the beef industry is to produce high-quality, nutritious, and hygienic beef for consumers. The freshness of the red meat, healthy appearance and visible fat are some of the features of superior quality beef [16,17]. Figure 1 illustrates the various stages of the beef supply chain which begin at the farming stage and end at the consumer stage.

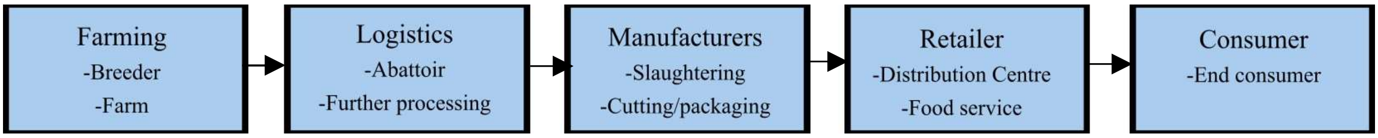

Figure 1. Beef supply chain stages (adopted from [18]).

Human health is also a key factor to consider when evaluating supply chain management since COVID-19 has occurred. Future waves of the pandemic (or future pandemics) heighten the risk of random workforce disease epidemics disrupting food processors' operations. Unlike the situation in early spring 2020, however, there has been time for food processing plants to adopt methods to avoid these hazards. Within manufacturing plants, attention to hygienic practices and social distancing measures serve to limit the danger of the disease spreading among employees, hence protecting workers' health and well-being. Moreover, producing high-quality beef is also important and the chances of beef contamination due to human touch are a cause of concern for the beef industry. Adaptive solutions include Robotic Process Automation technology, which involves employing software robots to do jobs and improve supply chain processes and lower the risk of beef contamination. Beyond the technological viability of Robotic Process Automation in beef processing, an individual firm's or larger organization's economic feasibility is a significant decision factor. Increased automation is cost-effective to the extent that robotics increase production, improve quality control, and reduce food safety issues [19,20].

The RMIF allows and encourages all industry players to communicate their challenges and concerns to eliminate all risk factors and discover solutions to problems for long-term supply chain processes. The RMIF lays forth a ten-point strategy for beef or red-meat stakeholders to increase profitability and performance. The red meat industry's operations and functions have evolved because of digital development. The RMIF forum can track red meat marketplaces and make them more accessible, and trade can be carried out more efficiently by cutting expenses and improving earnings. To improve consumer satisfaction and provide value to achieve a competitive edge, it is critical to observe people's demands, maintain meat quality, and provide high-quality and healthy meat (beef) to merchants. The Red Meat Sector Forum allows everyone involved in the industry to discuss their thoughts and concerns [21].

Beef is one of the most popular foods in the United Kingdom. Beef production in the UK produced roughly 9.6 billion British pounds in 2020. In 2017, the value of UK beef production doubled compared to the preceding ten years, reaching an all-time high. Since 2015, the population of cattle and calves in the United Kingdom has been steadily declining, with an estimated 9.4 million in 2020. Only 3% of the cow population in the UK was organic that year. Beef product sales generated roughly 4.4 billion British pounds in 2021. From

2015 to 2019, the value of beef exports climbed by more than 200 million British pounds; however, it plummeted by more than 20% in 2020. The top destination for UK beef exports was Ireland, followed by France. The value of beef and veal output in 2020 was estimated to be around 2.93 billion British pounds [22].

Robotic Process Automation provides appealing workplace benefits because it frees human employees from monotonous activities in supply chain systems, allowing them to focus on company goals. RPA also collects and organises data, which aids supply chain systems in making future forecasts and process optimization. The activities that RPA carries out are typically structured, straightforward, and recurrent, such as automated email queries. RPA deployment in supply chain systems has resulted in significant cost reductions in terms of full-time equivalent (FTE), as well as a beneficial influence on corporate productivity and strategic goals. It also offers 24 h service delivery without any break, thus reducing the time cycle of production whilst improving operational efficiency and accuracy [23]. Robotic Process Automation tools can also adjust to demand, are more scalable, and can reuse components to assist in the automation of different jobs. Due to the enormous benefits of RPA technology in supply chain systems, businesses are likely to spend more on it [24–26]. RPA has several properties that make it distinctive, productive, and advanced enough to be adopted by FSCs and simplify SC processes. There are different perspectives through which RPA is explained by various authors in Table 1.

Table 1. Definitions of Robotic Process Automation.

Definition of Robotic Process Automation (RPA)	References
RPA focuses on automation of rule-based, repetitive, routine tasks to make supply chain processes easier.	[27]
RPA is a term used to replace human workforce and automate tasks.	[28]
RPA is described as using software bots to automate individual activities or tasks.	[23]
RPA is a technique or tool to execute administrative or scientific tasks to benefit organisational processes.	[29]
RPA can be described as a non-invasive automation method which does not require any major changes to existing business systems.	[30]
RPA is used to increase process efficiency and reduce business process costs by automating tedious, routine tasks.	[31]
RPA is a tool to improve supply chain processes and lower financial burden on organisations by automating tasks.	[32]
RPA is the use of 'virtual workforce' also called software, to operate applications effectively just as humans would do.	[33]

RPA tools attempt to relieve employees of the strain of repetitive, uncomplicated activities [34]. The demand for RPA products from commercial providers has increased dramatically. Furthermore, in the previous two years, numerous new vendors have entered the market. This is unsurprising, given that most businesses are still looking for methods to save money and instantly connect legacy systems. RPA is viewed as a means of achieving a high Return on Investment rapidly (RoI). Automation Edge, Automation Anywhere, Blue Prism, Kryon Systems, Softomotive, and UiPath are dedicated RPA providers that only sell RPA software [35,36]. Robotic Process Automation can help with loading/unloading, slaughtering, cutting or deboning and packaging tasks in various meat processing factories, such as beef supply chains. The enormous variety of carcass forms and sizes is one of the biggest obstacles to increased automation in meat processing plants [37]. Nonetheless, technological improvements have the potential to enhance the use of robotics in the food industry, and the COVID-19 epidemic is expected to drive the trend toward greater automation. The requirement for labour-intensive plants to run at lower processing line speeds to safeguard worker health, as well as the need to avoid major revenue losses if production is halted or suspended owing to illness within the workforce, may have been added to this arithmetic by the pandemic.

Many supply chain specialists are unsure how to proceed considering the rapid advancement of digital technologies. RPA is frequently the initial step in a company's digital transformation. Over 60% of supply chain experts questioned in 2018 said they were researching or adopting RPA to automate supply chain business activities [38]. Many repetitive jobs in sourcing, operations, and logistics can be automated by RPA in supply chains. For a variety of reasons, businesses begin their digital transformation using RPA. First, software bots from top vendors such as Automation Anywhere, UiPath, and Blue Prism make RPA deployment simple. Tech-savvy supply chain employees can quickly build up their own RPA programs without the help of their company IT teams with minimal training and without the requirement for coding experience. However, IT is included in RPA adoption decisions so that systems are interoperable and IT skills can be efficiently exploited. Second, rather than revamping a whole end-to-end process, RPA can be implemented to a single, manual pain point in a process. Before automating a process, companies must ensure that it is running well and that they understand how automating one aspect of a process can affect its entire performance. Third, once established, adding, or removing capacity and scaling up or down bots based on business needs is simple. Finally, making the case for RPA based on ROI is simple [39]. RPA requires a small investment. Speed and fewer errors are other advantages, which improve overall customer service and supply chain procedures.

The beef sector in the United Kingdom is highly fragmented, with powerful and massive merchants, leading to mistrust and a lack of common goals and objectives. Consumer faith in the beef sector has also been affected by the industry's intricate supply chain. The government, on the other hand, implements risk management procedures, while the beef sector focuses on developing innovative designs to improve beef marketing and quality. Quality can be described as a degree or attribute that meets the cattle industry's specifications. Requirements are defined as mandatory or necessary acts that must be executed successfully to improve supply chain performance. Safety, service elements, quality food, and ethical production are the quality criteria that are relevant to the beef sector [40–42]. Another important aspect of beef quality is features that are closely related to its nutritional and consumption properties. This covers the beef's fat content, fat composition, look, flavour, colour, and texture, among other things. All these characteristics are influenced by the animal's breed, sex, production method, feeding regimen, and age. The Meat and Livestock Commission (MLC Services Ltd., China), which is responsible for its categorization in the United Kingdom grades beef carcasses according to their quality. On an alphanumerical scale, the EUROP grid is utilised to classify a carcass according to its conformation (shape) and fat level. The market most suited for each type of carcass is determined by combining conformation and fat ratings. Any abattoir in the United Kingdom or Europe that slaughters 150 cattle or more per week must classify beef carcasses. In the United Kingdom, there are two grid versions. Most cattle processing plants employ the standard grid. Conformation is graded on a scale of E to P, with E representing a convex and shapely carcass, R representing an average shape or straight profile, and P representing a plainer carcass with a concave profile. Fat is graded on a scale of 1 to 5, with 1 being very lean and 5 being extremely fat. In the United Kingdom, conformation classes U, O, and P are classified as high (+) or low (–), whereas fat classes 4 and 5 are classified as low (L) or high (H) (H). There are 56 distinct types of carcass categories in total [43].

This paper will be beneficial for the managers, stakeholders, or decision-makers in the beef supply chain, as it would help them improve the RPA adoption process and utilise its full potential. The maximized benefits of RPA will allow greater operational efficiency along with employee-level improvements within organisations in the beef supply chains. This paper also highlights potential barriers or risks to the full adoption of RPA in beef supply chains through simulation. Further sections will provide identification of the barriers or risk factors by analyzing 'what-if' scenarios through simulation using Simul8 software.

3. Materials and Methods

In this study, secondary data were sufficient, available, and extracted using existing literature, online published journals, government websites, organizational records, historical data, etc. These data were relevant to beef supply chain systems, beef supply chain management and the impacts of Robotic Process Automation adoption within it. The data and information collected relevant to RPA adoption in beef supply chains are used to form a process model using the Simul8 software for simulation and analysis. The process model is simulated and 'what-if' scenarios are analysed to choose the best approach for enhanced Robotic Process Automation adoption and elimination of potential barriers. The simulation approach evaluated the discrete event model in a virtual environment to analyse 'what-if' scenarios and identify potential barriers to Robotic Process Automation adoption. The process model is evaluated, and the software generates the output in the form of a report. The report generated via Simul8 evaluates the operational efficiency and the MORE plot generated highlights the risks or errors that might occur in real-life scenarios in the beef supply chains. This helps the managers and decision-makers to plan accordingly for the future and adopt strategies to avoid or eliminate the risk factors that are present.

Simulation and optimization help organisations map the beef supply chain processes and avoid potential barriers beforehand virtually. Simulation improves the adoption process of technologies such as Robotic Process Automation by allowing organisational leaders to utilise their full potential. Different software is used for the simulation of business processes; however, this study uses Simul8 for the simulation of the process model.

There were steps taken to form the process model for simulation starting from defining the main problem. Once the problem has been figured out then the next step is the conceptualisation of the model. Following the model conceptualisation is the data collection step. Secondary data are collected from existing information or the literature, government and organisational websites, online published journals, historical data, etc. relevant to beef supply chains and Robotic Process Automation in them. Model development is carried out after the data collection step. The process model is then simulated to analyse 'what-if' scenarios and identify potential barriers to the adoption of Robotic Process Automation. A report is generated by the Simul8 software along with a MORE plot which depicts the risk or errors that may occur. The identification of errors or risks at the initial stages in a virtual environment can help stakeholders or decision-makers to plan accordingly and avoid potential barriers. Figure 2 describes and illustrates steps for model development for the purpose of simulation.

Two scenarios are analysed, compared, and tested in the Simul8 software to observe which scenario has greater capacity, operational efficiency, and shelf-life in beef supply chains. The two scenarios are run to identify the potential barriers or errors in the adoption of Robotic Process Automation so that these are avoided in real-life scenarios. Table 2 gives an overview of scenarios 1 and 2 which are analysed and evaluated in the software in a virtual environment.

Scenarios 1 and 2 are tested, run, and analysed in the Simul8 software and the results are explored and compared in the following section.

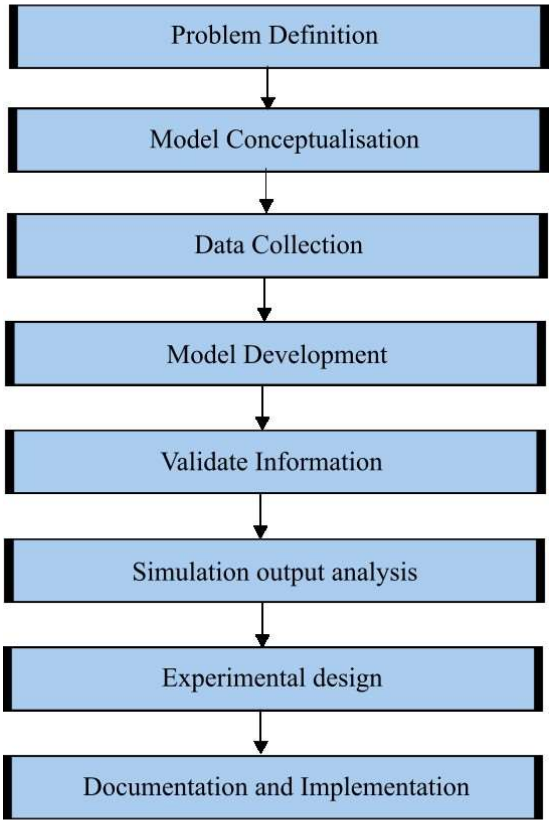

Figure 2. Simulation steps for the development of model [44].

Table 2. Scenario 1 and scenario 2 overview.

Scenario 1	Scenario 2
• Scenario 1 is tested and run in the Simul8 software. • Scenario 1 includes the stages of the beef supply chain, i.e., farm feeding, slaughtering, cutting, and boning, packaging and storage, retailer and consumer. • Scenario 1 uses a human workforce as a resource to observe the operational efficiency, time taken for tasks to complete, capacity and shelf-life in the beef supply chain. • Scenario 1 is tested to investigate beef quality, beef safety and beef traceability by using a human workforce as resource input in the software.	• Scenario 2 is tested, run and analysed in the Simul8 software. • Scenario 2 also includes the stages of the beef supply chain, i.e., farm feeding, slaughtering, cutting, and boning, packaging and storage, retailer or distribution centre and consumer. • Scenario 2 uses a human workforce along with RPA technology to evaluate the operational efficiency, capacity, time taken and shelf-life in the beef supply chain. • Scenario 2 is tested and run to examine beef safety, beef quality and traceability by using a human workforce along with RPA as resource input in Simul8 software.

4. Results

The secondary data are used which are available through online published sources and the relevant literature focusing on the impacts of RPA adoption in beef supply chains and its importance. There are several factors that affect the operations of the beef supply chain and RPA adoption within it. In this study, data are derived from existing information related to the beef supply chain process and stages, RPA adoption impacts on the beef supply chains and the importance of RPA technology in beef supply chain operations. The model is formed based on the beef supply chain operations and stages with the parameters and variables extracted from the secondary data available. The parameters comprise the time taken by the entity (beef) for processing through different processing units across the beef supply chain, time consumed by the employees to perform their responsibilities and the number of employees designated at workstations. The resources are gathered for use in supply chain operations. A simulation is an effective approach for analysing 'what-if' scenarios and eliminating risks or barriers in supply chain systems. Simulation helps in improving the beef supply chain by identifying the potential barriers and choosing the best scenario for gaining operational and employee-level efficiency using RPA. This helps to achieve RPA's full potential and reduce the human workforce for a progressive beef supply chain system.

The second part of the analysis calculates and evaluates the effect of research parameters that have been selected based on the secondary data available. The relationship formed between the parameters and the operational efficiency is assessed using simulation and analysation of 'what-if' scenarios. The literature depicts several factors that determine operational efficiency with and without the adoption of RPA in the beef supply chain. In relation to the attributes and characteristics of the beef supply chain mentioned in the previous section, a model is formed in Figure 3, which displays the factors that are important and contribute to a well-organized beef supply chain with the adoption of RPA. The arrows shown in the model also depict the relationship between the variables. The research parameters are key factors that influence the efficiency of beef supply chains. The factors as projected in Figure 3 are shelf-life, quality, and beef safety. These factors help in improving RPA efficiency in processing high-quality, nutritious beef leading to increased shelf-life and safety. The research parameters are the base for the formation of scenarios using the process model. Figure 3 shows the relationship between the factors of the beef supply chain.

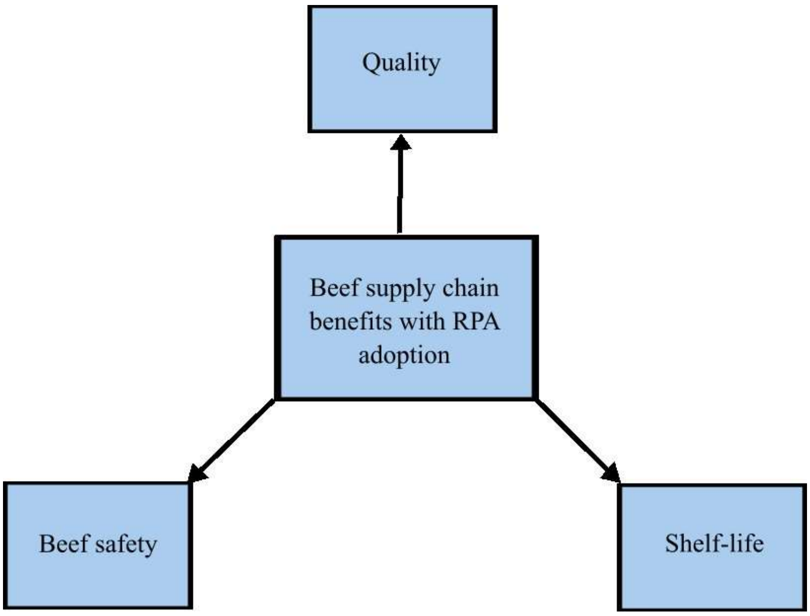

Figure 3. The relationship between factors.

A process model is created in the Simul8 software and simulation of the process model saw operational efficiency, capacity and shelf-life of the beef processed. Furthermore, the process model highlights various stages of the beef supply chain adapted from real-life supply chains. There are various processes mentioned in the beef supply chain and those processes are as such displayed in the model. Thus, the process model depicts the entire beef processing process until it reaches the end consumer. The data are collected using available secondary information based on the beef supply chain's stages and Robotic Process Automation adoption in its various phases. Thereafter, the data are analysed in Simul8 through a simulation approach. The following Table 3 projects the key processes or stages of a functioning beef supply chain. The process model includes all the stages observed in Table 3.

Table 3. Beef supply chain process or stages involved.

SI No	Process
1	Farm feeding
2	Slaughtering
3	Cutting and boning
4	Packaging and storage
5	Retailer or distribution
6	End consumer

4.1. Discrete Event Simulation Model and Result Analysis

Simulation is an imitation of a process, situation, or operation of a real-life scenario. It evaluates a model numerically by data collection to analyse the actual features of the model. Simulation estimates and explores the impacts of changes made to a system and can help decision-makers identify potential risks or barriers [45–47]. There are two categories of simulation models which are continuous and discrete simulation models. The discrete systems model changes intravenously at different points in time, whereas the continuous simulation model has variables changing continuously with respect to time. Discrete event simulation is an event-based simulation normally used in manufacturing, logistics, etc., [48–50].

The process model formed mentions the beef supply chain stages that process beef production. The data extracted use secondary information based on the parameters. The model shown in scenarios 1 and 2 is formed using the Simul8 software. There are two different scenarios evaluating the model with different efficiency and risk levels. The simulation model is then assessed and run for 12 h per day and repeated five times. It can be understood from the model that resources are utilised for supply chain system performance. For instance, in the slaughtering stage number of employees work to process the carcass further and prepare it for cutting or boning. On the contrary with the help of RPA collaborating with humans in the slaughtering stage, 300–400 carcasses can be slaughtered for further processing at a much faster pace and with fewer humans in the workforce. This increases the operational efficiency, speeds up the beef supply chain process and reduces the chances of beef contamination that might have occurred due to human touch. This ensures high-quality and hygienic beef production with less human error.

4.1.1. Scenario 1: Process Model Using Human Workforce in Simul8

The model created in the Simul8 software uses a human workforce as a resource to perform tasks at various stages of the supply chain such as slaughter, cutting and deboning and packaging. The model created and simulated in the software is shown in Figure 3. The model was run five times in replication with 12 working hours a day. It is investigated from the results that the main bottleneck occurred in the following areas:

1. Slaughtering stage;
2. Cutting and boning stage;
3. Packaging and storage stage.

The result is assessed in seconds for the overall testing of the model. It is observed that the average value time for the carcasses was 995.28 min, i.e., 16.5 h to go through the processes. A detailed KPI has been provided in Table 4, which shows the working percentage as 47.27% of the carcass processing in the system. There were many flaws observed in the process and the process was slow and took too much time due to tasks being carried out by the human workforce alone which dropped the efficiency of the supply chain. The capacity reduced over time in the supply chain, starting at nine and lowering to four in the last stage, i.e., the retailer or distribution centre. From the in-depth analysis, this process has been slow in terms of efficiency and higher in time consumed. It is evaluated that tracking and traceability are poor once the carcass is cut and sent to the packaging stage.

The tracing technique is employed in various places; however, due to humans managing most of the supply chain process, it becomes difficult to manage once the product reaches the cutting unit. Resource utilisation is inefficient and effective management and feedback systems are required to improve operations and functions across the beef supply chain. In this scenario, the human workforce causes human errors and high chances of carcass contamination due to human touch. Thus RPA's excellence and adoption provide enhanced operational and employee-level efficiency.

Table 4. KPI values for the beef supply chain simulated model.

		Less 95% Range	Average Result	High 95% Range
End Consumer	Average time in systems	883.08	995.28	1107.47
Cutting and boning stage	Waiting%	0.00	0.00	0.00
	Working%	45.06	47.27	49.27
	Blocked%	10.96	13.72	16.48
	Stopped%	38.15	39.01	39.86
	Change Over%	0.00	0.00	0.00
	Off Shift%	0.00	0.00	0.00
	Resource Starved%	0.00	0.00	0.00
	Maintenance%	0.00	0.00	0.00
	Number of completed Jobs	106.67	113.60	118.53

Furthermore, based on the assumed scenario, the model is purposely run to analyse and observe the impact of the human workforce on the beef supply chain and their performance in the Simul8 software. The process model is simulated in Figure 4 to evaluate the operational efficiency and capacity of the beef supply chain at various stages. This is scenario 1 and the process model is simulated using the human workforce as resource input. It is evident in scenario 1 that the capacity decreases with the progression of time and this also lowers the operational efficiency. The capacity is observed to be nine in the first stage, i.e., the farm feeding to slaughtering stage, and this impacts the efficiency, reduces the production of beef and more time is consumed. In stage 2, the slaughtering to the cutting stage, the capacity decreases to seven, which lowers the efficiency and increases the processing time of beef. As more time progresses, the capacity lowers to five in the packaging and storage stage and this further reduces the efficiency level. The last stage is the retailer or distribution centre where the capacity lowers to four. The human workforce as the input in scenario 1 experiences more time consumed and a lower operational efficiency, which leads to higher costs and less production of beef. In scenario 1, there are higher chances of beef contamination and less production of beef due to humans performing tasks. This reduces operational efficiency and increases operational costs in processing beef in the supply chain. Figure 4 shows the stages of the beef supply chain as it is simulated and depicts the efficiency of the human workforce, which decreases with time. Overall, scenario 1 is observed to have less capacity and operational efficiency which results in low-quality beef production. It is also evaluated that low capacity and operational efficiency raise processing costs and time.

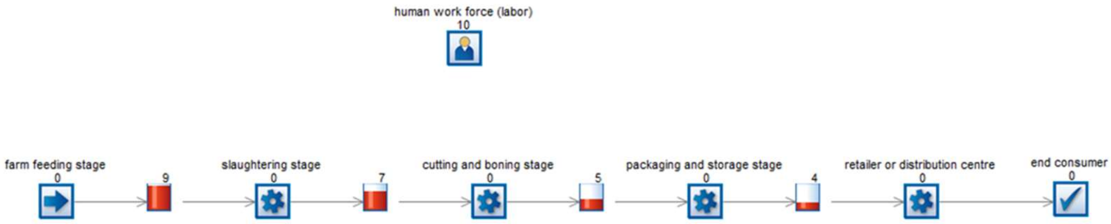

Figure 4. Scenario 1 simulation model of the beef supply chain.

Table 4 shows the KPI generated from the Simul8 software and depicts the results for a better and enhanced understanding. According to the KPI values generated through the software, the average result for the blocked percentage is 13.72 and the stopped percentage is 39.01. The average number of jobs completed is 113.60. The KPI provides average results in accordance with the stages of the beef supply chain.

Figure 5 shows a Measure of Risk and Error (MORE) Plot which displays risk and error for future support and decision-making. Once trials are run, a MORE plot is generated in Simul8 for each KPI. It displays the trial run results as a graphical illustration similar to the one seen below in Figure 5, which shows risks, written in red, as unlikely. It depicts that the average time for carcass processing was 995.28 min over five runs.

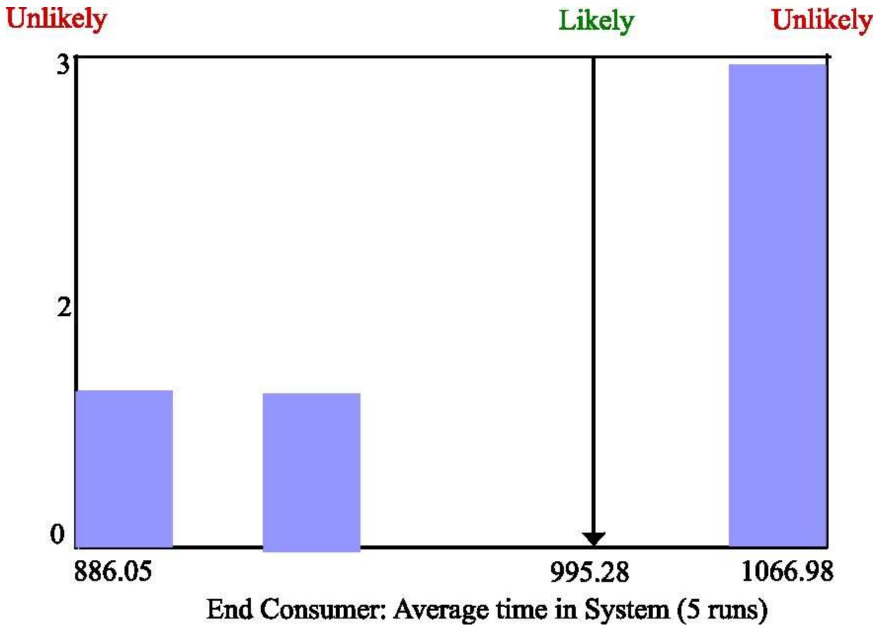

Figure 5. MORE plot for the average time in a system for the end consumer.

Another MORE plot, shown in Figure 6, depicts the working percentage for the cutting and boning stage, i.e., 47.27%. It also observes the unlikely risks that are present and may occur.

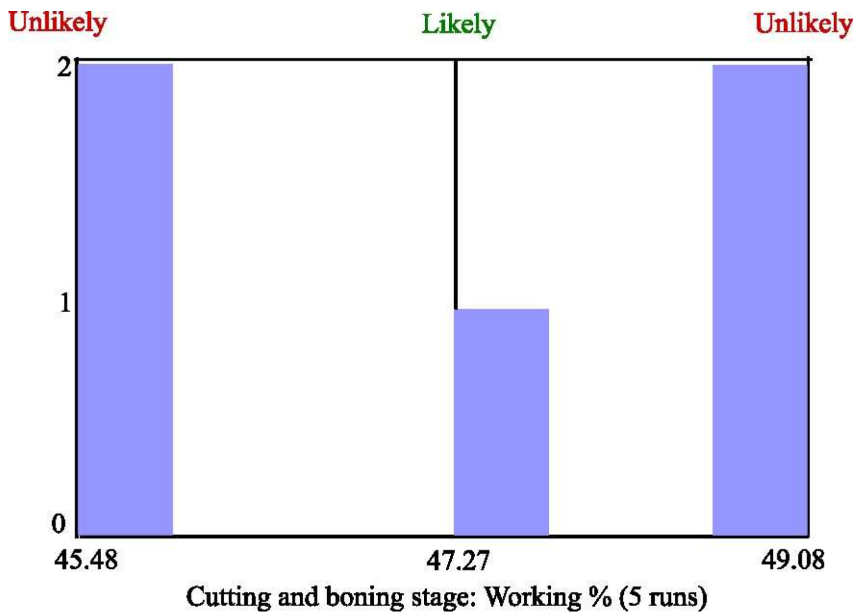

Figure 6. MORE plot for working% in the cutting and boning stage.

4.1.2. Scenario 2: Process Model Using the Human Workforce along with RPA Technology in Simul8

The model simulated in the Simul8 software used both the human workforce and RPA technology for performing operations and beef supply chain processes. The average time in the system for the carcass in the beef supply chain was 805.32 min, i.e., 13.4 h. The working percentage for the beef supply chain process in the packaging stage was 88.33%. The capacity and efficiency in distinct stages of the supply chain process are observed to be on the higher side and increased. The beef supply chain had better operational efficiency as seen in the simulated model. This meant that due to the adoption of RPA in beef processing, the supply chain worked better and increased its functionality. The use of RPA reduced human error, due to which high-quality beef is produced and cut for packaging. The shelf-life of beef, which is a key factor in beef safety, also increases due to its faster production times. Regarding this scenario, RPA adoption enhances operational efficiency and beef safety and traceability. This also enhances beef production due to the fast-paced processing supply chain. Scenario 2 has two resource inputs, i.e., the human workforce and RPA technology. Scenario 2 sees sustained and increased capacity and operational efficiency. In stage 1, farm feeding to slaughtering, the capacity is seen to be on the higher side, i.e., 19, and so it depicts higher operational efficiency and less time consumption for beef processing. The capacity slightly dropped to 18 but remained at a higher rate in the cutting/boning and packaging stage. This means that the beef processing operational efficiency was high, and processed beef has a greater shelf-life and quality in stages 2 and 3. The last stage, i.e., the retailer/distribution centre, had a capacity of 19, and so the overall supply chain operational efficiency increased. Therefore, scenario 2 produced high-quality and safer beef. Less time is consumed as the beef processing line remained fast due to higher efficiency levels and this leads to lower operational costs. Figure 7 shows a scenario 2 simulation model of the beef supply chain formed in Simul8 software.

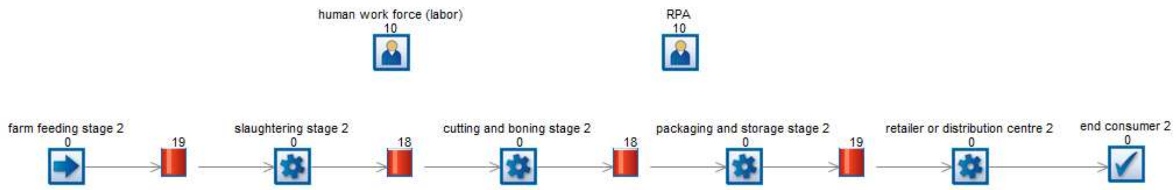

Figure 7. Scenario 2 simulation model of beef supply chain.

Table 5 depicts the KPI report generated through the Simul8 software. The KPI values give a detailed overview of the simulation carried out on the process model and evaluate any changes in the supply chain process in a virtual environment. In accordance with the KPI values generated from the simulation, the average result for the blocked percentage in packaging and storage is 1.81. The stopped percentage observed in the packaging and storage stage is 10.06. The KPI values are calculated by the software to give an insight into the beef supply chain operations, the time consumption, the work and the risks involved.

The graph in Figure 8 shows a MORE plot which depicts the risks and errors. The MORE plot identifies the risks and errors for stakeholders and managers of the beef supply chain so they can reduce or alleviate them. The plot shows the unlikely risk factors that may have a chance to occur due to uncertainties. It also shows the average time in the system for end consumer 2, i.e., 805.32 in five runs.

The MORE plot shown in Figure 9 depicts the working percentage for packaging and storage in stage 2, i.e., 88.33 over five runs. The errors or risks are observed in the MORE plot so that they can be avoided or eliminated in a real-life environment.

Table 5. KPI values for beef supply chain simulated model.

		Less 95% Range	Average Result	High 95% Range
End Consumer	Average time in systems	720.14	886.32	890.64
	Number completed	207.72	215.80	223.48
	'In system less than' time	10.00	10.00	10.00
	% in system less than time limit	0.00	0.00	0.00
	St Dev Of	13.00	37.28	80.68
	Maximum time in system	812.47	870.00	927.72
	Minimum time in system	612.55	725.84	831.13
Farm feeding stage 2	Number entered	222.83	240.60	258.37
	Number lost	12.38	30.00	47.62
	Net Number entered	207.74	210.60	213.46
	Waiting%	0.00	0.00	0.00
	Working%	84.94	88.33	91.73
	Blocked%	0.00	1.61	4.47
	Stopped%	8.80	10.06	11.32
	Changeover%	0.00	0.00	0.00
	Off shift%	0.00	0.00	0.00
	Resource starved%	0.00	0.00	0.00
	Maintenance%	0.00	0.00	0.00
	Number completed jobs	206.99	211.60	216.21
	Minimum use	0.00	0.00	0.00
	Average use	1.00	1.00	1.00
	Maximum use	1.00	1.00	1.00
	Current contents	1.00	1.00	1.00

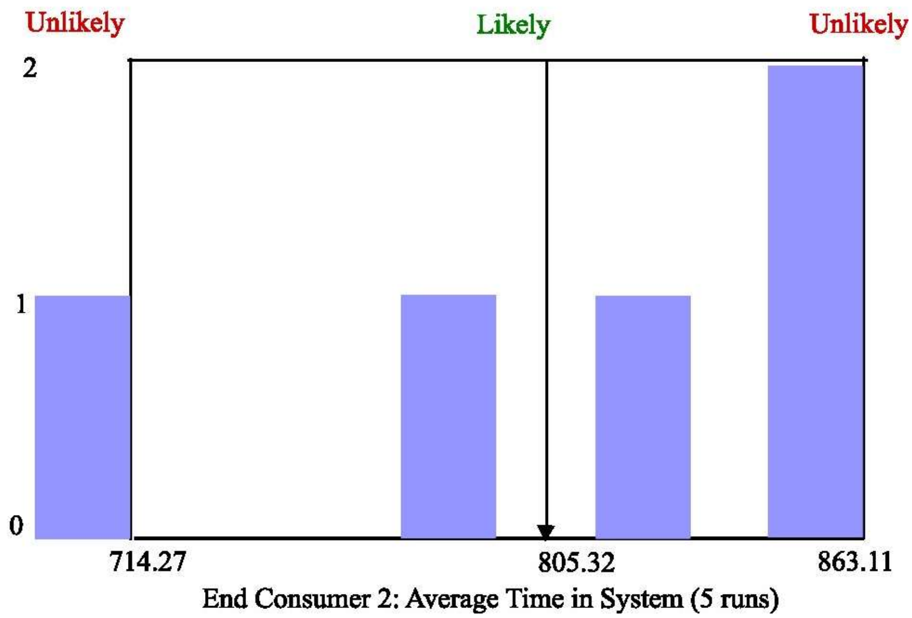

Figure 8. MORE plot for the average time in systems for end consumer 2.

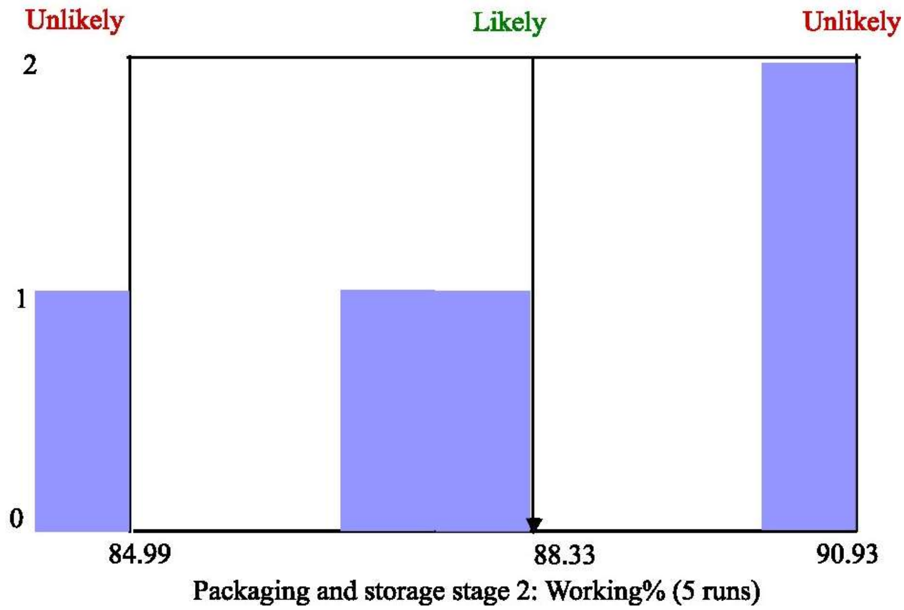

Figure 9. MORE plot for working% in packaging and storage in stage 2.

4.2. *'What-If' Scenario Analysis—Scenario 1 and 2 Process Model Comparison*

The simulated model in Figure 10 depicts a comparison between the two scenarios simulated in the Simul8 software. In scenario 1, the human workforce alone manages and executes the tasks for beef supply chain operations at all stages. In scenario 2, Robotic Process Automation, along with fewer humans in the workforce, operates tasks with greater efficiency and less time taken. In scenario 1, the average time taken for carcass processing is 995.28 min (16.5 h), whereas in scenario 2, the average time taken is 805.32 min (13.4 h). Scenario 2 uses RPA with a greater capacity and efficiency and reduces human errors and risk factors. Beef nutritional value, hygiene, safety and traceability are greatly enhanced in scenario 2 due to the fast-paced production and beef processing at all stages in the supply chain. The working% in scenario 2 is 88.33, which is almost double the percentage in scenario 1.

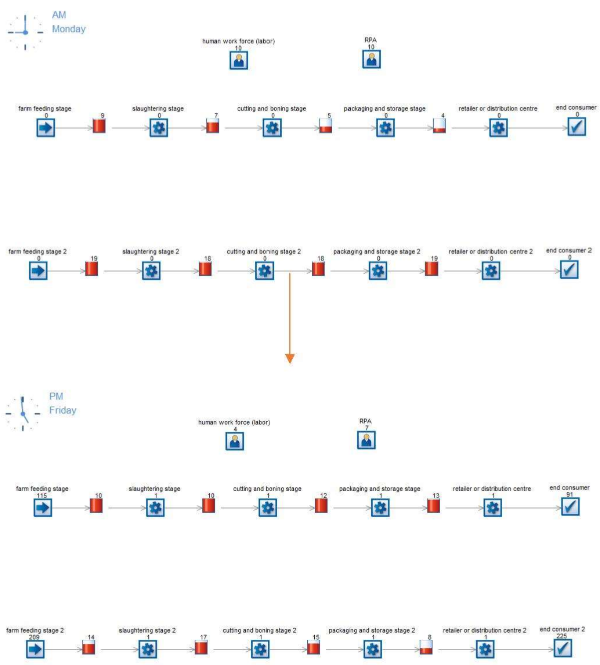

Figure 10. Simulated model—comparison of scenarios 1 and 2 modelled using Simul8.

Hence, the operational efficiency, cost-effectiveness and beef standards are much better in scenario 2 with the usage and implementation of Robotic Process Automation as shown in Figure 10.

5. Discussion

Simulations are relatable to dynamic models and the process model represents the evolving time of the real system. Simulation can also be described as an imitation of another process [51]. The benefits of simulation include economic and operational supply chain efficiency and supply chain risk management. The simulation also helps in the identification of potential risks or errors in the supply chain system and improves the process of decision-making for managers or stakeholders [52]. Through the simulation approach, various 'what-if' scenarios can be compared and analysed with respect to performance indicators. It is time-consuming to build a simulation model accurately; however, it is a powerful tool to analyse and evaluate operational processes and avoid risks in real-life applications. To evaluate the impact of a tactical or strategic move beforehand, decision-makers need advanced systems. 'What-if' analysis enables supply chains to compare and understand different scenarios. Moreover, it helps to adopt a better approach to improve business processes and eliminate risks [53].

In this study, scenario 1 changed the capacity at different stages of the beef supply chain and used only the human workforce as a resource to perform tasks in the entire process. The initial model in scenario 1 used greater time taken, in minutes, to perform the operations and functions across the beef supply chain. In the results, we can see a decreasing capacity as the carcass progresses to further stages along with decreasing operational efficiency. The three stages which include the slaughtering stage, cutting and boning stage, and packaging and storage stage changed their efficiency when RPA and human workforce resources were added together. The efficiency, storage capacity and shelf life were lower when the trial was run five times in this scenario. The working% was also on the lower side, i.e., 47.27, which was half the efficiency of scenario 2. This also resulted in poor management of beef traceability, quality, and safety. With the human workforce increasing as an input resource in scenario 1, the MORE plot evaluated unlikely risks or errors that might occur, peaking at 1066.98. The MORE plot depicts unlikely chances of risks or errors that might appear in real-life environments due to human error.

Scenario 2 considers the addition of Robotic Process Automation as a resource along with the human workforce. As a result, less time was taken for the carcass to be processed for the end consumer. The capacity and efficiency were observed to be much better and greater than in scenario 1. The implementation and adoption of Robotic Process Automation enhanced the overall beef supply chain functions in stages such as slaughtering, cutting, and boning, packaging and storage and retailer. The efficiency, shelf-life and capacity were enhanced when a trial was run five times the software. The working percentage depicted in the KPI report was seen at a higher side, i.e., 88.33%, which means that an increase of 41.06 percent was experienced. This resulted in almost double the working percentage in scenario 2 in comparison to scenario 1. The risks and errors that might happen were also evaluated by the software-generated MORE plot. These were also lower in percentage as the risks are reduced due to the adoption of Robotic Process Automation in various stages of the beef supply chain. The average time in the system in scenario 2 was 886.32 min which was 108.96 min less time taken than in scenario 1. This is because the operational efficiency is enhanced as a lower average time is taken by the carcass for further processing. The shelf-life also increased along with the capacity and the beef produced was safer, healthier, and nutritious in scenario 2 due to the fast-paced production line. Automation improves production lines and there are fewer chances of producing contaminated beef due to fewer human touches and errors. This is because repetitive and strenuous tasks are performed by RPA in the slaughtering, cutting, and packaging stages.

The scenarios in this study are developed to provide analysis and an in-depth evaluation of the impact of RPA in beef supply chain stages. The 'what-if' scenarios are analysed and evaluated to understand the best approach to adopt Robotic Process Automation and utilise its full potential for enhanced benefits that the technology can provide. The risk, errors and barriers such as beef contamination, low-quality beef production, poor management and traceability are key issues that can be tackled or avoided by the decision-makers beforehand.

The study provides a generic process model for beef supply chains which can be standardised for use within various organisations in real-life scenarios. The generic process model can be modified for use in accordance with the business needs, requirements, and scenarios of an organisation. The process model is a standard model which can be adopted by beef supply chains in future to enhance their operational and employee-level efficiency and identify any potential barriers to RPA adoption. Two scenarios are analysed using this process model which consists of beef supply chain stages. The scenarios are based on the research parameters of this study, i.e., beef quality, shelf-life, and safety. The scenarios use research parameters whose values are altered and tested to analyse the operational efficiency at various beef supply chain stages. This will allow beef supply chains to achieve operational and strategic goals whilst reducing cost and quality concerns regarding beef production. Moreover, the use of the process model enhances RPA efficiency and accuracy, increases quality beef production, and improves beef safety and security. This will help in resolving practical problems associated with beef supply chains regarding production of nutritious, high-quality beef which is safer and healthier for consumption. The adoption of RPA in a robust manner will also enable managers and decision-makers to achieve strategic, financial, and operational goals.

It is significant to highlight that RPA has brought visible changes to the work environment as it replaces the human workforce with software bots to do repetitive and boring tasks. However, this motivates employees to concentrate on skilled-based, talent-oriented jobs which require managerial and decision-making skills. This opens new job opportunities for the human workforce who can enjoy and focus on meaningful tasks in beef supply chains. RPA accuracy and full adoption in beef supply chains can also resolve problems such as a shortage of the workforce [54].

Furthermore, it is possible to explore and evaluate other possible scenarios in the Simul8 software in future research. Other parameters such as financial factors can be considered in future works.

6. Conclusions

The study has both theoretical and practical contributions as it adds value and scientific knowledge to literature by focusing on the efficient adoption process of RPA. Previous studies provide limited information and literature that focuses on factors that influence the overall adoption process of the RPA technology and lacks scientific knowledge related to the adoption and implementation of RPA in an efficient manner within beef supply chains. The study has practical implications for stakeholders, decision-makers and managers who are concerned with the adoption of RPA which is an emerging technology in beef supply chains. The study provides a generic process model which can be standardized for use in real-life scenarios and can be modified by decision-makers according to their own organisational needs and requirements. This information could provide practical knowledge and add value to beef supply chains by providing a generic process model which could help managers with the goals and objectives of enhancing RPA's potential and accuracy. The generic model can be modified and utilised by organisations according to their own individual business needs, requirements, and circumstances. This can further help organisations to achieve maximal benefits from RPA and enhance beef quality, safety and security, which are growing concerns for beef supply chains in present times.

Moreover, this study explains the importance of Robotic Process Automation and the adoption of the technology at its full potential in the beef supply chain system. Production of hygienic beef with enhanced nutritional value and shelf-life is the main concern for organisations. Robotic Process Automation improves operational and employee-level efficiency by making supply chains less complex. Different scenarios have been tested and run to maximize the benefits and accuracy of Robotic Process Automation. Scenario 2 observed an increase in operational efficiency, faster production rates and enhanced capacity, with the adoption of Robotic Process Automation in various stages of the beef supply chain. Risks and errors have been highlighted through the simulation of the process model. This will particularly help managers and decision-makers to eliminate potential barriers in real-life scenarios. The impact of Robotic Process Automation has been analysed and it is observed that it reduces human error, increases efficiency, and reduces production time.

The findings of the study indicate that Robotic Process Automation enhances beef safety, quality and traceability which is a growing concern for beef supply chains at present. Future studies could potentially evaluate further scenarios by considering other factors to enhance beef supply chains and their performance level. Other scenarios that influence the RPA adoption process and may be assessed in the future include financial costs, RPA governance and management, RPA assistance, etc. Hence, more scenarios can be evaluated in the future based on other parameters that influence the adoption process of RPA and can enhance RPA's excellence. Moreover, studies in the future can also focus on the employee-level acceptance of RPA adoption in beef supply chains. It can also concentrate on areas such as human–robot integration and relationships in the supply chain system. This study focuses on the adoption of RPA in the beef processing supply chain; however, future work can evaluate the adoption process of RPA in other meat supply chains such as poultry, fish, pig meat, etc., and can investigate scenarios using different parameters. Moreover, organisational culture and its dynamics play an important role in RPA adoption and can transform businesses. There are no extensive studies in this direction, so future research can possibly focus on the impact of organisational culture and its role in RPA's success.

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