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ABSTRACT

The agricultural sector in the UK is facing unprecedented challenges as a result of changes in the macroeconomic environment and the future of the livestock sub-sector is particularly uncertain. Farmer's businesses and livelihoods are at risk with the planned removal of subsidy payments as a consequence of emerging agricultural policy change as a result of Brexit. Farmers are forced to seek adaptive strategies to survive because of changing socio-political circumstances. This study explores the potential of an analytical tool, Discrete Event Simulation (DES) applied within the agricultural sub-sector of livestock management. It utilises a multi methodological approach using both interviews with farmers and a simulation of a real case; Colclough livestock farm, located in Yorkshire, England. The findings show that DES can be used by livestock farmers, helping to simulate potential growth strategies and observe the impact in relation to existing farm processes. Barriers to the sector wide adoption of new farm technologies are presented. This research captures the current views of farmers regarding technology adoption, showing empirically that technologies and software exist which can improve economic performance of farming enterprises, however, contingent factors, such as age, attitudes, skillsets and broadband connectivity, limits successful adoption.

1. Introduction

The UK agricultural sector is currently faced with uncertainty following the result of the June 2016 referendum on the UK remaining or leaving the EU, prompting organisations within the sector to adapt to the changes in the macroeconomic environment (Hill, 2017; NFU, 2019). For the first time since 1975, the UK government has the opportunity to redesign the country's agricultural policy without consultation, but being aware of the consequences for its European partners, once the industry is no longer a beneficiary of the European Union's Common Agricultural Policy (CAP) (Gov.uk, 2018). The new Agricultural Bill, once approved by the UK parliament, will determine the course for agricultural policy creation with a focal emphasis upon the creation of "Public Money for Public Goods" (Downing and Coe, 2018.16). A change to existing conditions also creates uncertainty for farmers in the UK, with one of the core elements of the bill being the proposed removal of the previously EU direct payment subsidies. Instead the government will require farmers to make further efficiency gains, increase sustainable farming practices, and deliver public goods, all of which are controversial initiatives.

'Direct Payments are a poor tool for income support and can introduce distortionary incentives that inhibit productivity' (DEFRA, 2019.6). However, subsidies are crucial for supporting the UK's upland farm economy. The implications for farmers from a policy/governmental perspective is that payments based on simply owning land does not promote productivity, providing little traceability of public money with no indication that it is being reinvested into British food production (DEFRA, 2018). However, from an individual farmer's perspective, a different interpretation is evident. The removal of farm subsidies is likely to be problematic for the UK's food producers. Over £3 billion was provided to UK landowners in Direct Payments in 2018. The nature of economic reliance on subsidy varies depending upon sector, with livestock farmers relying on subsidies for almost 90% of their profits (Abboud, 2018). Indeed, 20% of all UK farms are unable to sustain a positive Farm Business Income (FBI),[1] and wages are typically 40% lower than in other sectors (DEFRA, 2018). The livestock sub-sector requires provisions in place for farmers post-Brexit, with the average income of Less Favourable Area (LFA) grazing livestock farms being £15, 500 and making a net loss on agricultural activities when compared to other sectors (DEFRA, 2019). With stringent industrial challenges

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[1] Farm Business Income = total output from agriculture + total output from agricultural/environmental schemes + total output from diversification + single payment – expenditure + profit/(loss) on sale of fixed assets (AHDB, 2019). FBI is a farm accounting term used to indicate the general wealth of a farm business.

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impacting on the sector, external pressures on farmers are growing. Achieving a profit is difficult, farmers must seek new adaptive ways to survive, transforming their operational practices and developing entrepreneurial strategies in accordance with the market and governance needs (McElwee, 2008). Under such economic uncertainty, farmers are faced with making decisions which, if made poorly, could cost them their businesses and homes. The deactivation of farm direct payments suggests many farmers will be seeking new ways to sustain FBI, with those farmers who are more entrepreneurial adopting new farm technologies and software. Innovation, the continual process of learning and creation, plays a fundamental role in the meeting of farm business strategies (Suess-Reyes and Fuetsch, 2016). Farmers may turn to technology and new software adoption to help facilitate farm innovation and the meeting of the goals of the farm enterprise.

Simulation models have the potential to capture a large number of operational details and support the decision making process in what may happen and what can be done to achieve a set goal. Although extensive literature exists (Robinson, 2005, 2008; Tako and Kotiadis, 2015) dedicated to simulation methodologies, they have not been overly researched in the farm sector. This paper explores the value in the utilisation of Discrete Event Simulation (DES) in the context of the livestock sub-sector, understanding the practical benefit of the tool from the perspective of the farm manager. It utilises a novel methodological approach, practically exploring the benefits of DES through a simulation methodology applied to the case of Colclough farm[2], followed by subsequent interviews with the farm manager and other farm managers within the region, determining the usefulness of DES for livestock farmers, the role it plays in helping farmers combat the sectoral challenges alongside gaining a deeper understanding into the attitudes towards new farm technology and software adoption.

With increasing market challenges, modelling techniques, like DES, can arguably aid in the Farm Management Decision Making (FMDM) process. DES has already proved useful within other sectors such as: construction, healthcare and the automotive industries, aiding managers in decision making, cost reduction, and streamlining processes (Vidalakis et al., 2011; Eldabi et al., 2007; Pierreval et al., 2007). This paper contributes to the growing literature within the fields of rural studies, complimenting the work on barriers to new technology adoption within UK upland farm economies (Bowen and Morris, 2019; Morris et al., 2017). Moreover, it neatly aligns with the growing body of research within agricultural supply chain management, understanding how modern technologies associated with 'Industry 4.0[3]' can be used by farmers to meet the strategic objectives of the farm enterprise. This study illustrates the benefits and challenges associated with farm technology and software adoption through the applied case of Colclough farm, building upon Bowen and Morris's (2019) research, understanding whether the digital revolution really is bypassing that of the upland farm sector.

Two research questions are formulated:

- RQ1: To what extent can a simulated livestock model using DES be used as an effective farm management tool?
- RQ2: What are the attitudes of livestock farmers regarding policy change and new technology and software adoption?

The paper is structured as follows. The next section introduces the case study, Colclough farm, to explore the capabilities of DES. The literature review is then presented, positioning the study within the wider contexts of DES, agricultural supply chain and livestock management research. The methodology is then introduced, highlighting the multi-methodological approach consisting of simulation research and qualitative interviews, followed by a summary of the research findings. Finally, we provide our conclusion, answering the study's research questions and summarising the contributions made.

2. Colclough farm

Colclough farm is representative of the many upland livestock farms in the UK. It is a third-generation family run livestock farm situated in West Yorkshire, England. The system consists of 140 head of mixed breed commercial sheep (Gritstone, Texel, Zwartbles, and Suffolk) and around 50 head of suckler beef cattle (Limousin, Simmental, and British Blue). Over the years, the farm has transitioned steadily alongside the market and family needs. The farm manager (and owner), Joseph (64), has been running the farm for the last 40 years. Joseph can be regarded as a traditional farmer, left school at 14 and has no interest in modern technologies, does not own a smart phone, and relies on a small inner network for advice and companionship. The farm used to be a dairy farm, with the herd milked twice a day and milk sold directly to the customers of a small town through Joseph's own milk round. However, as the years went by, Joseph's market became saturated, with local customers demanding more varieties than he could provide. Regulations increased, raising input costs, reducing profit margins, and generally reducing Joseph's and his product's appeal to the sector. Joseph made the decision to sell his milking herd, exit the dairy sector, and enter beef and sheep production, a strategy which has served him well to date.

Nowadays, Joseph is still farming, but is approaching retirement age, looking to maintain a comfortable living until his son Ben (16) takes over the farm. Ben has left school early to take up full time employment on the family farm, everything he learns is from his dad. Financially, the farm has performed well, with Joseph owning outright his farm with zero outstanding liabilities. The total Farm Business Income is approximately (FBI) £45,000 per annum, with around £30,000 of that coming from Direct Payments[4] and the Countryside Stewardship Scheme.[5] The farmland is approximately 95 ha of hill and moorland. Diversification opportunities are limited due to the geographical location of the farm and Joseph's traditionalist views. Joseph, is not an entrepreneurial farmer (Smith et al., 2017). Like many other farmers in the area, Joseph and his family are faced with uncertainty and are unaware of the consequences policy change in alignment with the EU exit will have to his family business.

Strategically, there are a number of endogenous and exogeneous concerns affecting the long-term objectives of the farm. A key agenda highlighted within the Agricultural Bill is the planned removal of subsidy payments, gradually phasing out Direct Payments, and replacing existing EU funded environment schemes with new Environmental Land Management Systems (ELMS). The result of which could impact the farm's profitability, as the majority of Joseph's income comes from EU CAP payment, and position Joseph in a fight for survival situation, pressuring him to develop innovative ways to sustain competitiveness through economic uncertainty. After his lifelong experience of running the farm, Joseph wants to successfully transition the farm to his son in the best possible state. A costly legal incident involving a dog walker and his herd of cattle, and his own personal beliefs, has prompted Joseph to

[2] The name of the farm and individuals are anonymised.

[3] Industry 4.0: The 'fourth' industrial revolution, the data age of connectivity where technology is changing our lives. Examples of Industry 4.0 technologies and platforms include robotics, sensors, drones, virtual reality, simulation powered through internet of things and internet of everything, artificial intelligence and big data.

[4] Direct Payments- Subsidy payments paid to active farmers in the UK calculated based upon the amount of land entitlements the farmer holds.

[5] Countryside Stewardship- An EU funded environmental scheme whereby farmers can achieve additional income by following government initiatives to enhance rural development i.e not cutting grass until late summer to allow native bird species to flourish. Agri-environmental schemes like the Countryside Stewardship are to be replaced with Environmental Land Management Systems once a UK domestic agricultural policy is established.

think about moving to a sheep only livestock system to increase farm profitability. Joseph emphasises that the increased sheep production would have implications on various livestock-handling processes, mainly on the flock handling activities of sheep shearing and dipping, which are resource intensive, performed once per year and allows welfare of the livestock to be assessed, ensuring that Joseph's stock remain in quality condition. An increased production scenario would have the biggest implications on these two processes as these are the only time in which all the sheep are handled simultaneously. Joseph maintains that in the event of switching to a sheep only system, he would increase his flock from 140 sheep to 420.

Thus, an opportunity is presented, DES can be used as a tool to explore its capabilities within the livestock sector, assessing the intended strategy of an increased sheep production scenario and exploring the implications it would have upon current farm operations. The tool DES allows for this to be explored virtually through computerised software. We can utilise DES to model the existing sheep handling processes (shearing and dipping) based on real farm data, then simulate an increased sheep production scenario and analyse the effects it has upon the current farm set-up, making changes to the simulation to explore the impact this increased production scenario has upon existing farm resources. We provide an innovative application of DES to address the real-world problems within livestock management.

3. Literature review

Simulation in this study is both the methodology and the focal topic addressed, determining how DES can be applied in livestock management. The analytical tool, DES, is taken from the discipline of operational research and applied to the farm sector, focusing on the practical use of the tool for livestock farmers. In this review three areas of literature are explored, DES, agricultural supply chains and livestock management.

The aim of the literature review is to position this multi-disciplinary study in relation to existing literature. The literature review is structured as follows. Three areas of literature are explored, DES, agricultural supply chains and livestock management. The DES literature begins with a definition of the simulation methodology alongside its applications across sectors, particular attention is paid to the design of simulation studies, thereby influencing the simulation design within this study. The following section looks at the use of DES and other OR tools in the context of agri-supply chains, alongside exploring further sectoral issues relating to barriers towards technology adoption. In the final section, the limited number of papers which have utilised DES methodologies are reviewed, creating a sound methodological underpinning for this study.

3.1. Discrete Event Simulation

DES is a computer-based simulation which creates a virtual replication of a real-life process, modelling 'what if' scenarios all within a virtual setting (Hollocks, 2006; Jacob, 2013). 'DES is one in which the state of a model changes only at a discrete, but possibly random, set of simulated time points' (Schriber et al., 2014.28). DES operates around entities (people, animals, information etc.) flowing through a design of system stages created by a modeller, interacting with various resources under the created parameters, collecting an output of tailored statistical information which is of use to the analyst/decision maker (Opacic and Sowlati, 2017). DES can be used as an effective modelling technique allowing [farm] managers to create their own virtual experiments based upon real-world empirical data (Schriber et al., 2014). DES methodologies and software can be used as analytical tools to help support management decision-making and to gain inside knowledge of complex systems leading to greater process understanding, allowing change to be examined without physically changing real-world systems, and allowing strategic visions to be modelled aiding in effective strategy formulation, leading to increased positioning within the market place (Rossetti, 2016; Oliveira et al., 2016; Palma-Mendoza, 2017). However, a number of organisational resources are required for simulation to be adopted as an effective analytical tool, and consequently analysts need to be aware of the costs of adopting the simulation software i.e. running an cost/benefit analysis, ensuring skillsets exist within the organisation for the simulation to be used i.e. who is going to use it, and have an awareness of the organisational culture, for example having an understanding of the impact of new software and ways of doing things will impact upon how the organisation is currently functioning (Rossetti, 2016).

Although there are numerous simulation methodologies available: agent-based; monte carlo and System Dynamics (SD) modelling and so forth, DES is chosen as the simulation methodology for this study as there is extensive literature around its applied use (Bosilj Vukšić et al., 2017; Opacic and Sowlati, 2017; Tako and Robinson, 2012; Van Der Vorst et al., 2009). Moreover, the software packages, ARENA for example, has developed to include easy to use drag and drop software interfaces, making this an ideal simulation methodology to be used by farmers who typically, within the livestock sector, use minimal amounts of new technology and software (Siebers et al., 2010; Lima et al., 2018).

There are a number of studies which have incorporated DES methodologies, Kampa and Gołda (2018) utilised DES to create various models which analysed changes to a manufacturing system, simulating the replacement of a human workforce with automation and assessing it in relation to an array of performance measures. Whereas, Tako and Robinson (2012) do not apply the simulation methodology itself but provide insight through a literature review regarding the uses of DES and System Dynamics (SD) in the use of modelling micro and macro level problems. Kampa and Gołda (2018) illustrate the practical use of DES being utilised at the micro, process improvement level. The implications of this prior work suggest that the capabilities exist for simulation methodologies to be used within the livestock sector, modelling livestock systems at a micro (farm) and macro (wider-supply chain) level, however, as will be demonstrated further in the literature summary, there is an absence of studies exploring this.

Robinson (2004) suggests that simulations work on three levels; (1) implementation of findings into the real world, (2) implementing the model, as opposed to the findings and (3) implementation as learning. Implementation as learning is the focus of DES in this study, whereby the client (the farmer) can gain an understanding into future decision-making based upon the model results and learn from the entire simulation experience. The simulation process is utilised as a learning experience both for Joseph and for us, the researchers, whereby the methodology goes beyond that of simple simulation studies which are concerned solely with quantitative model results. We focus on the wider picture of not just the analysis of model results i.e. interpretation of the results for the farm manager, but also the intangible outputs of the farmer using DES, i.e. the experience of the farmer using new software.

Other influences include Monks et al. (2016), who emphasise the importance of stakeholder inclusion within the design of simulation methodologies, suggesting how parties can benefit from effective knowledge exchange. A multi-stage methodology builds upon the criticism of studies which, simply, end with the model findings, whereby data is collected to feed the model and deliver a statistical output. The inclusion of qualitative interviews, such as a post-DES interview and interviews with other livestock farmers, allows a reflection on the entire simulation experience and gain insight into information outside the model and learn through the 'double loop'.

3.2. Agricultural supply chains

The use of simulation, and other Operational Research (OR) techniques, have been substantially used within the context of Agricultural Supply Chains (ASC's) (Yared Lemma and Gatew, 2014). Borodin et al. (2016) highlight how OR techniques have been applied to the agricultural sector since the 1940's, noting that they have only been recently acknowledged in the academic literature. The mixture of OR techniques comprising DES, agent-based modelling, hybrid classifications and mathematical modelling has been used in agricultural contexts at both macro and micro levels, focused around; policy development, management advice, resource planning, mixed-crop-livestock systems, and adaption to climate control food security (Holzworth et al., 2015). The use of simulation has generated interest within arable practices, relating to crop production, resilience, and natural disasters (De Toro and Hansson, 2004; Moghaddam et al., 2018). Soto-Silva et al. (2016) analysed OR techniques in the context of fresh fruit supply chains, Utomo et al. (2018) consider agent-based modelling within agri-food supply chains, and Borodin et al. (2016) analysed how uncertainty is handled within agricultural supply chains through the use of OR techniques.

However, there is a wider issue within the agricultural supply chain management literature, concerning the barriers to new technology adoption. Micheels and Gow (2012) regard agricultural production as a hostile market, with farmers selling homogeneous products, coupled with the upcoming policy and market shifts (Grant, 2016; Swinbank, 2017). Those more entrepreneurial farmers may turn to new farm technology to create efficiency gains and sustain positioning during economic times. Bowen and Morris (2019) investigate the impact of digital connectivity challenges on rural agri-food businesses, finding that connectivity is a key barrier in the technology adoption process, one which impacts upon the entrepreneurial activities relating to the farm enterprise. Morris et al. (2017) sought to understand the general attitudes and barriers to farm technology adoption, finding a number of sectoral factors preventing adoption, including geographical and topographical makeup of area, education, age and skillset of the farm holder, alongside the applicability and suitability with the farming activities. Furthermore, Suess-Reyes and Fuetsch (2016, p.119) highlight how family farms need to adopt innovative strategies to sustain business competitiveness, defining innovation as 'a continuous process of searching, exploring and learning, resulting in new processes, products, marketing methods or types of organisation'. The adoption of new technologies can lead to innovative farm strategies, thus, this paper builds upon existing work by practically applying a new software/technology to a farm case study, building upon prior work on OR tools within an agricultural context, alongside the rural studies focusing on technology adoption within the farm sector.

Lima et al. (2018) explore the uptake of Electronic Identification Technology, considering the drivers and barriers of technology adoption amongst English and Welsh sheep farmers. The study concludes that technology adoption is influenced by three factors: practicality, usefulness and external pressures and negative feelings. Rose et al. (2018) use a mixed-methods approach to explore the impact of decision-support tools has on the farm. Whilst they do not explore and state specific decision support tools i.e. simulation modelling, forecasting, linear programming etc, they do provide insight into the barriers of decision support tools in farm practices, such as the tools are often built into software on computers located in the farm offices but that the majority of decisions farmers make, occur in the field away from the computers. Moreover, the authors highlight how many farmers do not use computerised decision support tools due to the complexity involved and have no need for computers, as farmers can access information from family, friends and advisors to support their decisions. This paper compliments this research by exploring the use of DES which can be used as a decision support tool.

3.3. Livestock management

There are a limited number of applied simulation studies in the context of livestock management. Snow et al. (2014) analyse six specific simulation software within the pastoral sector, stating that simulation software plays a detrimental role in understanding farming systems. Martin et al. (2011) develop a DES for grassland beef systems, using an application example of a case farm in France, simulating two scenarios; 1) the current farming system and 2) the farm with increased focus on exploiting plant and grassland diversity. The findings show that under the simulation of the second scenario, fodder yields could be doubled, thereby impacting upon financial performance. A limitation of this study is that the authors do not build upon the simulation experience through interviews with the farm manager nor engage with any other farmers.

Other simulation studies in livestock management include; Plà-Aragonès et al. (2008) who created a DES model within an intensive piglet production system; Cournut and Dedieu (2004) used DES to simulate the effects of a three lambings in two years sheep production system. Rutten et al. (2018) used DES to simulate a farm of 100 dairy cows and estimate the net present value of investing in sensor technology. The authors, through the simulation model, were able to provide clarity into the benefits sensor technology has to dairy farmers, providing clear economic indicators of how adopting such technology would benefit the farm manager. However, whilst DES is used in the study, it is not the focus of the study, it implicitly shows how it can be used to understand the financial implications of adopting new technology but the focus of the paper is not on the benefits of farmers utilising simulation software.

So, the existing work contributes to this study by providing examples of applied simulation studies, helping to inform our methodological approach when designing the simulation. However, a review of this literature has made us aware of the methodological issues within the existent DES studies within livestock management. No studies can be found which specifically explored the usefulness of DES for livestock managers. Furthermore, the methodological underpinning of simulation studies are, in our opinion, underdeveloped, Cournut and Dedieu (2004) study is an example of this, the level of simulation implementation (Robinson, 2004) does not extend as far to implementation as learning, and the authors are only concerned with the quantitative results of the simulation. Further data could have been collected, exploring outside the single case study, talking to other farmers and making the results more generalizable to other farms within the sector. A multi-methodological approach could have done this.

We recognise the criticisms of studies which have used DES in a livestock management context, arguing that a multi-methodological approach is needed to better understand, how DES can be used practically by livestock farmers in response to policy and market shifts. This paper explores the capabilities of the tool, the simulation model itself will only provide a statistical output, further stakeholder inclusion through the incorporation of qualitative means could build upon findings, generate new knowledge, and identify further areas of how DES can be utilised by farmers, thus helping to achieve the study's research questions.

4. Methodology

The methodological approach comprises three stages; simulation creation, post-simulation interview, and five interviews with other livestock farmers (See. Fig. 1). This approach is chosen because the creation of a DES livestock model at Colclough farm allows a practical exploration of the effectiveness of DES as a farm management tool (RQ1). A post-simulation interview allows Joseph to reflect on the process and model itself alongside building upon the simulation findings and validating the model. Interviews with other livestock farmers explores the generalisability of simulation tools being used exploring barriers and current attitudes towards new technology and software adoption in the sector (RQ2). In stage one, the two livestock processes, shearing and dipping, were modelled using the software ARENA selected because it is designed to create DES models and has a proven track record within simulation literature. Stage two consisted of a qualitative interview with Joseph in order to validate the model, and to gain further insight into the capabilities of the software. This provides further insight into the contextual challenges within the sector, looking at potential barriers to technology and software adoption, and providing an indication whether the tool could be utilised with other farmers. Joseph's

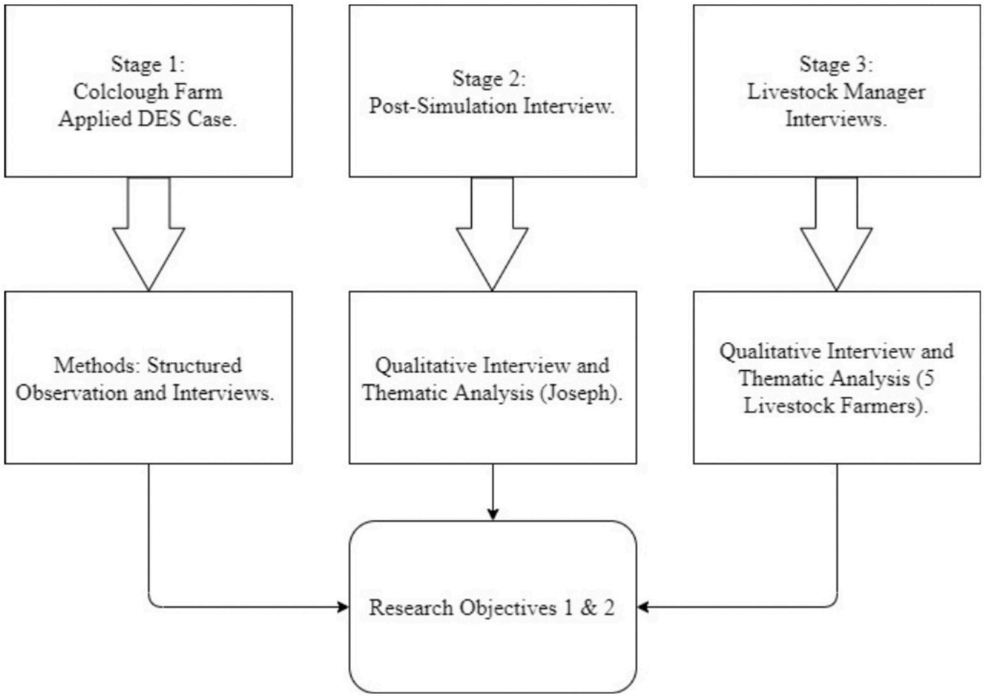

Fig. 1. Methodological design.

role in the model building was relatively passive in the sense that he was observed during the observations of the two processes, however, he acted as a key influencer when it came to transitioning the conceptual model to the simulation software, verifying input data by ensuring it is error free and providing data for activities missed during the observations. He acted as a source of model validation ensuring that the process activities represented that of real-life. Both the simulation and post-interview simulation is used to answer RQ1, understanding the use of DES. Stage three comprised five interviews with livestock managers in October 2019. The interviewees were asked numerous questions relating to the current political climate, relating to their knowledge and awareness to the post Brexit[6] policy change, their intended strategic choices of what they would do under expected scenarios, such as the removal of subsidy payments, alongside their attitudes in general to computer software and applications used in farming. These interviews were conducted to help answer the second RQ, looking at the sector wider, understanding general attitudes and awareness to policy change and attitudes to farm technology.

4.1. Stage one: simulation

To create the simulation model within the software ARENA, an observation of the two farm processes, shearing and dipping, occurred. Two visits were made to Colclough farm to observe the processes in summer, 2019. A structured observation was carried out, detailing the exact activities involved in the two processes, the resources required, and how long each activity took. The intention then is to capture accurate input data to run the model, ensuring the created simulation model is as close to the real-life process as possible. A process map was then created, providing a skeleton of how the simulation should look within the software. Joseph outlined the processes which he regarded as the most important: completion time, the right number of employees to help, and finally cost. These elements can be transferred into the model as Key Performance Indicators (KPI's) categorised as; cost, productivity, and speed. The results allowed the collection of specific data relating to the three KPI's (Table 1) which could be relayed easily to Joseph in terms he understood and allowed clear comparisons to be made between the simulated scenarios:

Scenario 1- Modelling the existing processes using recorded observational data.
Scenario 2- Modelling the increased production scenario (Joseph's 140 Sheep were tripled to 420 in this scenario).
Scenario 3- Making changes to the simulation to manage the increased production scenario efficiently.

The results of each scenario could then be analysed in relation to the KPI metrics and relayed presented to Joseph in the post-interview simulation to offer further understanding into the aspects he was interested in.

4.2. Stages two and three: qualitative methodology

The qualitative methodology consists of two stages of interviews. The first interview is with Joseph offering a post-simulation interview to reflect on the simulation experience itself, probing the results further, and to discuss the applicability of the tool being used further within the sector. The post interview simulation occurred in the farm office, whereby Joseph could view the simulation itself through a laptop, looking at the statistical output reports in relation to the KPI's, and have

Table 1
KPI's and performance metrics.

Key Performance Indicators (KPI's)	Performance Metrics
Speed	Total Process Time. Time to shear/dip each sheep.
Productivity	Value-added time. Non value-added time. Machine/ resource utilisation. Waiting times/queuing times.
Cost	Busy cost, idle cost, total cost, labour costs per hour.

6 Brexit- British, Exit. The term used to describe the UK's leaving process from the European Union, referring to the UK referendum in June 2016 where a majority of 51.9% voted to leave the pollical and economic union. The British people remain deeply divided.

the opportunity to discuss and clarify the results.

The second stage of qualitative interviews was with other livestock managers within the same region of West Yorkshire. This was to determine if there is a further opportunity for DES to be utilised by other livestock farmers and observe how the tool could be used. The focus of the interviews is to help answer the second research question, understanding the current political climate, exploring attitudes towards upcoming policy and further exploring farm technology adoption, building upon the rural studies literature.

The interviews occurred between March and July 2019, with one qualitative interview with Joseph to build upon the model findings, and separate interviews with other livestock farms to address RQ2. 5 qualitative interviews were conducted with livestock managers located within West Yorkshire. The interviews lasted approximately 35 min in duration. All the interviews took place at the farms themselves, either in the kitchen or offices.

4.3. Sample

The non-probability snowball sampling technique was used. Joseph suggested five livestock managers to interview (Saunders et al., 2012). This sampling method was used because it is a convenient way to identify similar farmers to Joseph, allowing us to overcome the limitations in data access. We did not want to identify those farmers who have proficient use in precision farming technologies, as this level of skillset is rare in the upland farm sector and would not represent fairly the average upland livestock farmer. We want to explore the extent of DES through an applied case of a traditional Yorkshire livestock farm. Joseph, and all the other farmers in this case study, are representative of many farmers in the UK's upland farming communities i.e. of an older age demographic, have limited technology use and have little formal education. This small, in-depth, sample allowed us to practically explore DES in one case then explore the wider attitudes of adoption amongst other farmer cases.

Five interviews appears ample as the core focus of this study is centred around the use of simulation through the case study of Colclough farm. This seemed adequate as livestock management is a niche area, so access to data may be restrictive and gaining access to rural farming networks can be overcome by using this technique. The selection criteria were all participants must be the primary decision-maker in the farm enterprise, operate a livestock system and be situated in the same region as one another (i.e. West Yorkshire, England). The sample is representative of the many traditional livestock enterprises within the region. Interviews with other farmers provide a flavour of whether this tool can be used more within the sector without distracting from the primary aim of the study, understanding tool potential of DES.

4.4. Thematic analysis

All interviews were analysed through thematic analysis. Upon completion of the interviews, all interviews were transcribed, then coded based upon pre-coding requirements:

- Results relating to literary debates.
- Results relating to RQ's.
- Information not presented within the literature.
- Similarities between result findings.

Coding was conducted manually, reading line by line each transcript. Coding was conducted manually, as opposed to through software, so we could familiarise ourselves further with the data. Anything relating to the precoding requirements were highlighted, receiving a numerical code and grouped accordingly. From these groups categories were created, showing key themes between interviewees relating to policy change, strategic choices, attitudes towards current technologies, and resources and constraints within the farming sector. These themes are presented and discussed in the findings section of this paper.

5. Results and discussion

5.1. Stage one: simulation findings

Scenario 1: Modelling the Existing Processes

The data collected through the observations were inputted in the simulation software, creating a computer simulated process consisting of the main activities of the observed processes, with real-life data. A snapshot can be seen below illustrating the three stages of the shearing process (See. Fig. 2).

Through the simulation modelling of both the shearing and dipping processes (See. Fig. 3) based upon the observed input data, a number of things became evident. First, that DES can be used to model livestock processes, both simulated processes captured the activities recorded within the observations, such as the wool collection taking part immediately after a sheep has been sheared, alongside the simulations matching a similar time to that of the real processes. Without conducting observations, collecting timings and process mapping, an accurate reflection of the real processes could not have been captured. Second, through the use of KPI's, useful information for Joseph was collected, such as the time taken to complete individual activities to the overall process completion time, the running costs, and aspects relating to the productivity KPI, such as resource utilisation. One finding was that even though the shearing process appears more complex than the dipping process, and believed to be so by Joseph, involving fewer activities, staff and stages, only 18% of the total resource costs were categorised as 'Busy Costs[7]', which can be contrasted to 62% of the costs being regarded as busy costs in the shearing process. The dipping process was far less efficient than the shearing process, primarily due to the under utilisation of the labourers throughout the process. The results provide some internal process information which otherwise may have gone unnoticed had the simulation not been run, suggesting that Joseph should consider ways to enhance efficiency within his farming activities. DES could be used to do this, as an operational improvement tool for farmers to explore characteristics of existing processes, recognising process inefficiencies and making efficiency gains, thus, supporting the strategic objectives of the farming enterprise (RQ1).

Scenario 2: Increased Production Scenario

This scenario ran exactly the same as the previous one, but with triple the number of sheep (420) within both processes, modelling Joseph's growth strategy of tripling sheep production in an aid to increase profitability in relation to the current economic conditions. The results impacted greatly upon the time to complete both processes (as expected), with sheep shearing now requiring three 12 hour working days with the total process cost being £1520 with the same number of resources, which can be contrasted with a process cost of £499 and one full day to complete in the first scenario. The process costs were calculated based upon the simulation run time and the costs per hour of the employees involved provided by Joseph.

Scenario 3: Managing Increased Production

This scenario simulated changes to the increased production

[7] Busy- Referring to when the simulation is running an entity (sheep, wool) is being processed during an activity (Sheared, wormed, inspected) by a resource (farm manager, labourer, contractor). This can be contrasted with 'Idle' which refers to the time in which a resource/activity is not busy processing an entity, for example the farm manager is waiting 10 min for the sheep to be sheared before checking medicating the sheep.

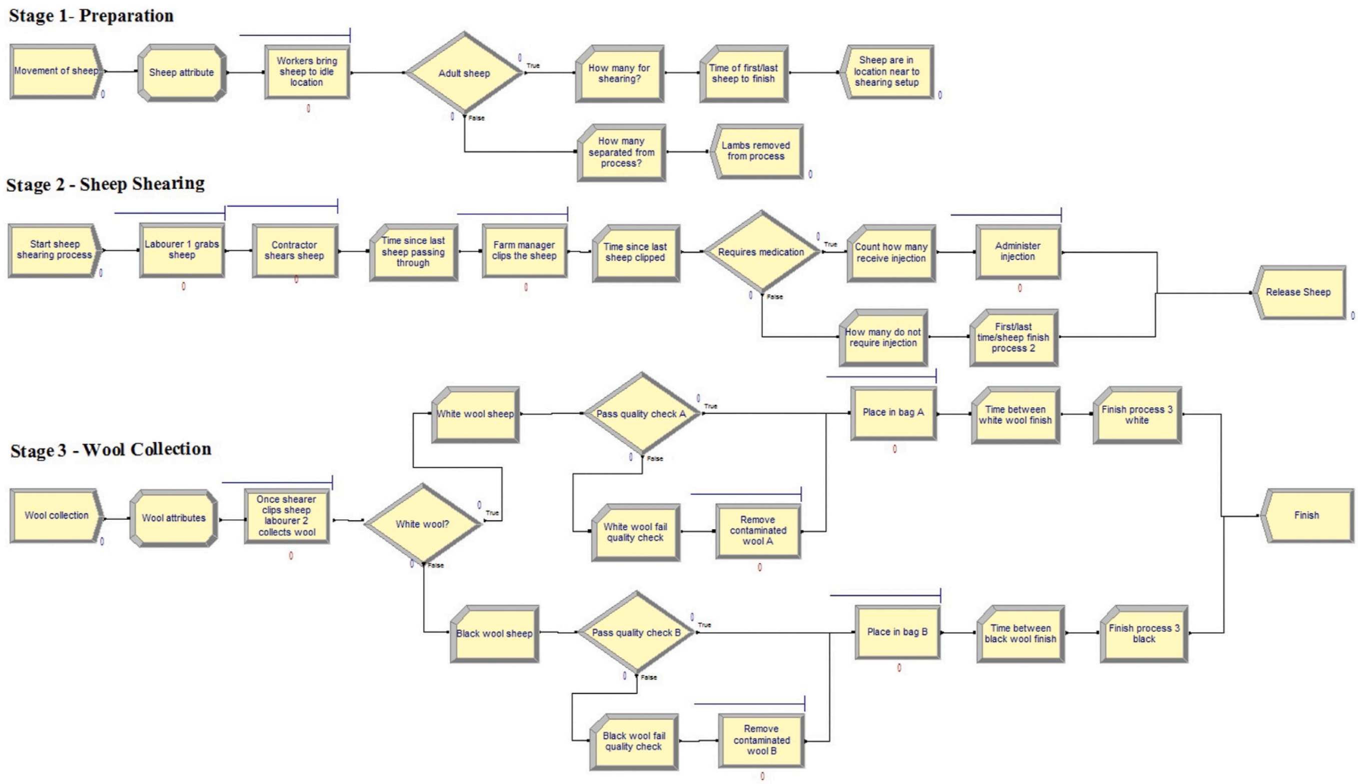

Fig. 2. Sheep shearing simulation.

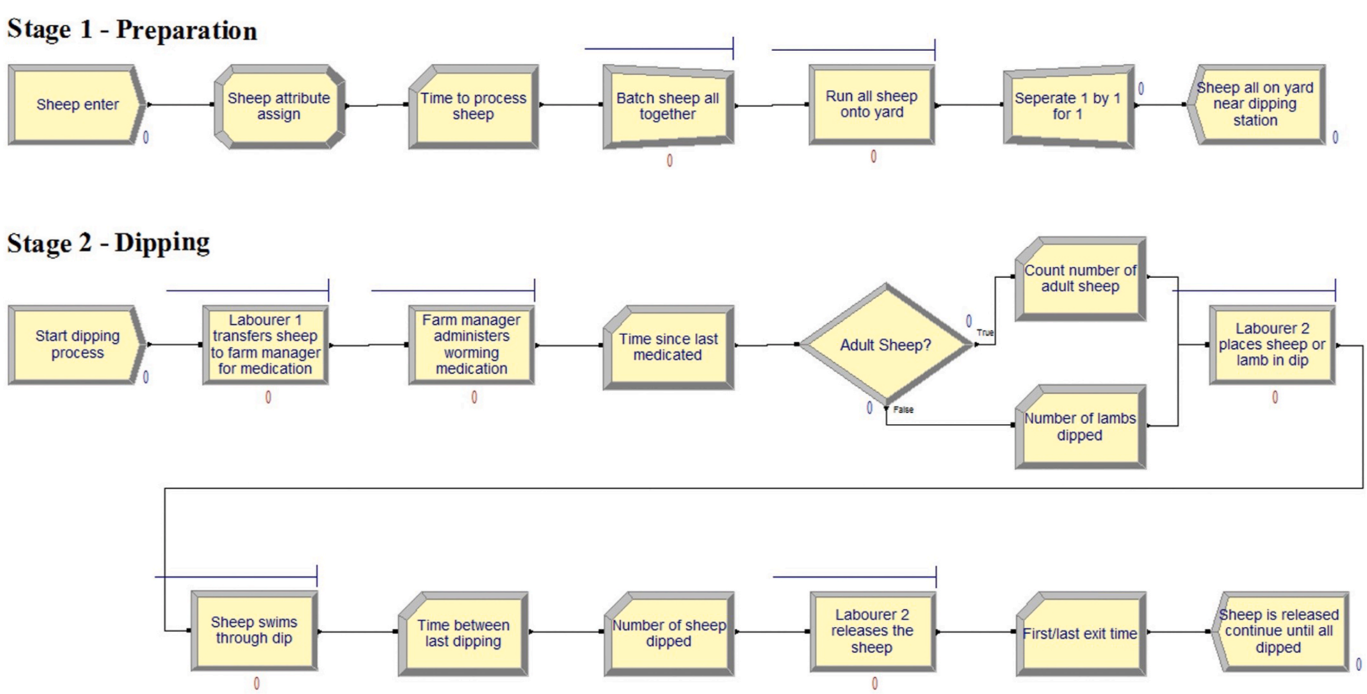

Fig. 3. Dipping model.

strategy, understanding how the process could be modified to decrease costs, process time, and increase productivity. The introduction of two additional shearers (on the same pay per hour as the original i.e. £12/hr) and another farm labourer (same pay, £10/hr) were added into the shearing process. The results of which led to the completion of the shearing process in around 800 min, improving completion speed and having a positive correlation with productivity, resulting in a total system cost of £1161, which can be contrasted with the system cost of £1520 in the second scenario. Overall, the application of DES at Colclough farm presents several findings. Firstly, that DES can be used to model livestock systems. Secondly, it has allowed a virtual exploration of an intended strategy proposed by the livestock farmer to be carried out. It has provided some in-depth statistical information which can be provided to the farm manager which without running the simulation models may have gone unnoticed. This has implications for process improvement, thus helping to make efficiency gains and improve profitability in the long run, supporting government policy plans of wanting farmers to become more efficient post-Brexit (Downing and Coe, 2018). Joseph was able to view, through the comparison of model KPI's, the effect on speed, productivity and cost. Furthermore, the farm manager, through relative ease, was able to view virtually how they could manage coping operationally under the increased production scenarios, trialling the system under different conditions, such as adding more labourers and viewing the effects it has upon cost, speed and productivity (Scenario 3). This implementation study has practically trialled DES at Colclough farm. The following section builds upon the simulation findings and offers a perspective from Joseph himself, offering a reflective process and his views on the tool of DES.

5.2. Stage two: post simulation interview

Following the creation of the simulation models based upon the carried-out observations, the models and results were shown to Joseph. The simulation itself was run, showing him the various models and providing an explanation of the model output reports. The 3 scenarios were presented to Joseph in regard to the shearing and dipping processes. Joseph was asked if the model shown was representative of the real system:

"*Yes, I think it did look well. It captured the main activities within the process … I like how it captured other things like how we medicate the animals to prevent diseases within our stock*." Voinov and Bousquet (2010) highlights the importance of stakeholder involvement in model building. Without stakeholder engagement through the observations, activities like medicating the animals could have been missed, thereby not capturing the true process characteristics of a livestock system (Jahangirian et al., 2010). This could have implications for model validity and making it of little use to Joseph to examine how an increased production scenario would impact upon existing farm operations.

Joseph was asked to recommend improvements to the model:

> "It didn't factor in every little detail … there are things which happen within farming every day that occur randomly … Sheep can run past you and knock other sheep into the dip before they have been wormed. And even some small lambs can fall into the dip … I am curious as to how advanced a computer can factor in this happening."

Within a livestock system, the entities are animate, causing greater variation and difficulty to control, supporting Jones et al. (2017) viewpoint that modelling dynamic agricultural systems is difficult due to factoring in human factors, natural resources, and the macro-and micro environment.

One of the benefits of simulation allows managers to gain a better understanding of their business processes (Robinson, 2004). Joseph was asked if he felt seeing the model allowed him to understand the farm's own processes better:

> "Yes, it did. I think I had a rough estimate of the timings it would take to do each thing within the process. However, I have never sat back and looked at it externally, seeing which parts take the longest and which takes the shortest."

This supports Rossetti's (2016) position, that simulation can be used as an effective management tool to understand system behaviours. Joseph also presented a further barrier towards software adoption. He suggested that no matter how beneficial this tool could be to a farmer, it may be met with resistance by the farming community and may never be adopted by many due to pre-existing attitudes held by traditional farmers.

> "even the most sophisticated computers couldn't convince old fashioned traditional farmers. They are just not interested in changing."

This is interesting as evidenced from the simulation application that it can be used to provide useful tailored information to the farm managers which could be utilised to aid in decision support and increase competitive positioning. Yet, ironically, farmers in the livestock sector appear to be reluctant to adopt new technology supporting Morris's et al. (2017) work who notes similar findings in upland Wales. Joseph was probed further on barriers to tool adoption within the sector, and was asked to comment on the cost of using the software, and in particular would high costs deter him.

> "The costs wouldn't bother me if there was a benefit. If there was potential to increase my profits and make farming easier than that would outweigh the costs. Having said that, if the costs were too high and not many farmers round here were also using it, I may be a little put off."

This is highlighted by Greasley (2017), who notes the importance of running a cost-benefits analysis before using simulation. The interview findings build upon this by providing insights into how farmers may be attracted to using this tool. A notion presented here, which was not found in the literature, is how the perceptions of technology by other farmers acts as a factor in tool adoption. Thus, for the tool to be adopted sector wide, it must have demonstrable advantages to the farming community.

Finally, Joseph was asked to think of any other potential uses of the software. Determining if it could be used on other livestock farms:

> "Well I suppose it could be used within almost any farming activities … Maybe looking into how the farm would be if you had access to more land. How this could make managing livestock easier throughout the summer months … especially if there was a drought like this year. Or maybe that could have been simulated. That would have been interesting to see. We could have used that now (laughs)."

The results here present, from a livestock management perspective, other areas of potential use for DES, suggesting other applications of where DES could be used, such as through simulating land acquisition strategies and viewing the implications it has on livestock welfare, or the simulation of how unpredictable changes of weather, such as droughts, would impact operations. The next section shows the results of the five interviews with other livestock farmers, exploring attitudes to policy change and technology adoption, exploring outside the case of Colclough farm to determine wider areas of DES use (see Table 2).

5.3. Stage three: further areas of use

5.3.1. Policy attitudes and awareness

All interviewees were asked questions relating to the upcoming post-Brexit policy change set out in the Agricultural Bill, in order to determine whether they possessed a proactive or reactive stance in regard to strategic planning (Downing and Coe, 2018).

Table 2
Categorisation of livestock managers.

Interviewee	Livestock Type	Size of Farm (Acres)	Age
Patrick	65 beef cows. 160 sheep.	270.	64
Howard	90 dairy cows. 300 Sheep	300.	60
James	35 beef cows.	80.	35
Steven	200 dairy cows. 400 sheep.	400.	69
Jim	50 beef cows. 300 sheep.	200.	71

All subjects showed an awareness of the proposed change. All subjects, except Patrick, regarded themselves as having a 'wait and see' approach.

Steven states:

"it is too early for us to start for these 'What ifs'. With this 'No Deal[8]', 'Hard/Soft Brexit[9]', it is too early to respond on speculation. However, when we leave I do believe it will reshape the industry."

Patrick states:

"I would consider myself actively intrigued by it … There is major change happening within the sector, you have to be prepared."

The viewpoints reflect Grant's (2016) findings who argues that leaving the EU will add industry wide pressures. While the majority are not planning strategically due to governmental uncertainty, all farmers are aware, and identify potential implications Brexit could bring. In relation to pillar 1 of the CAP, all interviewees categorised themselves as reliant on farm subsidy payments.

Patrick States:

"We are reliant upon these payments, some years the commodity prices are stable, and we can turn over a nicer profit. Other years they are dismal, and we are losing money. We need these payments just to stay afloat".

Similarly, James states:

"Yes, it forms a large part of my income. I am only a small farm holder … But the Single Farm Payments [Direct Payment Subsidy] allows me to continue farming, it is a passion of mine. It is not the most profitable, but it is a job I love."

These responses support the work of Grant (2016) and Swinbank (2017) who stress the reliance on these subsidy payments by hill farmers, suggesting, first-hand, through the views of the farmers the financial uncertainty which could be caused if removed.

5.3.2. Strategic choices

All the subjects were asked to provide an example of potential strategies they could use if direct subsidies were completely removed. Patrick states:

"we would need to take a long hard look at what we've got. Our finances, our stock, our workforce, our potential to acquire new equipment … we have the capacity to expand our livestock numbers, however we have been reluctant to do that because we have been making ample profit so far."

James and Patrick also mention how, depending upon the financial rewards, joining environmental schemes such as the Countryside Stewardship may be a viable strategy. Howard supported this viewpoint, looking at entering different government funded schemes, but also introduced the aspect of diversification, suggesting he could look into renting some of his 300-acre land to other businesses to sustain competitiveness.

Steven advocates increasing their milking production, but also some additional insight into the challenges hill farmers might be faced with as a result of Brexit, and how the supermarkets may be used to 'soften the blow'. Steven suggests that a reform of CAP or change to domestic policy could bring benefits to dairy livestock farmers, remaining hopeful that supermarkets may pay higher prices for products if the subsidies are removed.

"I would continue milking. I make enough living from milking, and farming is a way of life. I may increase milk production, but hopefully the supermarkets will negotiate a better deal with us, so we can make up the loss from the payments on our milk. That being said, It would be difficult for other hill farmers which don't milk"

However, Steven also mentions the challenges within dairy livestock farming, one being supplier control, supporting Micheels and Gow (2012) viewpoint of farmers operating within a harsh and hostile environment, with above average performance being difficult to achieve due to homogenous products.

Jim offers an alternative response, downsizing the farm, keeping only sheep, suggesting that they can increase profitability this way. Coinciding with the rationale of Colclough farm, who also proposed keeping only sheep as a viable growth strategy.

5.3.3. Application in practice

The broader concept of computer software was then explored through the interviews to understand the general perceptions towards the implementation of current technologies and software, determining the viability of DES being utilised across the sector. The findings coincide with the findings within Morris et al. (2017) study who finds similar barriers to technology adoption within the farm sector.

All 5 of the responses were similar. A comparison of Patrick and James's responses illustrates this.

Patrick states: "*Being 64 I have no interest into modern technology, but I am sure that new entrants into farming will embrace new technology … I would be a bit sceptical with computers though. They are not always as accurate as you think and tend to stop working when you need them*".

James States: "*It is limited by the technology … Can the average hill farmer use it? I think it would be more applicable to those farmers whom have grown up with technology … I highly doubt, that even with the best software, it could factor in the out of the ordinary. Such as natural disasters, droughts, flooding, livestock diseases etc.*

All interviewees highlighted that accuracy was a key issue with farmers adopting computer software. They questioned the ability of the software to factor in randomness which occurs daily within farming systems, a factor similarly supported by Colclough farm.

When discussing the potentiality for simulation to be used in practice at the farm level, James suggests farmers' age can be a barrier towards the adoption of farming software. He suggests it may be more beneficial to younger generation farmers, supporting Joseph's views. However, James revealed if it was used more by other farmers successfully they would be more inclined to try it for themselves.

James states:

"If more within the area did, and heard success stories, then yes, I would be more inclined to looking into it before making a big decision."

However, none of the managers stated they would feel comfortable making a business decision purely on the results of software, only using it in compliance with other factors.

Because age was picked up as a barrier to adoption, Howard was probed further to understand if he would use the software through some type of agent or a consultant:

"No, I do not trust consultants. Only had negative experiences with them. I would only use it myself, but as I said I am not interested in modern farming technology."

Overall, none of the sample interviewed seemed to embrace current innovations, which could pose as a threat towards simulation being adopted within farming practices. Moreover, it could provide justification as to why, as shown within the literature review, there is a lack of

[8] No Deal: Refers to Britain leaving the EU without securing a trade deal and operating under World Trade Organisation rules.

[9] Hard/Soft Brexit: Referring to how Britain leaves the EU, hard being crashing out of the EU without securing a trade deal for example, with soft referring to Britain securing a trade deal which resembles the same conditions as operating within the EU.

contemporary research within this field regarding simulation at the farm level. Only 3% of farmers in the UK are under the age of 35, with an average farm holder age of 59 (Conway, 2016).

However, we argue that this is not a complete barrier to adoption sector wide. Only a small sample were interviewed, so a generalisation nationwide is not reflective of the results. Furthermore, all farm types can be categorised as the 'traditionalist' type, no farms could be considered 'large', for example keeping 5000 breeding ewes, automated milking facilities inter alia. If a different sample within the livestock sector were interviewed, perhaps different results could have been presented, for example, factoring in age as a unit of analysis, discovering what young farmers thought of the tool. Finally, the farm manager is not 'the be all and end all of decision making', families play a key role in farming communities. The idea of the tool being introduced via a consultant was poorly received within this sample group, however, perhaps a younger entrant into farming, for example, the farmer's son or daughter, may learn more about tool capabilities and have an influence in tool adoption and use.

The simulation model was implemented within Colclough farm, a traditionalist livestock farm representative of many farms within the sector, and proposed benefits which could aid in making efficiency gains to increase market positioning. This promotes generalisability for DES to be utilised further within the sector. However, it is clear that before it is adopted within farming practices industry wide, more research needs to be undertaken in regard to the barriers to technology adoption.

5.3.4. Resources and constraints

Resource access and utilisation play a key role to sustain competitive positioning in farming, yet all resources face an array of constraints. Patrick, Howard, and Steven regards access to land as their greatest resource. Patrick states:

> "the land and grass crops grown. Without this natural resource, how could the animals be fed? How could countryside stewardships exist if farmers didn't look after the countryside?"

Land is a physical, tangible asset, whereby in theory can be acquired by anyone with financial capital. However, in farming, land is regarded as a scarce resource, which is difficult to acquire, taking years for plots of land to become available and serves multi-purposes to leverage the strategic positioning of the farming enterprise.Whereas, James regards management style as his greatest resource:

> "My own personal skills are my greatest resource. It comes from my years of experience and passion for farming … without the correct mindset, ability to learn, the business is constrained. The farmer makes the decisions, it could be based upon the land, or the livestock, or the market, but it is the farmer that makes the decisions".

Jim also notes that finance is an intangible but significant resource. Suggesting that the greater access in which the business has to money, the more resources can be acquired, leveraging their strategic positioning.

These resources are both intangible in nature. If DES can be proven as a valuable and useful tool for livestock managers to increase positioning, then it may appeal more to livestock farmers like James and Jim (Kamasak, 2017).

All the farm managers were then asked about the greatest constraints overseeing the sector. Government, bureaucracy, and increased regulation were seen as the major constraints within the industry.

James states:

> "the government regulates the industry. In principle we do as they say. We have to adapt to their needs, and sometimes that doesn't always benefit us."

Howard's response:

> "The biggest problem we have today in farming is the lack of reward, and the politics with their regulation."

The findings show that the position of the government is negatively perceived by the sample group, being regarded as the greatest constraint within livestock farming. With access to land, finances, and management style being the greatest resources to a livestock manager. Whilst the sample group may not embrace the adoption of current technologies, there are conditions within the agricultural sector which exist in other industries which have adopted and rolled out technology sector wide. There are a great number of challenges within the sector which the utilisation of DES could aid in solving. The interview findings show areas in which DES could be used further within livestock management. However, there are a great number of industrial barriers which need to be overcome before the tool can be integrated within livestock farming practices.

6. Answering the research questions

> RQ1: To what extent can a simulated livestock model using DES be used as an effective farm management tool?

Overall, it has been practically shown that DES can be used within a livestock management setting. Joseph at Colclough farm is able to explore, virtually, his intended strategic choices in relation to the sector challenges, demonstrating an innovative application of DES. The tool led to further understanding of Joseph's sheep handling processes, illustrating process inefficiencies, allowing him to take an external view at his process set ups. Supporting Robinson's (2005) viewpoint that simulations allow organisations to gain a better understanding of their internal processes, showing that DES can be utilised as a process improvement tool to increase farm economic performance.

DES has practically allowed the increased production scenario to be explored, showing Joseph how current processes could manage on an increased livestock system via various scenario analyses. The change was examined in relation to cost, productivity, and speed KPI's, presenting to the firm that an increased number of resources could help manage this change, decreasing overall speed, cost, and boost productivity in comparison to current farm resources. This supports Kampa and Gołda (2018) view that simulations allow business strategies to be explored virtually before implementation, helping to understand the extent in which it has on increasing firm competitiveness. The creation of the models promotes practical solutions to real-world farming challenges, helping farm managers to enhance strategic and operational planning, and visually observe alternative scenarios in relation to tailored performance metrics. The results of the simulation had a practical benefit for Joseph which he may use to enhance his process set up and inform his future decisions. However, Joseph expressed concerns with the adoption of the software sector-wide, suggesting the tool has potential to be used within the sector but may be met with resistance by traditional farmers. It is clear that more research needs to investigate the barriers into software and technology adoption within farming enterprises.

> RQ2: What are the attitudes of livestock farmers regarding policy change and new technology and software adoption?

Overall, all the sample group were aware of the proposed policy change, yet only 1 of the 5 were planning strategically for it. The UK government managing the policy change were perceived in a negative light, being regarded as the greatest constraint to livestock farmers, alongside increasing regulation of farming activities and not providing enough financial reward. Similarly, all the farmers regarded themselves as reliant upon farming subsidies, with all of them presenting an alternative strategy should these payments be negatively affected following the creation of a Domestic Agricultural Policy (Swinbank, 2017).

The industrial scenario promotes an environment whereby DES could be utilised further. Borodin et al. (2016) previously explores the vast OR techniques involved in assessing uncertainty in agri-supply chains. This study adds to this body of knowledge, whereby, DES can specifically be used by farm managers to increase positioning and as a tool reduce uncertainty in making changes to the farm business. The discussion of simulation, and more generally farm computer software were explored presenting what appears to be a barrier to adoption of the tool within the livestock sector. The findings from the sample interviewed showed technology was generally perceived in a negative light. However, it was presented through the sample group that young or new entrants into farming could be a target group for tool adoption. The findings here build upon the rural studies work which has explored technology and software implementation in the farm sector (Morris et al., 2017; Bowen and Morris, 2019).

7. Research contributions

The overall findings of this paper contribute mainly in a practical and methodological manner. The practical benefits of DES are explored through the applied case of Colclough livestock farm. The study demonstrates that DES can be utilised in the context of a 'traditional' livestock farm, Joseph saw value in the tool utilisation, enabling him to observe a proposed growth strategy in relation to the changing economic landscape, something which could not have been done without simulation. The incorporation of DES extends beyond that of spreadsheet modelling by giving Joseph a visual method to view the consequences of implementing a strategic change and observing the impact it may have to his farm business operations. This promotes a certain generalisability of results, if a traditionalist technology averse livestock farmer can see value in DES utilisation, other farmers, more technologically inclined ones, may be willing to adopt the tool to help solve the practical real-world problems which farmers are facing. Furthermore, this paper has placed a strong emphasis upon methodological novelty, utilising a multi-method approach to undertake a simulation as a learning experience, extending beyond that of existing simulation in livestock studies by focusing on the benefits DES as a software has to offer farmers, making use of simulation and qualitative data collection and analysis techniques to practically explore DES within livestock management.

There are, however, clear sectoral and national challenges preventing the adoption of simulation tools by farmers. The recent round of the Rural Development Programme for England's Countryside Productivity Scheme issued financial incentives for farmers to invest in new farm equipment (i.e. automatic cattle crush, cattle handling systems, electronic weigh systems etc.). Further incentives, alongside training, could be provided to farmers to invest in farm management tools (i.e. simulation software). Incentives could be provided for training and licences in simulation software, and farmers could use the software itself to, as was done in this paper, simulate the effect of a change on their livestock system i.e. simulating the impact on processes of a sheep conveyer system on a farm with 2000 ewes. The use of this software could better support farm management decision-making, analysing potential productivity and cost-savings before investment in new technologies. More work could be done across the different agricultural bodies (i.e. AHDB knowledge exchange programmes) to work with farmers to make efficiencies gains and re-enforce strategies, alongside advancing research into OR tools in the farm sector.

Moreover, further emphasis on a 'Green Brexit' and upland farmers paid for environmental goods under the new ELMS, means many farmers will be rethinking their strategies in alignment with environmental needs. Further funds could be reallocated to this to support farmers by filling the gap in the digital divide (Bowen and Morris, 2019). For farmers to assess the feasibility of their farming strategies in accordance with DEFRA and Natural England's requirements, simulation software could be a valuable tool. However, it is the cost, practicality, accessibility and benefit of the tool which, ultimately, will impact its adoption. Farmers must be able to access both funding and training to successfully use simulation tools in their farming systems.

8. Limitations

One limitation of this study could be both the sample type and sample size. The sample size is small, with an in-depth exploration of DES shown through Colclough farm, and five interviews with other livestock farmers within West Yorkshire. An increased sample size could have been used, however, we argue that the depth of exploration of the tool would have been negatively impacted, rather that the tool was efficiently explored through one case rather than scattered across many. In addition, the focal aim of the study is to explore the use of DES, so by having a small sample size of livestock farmers, it does not draw away from the main aim of the study. The small sample potentially illustrates the tip of the ice berg for DES use within the sector, identifying multiple directions for future areas of research.

9. Future research

Through the findings and analysis, it is shown that simulations can be used practically within livestock management. However, attitudes towards computer software within the farming community were generally perceived negatively. With 'traditional farmers', not embracing technology, posing as a barrier to adoption. With the findings presenting that the 'younger generation' of farmers are more welcoming of technology and software. However, this does not replace the fact that Joseph, who can be classified as a 'traditional farmer' saw value in the utilisation of DES.

Future research can focus on many factors for example how to overcome the barriers of technology adoption within sectors which have a typically higher age demographic, such as livestock management. Moreover, a similar study to this could be conducted again, restricting the sample size to the 'younger generation' of livestock farmers. Looking at the 3% of farm managers under the age of 35 and drawing comparisons between their views of the tool and other farming software packages in comparison to the traditional farmers (Conway, 2016).

One further issue to explore is the extent to which technology adoption is a shared experience and is dependent on a collective view of its benefits. A number of the respondents infer that they would look more favourably on change if it was embraced by other farmers. This raises the question as to whether there is a somewhat imitation effect occurring in the farm sector? Age was noted as a barrier to adoption in the findings, however, it was noted that if other farmers in the local community successfully used the software or technology, and it added value to the farm enterprise, then more farmers would be inclined to adopt. Joseph is a 'traditional' farmer, of a higher age demographic and, after explanation, was capable of interpreting the simulation results. Future research should focus attention on how to get new software and technology into the farm enterprise, perhaps through the farm holder's family. Farm managers often outsource activities (i.e. farm subsidy applications, farm accounting) to members of their family, so there is further potential to explore farm technology adoption through the lens of the farm family.

As the industry changes as younger, educated, farmers enter the sector, there is potential for the tool to be used further. Looking at not just how to use simulation in regard to policy change, but other industrial factors. The potential for further tool utilisation is great, with the ever-growing sector challenges impacting upon farmers, meaning that farmers are having to find new innovative methods of managing their farming operations. With more young entrants entering the sector each year, and the ever-growing complications impacting the sector as a result of Brexit, Simulation could be the tool livestock managers have been searching for. Moving the 'traditional farmer' to the 'modern day' farmer, working smarter, not harder, helping farmers achieve lengthy prosperity through innovation and technology adoption. The utilisation of these emerging innovative farming practices could help promote integration of farmer and government needs, helping farmers sustain a profitable enterprise whilst advancing the industry forward by meeting, and exceeding, society's demands.

Author statement

Gittins Undertakes primary research in the field and compiles initial draft. McElwee edits work. Tipi provides additional reading and advice on logistical processes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jrurstud.2020.06.039.

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