The design and validation of a process data analytics methodology for improving meat and livestock value chains

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Abstract. This research aims to develop a process data analytics methodology which will improve meat and livestock value chains resulting in greater profitability for Australian farmers. With little integration across Australian meat and livestock value chains, the cost of meat production is significantly higher than many competitor countries which impacts export growth. Through a combination of best practice determination, modelling, as well as data and process mining, decision support will be provided for improvement. Real world industrial challenges are addressed in this research which also aims to contribute to the academic field of process science drawing on Internet of Things sensing, process mining methodologies, best practice reference models, simulation and digital twining to improve value chains.

Keywords: best practice reference model, compliance of the meat and livestock value chain, conformance checking, data mining, digital twin, food supply chain management, meat and livestock, process data analysis, process mining, optimisation of the meat and livestock value chain

1 Introduction

The meat and livestock industry which comprises the beef, sheep meat and goat meat sectors has a turnover of $62.3 billion including $14 billion in export revenue, supplying over 100 global markets while contributing 405 000 Australian jobs through direct and indirect employment. The meat and livestock industry is the second largest contributor to Gross Domestic Product in the agriculture sector at 37.3% [1]. A recent report commissioned by the Australian Meat Processor Corporation, identified six critical strategic risks to the meat and livestock processing industry: competition, changing consumption patterns, climate change, social license to operate, the regulatory environment and lack of value chain integration [2]. Integration in the context of the meat and livestock value chain is the connection between cattle from breeding farms and backgrounding farms to feedlots and processing plants.

The purpose of this research is to design and validate a process data analytical methodology which will improve the meat and livestock value chain. It is hypothesized that a methodology which captures and shares both performance data as well as process data, conformance checked against best practice provided by a reference model, will improve both the integrated and non-integrated value chains. To test this methodology,

the meat and livestock value chain is to be modelled, in a hierarchical manner, to a data and system integration level and process data analytics solutions designed to improve the value chain performance, based on inputs and insights from farmers and managers of these value chains.

The methodology will initially be tested on simulated data. Once the methodology has been validated it will be tested with data from physical meat and livestock value chains. Where complete data sets are not available, simulated data, based on historical and predictive information will be used to close the gaps. Such an approach allows benefits to be realized without having to wait for sensors to be installed or individual animals to move through the entire value chain before results are obtained. It also helps justify the business case for deploying additional sensors.

2 Research Questions

RQ1a. What performance and process data needs to be shared across the meat and livestock value chain to improve quality and price?
RQ1b. What key data driven decisions are required to improve the meat quality?
RQ2a. What process data analytical methodologies are required to provide decision support that will improve the meat and livestock value chain?
RQ2b. How can a digital twin of the meat and livestock value chain, which combines process modelling, reference process and decision modelling as well as process orchestration effectively simulate the output of the physical value chain?

3 Research Methodology and Techniques

With this research aimed at solving current and anticipated problems in managing and controlling the meat and livestock value chain, Action Design Research (ADR) was selected. This research methodology was found to be well positioned at the nexus of addressing industry challenges, while fulfilling the academic contribution requirements of Information Systems Research [3]. A key differentiator between ADR and other Design Science Research methodologies is the integration of the evaluation stage. The build of the artefact ensemble is constantly evaluated by both the practitioners and researchers in a highly agile and dynamic process. Field problems such as the challenge of managing meat and livestock value chains are considered knowledge creation opportunities in ADR. This research methodology also ensures that the ensemble artefacts are informed by theories. Applying ADR, the following detailed research methodology was established.

An a priori process analytic methodology was developed, based on process and data models as well as the defined use cases. This methodology presented below will be validated with participants and improved as per the ADR cycles.

Step 1: The meat and livestock value chain is mapped to a data and system integration level.
Step 2: The value chain is analyzed to determine:

- Gaps in data availability
- Availability of best practice process and conformance to these standards
- Key data driven decisions on when to move animals to ensure best meat quality and price per animal

Step 3: A reference process model is developed based on best practices published by Meat and Livestock Australia [6].
Step 4: A digital twin simulation of the meat and livestock value chain is developed to generate data, based on prediction from historical information when actual data is not available. This will include the development of the following artefacts:

- A digital cow (as well as bull, heifer and steer) which will generate attributes such as rate of weight again, based on its environment, for example, available edible biomass.
- A digital paddock, which will generate biomass based on factors such as soil type and weather including rainfall.

Step 5: Both the actual meat and livestock value chain as well as the digital twin will be configured to run on a Business Process Management System (BPMS). In the case of the digital twin, the BPMS will be configured to extract data from the digital animals and digital paddocks and manage the flow of animals and data through the value chain. For the actual value chain, available data will be extracted from the various data bases and presented for decision modelling.
Step 6: The BPMS will manage process mining actions on the actual event data for the purposes of conformance checking against the reference model.
Step 7: When key actual data is not available it will be substituted, when necessary by data from the digital twin. The gaps in actual data will be noted so that recommendations can be made to collect the data, for example by installing additional sensors.
Step 8: A dashboard will be developed to provide key insights, data trends and decision support to the users.

A rigorous review of the outputs of each step will be done with stakeholders to ensure the objectives are being met and the research questions adequately addressed. Should the objectives of a stage not be met, alternative methodologies will be investigated.

4 Proposed contribution to the field of Process Science

This research will draw upon several Process Science methodologies to solve a real-world problem: Data Mining, Process Mining, Process Orchestration, Supply Chain Management through event data, Simulation and Digital Twining and Data Driven Decision Making. In integrating these methodologies new design principles will be developed, for example, using simulation from a digital twin of the physical supply chain

to generate missing data. The research will also introduce new design principles to the food supply chain discipline, leveraging supply chain event data in process data analytics.

The concept of creating 'digital artefacts' that will generate current data, based on historical data and prediction, is innovative allowing for the overall value chain to be optimized while enabling the development of business cases for additional IoT sensing. This integrated approach allows for a rapid adoption of process analytics into food supply chain management as illustrated in Figure 1.

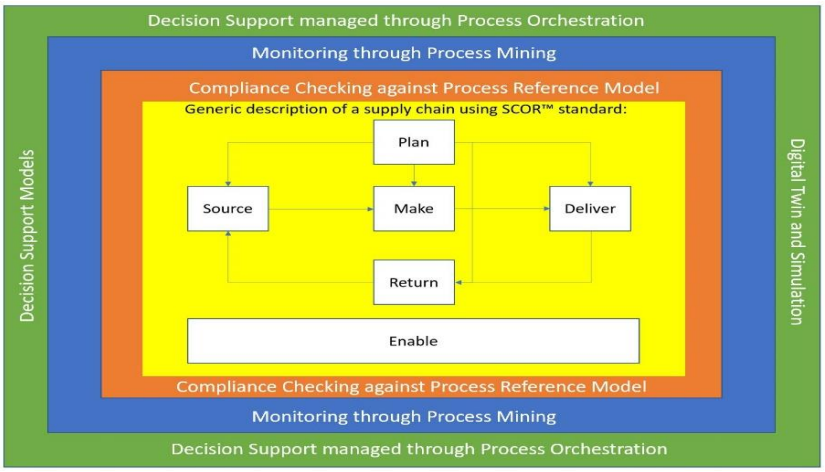

Fig. 1. Contribution to Food Supply Chain Process Science

5 Current Challenges to the Research

The biggest challenge to this research is availability of individual animal data due to the lifecycle of an animal in the meat and livestock value chain, which can range from two to ten years, making it difficult to track individual animals through the complete process. There is also a lack of trust between processors and farmers resulting in a reluctance for meat quality data to be shared back through the value chain. This challenge was anticipated and hence the development of simulation and digital twining methodologies to predict and substitute data when such data is currently not available. Key to the success of this research will be the focus on obtaining as much actual meat and value chain data as possible, this will significantly increase the adoption of process analytics methodologies in the industry and help drive productivity improvements. Simulation and digital twining is to be used to substitute key data when not available along the value chain, it's core purpose will however be to show the value of having physical data available and help drive the business case for increased deployment of sensors and the capture and sharing of data.

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