DISCRETE EVENT SIMULATION OF A PIGMEAT PACKING PLANT

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ABSTRACT
This paper is presenting the development of a discrete event simulation model of a pig meat packing plant located in Navarre (Spain) as result of a research collaboration between the pig industry and the University of Lleida. The packing plant processes between 900 to 800 pigs a day and it is located apart of the slaughterhouse. The simulation model was developed to represent all the tasks performed in the plant. The development was incremental as the whole model is made of different sub-models focused in different products as for example ham, ribbon or sirloin. The collaborative work with the employees of the company was essential for the success in the model outcome. The main utility of the proposed model was to compare different processing alternatives for primary cuts and a better production planning of the tasks for a day.

Keywords: meat plant operation, production planning, discrete event simulation

1. INTRODUCTION

Simulation is recognized as the second most widely used technique in the field of operations management, the most popular being 'Modelling'. Generally speaking, a simulation-based approach does not provide exact or optimal solutions to problems but it allows users analyzing the behavior of complex systems, performing what-if analysis and choosing correctly among different possible scenarios/solutions (Bruzzone and Longo (2013). Its use as a tool to help in the design and operation of manufacturing systems has been transformed by the invention and evolution of the computer, which has supported the uptake of practical simulation tools and techniques. (Jahangirian et al. 2010). These complex, dynamic and stochastic systems involve large capital investments, making cheaper and easier to experiment and compare alternative management strategies with simulation models, instead of experimenting with the real system (Negahban and Smith 2014).

Different surveys of the current state of the art clearly reveals discrete event simulation has been applied to various sectors, such as manufacturing, services, defense, healthcare, and public services (Jahangirian et al. 2010, Negahban and Smith 2014). In particular, different simulation models for manufacturing systems operation have been published (Negahban and Smith 2014) and few of them are related to the food industry as referred Bruzzone and Longo (2013). That is also the case for the pig industry where most specialized software programs focus on herd management tools developed and introduced for on-farm use and less for slaughtering and meat processing plants (Plà 2010). This means that there are management areas where decision tools are less developed in the pig sector. A surprising fact, taking into account that decisions at different levels are important for the pig industry viability and for meat packing plants in particular. Then, there is a growing need to address the complexities of the whole pig enterprise and the difficulties of dealing with different layers of decision-making within a system (Rodriguez et al. 2014). Maybe the simplicity required in getting the big decisions right and making correctly the major tactical adjustments for the risk averse primary sector (Pannell et al. 2000) are the reasons.

Consequently, scarce examples exist about meat packing processing plant models and even less for pigs. The more similar approach to the problem presented here is that of Bixby et al. (2006) who presented a set of LP models developed to schedule dynamically beef packing plants operations for a beef company. Proposed models were deterministic and developed ad hoc given the characteristics of this specific beef company with five different plants to coordinate.

In this paper, we are concerned with the modelling of the tasks performed in a pig meat packing plant processing pig carcasses and selling different products, i.e. meat cuts and by-products in fresh or frozen, to wholesalers and local butcheries. The analysis is focused first in valuing the cost-benefit of the different alternatives for a products' family as the plant receives many local offers of different products they do not produce usually and they meet problems to assess a convenient sale price. Hence, the goal of the model is to facilitate the analysis of different production alternatives for a working day either to compare specifically a products' family or globally to assess the daily production plan (a sole meat plant simulation model with all ordered products integrated).

2. MATERIAL AND METHODS

The company “Carnicas Iruña Velasco SA” settled in Orcoyen (Navarre, Spain) provided the data, collaboration and support for this project. The framework was a collaborative project understood as a joint collaboration between University of Lleida and “Carnicas Iruña Velasco SA” (“Carnicas Iruña” for short) to improve the knowledge in this kind of processes. The meat packing plant is embedded in a pig supply chain (PSC) where different long term agreements with pig producers and abattoirs are settled to assure the procurement of carcasses (body of the animal eviscerated) to process.

Broadly speaking, the PSC includes organizations in charge of procurement, production, slaughtering, processing, distribution and marketing of pork, derived and by-products to the final consumers. Different PSC agents under one or more vertically integrated companies work together in a coordinated way for producing and fattening pigs transferred to abattoirs for eventual slaughtering. Resulting carcasses will then be processed in a meat packing plant to satisfy customer’s demand for different products either fresh, cured or manufactured. Retailers, supermarkets and butcheries work in the final stage of the chain, supplying pork products to customers (Rodriguez et al. 2014).

The processing capacity of the “Carnicas Iruña” plant range between 800 to 900 carcasses as maximum per day. Three trucks a day coming from two different abattoirs, sending each one approximately a half of the stock, serve the plant. The day before, abattoirs communicate the information of slaughtered animals to the plant and so, the meat packing plant can plan the production planning for the following day according to pending or already received orders. The plant has only one line operating at a speed of 150 or 120 carcasses per hour. Usually, operations in the plant are deployed around the cutting tree of the pig carcass and the means to perform the disaggregation in commercial cuts. In a first stage, primary cuts are produced leading to a second stage where each primary cut is processed and first commercial cuts obtained. These cuttings are done along a processing line with two sides, one devoted for each semi-carcass. Depending on the product, off-line cuts may be required involving additional personnel, variable workload and time. The objective for the plant is to extract the maximum value of the carcass performing a disaggregation plan leading to the right (best valuable) products.

The simulation model was implemented in ExtendSim (see Figure 1), an interactive simulation tool (Krahl 2013) with 2D animation capabilities. The ExtendSim simulation environment provides the tools for all level of modellers to create accurate, credible, and usable models in an efficient way. The selection of a proper simulation software can make a significant difference in how well simulation analyses support managerial decision making. Thus, ExtendSim was chosen because it facilitated every phase of the simulation project, from creating, debugging, verifying, and validating the model, to the construction of a user interface. This way, developers and target users could collaborate in the conceptual development of the model and later in the analysis of the system. An ExtendSim model is created by adding blocks to a model worksheet, connecting them together, and entering the simulation data. Each block has its own functionality, dialog, help, icon, and connections. Each instance of a block in the model has its own data. The logical entity that moves through the system is referred to as an item. Items carry properties or attributes with them as they progress from one block to the next. Items are represented using data structures allowing large numbers to exist simultaneously within a model. An additional advantage for developers is the ExtendSim’s built-in, compiled language, ModL, to create reusable modelling blocks beyond the standard libraries provided by ExtendSim. All of this is done within a single, self-contained software program that does not require external interfaces, compilers, or code generators. Hierarchical help to organize the model. Hierarchical blocks are elements that can be added to the model in number equal or greater to one and they are very useful to make the model more readable. For instance, each primary cut or product can be encapsulated as a sub model into a hierarchical block.

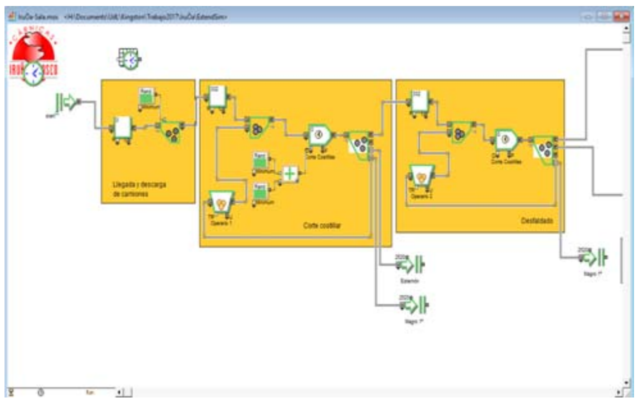

Figure 1: Overview of the model

3. BRIEF OVERVIEW OF THE SIMULATION MODEL

Based on the description of the process assisted by the employees of the company a conceptual model was developed. A first prototype was implemented according the first description. Later on, the conceptual proof was refined and the rationale of the model corroborated with different visits and inspections to the plant till the version was accepted by both parts.

The model represents carcasses as items that flow through the different blocks of the model. As the simulation progresses, initial items are split on other items as result of different activities: cutting operations. Then, an original cut can produce different sub cuts according to a pre-stated cut tree. In this sense, it is crucial the cutting tree with the representation and product branch location of all the different cuts relevant for the Spanish market and corresponding products' family. In general, all products and by-products have a different commercial value and this can even vary from order to order. It is a task of the sales' department to agree the final value with clients when placing orders.

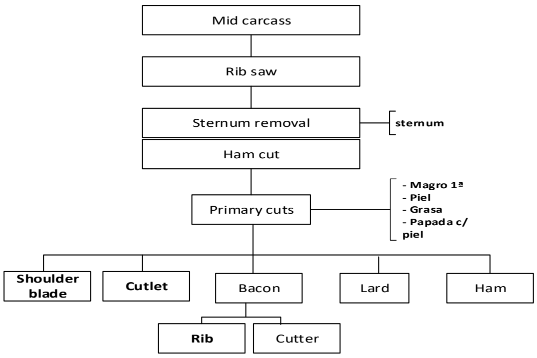

Figure 2: Primary cuts

The first part of the cutting tree produces primary cuts as shown in Figure 2. Before proceeding explicitly with primary cuts some preparation of the carcass is needed: to cut completely the carcass in two, to saw the rib for a later easier processing in the line with only knifes, to remove the sternum and give a helping cut in the ham to ease its later separation from the rest of the mid carcass. As result, there are subproducts that can be obtained during this primary process like lean, skin, fat or dewlap with skin.

There are five primary cuts for each mid carcass (Figures 2) operated in one line. Once primary cuts are produced some of them can be marketed as such, like ham, lard or shoulder blade. However, it is more common to go on processing and getting additional and more elaborated/processed products. For instance, figure 3 represents the different products can be obtained from ham. First of all, a ham can be with skin or skinless. The latter is mainly used for York ham production. It is the result of removing skin, tail, ankle bone, foot, minor cuts of lean and fat to shape the ham. Further products are obtained with additional processing of the York ham: Ham 3D (boneless ham), Ham 4D (boneless and sinew removal), Ham 5D (like a leaner 4D) and Ham 6D (like a ham 5D without the aponeurosis). Ham with skin is the raw to produce cured ham products.

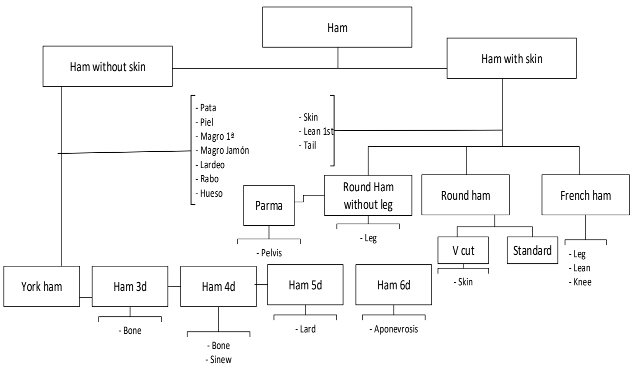

Figure 3: Ham cuts

Each cut information includes attributes as weight, lean, bone, fat and skin percent. If a meat cut can be processed further, each resulting cut is defined with the same attributes referred before. In order to consider different carcass composition a sampling by genotype (only Pietrain and Large White breeds are processed by Carnicas Iruña) and weight (three categories: low, regular, heavier) was performed considering normal distribution for weight attributes.

Table 1: Sample example

Low weight range			
#	Weight	Gender	%Lean
214	76.1	H	68.3
215	75.6	H	65.8
220	81.2	M	69.0
221	81.4	H	65.4
251	78.5	H	66.8
256	82.0	M	62.8
257	84.0	M	64.4
306	71.1	M	68.5
324	78.9	M	68.0
349	75.6	M	66.6

Table 1 shows an example of one sample of ten pietrain pigs of low weight category used to estimate the normal distribution for this genotype x weight category. Gender was not considered in the simulation. A t-test was performed over different samples to check no statistical differences to this measures between genders. Main results of the carcass composition for this sample is shown on table 2. Figures on table 2 are the base to randomly derive primary cut attributes. Similarly, each product family in the cut tree was sampled in similar terms to simulate them properly. It should be noted that several products or by-products come directly from the abattoir without no processing on plant like heads, blood or liver.

Table 2: Carcass composition for Pietrains of low range weight (total sample weight 784.4 kg)

Cut	Weight	Percent
Ham	255.2	32.4
Shoulder blade	110.3	14.0
Dewlap	24.9	3.2
Lard	47.5	6.0
Bacon	121.5	15.4
Cutlet	169.3	21.5
Skin	5.0	0.6
Lean 1st	0.6	0.1
Fat	0.25	0.0
Heads	42.6	5.4
Hands&feets	7.6	1.0
Sternum	2.9	0.4

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4. RESULTS AND DISCUSSION

For verification purpose, the model was compared with analytical results (Kleijnen, 1995) running the model in a deterministic mode and later with the random capabilities for each category. The simulation model was not run with all possible parameters, only those compatible with the analytical model were set. Verification process was automatized by developing specific calculations keeping track of main variables for each meat cut as total meat weight and bone percent.

Later on, in order to validate the model and assess the suitability of the proposed simulation model a comparison was established between results performed without random variability of variables and correlations (i.e. adopting expectations for random parameters) and the same simulation model but taken into account full capabilities of the model to reflect real systems (i.e. generating random values for each random variable considered). Thus, a group of parameters satisfying the needs of both runs was set. This process was assisted by the personnel of "Carnicas Iruña" involved in this research. Results at this stage were also verified and discussed by the company giving their approval.

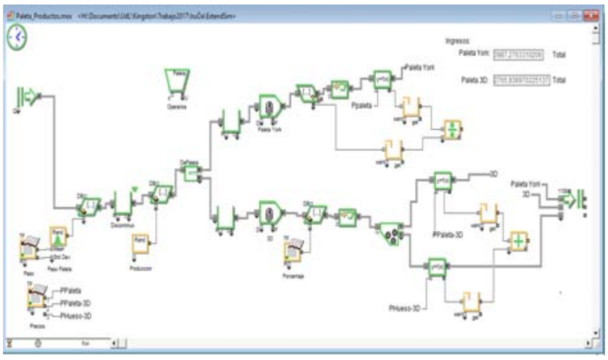

Figure 4: Comparison between incomes of two products: york ham and ham 3D (i.e. boneless)

The more interesting part of the model and the focus was the different sub models developed for each product (see e.g. Figure 4). For instance, ham. All the family products are those described in Figure 3 and also de subproducts associated to them (e.g lean, bone, skin, fat,…). However, in this example we limit our interest to two products: York ham and ham 3D. Figure 4 is shown the result of an instance comparing the two products mentioned according to the incomes generated. Hence, the manager of the plant can explore the range of prices for each product and subproduct involved that can make more interesting to produce one product or the other. In addition, he has a tool to get the shadow price for a product in case an interested costumer request information about a specific product.

A real situation experienced by the meat plant was related to hams marketed in Spain and France. The plant has costumers from both countries and so the diversity of products make difficult sometimes to assess the commercial interest for the company to make one product or combine both demands. In addition, the value of the different costs affecting the manufacturing of one cut or a different one is not always evident. Hence a cost-benefit analysis product by product was very appreciated by the company.

As every product and products' family were represented by a block, the link of all of them in a ExtendSim sheet allowed the representation of the full operation of the plant. It was necessary to add labor adjusting labor capacity with the number of employees available and to fix the production planning structure, i.e. the internal sequence to fulfill the incoming orders. Labor modeling out of the line was easy as these tasks were assigned to hired personnel paid per products regardless the time invested in the cutting.

5. CONCLUSION

The simulation model described here represents a practical approach for planning pig meat production under different carcass disaggregation plans. It is more flexible and accurate than deterministic or stationary approaches, essentially because it better captures the dynamics of the plant production and cutting operation process. The use of a visual simulation tool like ExtendSim is essential to interact with specialist during the development of the model. Moreover, different advantages are drawn respect to previously published models for similar purposes in other fields like a greater understanding of the system, the reduction of operating costs by a better control of products to serve and personnel, a risk reduction in failing to fulfill orders, lead time reduction, reduction of capital costs, and faster configuration changes in production planning. The simulation model considered only variations in carcass weight and breeds but can explore alternative products from the same primary cut.

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