Process modelling for Yalumba’s Moppa winery

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Introduction
When a decision is made to construct a new winery naturally some business questions have been answered, but as the project design phase begins many new questions arise. During the design phase of Yalumba’s Moppa winery project, APV Invensys were commissioned to create a process model to investigate and test the available processing options, with the aim of providing answers to some of these questions and optimising equipment installations. An explanation of the formulation and application of the model are provided below.

Development of a process model
Process modeling begins by taking a system and breaking it up into a series of logical steps. These steps form the basis of the model, enabling an end user to analyse how the system behaves under a variety of scenarios. A process system can usually be defined in three ways:

• Continuous process. (e.g. a winery)
• Discrete process. (e.g. an assembly line)
• Unit process. (e.g. the fermentation reaction)

Winery processes can be modelled in a variety of ways each with differing levels of sophistication, but they are basically split into two areas; static and dynamic models.

Static models
Static models focus on a specific area of the process, as such they are not time dependent and do not show interaction between different areas of the process. Static models are created using a series of mathematical expressions to simulate the process step in question. Examples of this can be found in tank storage calculations, or yearly grape intake figures as shown in Figure 1.

Dynamic models
Dynamic modelling encompasses a wider section of the steps involved in a process. They have the ability to show interactions between different areas and steps in the process and are time dependant. Using this method, ‘what-if’ scenarios can be studied to enhance knowledge of the process and its interactions and provide answers to more difficult questions.

In creating a model, the methodology used by APV involved progressing through the following phases to develop a usable dynamic model for the Moppa Winery.

Phase 1 – Modelling objectives
The first step in the modelling process is to create a scoping document outlining the objectives, resources and timeframe available for construction of the model. This process can be assisted by developing a list of questions that the modelling process needs to answer. Some of the questions asked at the beginning of the Moppa Winery project were:

• What intake in growth will the planned winery setup handle?
• How many centrifuges are required to handle the peak vintage flow?
• How many RDV filters are required to handle the vintage peak?
• What will be the requirement for consumables over the vintage period?

In this way assumptions made during the development of the model can be listed and tested when the model is complete. The testing provides a way to further develop and enhance the models accuracy as a planning tool when production has begun.

Phase 2 – Define the boundary
In constructing a model it is necessary to map the overall process as defined steps and then decide on boundaries that limit the scope of the overall model. The position of boundaries applied to the process will depend on the required outcome of objectives and timeframe detailed in Phase 1. Additionally at this stage an assumption must be made that steps outside the model boundaries will not impact on the results of the model. If possible the model boundaries should be selected to minimize the influence of this assumption. The process steps and boundaries for the Moppa Winery model were mapped and selected as indicated in Figure 2. In future these boundaries may be expanded to include additional areas of the process, providing expanded information for planning purposes and process management.

Phase 3 – Define the process
The process definition outlines how the incoming raw materials are converted into final product(s) through a series of operations.
Generally the information collected in Phase 1 and 2 is documented on a flow diagram. The level of detail will depend on the objectives and timeframe to produce this drawing. With the assistance of Yalumba production and winemaking personnel a process flow was defined and a flow diagram created for the intended process at the Moppa Winery. Clearly in planning a new winery decisions must be made at this stage as to how the winemaking process is intended to function. It must be noted that the decisions made at this stage have a major impact on the future production process and as such the basis of the model.

**Phase 4 – Define the equipment**

With the aid of the process flow diagram a list of the major pieces of equipment can be prepared. From this list design and process limitations of the equipment can be determined, defining the upper and lower limits of each machines capacity. For the Moppa Winery this included equipment such as crushers, presses, centrifuges, RDV filters, and winemaking consumables. It was also thought necessary to review the plant layout to confirm selected equipment could provide the desired process outcomes in an efficient manner. For clarity the flow diagram contained visual references to the selected equipment, which were positioned appropriately on the drawing.

**Phase 5 – Define stock position**

This phase involved collecting data on defined wine products for predicted:

- pre-vintage wine stock in tank from previous years
- vintage grape intake for the new winery
- bottling capacity to indicate stock leaving the winery

**Phase 6 – Material and energy balances**

The scope from Phase 1 defines the material and energy balances developed. For this project a product mass balance was completed for grape intake and wine production. It included estimations of winery waste streams (such as marc, and grape solids), but did not take into account energy, water or other possible utility balances which were outside the initial boundaries of the model.

**Phase 7 – Time-related data**

Time-related data can be studied to provide additional information for planning and management purposes. In this case it was outside the boundaries of the model, but it can include items such as:

- Time motion studies
- Break down data
- Shift data
- Material delivery schedule

**Phase 8 – Modeling**

The final model developed for the Moppa Winery included the following types of model for specific areas of the process:

- Static
  - Tanks storage calculation
  - Grape intake
- Dynamic
  - Process model from grape intake to wine filtration
  - Tank layout
  - Tank farm layout and process model to validate tank size and tank mix over the vintage period

The areas included in the Moppa Winery model are outlined in Figure 3.

As an example Figure 4 shows a section of the final model allowing for the installation of three centrifuges, and can be compared to Figure 5 showing the same data when applied to the installation of two centrifuges. From this data a decision can be made on the most cost effective number of centrifuge installations to satisfy various risk scenarios. The outcome is based on actual vintage intake data from various years, with a variation in processing load and timing for the different vintage conditions experienced. Based on the model a decision was made to install only two centrifuges, and use more traditional cold settling methods for the relatively small number of days (between five and 10 depending on vintage conditions) when there would be a shortage in centrifuge capacity (shown in Figures 4 and 5 as “No. of days above 100%”).

**Success of the model as a planning tool**

As indicated above throughout the process of developing the model assumptions are made especially when in the planning stages. The final success of the model is based substantially on the accuracy of these initial assumptions. As the Moppa Winery has now successfully completed two vintages, an appraisal of the model as a planning tool can be made.

Crushing operations functioned as expected due to the ease of determining crushing capacity in tonnes/hour when selecting this type of equipment. Other equipment such as wine line and pump numbers were also accurately predicted by the model. Similarly
the decision to install two centrifuges, rather than three, has been confirmed as correct, saving large amounts of capital that could be invested in more productive equipment. Additionally, because these decisions could be made at the early planning stages of the project, the other processes were tuned to easily handle the slight surplus of juice to be cold settled over a few weeks at the peak vintage intake.

**Challenges encountered**

As would be expected some of the assumptions made in developing the model proved to be inaccurate. Screw press capacity was overestimated, largely due to a change in balance of varieties being processed by this equipment. This resulted in changes made to the model to reflect the true press capacity (established over the 2005 vintage) and in turn the installation of an additional press for the 2006 vintage. It was also noted that processing flexibility such as delays in predicted fermentation times and fruit intake scheduling issues are not taken into account by a model such as this, but contribute substantially to the processing efficiency of a winery.

**Moppa model revisions**

After completion of the construction phase, the model has undergone several revisions to increase its usefulness as a planning tool for winery operations. Throughputs of equipment have been checked, based on the actual process, and the model fine tuned to provide more accurate production figures than could be achieved with initial estimations. Similarly machine running hours have been adjusted to more accurately reflect actual run times over vintage.

For ease of use a sheet summarising the main operational variables has been added with cumulative totals for each stage in the process. These cumulative totals provide a very accurate model of juice intake and a prediction of peak volumes several weeks in advance, thus providing management with more time to make critical decisions and take action for any perceived upcoming problems.

**An example of modelling for expansion**

Expansion in current processing capacity can be run through the model to provide an accurate prediction of capital investment required. For example in the case of the Moppa Winery if an expansion of 5,000 T in crushing capacity was proposed this figure can be easily inputted into the model providing the following information:

- Cold settling capacity would need to increase by 16,500 hL.
- If an increase in cold settling is not desired the number of centrifuges could be increased to three, giving no days with the winery above 100% centrifuge capacity.
- Ferment tank capacity would have to increase by 19 to 21,000 hL (depending on vintage conditions).
- RDV, Yeast propagation, and winery pump numbers are adequate.

Peak capacity variations can be modelled for hot or cool vintage conditions and a decision in total storage increase made on a risk vs outcome basis. For example if vintage followed the intake profile for 2006 with an additional 5000 T (spread evenly across the varieties), ferment capacity would need to increase from 117,000 to 136,000 hL. However, in a warmer year such as the 2001 vintage, ferment capacity would increase from 131,000 to 152,000 hL. With this knowledge educated decisions can be made on the desired increase in ferment capacity to minimise risk to production as well as the capital cost of an expansion project.

**Summary**

In summary forward planning using a process model for winery design and production enables the user to decrease both the capital and processing costs. Knowledge of the equipment capabilities assists with improved efficiencies in the winemaking process and provides benefits to the finished product in improvements to the quality of wine produced and minimization of waste. As a result the increasing pressure for capital funding can be satisfied by directing funds towards areas that have the highest need and priority, with a confirmed increase in production efficiency and well defined payback. Operational risks and problems are evident far earlier than would normally be the case and as such they can be better managed with any cost impacts minimised. Additionally the model can be expanded to include other areas of winery such as waste management that become more important from an operational management perspective once production is underway. However, a model is just that, a mathematical estimation of a real process. In order to satisfy the assumptions made, the model is still reliant on a well commissioned and efficiently operating winery process, combined with well-trained operators who understand how to use the equipment to obtain maximum efficiency and wine quality.