Design guidelines of food processing plant

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Abstract

The current increasing demand for healthy food has created a market opportunity for the food industry. Homestyle Vegetable Processors, a leading producer of salad has identified the need for an increased capacity to cater the rising demand of consumers nationwide and potentially within the Asian market. Homestyle's existing plant is operating with intensive dependence on human labour. Upgrading both efficiency and productivity of the plant creating a highly automated environment facilitates a move towards lean manufacturing. However, the creation of a fully automated factory may require significant capital investment and therefore several other options have been considered. These include remodeling of current plant and replacing labour intensive operations with automation. The current plant has been used as the base case against which the other options are compared. A financial analysis has been conducted separately for each case to identify the suitability of each upgrade option by matching the annual sales growth rate. This paper discusses the development of an approach to produce a design guideline to improve efficiency and assess the value of each upgrade in monetary terms. The project focused on an upgrade of the pasta salad production line in terms of efficiency. Upon completion of this project, the findings and recommendation are expected to lead to a significant reduction in production time and cost.

1 Introduction

This project is about designing a plant for fresh food manufacturing and, as such, issues such as freshness of products and hygiene are critical. In most other aspects, the manufacturing is analogous to conventional non-perishable product manufacturing. The client, Homestyle Vegetable Processors, is part of the Merenda Group of family owned companies with an annual turnover of $0.7 million; Homestyle is a leading producer of various fresh food products consisting mainly of dry and wet salads. Examples of dry salads are lettuce, spinach and dry coleslaw while wet salads are such products as Hawaiian rice salad, potato salad and pasta salad. Due to time constraints, this project was focused on pasta salad production in the wet salad line of the manufacturing facility-which is one of the most complex processes in the plant. The aim of the project is to upgrade the production efficiency so as to uphold and increase profitability, an intention which leads to the development of lean manufacturing. The current plant is heavily reliant on direct labour and is likely to reach its capacity during periods of peak production such

as immediately prior to Christmas. There is therefore a need to improve the capacity of the plant. It is also Homestyle's desire to reduce costs so as to uphold and improve market competitiveness, upholding and improving profitability. To do this, Homestyle will need to reduce the amount of direct labour in the line by moving to a fully or semi automated processing. These improvements are ultimately aimed at cost reduction and profit maximisation within the company.

1.1 Project Objectives

- Increase production capacity of processing plant.
- Reduce costs and dependency on human labour.
- Upgrade efficiency of processing plant.
- Cause all aspects of the existing and proposed facilities to comply with ***Food Standards Gazette - Amendment 101*** *(14 August 2008)*, hence increasing consumer confidence.

2 Background

Five options (A, B, C, D and E) of upgrade have been compared in this project. Each option is compared in terms of efficiency from the engineering point of view.

- Option A is a base case, retaining the current existing facility.
- Option B adds preventive maintenance and proper training of staff to option A.
- Option C is a remodeled version of the existing plant with current equipment positioned such that a straight product flow is achieved. This would be housed in a new building.
- Option D replaces activities requiring intensive labour with automated machines. This option also has the same product flow optimisation as in Option C and would also exist in a new building.
- Option E is a fully automated production line, in a new building with the benefits of all options above.

The approaches taken to increase production efficiency in the plant are as follows:

- Realignment of production lines

  In the current processing plant, unnecessary time is wasted in transporting unfinished product around the factory from one machine to another. Options C, D and E were designed to have a straight processing line, aligning machines next to each other to eliminate lag time during production.

- Upgrade of machine and equipment

  The production time in existing plant had been recorded and analysed, and possible upgrades were identified that could reduce the overall production time. Selection criteria of machines were developed based on a trade-off between cost and efficiency. Production time after the upgrade was then estimated based on machines specifications provided by manufacturers.

Finally, benefits sought after the upgrade in each option was then compared with the base case option.

- Efficient management of people and equipment in production line

Option B utilizes maintenance personnel available at the existing plant to undertake preventive maintenance of machines. Currently, when machines are running smoothly, these personnel are working in the production line. However, it is expected that the life of equipment will increase and the number and severity of downtime due to machine failure will be significantly reduced with preventive maintenance. In addition, option B also involves proper training of staff to handle and fix simple technical problems of machines. This allows immediate recovery from common machine breakdown during production. Option D is designed with aim of reducing production inconsistency due to human labour as well as cost effectiveness. In extreme cases, production time may be doubled due to human errors.

A financial analysis has also been produced for each option to assess the cost efficiency of each upgrade. The net present cost of implementing each option has been calculated using the discounted cash flow methodology over a period of 10 years. Then the NPV of each new option has been estimated. The discount rate used is Homestyle's Weighted Average Cost of Capital (WACC).

3 Methodology

3.1 Layout of new food processing plant

The layout of current food processing plant was first obtained from Homestyle. The paths taken for each process in pasta salad production is indicated by arrows as in Fig 1. The dimensions and arrangement of facilities in the current plant layout was used as a guide when designing the new plant layout. The new processing plant layout was then produced based on straight and direct production flow which keeps transportation of raw material and products to a minimum. The layout is then produced for each of the options.

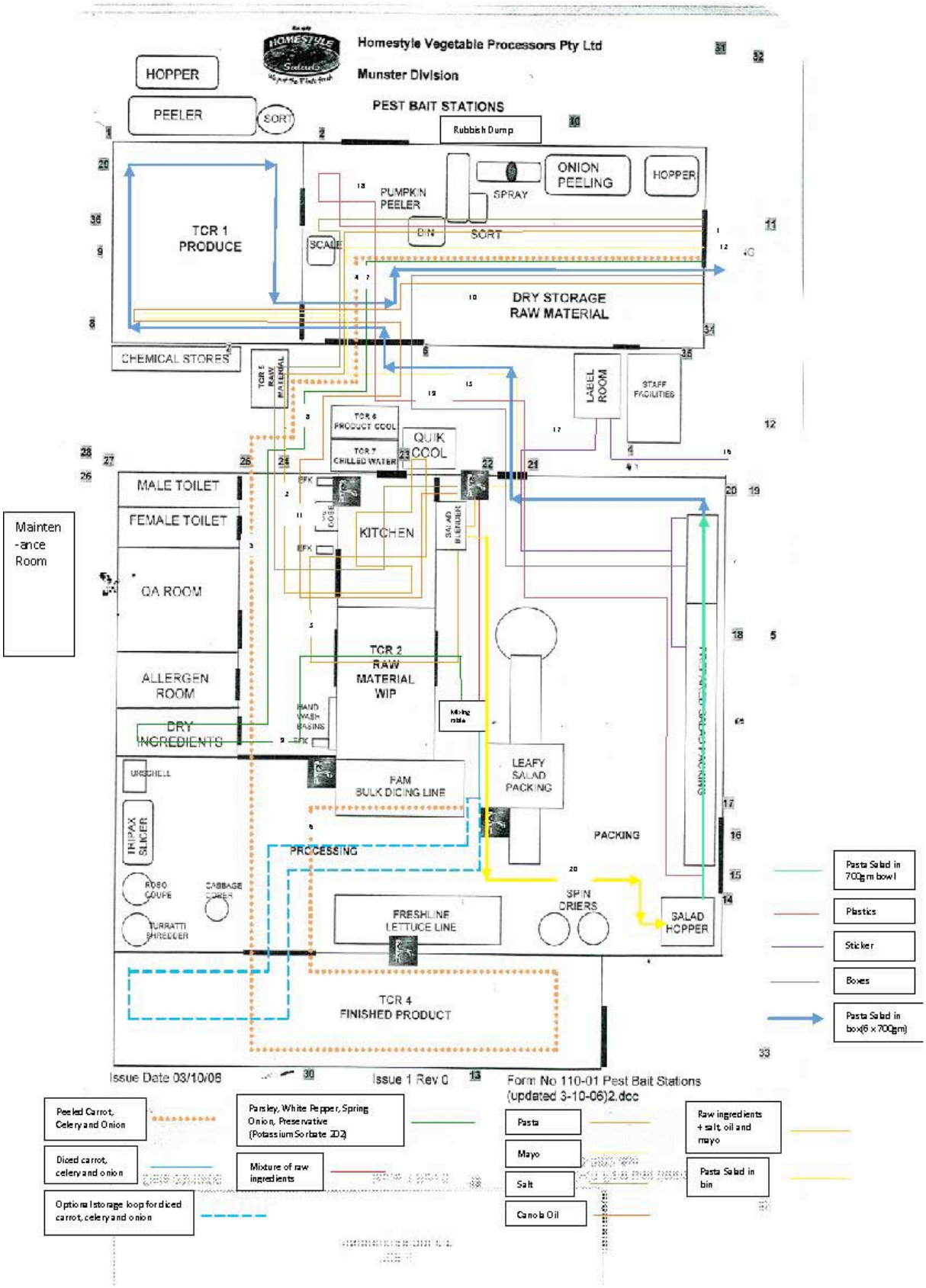


Figure 1 Homestyle's current food processing plant. Arrows indicate paths of process in production of pasta salad.

3.2 Preview of fresh food processing plant

As outlined in the project brief, Homestyle requested for a 3D representation of the new processing plant. To do this, CAD drawings of machines and robots were needed and obtained from manufacturer. The layout of the factory is then sketched using Google Sketchup, a freeware downloaded from http://sketchup.google.com/. Machines, robots and staff were included in this 3D representation and a fly-through of the plant is then developed.

3.3 Technical Analysis

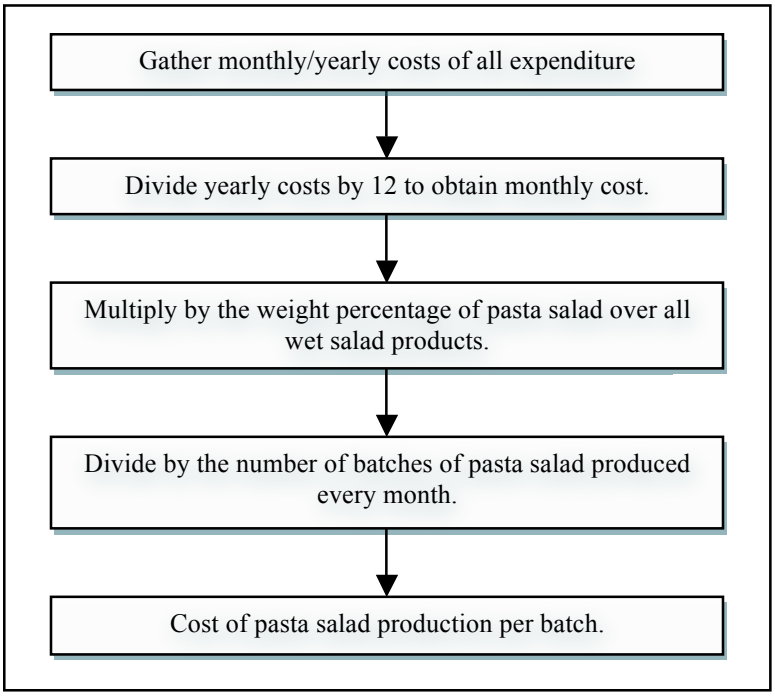
In order to compare the efficiency of design for each of the options considered, the following set of formulas was derived.

The production efficiency n of the pasta salad line is given by;

$$\eta = \frac{\text{Output}}{\text{Input}} \text{ x } 100\% \quad (1)$$

Where the "Output" is the total value of a batch of product leaving the factory in monetary terms (the weight of pasta salad in kg per batch times the selling price of pasta salad per kg), and "Input" is the yotal value of input including labour, electricity, water, raw material and capital invested for renting equipment to produce one batch of pasta salad, in monetary terms (the ost of machine maintenance + labour + electricity + water + raw material + equipment rental).

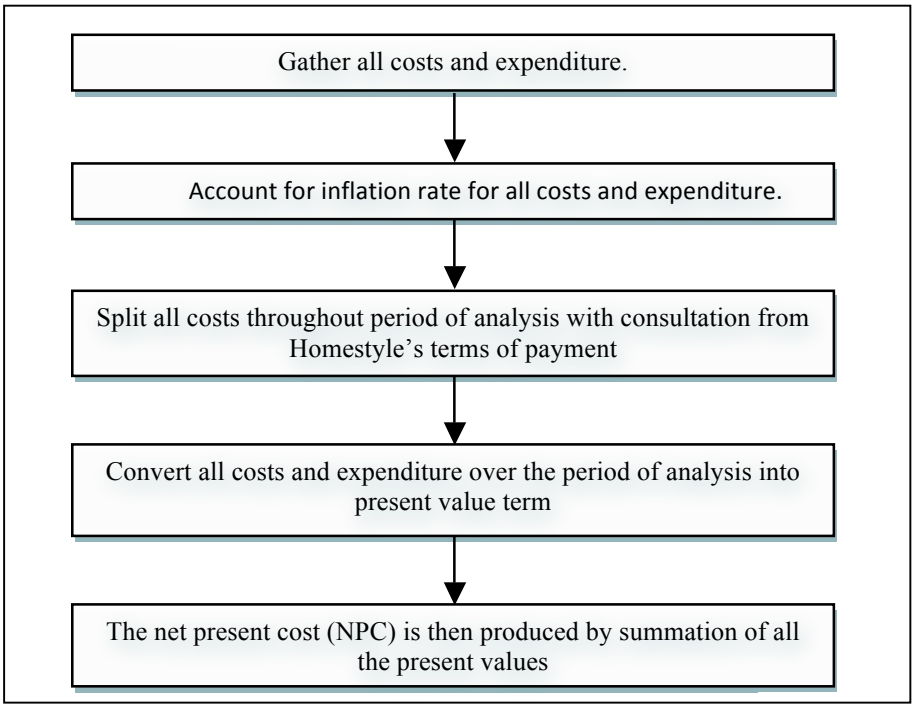
As the level of information available from the client was limited, sourcing appropriate data for the input expression above was crucial. The following is a flow-chart showing the steps taken to obtain the various input costs as mentioned above.



Production time for a batch of pasta salad in the current plant was recorded as a base line of comparison. Processing speed for new machines was then obtained from manufacturer to compare between all the options.

3.4 Financial Analysis

The following steps were undertaken to analyse each option financially.



The inflation rate of costs and expenditures were taken into account through consultation with machine manufacturers and based upon previous years. The Merenda Group's Weighted Average Cost of Capital (WACC), 9 percent was utilised as the discount rate to convert all costs and expenditure into present value terms. The steps were repeated for each option.

3.5 Project Evaluation

To evaluate and compare the efficient use of capital, the following formula was applied to each of the options.

Capital Efficiency,

$$\eta_C = \frac{\text{Net Present Value}}{\text{Discounted Capital Cost}} \tag{2}$$

Further on, a trade-off between capital and production efficiency, defined as the cost and production efficiency $\eta_{c\&p}$, was determined.

$$\eta_{C\&P} = (\text{Capital Efficiency}) * (\text{Production Efficiency}) \tag{3}$$

4. Result and Discussion

4.1 Results

The findings regarding implementation of each option is as follow.

- **Option B (base case + preventive maintenance + proper training of staff)**

Homestyle's average production speed is 26 minutes for a batch of pasta salad. With proper training of staff and preventive maintenance carried out at appropriate periods, the maximum achievable speed of production is 15 mins for a batch of pasta salad.

- **Option C (straight flow in a new building)**

With all process executed in a straight line, in the new building it is found that about 10 percent of labour cost is saved with reduced transportation of raw material and unfinished products around production floor.

- **Option D (replacing intensive labour with machines)**

By replacing intensive labour with machines, Homestyle saves about 45% of direct labour cost with reduced staff on production floor.

- **Option E (all benefits)**

Production time for a batch of pasta salad improved from a maximum achievable speed of 15 minutes to 9 minutes with the introduction of new machines and processing methods. This option also has all the benefits of the options above.

4.2 Discussion

4.2.1 Technical Analysis

The time consumed by each process may differ for every batches of pasta salad production. Hence, labour, electricity and water costs used for the analysis may vary from one batch to another. However, this variance is insignificant if human error and mistakes occurred during production is not taken into consideration To obtain a more accurate approximation, average production time for several batches was used to calculate the input cost.
In identifying the expenditure incurred namely maintenance of machines and rent of special equipment, for producing a batch of pasta salad, it was assumed that the costs incurred by all production lives are shared in weight proportion of each product. Nevertheless, a more detailed analysis may show a different proportion of sharing-possibly due to the nature and size of products which require less storage and processing cost.

4.2.2 Financial Analysis

Several issues arose when calculating the cash flows for each of the options considered. The costs assembled for building construction and purchasing equipment, including all associated costs, are

estimates which include a contingency allowance. All costs have been individually escalated over their lives.

4.2.3 Cost Estimation

- **Building Costs**

Consultation with the client's architect was consulted in order to identify approximate cost of building including water and electricity services, flooring, drainage and coolrooms. The overall calculation was then made based on an estimation figure of $3000 per square meter.

- **Maintenance of Machines**

Some of the proposed new machines are not off-the-shelf designs but are designs based on the client's specific needs. However, maintenance costs for one-off designs cannot be specifically estimated until an order is confirmed and a design is finalised by manufacturer. Therefore, to provide Homestyle with the most accurate possible maintenance costs, the parameters in British standard Blanchard's System Engineering book were used, with respect to the food manufacturing industry.

5. Conclusion

New processing machines and improved methods will reduce Homestyle's production time. In turn, with reduced production time, Homestyle Vegetable Processors will have a larger production capacity. Although at the time of writing, the full analysis has not been completed, it seems likely that dependency on human labour can be shifted cost-effectively to machines with the implementation of a highly automated environment. Thus, inconsistency between produced batches would be largely diminished.

A straight and direct processing line will also minimise raw material and product handling leading to reduced losses through spoilage and retained freshness.

Finally, food quality and plant productivity will be improved through better processing methods and equipment.

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