TOTAL QUALITY MANAGEMENT INITIATIVES FOR BUSINESS GROWTH

The Sprig & Fern Brewery Ltd

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This report has been prepared in partial fulfilment of the requirements for the Master of Engineering Management degree (2014/2015) at the University of Canterbury, New Zealand.

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A copy of this report will be made available to the University of Canterbury in keeping with the 'use of thesis' guidelines.

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EXECUTIVE SUMMARY

This report describes process improvements at the Sprig & Fern Brewery needed for business growth. Systems to improve the management of food safety and health and safety are provided. Production growth was modelled to determine the maximum production volume possible. The report recommends equipment and process changes to enable production growth, and reviews how Total Quality Management can be used to guide continuous improvement.

Background:

The Richmond-based Sprig & Fern Brewery ("the Brewery") produces a range of craft beers and other beverages for New Zealand consumers. In the last decade, the Brewery has undergone extensive changes to their business model, directorship, operations and production volumes.

Management wish to increase sales volumes. Although the craft beer market continues to grow, so too does the competition. Future sales growth in a saturated market will require:

- Innovations to the product offering to add value to the customer; and
- Increased operational efficiency to reduce costs.

In addition, keeping up with a growing demand will require extensive equipment and operational changes to increase the Brewery's production capacity. Internal barriers to sales growth include:

- High debt and little free cash flow;
- Uncertainty about the upper volume limit that can be produced;
- Limited space to add higher throughput equipment;
- Obsolete quality and compliance management tools;
- Staff culture of improvisation, rather than standardisation.

These challenges necessitate the implementation of a quality management system at the Brewery. This report hypothesises that quality management will improve productivity, product quality and staff culture. In addition, quality management tools can be used to determine production capacity constraints, which can influence the growth strategy, and hence revenue stream, of the business.

Project scope:

In order to guide a growth strategy and to ensure that growth is managed for quality, efficiency and regulatory compliance, the project had the following aims:

1. To finalise, implement and initiate the registration of a Food Safety Programme;
2. To develop a Health and Safety Plan for centralised management of Brewery health and safety, and to implement changes to high-risk operational procedures; and
3. To identify the maximum production output possible at the current Brewery site.

The Total Quality Management framework was used to guide these improvement initiatives for overall business alignment.

Food safety:

By law, all food and beverage manufacturers need to adhere to food safety standards. The Brewery is compliant with current food safety requirements; however, these are due to be replaced by more modern regulations in 2016.

To comply with both current and future food safety regulations, the Brewery is adopting a Food Safety Programme (FSP). The FSP is a set of guidelines and management tools to ensure that food and beverages produced are always safe to consume.

The Sprig & Fern Brewery FSP Manual was finalised and implemented. Further recommendations for ongoing food safety improvements are given in the summary table below.

Health and safety:

Through operational and staff expansion, the Brewery has outgrown their current health and safety (H&S) systems and management documentation. This poses a major risk to the safety of staff, and for the potential of non-compliance to H&S regulations.

The aim of this task was to ensure that the Brewery is compliant with current and future regulations set by the Health and Safety in Employment Act.

The approach taken was to design a H&S Plan that focused on managing significant risks, and engaging staff in H&S improvements, and that could act as a framework to develop H&S policies and procedures as the Brewery expands.

Further recommendations are given in the table below.

Brewery production maximisation:

The Brewery has been expanded and developed *ad hoc* in the last decade; therefore, the actual production capacity is not fully known. To understand what sales growth can be supplied by the current Brewery site, the question was asked: *"What is the maximum volume of product that can be made at the Brewery?*

First, the maximum theoretical production volume was calculated using the first step of the brewing process as the fundamental constraint. Next, the Theory of Constraints was used to determine production bottlenecks at the maximum theoretical volume in later process steps. These constraints were then analysed for ways to alleviate them, in order to achieve maximum capacity.

To maximise the production capacity of the Brewery, recommendations are given in the table below.

Project integration and conclusions:

Total Quality Management is a holistic philosophy that relies on a company culture of, and management commitment to continuous improvement. In this regard, the tasks within this project are only small pieces of the puzzle. Creating policies and regulations for food safety or H&S will only be beneficial if the staff see the value in the changes, and adhere to them. Expanding the Brewery's production capacity is only valuable if the Brewery can continue to improve its product offering and increase sales.

Total Quality Management is really a business overhaul, but can also be approached incrementally, developing momentum as the results begin to surface. Recommendations are given below, which provide the stepping stones towards a full continuous improvement culture.

Only when Sprig & Fern Brewery staff and management truly understand how to add the most value to their customers can they fulfil their growth strategy.

Summary of report recommendations.

Ref.	Recommendation	Resource commitment (and responsibility)	Timeline
	Food Safety		
FS1	Conduct internal and external audits of the FSP	**$ 2,600** 3 days total (PTL)	Feb-Mar 2015
FS2	Support suppliers in developing their own food safety documentation	No cost < 1 day total (PTL)	Feb-Apr 2015
FS3	Focus on good manufacturing practices to drive continued food safety	No cost Ongoing mgmt. (PTL)	Ongoing
FS4	Monitor upcoming regulations of the Food Act 2014 to ensure continued compliance	No cost Negligible time (PTL)	Jul 2015
FS5	Monitor changes to the Wine Act 2003 to ensure continued compliance	No cost Negligible time (PTL)	Ongoing
	Health and Safety		
HS1	Urgently implement changes to forklift use and procedures for working at heights	Included in costs for *HS2* Ongoing mgmt. (PTL)	Feb 2015
HS2	Invest in several low-cost items (described in report) to significantly improve H&S	**$ 1,450** 2 days total (PTL)	Feb 2015
HS3	Begin formal H&S training for current and staff	No direct costs Ongoing mgmt. (PTL)	Mar 2015
HS4	Formalise relationships with contractors by using the Contractor H&S Induction form	No cost < 1 day total (PTL)	Mar 2015
HS5	Measure key H&S metrics for continuous improvement	No direct costs Ongoing mgmt. (PTL, MD)	Ongoing
HS6	Use the H&S Plan as a repository for new information as the Brewery grows	No direct costs Ongoing mgmt. (PTL, MD)	Ongoing
HS7	Drive positive H&S culture change to allow continuous improvement	No direct costs Ongoing mgmt. (PTL, MD)	Ongoing
HS8	Join ACC Workplace Safety Discount programme	+ $ 200/annum (PTL)	2015
	Production Volume Maximisation		
PM1	Have specialists review technical details of the analysis	Unknown cost/time (MD)	Feb 2015
PM2	Determine the Net Present Value of capital expenditures within recommendations	No direct costs 1 day total (MD)	Mar 2015
PM3	Upgrade equipment and make operational changes over time (roadmap given in report)	**$ 477,200** (+/- $ 50,000) Significant mgmt. (MD)	2015/2016
PM4	Seek sales opportunities with reduced summer demand spikes, to reduce seasonal production bottlenecks	No direct costs Significant mgmt. (SM)	Ongoing
PM5	Conduct an equipment risk analysis	No direct costs 2 days total (PTL, MD)	2015
PM6	Investigate the value of production scheduling software	No direct costs Significant mgmt. (MD)	2015
PM7	Consider a further quality management initiative aimed at reducing product waste	No direct costs Ongoing mgmt. (PTL)	2015/2016
	Future Total Quality Management Initiatives		
TQ1	Undertake a market research project to fully define the customers' perspectives of quality	Significant cost and mgmt. (ME, SM, MD)	2015
TQ2	Train staff in TQM philosophies and the customers' perception of quality	No direct costs Significant staff time (MD)	2015
TQ3	Begin measurement of metrics for food safety, H&S and staff satisfaction	No direct costs Ongoing mgmt. (PTL, MD)	2015
TQ4	Develop a long-term plan for fostering positive culture change	No direct costs Significant mgmt. (MD)	2015
TQ5	Share the growth strategy with staff to create a continuous improvement driving force	No direct costs < 1 day (MD)	2015, after strategy

PTL – Production Team Leader; MD – Managing Director; SM – Sales Manager; ME – Marketing Executive

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TERMINOLOGY

ACC	Accident Compensation Corporation
AMBO	Annual maximum brewing output
Brew	Refers to one complete brewing cycle, in this case to product 2500 L of wort
Brewery	Often specifically used to refer to the Sprig and Fern Brewery
Brewing	Process of producing wort from barley, water and hops
Bright beer	Filtered beer (or other product) that is ready for packaging
Conditioning	Process of aging fermented beer for a number of weeks at 0-4°C
CCP	Critical control point
CIP	Clean-in-place
CO_2	Carbon dioxide
FCP	Food Control Plan
Fermentation	Process whereby yeast converts wort to beer
Filtration	Removal of yeast and other solids from beer
FSP	Food Safety Programme
H&S	Health and safety
HACCP	Hazard Analysis and Critical Control Points
HSE	Health and Safety in Employment
HSNO	Hazardous Substances and New Organisms
MPI	Ministry for Primary Industries
NCCP	Non-critical control point
NP(3)	National Programme Level (Three)
QMS	Quality management system
Rigger	PET bottle, in this case 1.3 litres in volume
S&F	Sprig & Fern
Wort	Unfermented malt-based liquid, precursor to beer
WSMP	Wine Standards Management Plan

1 BACKGROUND

1.1 INTERNAL BUSINESS ENVIRONMENT

1.1.1 Business history

The Sprig & Fern (S&F) Brewery ("the Brewery"), located in Richmond, supplies a range of beverages to New Zealand consumers. The site where the Brewery is now located was initially used as an indoor sports centre, and later repurposed into a decentralised Harrington's Brewery plant. In 2006 the Brewery became independent, trading under the Tasman Brewing Company name. The Tasman Brewing Company sold product on-site and distributed products to several S&F taverns. Finally, in 2009, the Brewery consolidated the brand by renaming to the S&F Brewery.

Over this period, the directorship of the Brewery has also changed significantly, at one point having three separate equity parties. Tracy Banner, the Managing Director and Head Brewer, now co-owns the Brewery with husband Ken Banner.

The Brewery has also undergone rapid production expansion. Since the 2008/2009 financial year there has been a 2.4 fold increase in sales volume, up to 560,000 litres in 2013/2014 (Figure 5, Appendix 1).

1.1.2 Scope of operations

The S&F Brewery produces a core range of 17 beers, ciders and ready-to-drink beverages, as well as a range of limited release products. This includes all steps from the receipt of materials and ingredients, production of beverages, packaging and distribution (Figure 11, Appendix 2). The products are packaged in either 1.3 litre PET bottles (riggers), or kegs, in sizes of 50, 30 or 25 litres.

1.1.3 Business model

Products are distributed through three main channels – beer is served at franchised S&F taverns and privately operated outlets across much of New Zealand; riggers of selected beer are distributed through nationwide supermarket chains; and local consumers can purchase beer at the shop within the Brewery. The breakdown of these channels is shown in Figure 6 (Appendix 1).

1.1.4 Recent business results

After a rapid rate of growth, total sales in 2014/2015 have plateaued (Figure 5, Appendix 1). This may be for a number of reasons [1], including:

- Turnover of key sales and marketing staff;
- Turnover of external sales representatives;
- Reduced promotional effort in supermarkets;
- Increased competition within the craft beer market (described below).

The Brewery has little free cash flow [1] as a result of:

1. A contractual commitment to an unused central Auckland property lease; and
2. High debt from capex and equity purchases.

However, the Brewery has spent the last twelve months investing in new key staff members, and turnover remains strong [1].

1.2 External Business Conditions

Note: For a full market analysis for the Sprig & Fern see Appendix 3, page 31.

1.2.1 New Zealand craft beer market

Since 2008, beer consumption in New Zealand has dropped by 10%, but craft beer sales have soared [2, 3] - in 2013 alone craft beer sales increased by 30% [2]. This growth is driving an increasingly competitive craft beer market, with the number of breweries in New Zealand more than doubling since 2009 [2, 3]. Although the rapid market growth has often been referred to as a "bubble", there is evidence to suggest that the craft beer industry will not "burst" but instead begin to plateau [4].

In a competitive market consumers can afford to be choosy. Indeed, there is an increasing demand for craft beer innovation, through new beer styles [2, 5, 6], new packaging types [7], and business models [8, 9]. Therefore, the outlook for craft breweries is promising if they are able to differentiate themselves, and continuously improve their offerings.

1.2.2 Demand for further Sprig and Fern Taverns

There are currently six S&F taverns operating in the Nelson/Tasman region, and a further two in Wellington. A ninth S&F Tavern will open in Mapua within the next few months [10].

In 2013 the Brewery opened a S&F Tavern in Drake Street, Auckland. Unlike other taverns, this venture was financed internally rather than franchised to external investors. The Drake Street tavern underperformed and was closed less than one year later. Despite this set-back there is strong evidence to suggest a high demand for new S&F taverns (see market analysis, Appendix 3). Indeed, several parties have expressed interest to invest in the S&F Tavern franchise [1].

1.3 Project Rationale

To summarise the internal and external business conditions, the S&F Brewery has:

- Had significant directorship changes;
- Undergone rapid growth in production capacity and sales, coinciding with the growth of the craft beer market;
- Developed production capacity through *ad hoc* equipment upgrades;
- Become space-limited at the current Brewery site;
- Outgrown many of the quality and compliance management tools;
- High debt;
- Little free cash flow;
- Increasing market competition.

Under these conditions, it is imperative that the Brewery develop strong quality management systems (QMS) and continuously improve their offering, while reducing operational costs.

In addition, having regained some stability in the last twelve months, the Brewery is now ready to develop and pursue a growth strategy, in order to increase sales and cash flow.

Understanding the limitations of the current Brewery site and equipment will guide the growth strategy, and expose areas for quality improvement. Quality improvement will entail increasing productivity, aligning the internal business operations, and ensuring that external compliance regulations are met.

1.4 Project Approach – Total Quality Management

For a full review of quality management systems, see Appendix 4, page 33.

A QMS guides a business in continuous quality improvement, as dictated by the customers' perception of quality (Figure 1). Total Quality Management (TQM) is one such QMS that gained popularity late in the last century. As illustrated in Figure 1, TQM is a holistic and integrated approach, focusing on continuous improvement in all business aspects.

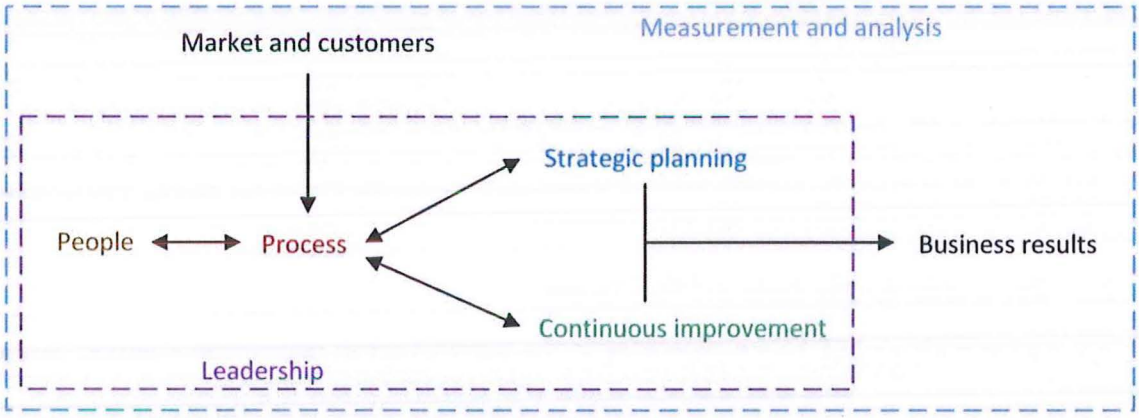

Figure 1. TQM focus areas.
The market and customers dictate the quality required of the product (process). The process is carried out by the workforce (people), and guided by management (leadership). Through continuous improvement of the process, and strategic planning, a business can achieve positive results. All of these aspects must be measured and analysed to enable continuous improvement.

The principles of TQM have been used to guide quality improvement initiatives throughout this project. This is so each initiative is aligned with the overall business objectives, and to consider the "soft" impacts of quality management, such as culture change and management commitment. The project has also utilised tools from other QMS, such as the Theory of Constraints (Appendix 4).

1.5 Summary of Project Aim and Scope

Aim: To increase the productivity of the Brewery, such that production can continue to meet a growing demand, while ensuring continued regulatory compliance and alignment across all business aspects.

Scope:

1. To finalise, implement and initiate the registration of a Food Safety Programme, to be compliant under the current Food Act 1981 and to enable easy transition to future food safety legislation;
2. To develop a Health and Safety Plan for centralised management of Brewery health and safety, and to implement changes to high-risk operational procedures;
3. To identify the maximum production output possible at the current Brewery site through the identification of key constraints, and to give recommendations on ways to circumvent those constraints.

2 Food Safety

2.1 Current State of Food Safety Compliance at the Brewery

Note: For a full analysis of the food safety regulatory requirements, see Appendix 6, page 37.

All food and beverage manufacturers in New Zealand must comply with food safety standards as a minimum to ensure that products are safe for consumption. As of January 2015, the S&F Brewery operates under the Food Hygiene Regulations 1974 (Figure 2). This regulatory framework essentially requires that food manufacturers operate with clean, hygienic and appropriate premises and equipment. Under the Food Hygiene Regulations 1974, the Brewery is exempt from the Food Act 1981 and the Wine Act 2003 [11] (for ciders) (Figure 2).

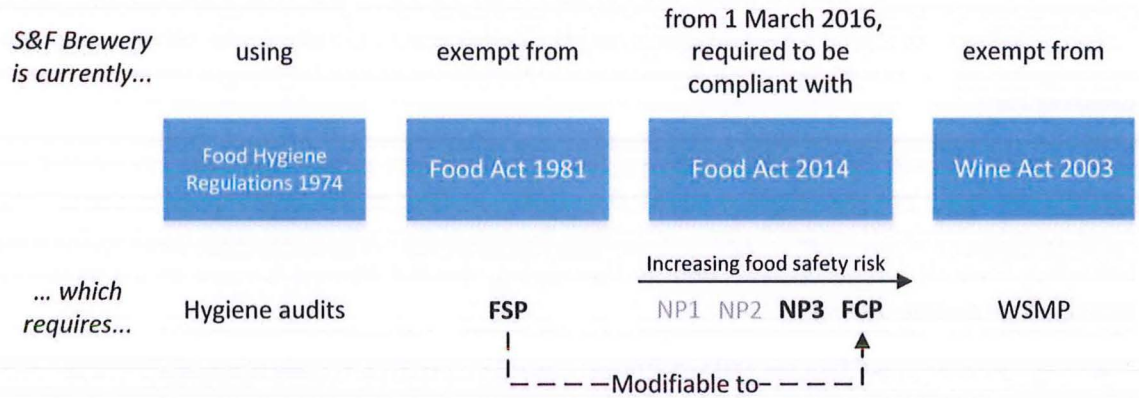

Figure 2. Summary of the food safety requirements for the S&F Brewery.

2.2 Rationale for Upgrade to the Food Safety Programme

The Food Safety Programme (FSP) is a set of procedures for consistently producing safe food or beverages [12], and it is a requirement of the Food Act 1981. It is seen to be more proactive in minimising the risk of food contamination than by simply having a hygienic operating environment. Effectively, the FSP asks "what might go wrong, and what do we do to prevent it?"

The S&F Brewery initiated the development of a FSP, because:

1. It supports improved food safety, reducing risk of non-conformance or recalls;
2. The Food Hygiene Regulations 1974 will soon be phased out [13]; and
3. Existing (significant) customers have requested that the products be made under a FSP [1].

The S&F Brewery FSP Manual [14] was partially developed by Rodney Finch (Assurance Services Ltd) and Tracy Banner in 2013, but had not been finalised, implemented or registered.

Since then, the new Food Act 2014 has been announced; this will change the requirements for food and beverage manufacturers. From March 1, 2016 (and phased in over three years), breweries are required to operate under the regulations for the National Programme Level Three (NP3), or a category with a higher food safety requirement [13] (Figure 2). Although the requirements for these categories are yet to be set, it is highly likely that the FSP will be easily modified into the requirements for the Food Control Plan (FCP) [15]. By modifying the FSP into a FCP, the S&F Brewery will not only meet, but exceed their legal food safety requirements.

Therefore, it was decided that the FSP should continue to be developed, implemented, and registered as originally planned.

2.3 Approach and Outputs

The aim of this sub-project was to modify and finalise the FSP Manual, ensure the policies had been fully implemented, and to initiate registration for the FSP.

The existing draft FSP Manual was reviewed and compared to literature and New Zealand food safety regulations. These were all viewed in light of the actual operating environment of the Brewery in order to make the manual as concise and tailored as possible. The major changes made resulted in the manual becoming more than just a compliance-driven document, and actually helping staff to practice food safety procedures.

The FSP is based on the Hazard Analysis and Critical Control Points (HACCP) framework. Using HACCP, manufacturers list process steps, identify biological, physical and chemical hazards for each step, and demonstrate the ways that each hazard will be controlled and monitored to ensure the safety of their products [16].

It was noted that the HACCP plan identified zero critical control points (CCP); this means that no brewery process individually determines the safety of the product. Although accurate, the consequences are that the HACCP plan, the defining feature of the FSP Manual, does not drive brewery behaviour towards producing safe food; in this regard, the FSP Manual is more of a compliance exercise than a value-adding tool.

In an attempt to improve this, several non-critical control points (NCCP) were highlighted. These NCCP singularly do not determine food safety, but cumulatively are described as 'good manufacturing practice'. By highlighting these to staff, good manufacturing practice may be encouraged, which would contribute to the long-term safety of the products produced at the S&F Brewery. These were highlighted through the development of the:

1. Staff Food Safety Programme Summary (Appendix 19.0 of the FSP Manual) – a four-page document, distributed to all staff, that describes the importance of food safety in the Brewery, and the good manufacturing practices that need to be observed to ensure food safety; and
2. Summary of Control Points (Appendix 20.0 of the FSP Manual) – a one-page visual presentation of the NCCP, displayed in several areas of the Brewery, to act as a continual reminder of good manufacturing practices.

After the S&F Brewery FSP Manual was finalised (see the Table of Contents of the manual in Appendix 5), responsibility was transferred to the new Production Team Leader at the Brewery.

2.4 Recommendations for Food Safety Improvement

FS1. Conduct internal and external audit

In order to fully register a FSP, the Brewery must first:

1. Implement and maintain the policies specified in the FSP Manual, confirmed by an internal audit; and
2. Have the FSP externally audited by an authorised representative of the Ministry for Primary Industries (MPI); and
3. Register the externally approved FSP with MPI [17].

Although the law will not require this until the new Food Act 2014 is in effect, some customers may wish to see evidence of a FSP at any time. Therefore, the FSP should be internally and externally audited as soon as practicable, and registered with MPI (detailed description given in Table 1).

Table 1. Recommended steps for registering the FSP.

Step	Carried out by, and how	Resources required	When
Internal audit	Production Team Leader (Nicholas Crosswell) – use the Internal Audit Checklist found in Appendix 21.0 of the FSP Manual	1-2 working days; no additional costs expected	February 2015
External audit	Suggested auditor: Helen Jane McDonald (Assured Audits New Zealand Ltd) hmcd@xtra.co.nz / 03 540 3776	$ 2000 audit fee (inc. GST and follow-up); 1 working day (Nick Crosswell)	Early March 2015
FSP registration	Tracy Banner – use the Food Safety Programme Registration Application Form FA1, available at http://www.foodsafety.govt.nz/elibrary/industry/food-safety-programme-registration-fa1/FA1.pdf	$ 600 registration fee	Late March 2015

FS2. Support the apple wine supplier in developing his own food safety documentation

To be fully compliant, the S&F Brewery should only source supplies from FSP-registered (or WSMP-registered) suppliers. The supplier of apple wine (Tullybarden Fruit Wines) currently does not have a WSMP, but has initiated the development of one [18]. By simply offering templates or examples, the Brewery may support and speed up this process.

FS3. HACCP plan has zero CCPs – focus on NCCP in the Brewery to reduce risk of non-conforming products and product recalls

This will transpire through a continued culture of good manufacturing practice, supported by regular training for all staff and engagement in continuous improvement initiatives (see discussion in Appendix 4). Recording the number of product recalls or non-conformances and reporting these back to staff may support this.

FS4. Monitor new regulations that will come in for the NP3 or FCP

The regulations for the NP3 and FCP are expected to be released in mid-2015. These should be checked as soon as possible, and a plan should be developed for modifying the FSP into a FCP.

FS5. Monitor any changes to the Wine Act 2003 that may influence cider production

While currently exempt from the Wine Act 2003 [11], the S&F Brewery should monitor any changes in this regard to ensure continued compliance. If exemption from the Wine Act 2003 were to cease, the Brewery would need to develop a Wine Standards Management Plan; this would be a relatively simple task, as most of the information could be cross-referenced from the FSP Manual.

3 Health and Safety

3.1 Rationale for Improving Health and Safety Systems

New Zealand has a poor workplace health and safety (H&S) record; in 2012 there were 40 confirmed workplace fatalities [19]. The manufacturing sector is notoriously high risk, and the 'food, beverage and tobacco' sub-sector has the highest injury rate within that – an average of 52 injuries per 1000 employees are notified every year [20].

Health and safety at the S&F Brewery has emerged as a focus area for a number of reasons:

- As evidenced above, the Brewery is a high-risk area;
- The Brewery continues to expand, with approximately double the number of operational staff now than in 2012, and a more complex and busy operational environment;
- Much of the H&S-related documentation and procedures were developed *ad hoc* as required, with no unified vision or centralised management tools;
- There remains a lingering culture among operational staff of improvising and using "common sense", instead of following developed procedures [21];
- New H&S legislation will soon be deployed, and will pose a greater non-compliance and financial risk to those companies who do not comply with H&S regulations.

3.2 Health and Safety in Employment Requirements

Note: For a full analysis of the H&S regulatory requirements, see Appendix 7, page 44.

The Health and Safety in Employment (HSE) Act 1992 guides businesses in ensuring that work premises and practices are safe for all staff, contractors, volunteers, visitors, and anyone else in sufficient proximity to the business operations.

The HSE Act does not specify what measures should be taken to make particular work situations safe; instead, it acknowledges that those involved with the work are generally in the best position to decide on safe working measures. In that regard, the HSE Act demands a high level of employee participation in improving H&S systems.

The standard that must be achieved is that of having taken "all reasonably practicable steps" to make work safe – that which can be reasonably achieved given the circumstances, resources and state of knowledge [22].

In 2015 a new HSE Act will be published. This will have the following relevant changes [23]:

- Greater focus on major risks;
- Increased requirements for worker engagement in H&S improvements; and
- Paid directors will have a duty of due diligence to ensure the H&S of workers.

3.3 Approach and Outputs

The aim of this sub-project was to develop a H&S manual for the Brewery, and to initiate any changes necessary to be compliant with the current and future HSE legislation.

In order to identify the H&S requirements for the Brewery, a number of steps were taken:

1. Desk research on legislative requirements;
2. Discussions with H&S professionals [24, 25];
3. Feedback from current operations staff through discussions [21] and a submission of written ideas, as well as personal experience from having worked in operations for 12 months.

The key learning outcome from this process was that there were several high risk areas H&S issues at the Brewery (see Health and Safety Risk Assessment, Appendix 7, page 45), and that these were unlikely to be improved through simply developing a H&S manual. Instead, a H&S improvement plan was created, which focussed on:

1. Defining a S&F Brewery policy on H&S that would guide future actions;
2. Expressly stating the Brewery's expectations for work conduct and responsibilities;
3. Improving workers' attitudes and culture towards H&S;
4. Targeting and reducing the risk of major hazards specific to the Brewery;
5. Improving the interactivity between management and workers regarding H&S;
6. Providing a singular body of H&S information and management tools;
7. Demonstrating an active and visible attempt at improving H&S systems to reduce the risk of potential non-compliance.

This H&S improvement plan was reviewed (in a non-advisory capacity) by two H&S professionals [24, 25], before being expanded on to create the S&F Brewery Health and Safety Plan (see S&F Brewery H&S Plan – Table of Contents, Appendix 6).

Engaging staff in H&S improvements was considered a high priority, both because of the upcoming HSE Act changes, and also from a TQM perspective; culture change will only occur if the staff are engaged in the improvement process (Appendix 4, Appendix 5). For this reason, a Staff H&S Survey was developed, which is intended to be a formal way of documenting staff's concerns or ideas about H&S at the Brewery. Another step taken to create staff "buy-in" was to focus on the major hazards in the Brewery, rather than producing regulations for every possible hazard (Appendix 5).

Lastly, the H&S Plan was described and passed on to the Production Team Leader as the new H&S representative. Importantly, this must be seen as just the first step in an ongoing process to improve H&S at the Brewery.

3.4 Recommendations for Health and Safety Improvement

HS1. Urgently implement changes to forklift use and procedures for working at heights

As shown in the H&S Risk Assessment summary (Table 12, Appendix 7), two critical risks are the forklift and working at heights. Changes must be urgently implemented to mitigate these risks.

Forklift use:

There has already been a team meeting regarding forklift use and the importance of communication and hazard identification when using this, and this has recently been supported by OSH Forklift Training sessions [21]; however, forklift use and conduct must continue to be monitored to ensure a heightened awareness of the risks it poses.

Working from height:

For routine and minor work at heights the regulations are somewhat ambiguous (Appendix 7). Working at heights occurs in the Brewery when changing light bulbs or doing maintenance tasks at the top of fermentation vessels. Heavy duty loop-bolt lugs should be installed in key areas in the

exposed timber roofing through which a safety rope can be attached. A guiding rope can be left in these loops permanently, and used to sling the safety rope, along with a safety harness for fall prevention. The estimated cost of this is less than $1000, including lugs, ropes, harness and installation. This equipment would act to save a person's life in the event of a fall from above three metres.

HS2. Make the following investments in equipment to improve health and safety

Based on discussions with brewery staff, equipment has been identified (Table 2) that would significantly mitigate safety risks for the operational staff and other workers, and should be considered for immediate purchase.

Table 2. Recommended equipment purchases to improve H&S in the Brewery.
Note: a full capital expenditure analysis is given in Table 16 (Appendix 9).

Item	Mitigates what risk	Approx. cost
Loop-bolt safety lugs	Falling onto concrete while working at heights	$ 600 inc. installation
15m safety rope with shock absorber [26]	Falling onto concrete while working at heights	$ 250
Safety harness [27]	Falling onto concrete while working at heights	$ 200
Safety helmet [28]	Head injuries while working at heights	$ 100
Aliquot pump for oxonia sterilant	Hand pump will avoid the need to tip 20 L container of sterilant, reducing risk of chemical spills and physical strain	$ 50
Manual trolley designed for moving kegs	Rounded shape will reduce risk of kegs slipping out	$ 200
Chain and lug added to existing keg trolley	Trolley to be retired for kegs, and instead used for transporting G-sized CO2 tanks without risk of toppling	$ 50

HS3. Train staff in health and safety

Training should be formally given to all staff members as soon as practicable to formalise the process, and should be given to new staff within the first week of their work commencing.

HS4. Begin use of the Contractor H&S Induction form

Phase this form in immediately as contractors come in for routine or scheduled work. This will formalise the relationship between the Brewery and long-time contractors regarding H&S expectations and responsibilities.

HS5. Start recording health and safety information for continuous improvement

Currently the S&F Brewery has no baseline for measured H&S improvement. The lack of specific information on breweries in New Zealand means that external benchmarking would be difficult. Instead, the Brewery should begin effective and systematic recording of important H&S metrics, such as:

- Percentage of staff satisfaction with Brewery H&S (as measured using the Staff H&S Survey);
- Percentage of initiatives from previous review actioned;
- Number of incident or accident reports filled out per month;
- Number of sick days taken per staff member per year.

HS6. Expand on what has been done

Treat the S&F Brewery H&S Plan as a work-in-progress, and 'flesh it out' as needed. Having effective H&S systems will be paramount to the business continuity of the Brewery; the business cannot afford avoidable injuries or the legal consequences of non-compliance. Therefore, the work that has been done should be seen only as a positive start.

Professional H&S consultation is recommended to ensure that there are no major flaws or gaps in the current systems or documentation. The recommended consultant is *Kay Bradley, Bradley Consulting.*

HS7. Concentrate on positive H&S culture change

Note: this recommendation is integrated with wider TQM initiative recommendations.

The biggest barrier to H&S improvements in the Brewery is staff reluctance to adopt new behaviours that are seen as "over-the-top" or unnecessary (see Appendix 5, page 37). Engaging staff with the H&S improvement process will be a significant challenge. Staff need to be actively encouraged to communicate concerns or ideas about H&S. This could be achieved by:

- Having a tangible incentive for using the Accident Register, even if only to report a minor incident or near-miss;
- Promoting staff input by conducting a quarterly survey on staff's perceptions of H&S;
- Managing out any behaviour seen to belittle H&S improvements; and
- Focusing on a culture of communication within the operations team, such that preventable accidents are avoided.

While many H&S changes may be seen as an unnecessary compliance task, some H&S improvements will actually come with tangible benefits to the staff. An example is reducing manual handling, which also reduces work effort. Efforts should be made to highlight the tangible benefits of H&S changes so that staff buy in to the continuous improvement movement.

HS8. Join ACC Workplace Safety Discount programme

Consider if there is sufficient value in joining the *ACC Workplace Safety Discount programme* [29], which offers a 10% discount on ACC work contribution levies - $212 annually*. Registration is a simple process, but requires that the H&S representative has relevant experience or training. In this case, the Production Team Leader will have sufficient experience after fully implementing the S&F H&S Plan.

**Based on a $45,000 average annual salary, ten employees, ACC levy rate of $0.41 per $100 earned for beverage manufacturers + GST* [30].

4 Production Volume Maximisation

4.1 Current Situation

The annual production volume since 2013 has been approximately 560,000 litres (Figure 5, Appendix 1). However, equipment utilisation is far from 100%, because:

- Products are manually batch-brewed, and are constrained by human resources;
- Additional brewing capacity has historically been added before demand exceeds capacity;
- The Brewery operates with contingency such that there has never been a core product unavailable for sale;
- There is a substantial seasonal demand variation (Figure 7, Appendix 1), resulting in a decrease in production during winter months.

Therefore, there is certainly room to expand production, but the upper production limit is unknown.

4.2 Rationale for the Analysis

There exists demand for further S&F Tavern growth as well as supermarket rigger sales (see Appendix 3). In order to determine if the Brewery can supply this demand, and to evaluate growth potential more broadly, we needed to understand the maximum production capacity of the Brewery in the current state. The question was posed:

> *"What is the maximum volume of product we could make at this site?"*

4.3 Approach

The Theory of Constraints (ToC) was used as a framework to analyse and circumvent production constraints. As described in Appendix 4, the ToC approach is to:

1. Identify – determine the process constraint;
2. Exploit – make quick improvements to the constraint;
3. Subordinate – ensure all other steps support the needs of the constraint;
4. Elevate – increase the effort if the constraint has not been lifted by the exploit step;
5. Repeat – start at step 1 again if the previous constraint has been lifted.

Usually the ToC focuses effort to one constraint at a time; however, because this is a theoretical exercise to determine maximum capacity, multiple constraints were analysed at once.

In order to constrain the possible options and to avoid options with very large capital expenditure, the brewing process (steps 1-5 in Figure 11, Appendix 2) was set as the independent variable – in other words, the fundamental constraint. By modelling the annual maximum brewing output (AMBO), this volume could be tracked downstream to determine processes that would further constrain the AMBO.

4.4 Annual Maximum Brewing Output Modelling

Note: Refer to Appendix 8 (page 48) for a full list of assumptions and calculations for each step.

The brewing equipment is constrained to 2500 litre batches per "brew"; however, two brews can be completed per day by adding a second, late-start brewing shift. By calculating the maximum number of brews that can be completed in the busiest months (October and November – Figure 7, Appendix

1), and using past sales history to determine proportional brewing demands during the rest of the year, the AMBO was modelled to be approximately 800,000 litres (Table 3).

At this volume of brewed product, we would need to accommodate the volumes shown in Table 4 for each main process.

Table 3. Brewing requirements for each brewed product at AMBO.

Product	Brewing volume proportions (mean 2012-2014)	Volume required at AMBO (L)	Approx. annual brews required at AMBO	Brews required at AMBO in Oct-Nov
Best Bitter	3.6%	28,755	12	2
Blonde	3.4%	26,786	11	2
Doppelbock	1.3%	10,478	4	1
Fern Draught	5.9%	47,391	19	4
Ginger Lager	2.1%	17,120	7	1
IPA	11.3%	90,142	36	7
Pale Ale	5.5%	43,554	17	4
Pilsner (inc. Fern Lager)	32.6%	260,450	104	22
Porter (inc. Fern Dark)	7.1%	56,956	23	5
Scotch Ale	6.6%	53,064	21	4
Tasman Lager	15.3%	121,770	49	10
Limited releases	5.2%	41,370	17	3
Total	100.0%	**797,836**	**319**	**66**

Note: Although the product range is larger than shown in Table 3, this is the full suite of products that are brewed, fermented, and conditioned, using steps 1 to 9 on the Process Diagram (Figure 11, Appendix 2).

Table 4. Volumes required to be processed in each step at AMBO.

Process	Required volume	Peak monthly units required
Fermentation	797,836 L (319 brews)	82,500 L (Oct/Nov)
Conditioning	797,836 L (excluding waste) (319 brews)	82,500 L (Nov/Dec)
Bright beer storage	917,970 L (399 brews)*	105,800 L (Dec)
Packaging: Riggers	213,671 L	18,124 riggers (Dec)
Packaging: Kegs	704,298 L	50 L kegs – 1,505 kegs (Dec)**
		30 L kegs – 197 kegs (Dec)

**Some products are produced at the "Bright beer storage" step, explaining the increase in number of brews required at this step.*

***Value for 50 L kegs is an over-estimate, as the source data includes sales from 25 L kegs.*

4.5 IDENTIFYING CONSTRAINTS

Note: Refer to Appendix 9 (page 52) for a full analysis of the production constraints.

The constraints in Table 5 were identified by manual scheduling, quantity modelling and discussions with key users or contractors. They are ordered by the level of constraint, and the estimated capacity that can be achieved without circumventing the constraint. Risks to achieving the AMBO are also given.

Table 5. Summary of production capacity constraints and risks.

Priority	Constraint	Details of constraint	Limits to
1	**Refrigeration**	During the summer months, the cold room refrigeration is overworked [21, 31]. Adding extra product will cause the cold room to operate above the maximum temperature and affect product quality.	575,000 L
2	**Fermenter cooling**	The same condenser is used to provide cold water for wort cooling and fermenter cooling. With double-brew days and increased fermenter use, it is likely that both processes will suffer, resulting in product quality issues.	600,000 L
3	**Conditioning capacity**	At AMBO, 66 brews need to be conditioned in the two months of October and November. With current tank space and conditioning process, capacity is only 44 brews in two months at 100% scheduling efficiency.	600,000 L
4	**Keg stock**	Not strictly a constraint as keg stock has been managed to be just above demand, but extra kegs will be needed.	600,000 L
5	**Electrical capacity**	Currently have 200 A fuses which are nearly fully loaded [32].	650,000 L
6	**Rigger storage**	In December, rigger storage before dispatch is challenging due to a lack of space. This can be managed up to a point by using alternative chillers, but will eventually have too great an impact on efficiency.	650,000 L
Risk	**Fermenter capacity**	Based on manual scheduling trials it is possible to ferment 66 brews over Oct/Nov, as required at AMBO. Equipment downtime or fermentation cycle overrun would put a significant constraint on the ability to ferment the AMBO in Oct/Nov.	915,000 L
Risk	**Scheduling**	Manual scheduling is increasingly time-consuming and complex as the number of brews increases. Scheduling is carried out by Tracy Banner, and is unlikely to be as efficient if carried out by someone with less experience.	915,000 L
Risk	**Hot water use**	Double brew trials have shown that the hot water can be managed adequately. However, as production volume increases, the risk of running out of hot water through error increases, which would put significant strain on key brewery processes.	915,000 L
Risk	**Water availability**	Possible water shortages during drought, depending on water infrastructure changes. See Appendix 9 – Water supply.	Unknown
Risk	**Cold water for dilutions**	Cold water tank has a limited capacity, and takes several days to cool. By increasing production volume water will have less time to cool, which will delay the carbonation of some products and cause a constraint.	Unknown

4.6 Alleviating Constraints

The constraints may be alleviated or circumvented through the options listed in Table 6. These options are listed under the level of action required ("Exploit", "Subordinate" or "Elevate"), and give estimates as to the capacity after the action has been taken. See Table 16 (Appendix 10) for a full capital expenditure summary.

Table 6. Summary of options to alleviate or eliminate the identified constraints.

Constraint	Action ref. # and ToC level	Details of action	Rationale	Cost	Increases capacity to
Refrigeration	**1** - Exploit	Minor changes to operational procedures to reduce refrigeration demand, including: •Regular maintenance of evaporators and condensers; •Ensure that no water is spilled onto the cold room floor; •Cold CIP procedures for bright beer tanks (Appendix 8); •Remove 600 L tanks, reducing the number of CIPs required.	Reducing cold room moisture and heat added to the cold room through hot CIPs and open doors will reduce the refrigeration workload [33]. Regular cleaning and maintenance of refrigeration equipment helps to maintain high efficiency [33].	Negligible	Unknown
	2 - Exploit / Elevate	Purchase and install five wind-driven ventilators into the Brewery ceiling [31, 34].	Temperatures in the Brewery can exceed 42°C in the summer (based on measurements taken in Jan 2015). This causes the high pressure hot air to rush into the cold room when the doors are open. Passive ventilators can reduce the air temperature to the ambient temperature (maximum 30°C), significantly reducing the amount of heat energy that enters the cold room, thereby reducing the workload of the evaporators and condensers.	$ 6,037.50	650,000 L with operational changes outlined above – uncertain
	3 - Elevate	Purchase and install additional condenser, evaporator and associated control units and pipework [31].	A 64% increase in volume from current production to the AMBO would require additional refrigeration capacity [21, 31].	$ 172,194.56 (although multiple options exist)	915,000 L
Fermenter cooling	**4** - Exploit / Elevate	Add insulation to fermenters and cooling pipework [35, 36].	There is significant cooling efficiency loss from the cooling pipework and fermenter jackets, through convection from warm air and conduction from condensation [21, 31].	$ 7,010.20	65,000 L
	5 - Elevate	Shift cooling condenser to the opposite side of the Brewery [31].	Condenser is currently poorly positioned so that the pressure and efficiency is low. Moving the condenser closer to the site of use will improve pressure and efficiency [21, 31].	Included in cost for new condenser/evaporator in "Refrigeration"	915,000 L
Conditioning capacity	**6** - Exploit	Reduce conditioning cycle time from 28 days to 14 days, especially for Pilsner and other 5% beers.	The conditioning cycle at the Brewery is a minimum of 28 days in order to achieve product quality and consistency. However, evidence [37-39] suggests that 14 days is ample to achieve the desired product quality. Reducing conditioning time has a major impact on conditioning constraints (see sensitivity analysis in Appendix 10, page 59).	Negligible	800,000 L or more with high scheduling efficiency
	7 - Subordinate	Add second draw-off points to five of the existing bright beer tanks [40].	Rigger-filling lines currently draw beer from small tanks. These small tanks add a disproportionate amount of effort to operations. Adding second draw-off points to the larger bright beer tanks will allow the removal of smaller tanks.	$ 3,881.25	(Supportive measure)
	8 - Subordinate / Elevate	Replace four 2500 L conditioning tanks and four 2500 L bright beer tanks with 5500 L tanks [40].	There is no room to add extra tanks, but replacing existing tanks to those with larger volume will add capacity. Any capacity additions to the conditioning tanks need to be supported by capacity additions to bright beer tanks, to ensure no constraint is added.	$ 125,235.00	915,000 L
Keg stock	**9** - Elevate	Purchase new keg stock as required [41].	Additional sales necessitate additional kegs. These can be purchased in stages, rather than one lump order.	$ 134,563.78 (total cost, paid in stages)	915,000 L
Electrical capacity	**10** - Exploit	Replace the 200 amp switchboard fuse to 250 amp fuse [32].	200 A fuses are almost fully loaded. We can upgrade to 250 A fuses without changing the switchboard or mains lines, which would provide 20-25 kW extra power draw [32].	$ 230.00	700,000 L – uncertain
	11 - Elevate	Replace the switchboard and main electrical lines from the transformer with those capable of greater power draw [32].	Increases in current draw over 250 A will require new mains lines and switchboard. Brewery expansions would add significant electrical loading. For example, the 20 kW increase of the refrigeration upgrades would on their own warrant an upgrade [32].	$ 23,575.00	915,000 L
Rigger storage	-	Solution not yet found.	-	-	-

4.7 Conclusions of Constraints Analysis

The theoretical maximum production volume was determined by setting the brewing process as the fundamental constraint. This is because any "brew house" upgrades would come at a significant cost. Through modelling and conversations with experts, it was determined that the AMBO volume of 915,000 litres could be achieved through a series of equipment and operational process changes.

The conditioning capacity constraint can be largely alleviated by a low-cost (or no-cost) measure through reducing conditioning retention time. However, the refrigeration and cooling capacity needs to be upgraded at significant cost. This capital expenditure can be delayed by low-cost initiatives, such as improving ventilation and insulation, as well as simple changes to operational processes.

Any further production increases beyond the AMBO may be achieved by strict process control to reduce wastes, or by seeking customers that have a different seasonal demand profile. An analysis of the seasonal sales to different channels has shown that some customers have a large variance of product demand between summer and winter (see "Tahuna", Figure 10, Appendix 1). This seasonal demand variation creates a production bottleneck, and dictates the annual capacity. A more even demand would enable higher annual production volumes.

There are a number of limitations to this analysis, including:

- The analysis has several assumptions based on historical data. A noteworthy assumption is that the seasonal sales proportions will stay constant with growth;
- Lack of accurate data on equipment efficiency under different conditions;
- Uncertainty about the efficacy of operational changes;
- Limited analysis of process equipment, which excluded minor equipment such as pumps, liquid lines, etc.;
- Rigger storage constraint has not been solved;
- The analysis did not include how production increases affect revenue or profitability.

In addition, by increasing the Brewery output to the AMBO volume, a number of significant risks may arise, including:

- Reduced production redundancy and contingency, potentially leading to scheduling errors or issues arising from equipment failure;
- Lack of management redundancy – manual scheduling and operations management procedures will become too onerous for the Head Brewer, and there is currently no other person with sufficient experience to perform this management functions.

4.8 Recommendations for Maximising Brewery Production

PM1. Have the uncertainties and unknowns in this analysis reviewed by experts

Any capital investment should be delayed until there is less uncertainty about the capacity gains that can be made, and about the costs of upgrades such as the electrical infrastructure.

PM2. Determine the Net Present Value of capital expenditures within recommendations

This study did not analyse product revenues or profit margins. Each of the options to alleviate constraints should be measured against the profits to which they will directly contribute, using the Net Present Value equation.

PM3. Upgrade equipment and make operational changes over time

If there is sufficient value in the upgrade options (as determined in recommendation PM2), make operational changes and upgrade production equipment. Changes should be introduced in stages to match the predicted sales growth, as shown in Table 7 and Figure 3. This will ensure that the cost of debt from capital expenditures is optimised*. Note that this timeline will need to be adapted according to the actual growth strategy (to be determined by management), and updated according to actual sales results.

**In Figure 3, at 2016-2017, there is a large difference between capacity and forecasted production, suggesting an under-utilisation of capital. However, due to the nature of the upgrades, production capacity cannot be incrementally increased (cost-effectively) to match forecasted sales.*

PM4. Seek sales opportunities that avoid summer demand spikes

As shown in Figure 10 (Appendix 1), there can be a large seasonal demand variance – in summer the Tahuna tavern purchases more than 2.6 times the volume as they do in winter. When seeking sales growth opportunities, consideration should be given to the seasonal demand variation, such that production bottlenecks in summer are not exacerbated.

PM5. Conduct an equipment risk analysis

By increasing the efficiency of the production process redundancy is inherently reduced. Unexpected equipment downtime could cause significant loss of productivity if there is no redundancy; therefore, the Brewery should conduct a risk analysis of all equipment. This will help to determine the required preventative maintenance activities and an inventory of parts or spare equipment.

PM6. Investigate the value of production scheduling software

As the production volume increases, and production equipment asset utilisation increases, scheduling must become more efficient and accurate. Currently the Head Brewer manually schedules all production processes. This poses a risk of error, and of a lack of other expertise to carry out this function if the Head Brewer is unavailable. To ensure that scheduling does not pose an added constraint to the process, the Brewery should investigate the value of automated, linear programming-based [42] production scheduling software.

PM7. Consider a further TQM initiative aimed at reducing product waste

Production volume analysis is based on an 8% total product waste from brewing to packaging and sale. Reducing this wastage by 50% would add over 30,000 litres to the total annual sales at AMBO, as well as reduce the cost of trade waste. "Lean Six Sigma" [43] is a comprehensive framework/tool for reducing process waste, and could be integrated into a wider TQM framework.

Table 7. Roadmap of Brewery changes to increase production capacity.
Note: the action reference number refers to that given in Table 6. Detailed costs are given in Table 16. It is suggested that Tracy Banner is responsible for actioning these tasks.

When	Recommended action (and action reference number)	Approx. cost
Winter 2015	**1** - Minor changes to cold room use	Negligible
	2 - Install ventilators	$ 6,000
	4 - Install insulation	$ 7,000
	6 - Decrease conditioning time	Negligible
	10 - Upgrade electrical fuses	$ 300
Winter 2016	**11** - Improve electrical supply infrastructure	$ 25,000
	7 - Install second draw-off points for 5 B tanks	$ 3,900
	8 - Install new U and B tanks	$ 125,000
	3 and 5 - Install new refrigeration capacity and cooling condenser location changes	$ 175,000 (Depending on option taken)
2015-2019 as needed	**9** - Purchase keg stock	$ 135,000 (Total, to be purchased in parts)
Total		**$ 477,200 (+/- $ 50,000)**

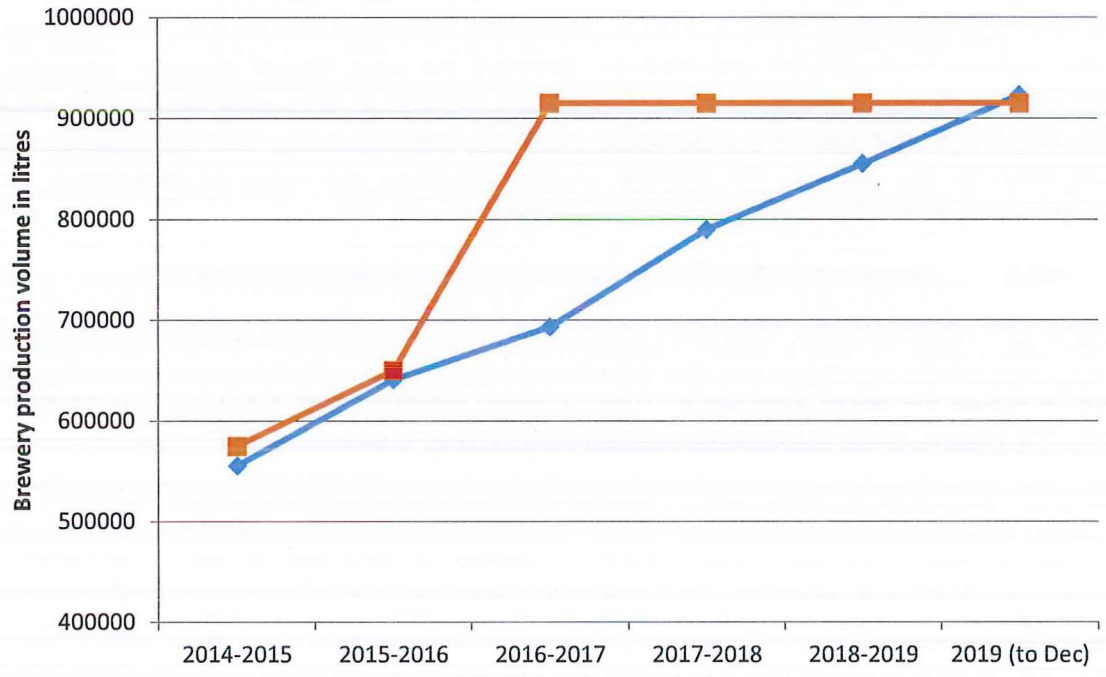

Figure 3. Future Brewery production capacity vs sales demand.
Brewery production volume expansion roadmap to December 2019, with the forecast sales in blue, and the expected production capacity in orange. The red point denotes a high level of uncertainty about the production capacity. The assumptions for this implementation roadmap are given in Appendix 1.

5 PROJECT INTEGRATION AND CONCLUSIONS

This project used TQM to direct the following sub-projects:

1. To finalise, implement and initiate the registration of a Food Safety Programme;
2. To develop a Health and Safety Plan for centralised management of Brewery health and safety, and to implement changes to high-risk operational procedures; and
3. To identify the maximum production output possible at the current Brewery site.

Each of these sub-projects is centred on the "process" aspect (Figure 1), but influences or is directed by each of the other business aspects. Below is a summary of the present and future considerations for each of these business aspects:

5.1 MARKET AND CUSTOMERS

There is a growing demand for craft beer in New Zealand. To capitalise on this, the S&F must expand their brand awareness through targeted, concentric growth from the Nelson and Wellington regions.

Historically, S&F taverns have performed well, but this could be for a number of reasons specific to their locality (significant brand awareness in Nelson), or timing (growing with the craft beer industry as a whole).

Future growth should not rely on the same market forces that drove historical growth.

5.2 PROCESS

Eliminating the production constraints identified will allow an increase in production of around 64%. This will require significant capital investment and changes to workflow, but can be managed if done so deliberately and with a unified goal.

Particular attention should be paid to improving process efficiency, by:

- Reducing error through measurement and standardisation. Six Sigma provides an effective framework for setting up the measurement metrics and reducing waste;
- Adopting automated process and management systems (see *recommendation PM4*).

Currently the Brewery holds a competitive advantage over many other craft beer manufacturers in that all orders are consistently fulfilled. This is a valuable trait that should be retained.

On the other hand, the Brewery should balance process optimisation and consistency with the experimentation required for product innovation. One way to achieve this is to change the product offering more often with contemporary beverage styles.

5.3 PEOPLE

Developing a culture of continuous improvement is paramount to the success of TQM initiatives (see Appendix 5, page 37). The current operations team has a range of attitudes towards change (see Table 10); all staff need to buy in to the benefits of the change initiatives if they are to be successful.

A continuous improvement culture can be developed by:

- Sharing the strategy with staff so that they have a goal to work towards;

- Focusing on only a few key change initiatives with tangible benefits to the staff;
- Implementing changes in trial periods prior to formalising changes with new rules and regulations;
- Setting-up standard processes for learning from mistakes;
- Focusing on improving the productivity and communication of the operations team through regular team meetings, clear task divisions and improved team coordination by the Production Team Leader.

Culture change should be seen as a priority, but also as a long-term initiative.

Training staff in TQM philosophies and tools will be necessary to enable them to take part. In addition, staff should be trained specifically in areas of food safety and H&S (*recommendation HS3*).

People in the supply chain are often neglected from a TQM perspective, but it is important to be collaborative with suppliers and distributors to smooth out the "rough edges" caused by process changes. In particular, the Brewery should support suppliers where there is a tangible mutual benefit (*recommendation FS2*).

5.4 LEADERSHIP

In a small company, the values and ethos of management very quickly disseminate and influence the culture of the organisation. Indeed, the staff have a deep respect for management at the S&F Brewery, and are therefore more likely to mimic their values. A continuous improvement culture will only develop if there is total management commitment.

There appears to be a strong management focus to cut costs (personal observation). This ethos may direct the behaviours of operations staff towards "cutting corners". By expressly focusing on standardisation and quality control to achieve cost reductions, operational drift may be reduced.

5.5 MEASUREMENT AND ANALYSIS

Continuous improvement is the main aim and result of self-assessment; therefore, efforts should be made to measure and analyse cultural evolution and process improvement. Suggested performance metrics are given below:

- Health & safety – see *recommendation HS5*
- Food safety and productivity – product recalls or non-conformance (*recommendation FS3*)
- Staff satisfaction
    - Staff H&S Survey
    - Informal monitoring and quantification

5.6 STRATEGIC PLANNING

By understanding the production limitations of the Brewery, management can now develop a growth strategy to match their sales volume boundaries. Undeniably, strategic planning requires more attention. In addition, staff should be made more aware of the strategic objectives so that they can better understand how their role affects the business results.

5.7 BUSINESS RESULTS

The ultimate driver for this project has been to increase cash flow for the Brewery.

The next step, in terms of the production maximisation modelling, will be to determine the revenue and cash flow forecasts based on sales growth and capex estimates. This will determine the true value of the proposed recommendations.

From a continuous improvement perspective, following the TQM path will likely have a greater effect on non-financial performance indicators [44], at least for the first few years. The Brewery should make a long-term commitment to continuous improvement to achieve financial business results.

5.8 Future Total Quality Management Initiatives

This project has drawn on TQM and other QMS tools, but was not intended to be a holistic overhaul of the business in the way that TQM demands. So the lasting question is: *should the S&F Brewery now implement a full TQM programme?* The answer is probably no, given the requisite time and resources far in excess of what is currently available. With that said quality improvement can continue to be approached in stages (see Table 8), to strategically improve critical business aspects [45]. By making incremental tangible improvements, a culture of continuous improvement may develop, enabling further TQM initiatives in the future.

A pre-eminent recommendation to kick-start a continuous improvement culture is to deeply understand the customers' perception of quality (Appendix 4). This can be achieved by:

- Extensive market research of current and potential customers, to uncover why they do or might buy S&F riggers, or drink at the S&F taverns; and
- Bridging the gap between Brewery staff and the customers, so that the staff gain insight into how their attitudes and behaviours in the Brewery affect the product quality.

Only when S&F staff and management truly understand how to add the most value to their customers can they fulfil their growth strategy.

Table 8. Summary of recommendations for TQM initiatives.

Ref.	Recommendation	Suggested responsibility	When
TQ1	Undertake an extensive market research project to fully define the customers' perspectives of quality, and market forecasts for the next five years.	Marketing Exec., Sales Manager	ASAP
TQ2	Train staff in TQM philosophies and the customers' perception of quality, such that they can see how their work impacts the value of the product.	Marketing Exec., Production Team Leader	ASAP
TQ3	Introduce measurement and analysis procedures for food safety, H&S and staff satisfaction.	Production Team Leader	ASAP
TQ4	Develop and begin to implement a long-term plan for fostering culture change using the recommendations given in Appendix 5.	Managing Director, Production Team Leader	ASAP
TQ5	Introduce all staff to the growth strategy to engage them in continuous improvement towards the growth goals.	Managing Director	After growth strategy has been defined

6 Personal Reflection – Lessons Learned During the Project

Of utmost importance, this project has taught me about my personal response to certain working conditions. Specifically, I found myself developing moderate anxiety, which negatively impacted my productivity ("Practice") through indecisiveness and "analysis paralysis" (Figure 4).

To understand the sources of my anxiety I used a series of self-reflection questionnaires. I found that a fear of negative evaluation from my supervisor and sponsor was driving my anxiety. In the past I have performed well academically (in "Theory"). However, in practice I found that I did not excel or meet my own expectations. This mismatch, along with a sense of perfectionism, caused the fear of negative evaluation (Figure 4).

The reason I performed below my expectations was because of the independence and complexity of the project (Figure 4). The S&F Brewery is a small company, managed largely by my sponsor. In this regard I had a lot of exposure to many aspects of the business, from customers, to process requirements, through to the pressures from external stakeholders. These issues compounded, with the result that analysis and decision-making became extremely difficult.

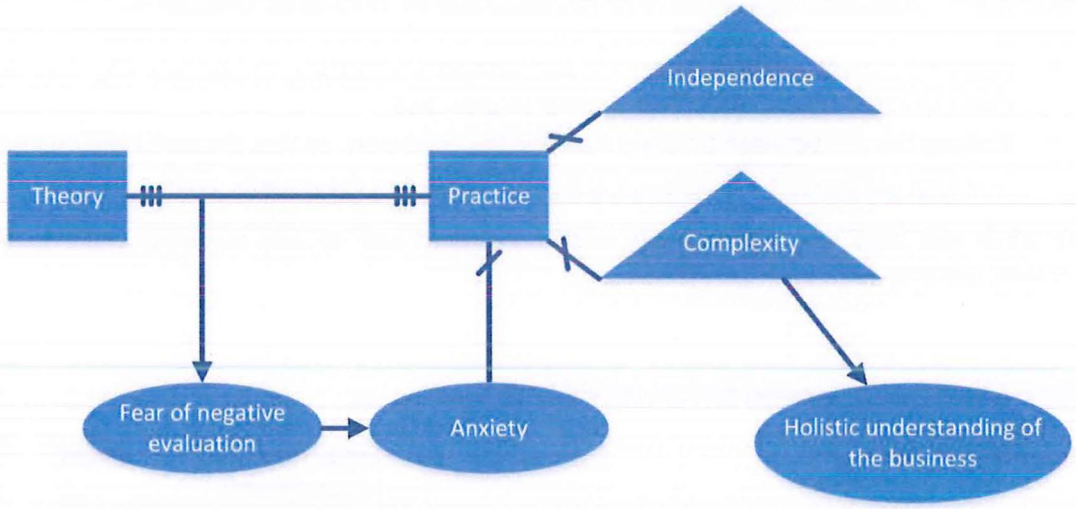

Figure 4. Summary of the influences this project has had on the author.

On the other hand, the complexity of the project has taught me a great amount about how small businesses might operate (Figure 4). This exposure to a complex environment will put me in a strong position to deal with complexity-induced anxiety in my future career.

Future MEM students suffering from anxiety during their project should follow the process below:

1. **Learn about anxiety.** Do some research into the different forms of anxiety and their causes.
2. **Identify sources of anxiety in your life.** Anxiety is a symptom created by a range of personality, environmental and lifestyle conditions. Only once you understand what causes your anxiety can you begin to manage it. Each time you become anxious, note the cause.
3. **Change or control the causes.** It could be something as simple as avoiding coffee, or might be a more difficult problem to get around; either way, changing or controlling it is essential.

In my case, I now understand how important it is for me to work in a collaborative team-environment. I can control my anxiety by surrounding myself with talented people who can act as "sounding boards" when I am facing complexity. This learning point will guide my career choices.

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Appendix 1. Sales Data and Demand Forecasting

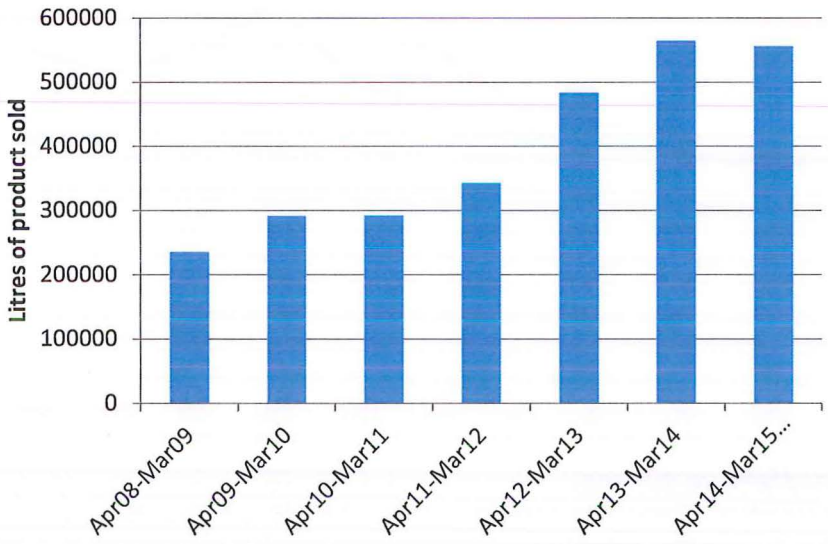


Figure 5. Historical annual sales volumes.
Annual sales volumes (litres) by year, including a forecast for the 2014-2015 financial year.

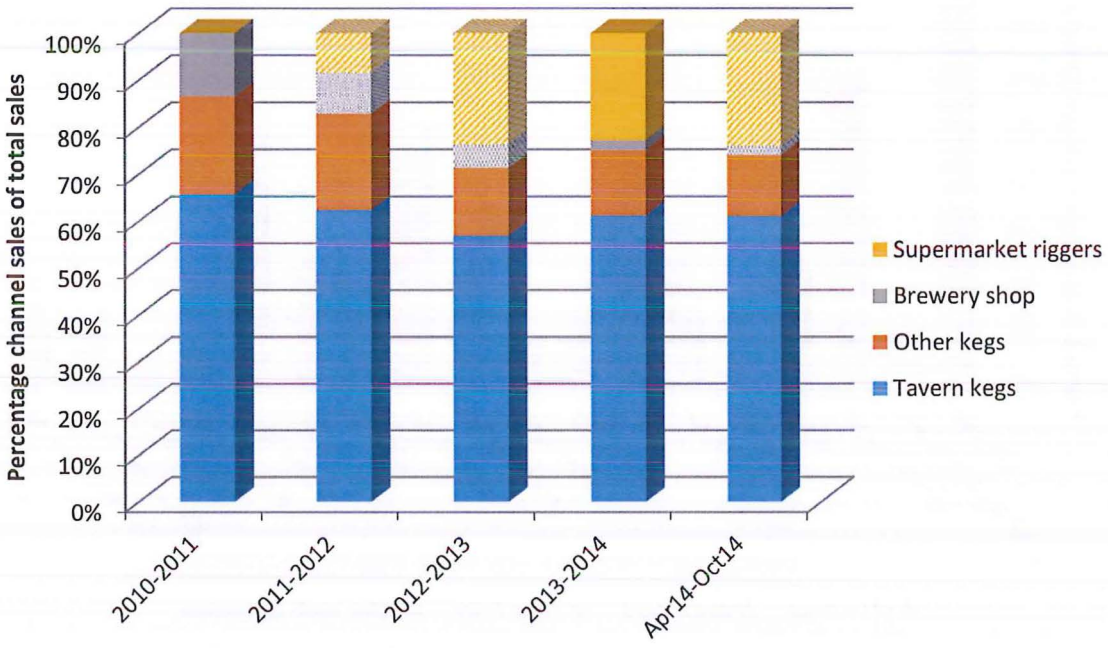


Figure 6. Annual sales proportions for different channels.
Annual sales for different distribution channels as a percentage of total annual sales. Semi-shaded bars represent predicted data.

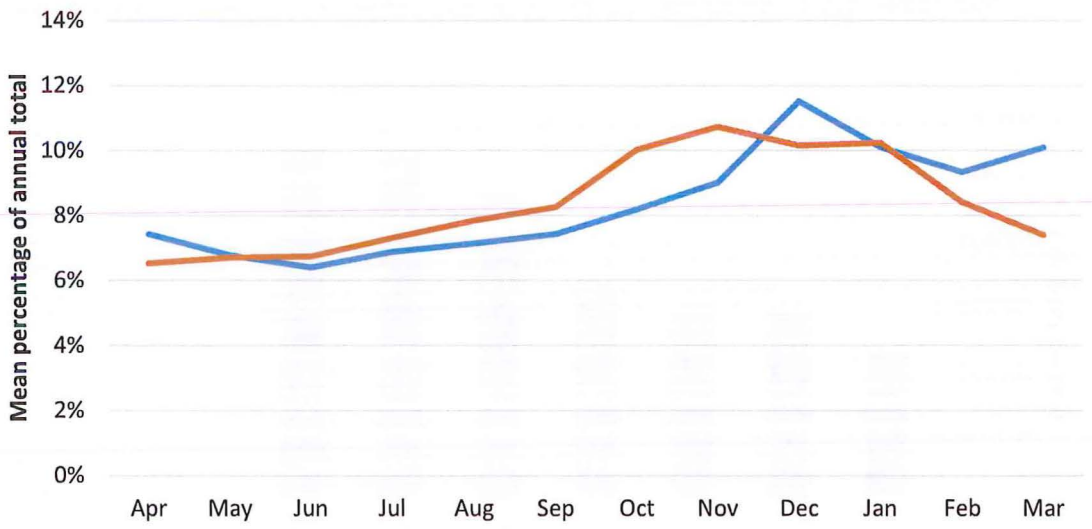


Figure 7. Seasonal sales and brewing demands.
Sales for each month as a percentage of total annual sales (blue line, mean of data from 2008-2014), and the calculated brewing demand as a percentage of total annual production (orange line, mean of data from 2008-2014).

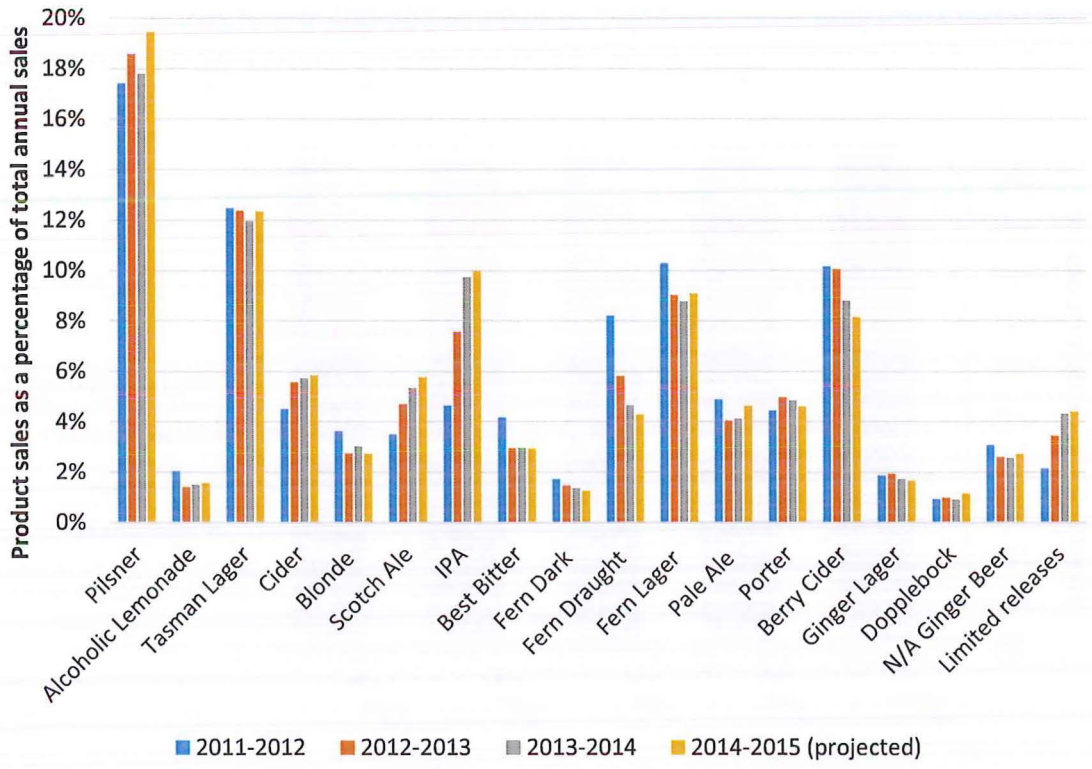


Figure 8. Product sales proportions.
Full list of the 17 core products plus grouped limited releases, showing their sales proportions as a percentage of total annual sales for the last four years.

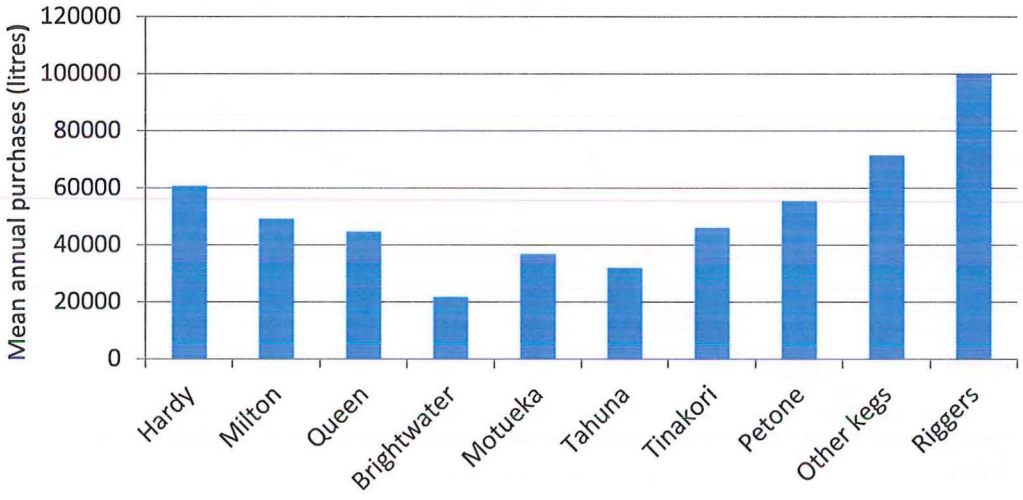


Figure 9. Product sales to different channels.
Annual product sales (mean of 2010-2014 data, where available) to the S&F taverns (Hardy, Milton, Queen, Brightwater, Motueka, Tahuna, Tinakori and Petone), keg sales to other outlets, and total rigger sales.

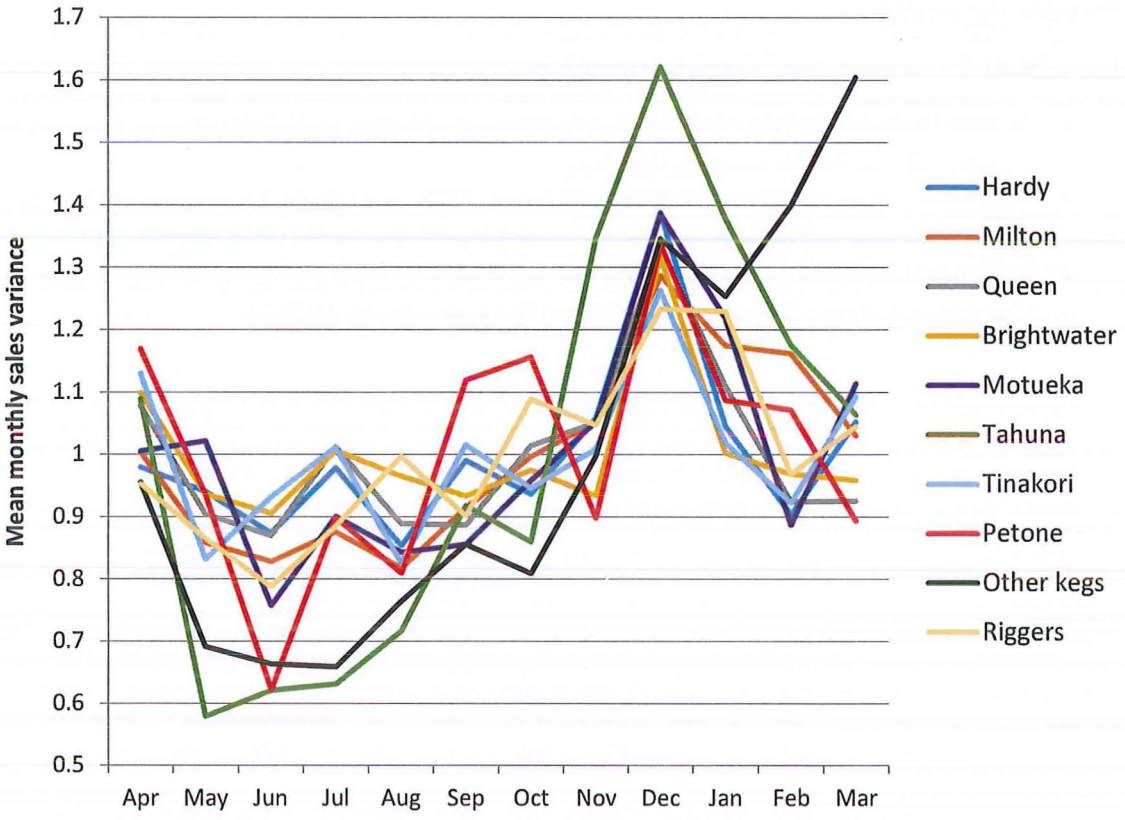
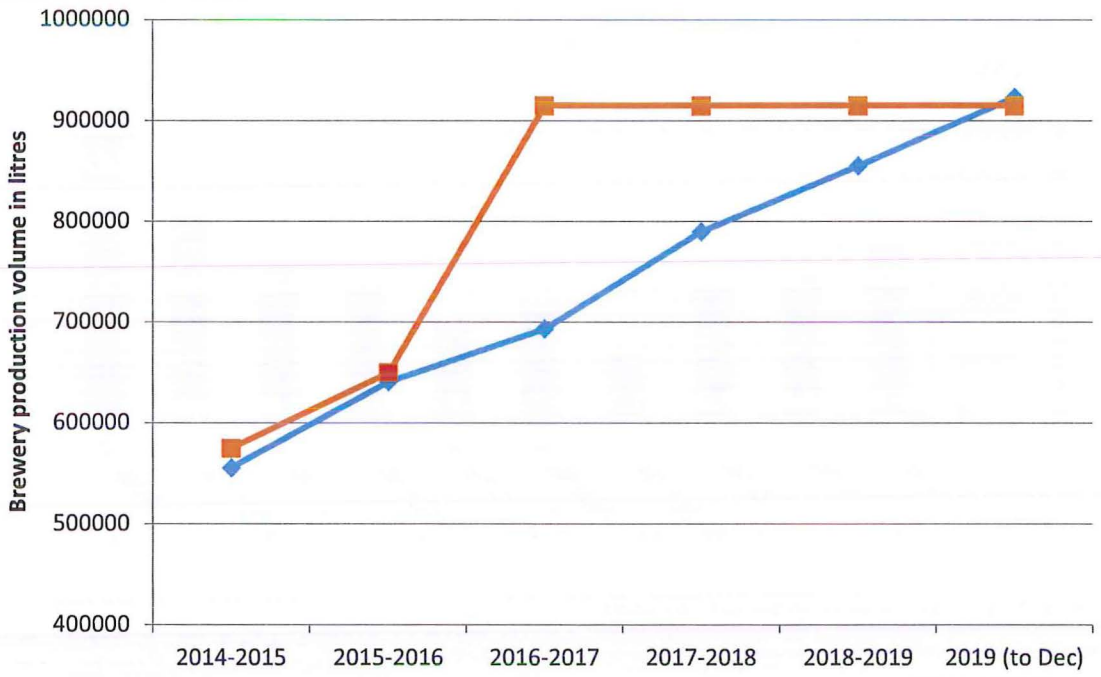


Figure 10. Variance of monthly product sales by channel.
Variance of monthly product sales (mean of 2010-2014 data, where available) to the eight S&F taverns (Hardy, Milton, Queen, Brightwater, Motueka, Tahuna, Tinakori and Petone), keg sales to other outlets, and total rigger sales. Variance is shown relative to the annual sales divided by twelve.



Copy of Figure 3. Brewery production volume expansion roadmap to December 2019, with the forecasted sales in blue, and the expected production capacity in orange. The red point denotes a high level of uncertainty about the production capacity.

Note: Figure 3 is based on the following assumptions:

- In 2015 there will be two new S&F taverns opening – Mapua, at 35,000 L annual demand, and "Tavern 10", at 30,000 L annual demand;
- Five further taverns will open between 2016 and 2019, at a rate of 3 taverns every two years. These are predicted to have a median annual sales demand of 40,000 L each;
- Rigger and "other keg sales" growth will continue at a compound rate of 10% each year;
- The Brewery shop will close in 2016, reducing rigger sales by 10,000 L.

Appendix 2. PROCESS DIAGRAM

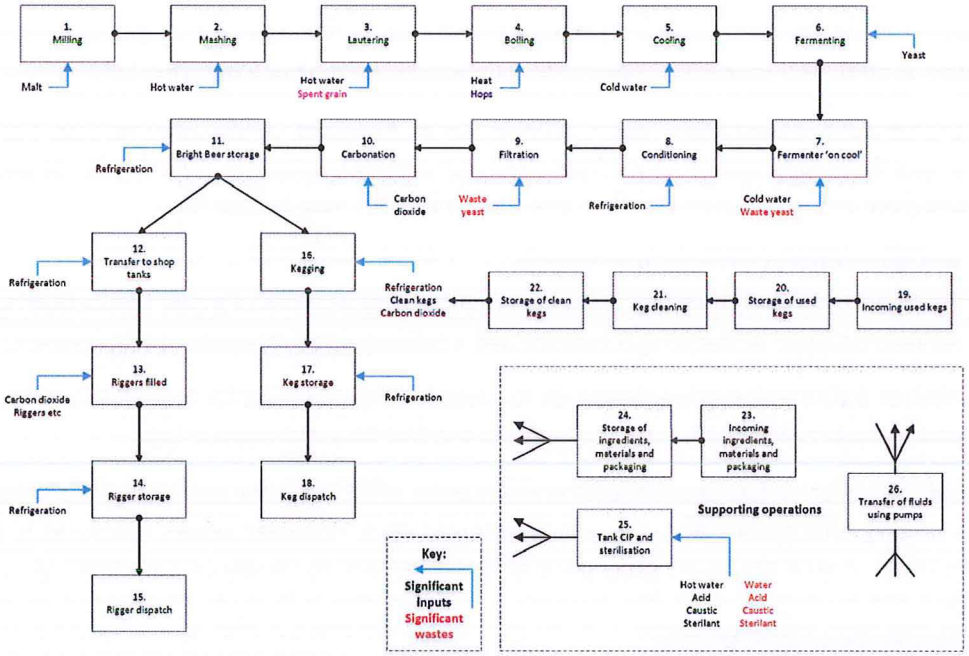


Figure 11. Brewery process flow-diagram.
Operational process diagram for the Brewery, showing significant inputs (black writing) and wastes (red writing).

Appendix 3. Market Analysis for the Sprig & Fern

New Zealand craft beer market

Since 2008, beer consumption in New Zealand has dropped by 10%, but craft beer sales have soared [2, 3] - in 2013 alone craft beer sales increased by 30% [2]. This growth is driving an increasingly competitive craft beer market, with the number of breweries in New Zealand more than doubling since 2009 [2, 3]. Although the rapid market growth has often been referred to as a "bubble", there is evidence to suggest that the craft beer industry will not "burst" but instead begin to plateau [4].

In a competitive market consumers can afford to be choosy. Indeed, there is an increasing demand for craft beer innovation, through new beer styles [2, 5, 6], new packaging types [7], and business models [8, 9]. Some innovative breweries are struggling to keep up with the growing demand [46].

Demand for further Sprig & Fern taverns

There are currently six S&F taverns operating in the Nelson/Tasman region, and a further two in Wellington. A ninth S&F Tavern will open in Mapua within the next few months [10].

In 2013 the Brewery opened a S&F Tavern in Drake Street, Auckland. Unlike other taverns, this venture was financed internally rather than franchised to external investors. The Drake Street tavern underperformed and was closed less than one year later. This may be due to:

- A lack of brand awareness in Auckland;
- Low pricing of food, resulting in the tavern appearing as more of a café than a tavern;
- An overestimate of the sales forecasts, and a subsequent over-spend on development [1].

Despite this set-back there is strong evidence to suggest a high demand for new S&F taverns. Indeed, several parties have expressed interest to invest in the S&F Tavern franchise [1].

Household consumption has been modest in many parts of NZ in recent years, largely attributable to reduced housing affordability and increasing consumer debt. However, recent measures to increase housing supply, as well as the declining price of fuel, may lead to increased household spending [2]. In the food and beverage sector, this increase in consumption is likely to be directed on-trade [2], supporting the demand for taverns.

Submarkets to focus growth efforts

Craft beer drinkers tend not to show brand loyalty, and instead seek new and varying products [3]. Contrary to the observed trend, a major competitive advantage of the S&F is the consumers' love for the brand [1]. However, this brand loyalty is likely to dissipate further away from its home in Nelson, evidenced by the failure of the Drake Street tavern. Therefore, growth of the S&F brand should be targeted towards proximal regions, such as Christchurch and Wellington.

Wellington and Christchurch both have relatively low unemployment rates [47, 48], and are pursuing economic growth in high value-adding industries, such as ICT and manufacturing [49, 50]. Consumers from these industries tend to be comfortable with relatively high levels of consumption, particularly in hospitality.

The Canterbury earthquakes caused and will continue to cause significant instability in Christchurch. As the city rebuilds there will be dynamic market forces within different suburbs. For example, when

rebuilt, the city centre is likely to draw back patrons from decentralised areas. Having "a finger on the pulse" in Christchurch will be paramount when assessing opportunities for new S&F taverns.

The two S&F taverns in Wellington have performed well by sales (Figure 9, Appendix 1). This is not surprising, given Wellington's status as a craft beer "hotspot" [51]. However, given the highly competitive and innovative craft beer landscape in Wellington, remaining "fashionable" may require sensitivity and responsiveness.

Conclusions and recommendations:

Look for ways to innovate products, packaging and distribution.

The outlook for craft breweries in New Zealand is promising if they are able to differentiate themselves, and continuously improve their offerings. The simplest way to do this is by distributing the limited release products to supermarkets along with the core product range. To innovate the beer itself, consider:

- Collaborative brews with speciality ingredient manufacturers or other craft breweries, in order to leverage off their brand awareness;
- Using new hop varieties in trial brews, as the S&F Brewery is well positioned to use hops from the Tasman-based NZ Hops Ltd.

Expand brand awareness

Riggers are distributed nationwide, while S&F taverns are only located in Nelson and Wellington. The Brewery should leverage the uncharacteristic "brand love" for the S&F by expanding the brand awareness in targeted areas. One way to do this is to focus rigger sales efforts in areas that are proximal to a S&F Tavern.

Improve sensitivity to local market conditions

The highly dynamic market conditions within Christchurch present both opportunities and risks for potential new S&F taverns. Any opportunities should be assessed with extra diligence, and potential franchise owners should only be considered if they have a thorough understanding of their market changes.

Wellington has a strong craft beer culture, and competes with Nelson for the title of "Craft Brewing Capital of NZ" [51]. The Sprig and Fern Brewery uses this term in some marketing campaigns. However, its use might prompt some Wellingtonians to buy a local Wellington product instead. Given that Wellington is a strong area for tavern and supermarket rigger sales, the use of this term should be reconsidered.

Appendix 4. Quality Management Literature Review

What is quality management?

Quality management aims to deliver a better product or service, based on the customers' perception of quality. Quality improvement initiatives often focus on the pursuit of:

- Consistency of offering
- Speed of manufacture or service delivery
- Flexibility to market demands
- Reducing operating cost to deliver a cost saving to the customer

These goals are clearly directed at improving the value for customers. Quite often, however, QMS are discussed in terms of their benefits to the organisation itself, which include:

- Fewer defects, leading to reduced rework and lead times
- Lower inventory levels
- Operating cost reduction
- Increased employee and customer satisfaction
- Enhanced business competitiveness

The combination of value added to the business, both directly through operational improvements, and indirectly through increased market share, logically should result in greater profit. Pursuing quality improvement, therefore, is a fundamental business imperative. But how do businesses go about it?

A quality management system (QMS) is a framework developed to improve product or service quality. Many different types of QMS exist, which may focus on one or two key business aspects, or may consider the business holistically. These QMS have evolved over the last 60 or so years, and some are more "fashionable" now than others. Essentially, though, each QMS strives to identify changes that will add value to the customer.

Total Quality Management

Total Quality Management (TQM) represents an integrated approach to pursue customer satisfaction. It has the following focus areas:

1. Market and customers
2. Process
3. People (workforce)
4. Leadership (management)
5. Measurement and analysis
6. Strategic planning
7. Business results

Each of these focus areas is considered in terms of how they can be continuously improved.

TQM focuses on how the company culture and organisation can influence the quality of products or services. The principle of TQM asserts that if a company's management and staff are driven towards continuous improvement, they shall achieve better business results. In this regard, TQM is centred on developing company culture.

Critical success factors of, and barriers to TQM implementation

Culture change is essential for the successful implementation of TQM [44, 52-55] – see the culture change literature review in Appendix 5 (page 37). In addition, full management commitment is paramount to the success of quality improvement initiatives. This transpires when managers or leaders:

- Focus on strategic quality planning – long-term planning about how quality improvements will influence the business;
- Empower the staff for continuous improvement – staff need to be trained in continuous improvement theory and tools, allowed to engage with customers to understand how their work contributes to customer satisfaction, and be provided with standards that make it simple to achieve process consistency;
- Promote open communication between the staff, and with management themselves – visual management tools provide an effective means of communicating goals and progress [44, 53, 55-57].

Small businesses may find some aspects of continuous improvement easier than do large companies, because:

- Culture is very perceptual. In small businesses, the workforce has more interaction with leaders, and therefore more opportunity to be influenced by the values and goals of management;
- Staff need to understand the customers' perception of quality in order to work towards improving it. Small companies often provide a greater opportunity for the workforce to interact with and learn about their customers [52].

On the other hand, small business must face the challenges of:

- A lack of human and capital resources;
- Lack of management support to focus efforts into indirect business improvements;
- Because there are few staff, one or two individuals who do not "buy in" to the continuous improvement culture may disproportionately affect the outcome;
- Small businesses find it more difficult to attract and retain high calibre staff [52].

These critical success factors – culture change and management commitment – are considered to be "soft" factors. Shin, *et al.* argues that TQM initiatives often fail, not because of the "soft" TQM principles, but because of a lack of effective systems to allow TQM execution [58]. TQM was popular in the 80s and 90s, but has since been overshadowed by Lean, Six Sigma, ISO9000, etc. This may be because these newer frameworks offer more systematic guidelines for undertaking continuous improvement initiatives [59]. However, TQM is adaptable in that it can frame a number of interlinked QMS into a holistic continuous improvement effort. For example, Six Sigma might be best applied to a particular process step, in which case its use would be appropriate for that step only. Here, TQM is the quality improvement framework, and Six Sigma is a quality improvement tool. Therefore, if TQM is pursued, it needs to be strategically planned with actionable tasks and systems to improve the quality of each business aspect (Figure 1).

Theory of Constraints

The Theory of Constraints (ToC) is one such QMS that is best thought of as a quality improvement tool to be utilised as part of a wider continuous improvement programme. It aims at expanding revenue by removing steps that constrain the business.

ToC assumes that every process has a bottleneck, and by focussing energies on that current constraint, rapid improvement to throughput can be made. The process is cyclic, and continually addresses the current bottleneck [60]. The ToC improvement process steps are described in the "Five Focusing Steps", Table 9 [60].

Table 9. "Five Focusing Steps" of the ToC.

Step	Objective
Identify	Identify the current constraint (the single part of the process that limits the rate at which the goal is achieved).
Exploit	Make quick improvements to the throughput of the constraint using existing resources (i.e. make the most of what you have).
Subordinate	Review all other activities in the process to ensure that they are aligned with and truly support the needs of the constraint.
Elevate	If the constraint still exists (i.e. it has not moved), consider what further actions can be taken to eliminate it from being the constraint. Normally, actions are continued at this step until the constraint has been "broken" (until it has moved elsewhere).
Repeat	For continuous improvement, once a constraint is resolved the next constraint should immediately be addressed. Go back to "Identify" step.

The ToC is an effective tool for systematically expanding productive capacity, and is much simpler than mathematical scheduling optimisation procedures to work around bottlenecks [42].

Implications for the S&F Brewery

The Brewery has recently undergone a period of rapid growth, followed by a production plateau (Figure 5, Appendix 1) and exposure to greater competition (summarised in Appendix 3). Two fundamental ways to remain competitive in a saturated market are to:

1. Improve the efficiency of operations; and
2. Add value to the customer offering.

Efficiency improvements can be achieved by increasing the productive output of the current Brewery plant (for example, by using the ToC), and by improving process consistency to reduce rework. This will require significant operational and culture changes. Key change management considerations include the need to:

- Design strategic activities with the Production Team Leader to make implementation as simple as possible for him [61];
- Communicate the strategy clearly and openly with staff;
- Use visual management systems to engage staff in the change process; and

- Train staff in a concise set of quality management tools so that they can help in the process to remove production bottlenecks.

Based on discussions with the Brewery operations staff, they are largely driven by the satisfaction of working in a productive and supportive team [21]. This strength must be leveraged to drive the culture change. It can also be used as a metric for monitoring the cultural evolution, e.g. by measuring staff's perceptions on team communication and productivity.

In order to improve the value of the product, both management and staff must have a thorough understanding of the customers' perception of quality. This will require:

- Extensive market research and improved sensitivity to market changes; and
- Exposing staff to the customers' perception of quality, such that they have a better understanding of how they can support continuous quality improvement.

So, should the S&F Brewery implement a full TQM programme now? The answer is probably no, given the amount of time and resources needed to overhaul the business. With that said, continuous improvement might initially be approached in stages, using sub-frameworks to improve some business aspects while always looking forward and keeping the next step in mind [45]. By making small and tangible improvements, a general culture of continuous improvement may develop, enabling further TQM initiatives.

Appendix 5. Culture Change Literature Review

An organisational culture centred on continuous improvement is essential for the successful implementation of TQM [44, 52-55], as well as for the management of H&S [62, 63] and food safety [64]. If staff don't buy in to the improvement changes, the resources spent developing tools, processes and management documentation will be wasted; after all, it is the actions of staff that dictates productivity and a safe working environment.

Organisational culture is dictated by past events [65], whereas a culture of continuous improvement requires the workforce to look forward and be driven by goals. This can only happen through effective communication and clear direction from management. Ways to lead a culture of continuous improvement include:

- Matching strategy and culture – determine the key performance areas for the business first, and guide the workforce towards that vision;
- Focus on a few critical areas – change is difficult, so you need to pick your battles and focus resources into the most important areas;
- Leverage the strengths of your existing culture – every team has strengths that can manipulated to achieve the desired change;
- Measure and monitor the cultural evolution – determine the key behaviours that demonstrate progress towards the strategic direction, and measure these behaviours. This will help to determine the efficacy of change efforts [66].

Culture change is often seen as a last-resort initiative to save a large organisation from crisis. However, small companies will equally benefit from efforts to develop positive culture. Small businesses may find culture change easier than large companies, because:

- Culture is very perceptual. In small businesses, the workforce has more interaction with leaders, and therefore more opportunity to be influenced by the values and goals of management;
- Staff need to understand the customers' perception of quality in order to work towards improving it. Small companies often provide a greater opportunity for the workforce to interact with and learn about their customers [52].

On the other hand, small business must face the challenges of:

- Lack of management support to focus efforts into indirect business improvements;
- Because there are few staff, one or two individuals who do not buy in to the continuous improvement culture ("Laggards", Table 10) may disproportionately affect the outcome.

Table 10. Change adoption characteristics.
Staff members can loosely be grouped into the following character categories with regards to adoption of change. Table adapted from [62] and based on [67].

Innovators	Eager for new experiences and willing to take risks, therefore the first to adopt. They are willing to experiment.
Early adopters	Make rational, informed decisions based on evidence and the experiences of the innovators. Early adopters pave the way for further adopter groups.
Fast followers	Eager to comply and fit in. As soon as the change becomes standardised this group will adopt the change.
Late majority	More sceptical or cautious about change. Non-compliance tends to be unconscious, meaning they need more reiteration of the new rules or standards.
Laggards	Take longer than others to adopt change, and may deliberately not comply. They will often have a rationale for non-compliance, which could be based on misinformation, or the result of traditional values. They may be confident that they know best.

Conclusions and recommendations

Small businesses have a fluid culture, but with every new staff member the cultural inertia increases. Therefore, directing the company culture should never be seen as a last resort to a crisis, but instead should be the first strategic approach [52, 66].

It is likely that staff numbers at the S&F Brewery will grow over the next few years. Some current staff members appear to be resistant to change initiatives (personal observation), and may pass this culture on to new staff. Therefore, the Brewery should already begin to focus on building a culture that fosters continuous improvement through consistency, standardisation and communication. This will not only aid but enable the transformations necessary to achieve the maximum production capacity.

Recommendations to develop continuous improvement culture are given below:

Let strategy guide culture evolution

The Brewery should first define its strategic positioning. For example, this could be:

- To consistently deliver quality craft beer; or
- To deliver innovative and contemporary products.

The implications of these two statements on staff behaviour will be very different; the former statement encourages standardisation and consistency, while the latter necessitates experimentation.

Once the strategic positioning has been clearly defined it should be shared openly with staff so that they can alter their day-to-day behaviour to match the company direction.

Focus on key change initiatives with tangible benefits

Early adopters of change (Table 10) need to see proven benefits before they buy in. By focusing on few key areas with some obvious benefits to the staff, they will begin to associate "change" with "improvement".

Implement changes before making the rules

Late majority adopters and laggards (Table 10) will be the greatest barrier to implementing improvements. To overcome this, avoid making rules and regulations at the outset, and instead implement change trials first. Setting rules can often have the effect of "turning staff off" and creating prejudice against the change. Therefore, trial a new process for some time, and then follow up with written formalities, such as regulations or standard operating procedures.

Create processes that enable learning and improvement

Management and staff need to be able to learn from their mistakes. Also, to engage staff in continuous improvement, they need to see that their feedback will be actioned. Therefore, it is important to set up processes that standardise learning and change initiatives. In the case of H&S, this can be achieved by accident reporting or using the Staff H&S Survey (Appendix 6 in the S&F Brewery H&S Plan). These processes should be supported by incentives to use them; staff need to know that acknowledging mistakes is a positive thing.

Facilitate communication between the operations team

The Brewing Technicians get job satisfaction from working in a productive and open team [21]. Enabling this productivity and communication will create a positive feedback loop, further improving the staff culture.

Ways to improve productivity and communication are:

- To initiate short, regular (daily) team meetings;
- To more clearly define and divide the tasks between Brewing Technicians;
- To encourage the Production Team Leader to take greater authority over the day-to-day management of the team, such that all staff efforts are coordinated.

Appendix 6. FOOD SAFETY

Food safety regulatory requirements

From a food safety perspective, the Sprig and Fern Brewery currently operates under the Food Hygiene Regulations 1974. This system focuses on merely providing a manufacturing environment that is unlikely to introduce food hazards, for example by maintaining clean premises. It has been recognised that manufacturers should take a more proactive approach to ensuring food safety; therefore the Food Hygiene Regulations 1974 will be phased out in favour of the Hazard Analysis and Critical Control Points (HACCP)-based food safety systems required by the Food Act.

Currently, the Food Act 1981 (from which the Sprig and Fern Brewery is exempt) requires that food manufacturers operate under a Food Safety Programme (FSP). The FSP is set of procedures, including HACCP, for consistently producing safe food or beverages [12]. Effectively, the FSP asks "What might go wrong, and what do we do to prevent it?" The manufacturer will develop a FSP manual that describes the HACCP-based food safety processes, as well as general policies on items such as:

- Company commitment to food safety
- Staff procedures that ensure food safety
- Staff responsibilities and authority
- Food safety documentation control
- Product recall procedures
- Plant and equipment cleaning and maintenance
- Approved suppliers and distributors
- Internal and external food safety reviews

Both the Food Hygiene Regulations 1974 and the Food Act 1981 will be replaced by the Food Act 2014. This will come into effect by 1 March 2016, and existing businesses will have three years from that date to transition to the new regulations. It separates food manufacturers into hierarchical categories based on the food safety risk of that industry to the public. Manufacturers will need to adhere to the regulations of their category as a minimum, but may voluntarily adopt a higher level of food safety management [13]. Breweries are classed in the National Programme Level Three category. The requirements for this category are yet to be set (expected in mid-2015), but it is unlikely that a FSP will be required [15]. However, the FSP manual is likely to be easily modified into a Food Control Plan [15], which is the requirement of a higher-risk food safety category; therefore, by implementing a FSP now, the Sprig and Fern Brewery will be investing in a food safety standard that not only meets, but exceeds their legal needs.

The Sprig and Fern Brewery currently produces two cider products. Cider production is regulated by the Wine Act 2003, which usually requires a Wine Standards Management Plan (WSMP), similar to the FSP. However, because the Sprig and Fern Brewery already operates under other food safety regulations, and does not export any cider, it is exempt from the Wine Act 2003 [11]. Cider production is instead covered by the same regulations as for other products (i.e. Food Hygiene Regulations 1974, Food Act 1981 or Food Act 2014).

Sprig & Fern Brewery Food Safety Programme Manual – Table of Contents

The full S&F FSP Manual is 121 pages long, and has not been included in this report. A copy is available on request.

Appendix 7. HEALTH AND SAFETY

Health & Safety regulatory requirements:

The Health & Safety in Employment (HSE) Act 1992 (due to be replaced in 2015 – see below) guides businesses in ensuring that work premises and practices are safe for all staff, contractors, volunteers, visitors, and anyone else in sufficient proximity to the business operations.

The HSE Act does not specify what measures should be taken to make particular work situations safe; instead, it acknowledges that those involved with the work are generally in the best position to decide on safe working measures. In that regard, the HSE Act demands a high level of employee participation in improving H&S systems.

The standard that must be achieved is that of having taken "all reasonably practicable steps" to make work safe – that which can be reasonable achieved given the circumstances, resources and state of knowledge [22].

Employers' responsibilities:

- To identify and manage hazards. This means being proactive and systematic about identifying potential hazards, and then having a systematic approach to dealing with those hazards, to eliminate, isolate or minimise those hazards;
- Provide the right information, training and supervision for workers. This commonly comes in the form of health and safety inductions, regular training workshops, specific training on the use of equipment, and standard operating procedures for tasks that clearly describe the safe completion of tasks;
- Ensuring that plant and equipment is safe to use, and that workers have the correct protective clothing and equipment to complete tasks safely;
- Provide reasonable opportunities for all workers to participate in the ongoing improvement of health and safety;
- To respond swiftly and effectively, through a systematic process, to H&S notices, changes, incidents or concerns [22].

Workers' responsibilities:

Note: the term "workers" is used instead of "employees", as it less ambiguously describes all those who do any work for the employer. This is the terminology used in the new HSE legislation, as employees, contractors and volunteers all have the right to be kept safe at work.

Workers must take all steps that are reasonable practicable to ensure their own H&S at work, and ensure that nothing they do causes harm to any other person. This means they must:

- Use protective clothing and equipment provided for them;
- Not undertake work that is unsafe, or any work for which they are not sufficiently trained;
- Make unsafe work situations safe, or if they cannot, inform their supervisor or manager;
- Understand and follow the workplace H&S regulations;
- Communicate openly about H&S concerns to both co-workers and managers [22].

Upcoming changes to Health & Safety requirements:

In 2015 a new HSE Act will be published [23]. This is expected to have the following changes relevant to the S&F Brewery:

- Stronger focus on major risks;
- Stronger focus on occupational health (e.g. manual handling chronic injuries);
- Simplified, clearer legislation, including combining the HSE Act with the Hazardous Substances and New Organisms (HSNO) Act 1996. HSNO-related regulations will be enforced by the new Regulator, WorkSafe;
- Emphasis on and increased requirements for worker participation. However, small-to-medium enterprises will still be able to involve workers on an informal basis as appropriate to the size of the business and risk profile of the work;
- New wording of employers' obligations – "so far as reasonably practicable to ensure the health and safety of their workers". This has different legal effects as it is more subjective as to what is reasonable.
- Suppliers will also have increased obligations to those within their 'sphere' – an example might be that Brewery kegs could cause harm to tavern owners if faulty, and this may be deemed the Brewery's responsibility;
- Paid Directors will have a duty of due diligence to ensure the H&S of workers [23].

Specific regulations to note - *Working from height*

Section 21(2) of the Health and Safety in Employment Regulations 1995: "Every employer shall take all practicable steps to ensure, in relation to every place of work under the control of that employer, that, where any employee may fall more than 3 metres, -

(a) Means are provided to prevent the employee from falling; and
(b) Any means so provided are suitable for the purpose for which they are to be used."

Non-notifiable, even if the height is over three metres, so long as the work is of a minor or routine nature [68].

Health and Safety Risk Assessment

Table 11. Risk assessment matrix used to quantify and categorise risks.

			Consequence / Severity				
			Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Probability / Likelihood	Rare	1	Low	Low	Low	Moderate	High
	Unlikely	2	Low	Low	Moderate	Moderate	High
	Possible	3	Low	Moderate	Moderate	High	Critical
	Likely	4	Low	Moderate	High	High	Critical
	Almost certain	5	Moderate	Moderate	High	Critical	Critical

Table 12. H&S risk analysis summary.

Risk	Potential impact(s)	Likelihood	Consequence	Level	Recommended mitigation step(s)
Manual handling	Chronic or acute injury due to poor technique, uneven handling conditions, heavy loads.	4	3	Mod	Thorough training of staff in correct manual handling, particularly of kegs; being conscious of staff's history with chronic back injuries; culture of communication when moving around the brewery; purchase keg-specific manual trolley, and add safety chain to old trolley for moving CO_2 tanks.
Forklift	Direct or indirect contact through normal forklift operations on the brewery floor, resulting in severe injury or death.	3	5	Critical	Immediately hold staff meeting to train staff in communication and conduct while using the forklift; ongoing monitoring of the forklift conduct and continual behaviour management; staff to observe forklift load ratings and forklift use regulations outlined in licencing process.
Compressed gas	Asphyxiation from CO_2 in cold room.	2	4	Mod	CO_2 levels managed by diverting waste gas out of the cold room – add this procedure to the Standard Operating Procedures.
Hot water	Minor through to severe burns.	4	4	High	Culture of communication during work on the brewery floor; continued regular maintenance of plant and equipment.
Cleaning chemicals	Minor through to severe burns or other skin or mucosa damage.	4	4	High	Culture of communication during work on the brewery floor; purchase 100 mL aliquot hand pump for the sterilant so that the 20L container does not need to be manually handled.
Working at heights	Falling resulting in minor injury through to death.	3	5	Critical	Install lugs in roof LVL and timber framing overhead of each brewery light, above fermenters, and in the centre of the brewery yard where the cooling water pipe runs overhead; purchase safety harness, climbing rope and guiding ropes; train staff in use, and encourage alternatives to working at height where possible.
Fire and earthquake	Range of injuries through to death.	2	4	Mod	Emergency exits/gathering areas clearly identified and unobstructed; workers trained in fire and earthquake response; working fire alarms and extinguishers.

Sprig & Fern Brewery Health & Safety Plan – Table of Contents

The full S&F H&S Plan is 21 pages long, and has not been included in this report. A copy is available on request.

Appendix 8. Production Volume Maximisation Calculations

Calculations for the maximum volume that can be processed in each step

1. Brewing:

Assumptions:

- October and November are the busiest months for brewing (see Figure 7, Appendix 1);
- Two 2500 litre brews per day (before waste);
- No brewing on Friday (caustic brew day), weekends or public holidays;
- No brew house downtime between October and January;
- Seasonal sales distribution remains constant to historical data;
- Brewing takes place approximately 40 days prior to the sale of beer (brewing demands are extrapolated back from sales data);
- Human and other resources are available.

Calculations:

- 33 brew days available in October/November
- 66 brews available when doing 'double brews'
- 66 x 2500 L = 165,000 L
- Extrapolated across the year, factoring in seasonal sales variation (see Figure 7) = 797,836 L
- = 319 brews of 2500 L each

2. Fermenting:

Assumptions:

- Same core assumptions for Brewing;
- Five fermenters have a double brew capacity, two have a single brew capacity;
- Double-brews are of the same product, and are fermented in the same fermenter;
- Total fermentation cycles for different products remain as stated below:
    - Fern Draught (4%) – 6 days;
    - 5% beers – 7 days;
    - 6.5% beers – 9 days;
    - Doppelbock (8%) – 10 days;
- Highly efficient manual or automated scheduling.

There are currently seven fermenting vessels. Five of these have a double-brew capacity (5500 litres), and two have a single-brew capacity (2500 litres and 4800 litres). With these seven fermenters it is possible to ferment (step 6 in Figure 11, Appendix 2) all products from the brew house at AMBO, as determined by manual scheduling trials.

Therefore, fermentation maximum = 797,836 L (319 brews of 2500 L each).

3. Conditioning

Assumptions:

- Same core assumptions for previous process steps;

- Conditioning cycle is at least 28 days, as dictated by good manufacturing practice to achieve product quality and consistency;
- Apple wine is stored in conditioning tanks, and takes up two U tanks (double brew capacity) at any point in time.

All fermented product must be conditioned, so the conditioning maximum = 319 brews. The actual maximum volume will be reduced compared with the fermentation maximum, due to waste yeast being removed upon fermenter transfer; however, this has no bearing on the practical maximum that can be conditioned.

This conditioning maximum must be achieved without the use of two large conditioning tanks (U tanks), as these are used to store apple wine for the production of ciders.

4. Bright beer storage

Assumptions:

- Same core assumptions for previous process steps;
- At the point of sale 2300 L remains from an original 2500 L brew (process wastage).

Calculations:

- Used "Approx. annual brews required at AMBO" from Table 3, and extrapolated across all products including non-fermented products (Table 13)
- Used monthly sales proportions (Table 14) to determine number of brews required at peak time (December) = 46 brews
- Multiplied number of brews by 2300 L (includes wastage) = 105,784 L required in December

Table 13. Monthly total product sales proportions.

Month	Proportion of monthly sales as a percentage of annual sales (mean of 2008-2014)
Apr	7.45%
May	6.80%
Jun	6.42%
Jul	6.90%
Aug	7.17%
Sep	7.45%
Oct	8.20%
Nov	9.02%
Dec	**11.52%**
Jan	10.10%
Feb	9.34%
Mar	10.10%
Total	**100.00%**

Table 14. Summary of bright beer product requirements at AMBO.

Product	Product sales ratios (mean of Apr'12 – Oct'14)	Annual bright beer brews required at AMBO	Bright beer brews required in December at AMBO	Litres required in December at AMBO
Pilsner	18.6%	74	8.6	19690
Alc. Lemonade	1.5%	6	0.7	1565
Tasman Lager	12.2%	49	5.6	12910
Cider	5.7%	23	2.6	6033
Blonde	2.8%	11	1.2	2840
Scotch Ale	5.2%	21	2.4	5626
IPA	9.1%	36	4.2	9557
Best Bitter	2.9%	12	1.3	3049
Fern Dark	1.3%	5	0.6	1426
Fern Draught	4.9%	19	2.2	5024
Fern Lager	8.9%	36	4.1	9472
Pale Ale	4.3%	17	2.0	4617
Porter	4.8%	19	2.2	5079
Berry Cider	9.0%	36	4.1	9521
Ginger Lager	1.8%	7	0.8	1815
Doppelbock	1.0%	4	0.5	1111
N/A Ginger Beer	1.9%	8	0.9	2064
Limited releases	4.0%	17	1.9	4386
Total	**100%**	**399**	**46**	**105784**

5. Packaging: Riggers

Assumptions:

- Same core assumptions for previous process steps;
- Brewery shop to close, removing all sales from this channel;
- The following products are packaged into riggers:
  - Pilsners
  - Tasman Lager
  - Cider
  - Scotch Ale
  - IPA
  - Porter

  - Berry Cider
  - Limited releases
  - (Fern Draught and Fern Lager are no longer packaged in riggers);
- Sales proportions are the same for supermarket riggers as for total sales.

Calculations:

- Shop sales are removed from sales proportions ratios
- Using the mean sales proportions of supermarket riggers (mean of 2012-2014) (Figure 6, Appendix 1), the number of litres required in riggers for supermarkets at AMBO was calculated:
  - 917,970 L x 23% = 213,671 L
- 213,671 L / 1.3 L (size of riggers) = 164,362 (annual number of riggers at AMBO)
- Used monthly sales proportions (Table 14) to determine number of riggers required at peak time (December) = 18,124

6. Packaging: Kegs

Assumptions:

- Same core assumptions for previous process steps;
- Sales proportions are the same for kegs as for total sales;
- Calculations for 25 L kegs is omitted due to lack of historical data;
- The following products are packaged in 30 L kegs (as dictated by the turnover rate of those products), and the remaining products are packaged in 50 L kegs:
  - Alcoholic Lemonade
  - Fern Dark
  - Ginger Lager
  - Doppelbock.

Calculations:

- Shop sales are removed from sales proportions ratios
- Using the mean sales proportions of total kegs (tavern and other) (mean of 2012-2014) (Figure 6, Appendix 1), the number or litres required in kegs at AMBO was calculated:
  - 917,970 L x 76% = 704,298 L
- Used product sales proportions (Figure 8 and Table 14) to determine volume required in kegs of each product
- Divided these numbers by 50 L or 30 L (depending on packaging requirement) to get number of each keg needed annually
- Used monthly sales proportions (Table 13) to determine number of each keg type required at peak time (December):
  - 50 L – 1505
  - 30 L – 197

Appendix 9. Production Constraints Analysis

Table 15. Analysis of production capacity constraints.
Note: Full calculations are available on request through an Excel spreadsheet.

Component	Status	Details
		Fermentation
Capacity and scheduling	**Manageable constraint** **Risk**	Based on manual scheduling trials it is possible to ferment 66 brews over the October/November period, as required at AMBO. Manual scheduling is increasingly time-consuming and complex as the number of ferments increases. Equipment downtime or fermentation cycle overrun would put a significant constraint on the ability to ferment the AMBO volume in October/November.
Wort and fermenter cooling	**Significant constraint**	See "Supporting processes" below.
Yeast	**Manageable constraint**	Yeast is currently cropped from fermenters, stored in steel containers, and re-pitched into subsequent batches. With increased fermentations the number of yeast movements would exceed the current storage capacity. Yeast would need to be managed differently, either by transferring from tank-to-tank directly, or by purchasing new yeast containers as required.
		Conditioning
Capacity	**Significant constraint**	At AMBO, 66 brews need to be conditioned in the two months of October and November. With 12 x 2500 L and 5 x 5500 L useable conditioning tanks, and a 28 day conditioning cycle, there is a capacity for only 44 brews at 100% scheduling efficiency. There is no extra floor area to add new conditioning tanks.
Refrigeration	**Significant constraint**	See "Supporting processes" below.
		Bright beer storage
Capacity	**Dependent constraint**	Because there is no minimum retention time for bright beer, bright beer tank capacity is largely a management and scheduling problem, rather than a physical capacity problem. However, to reduce the constraint on conditioning, bright beer capacity will need to be increased to ensure that 5500 L conditioning tanks can be

		moved in one step, rather than being temporally distributed into two 2500 L tanks. The requirements for this upgrade are dependent on the option taken for mitigating the conditioning constraint.
Refrigeration	**Significant constraint**	See "Supporting processes" below.
Packaging: riggers		
Product tank capacity	**No constraint identified**	Product for rigger-filling is currently stored in a number of 600 L and 1200 L tanks. By drawing product from a second take-off point on the main 2500 L or 5500 L bright beer tanks, such that it doesn't interfere with kegging operations, capacity will be easily managed.
Filling	**No constraint identified**	At AMBO, peak rigger-filling time (December) will require an average product fill rate of 2.7 L per minute per eight hour working day. Current fill rates are between 3.0 and 3.3 L per minute when using one tap at a time, and 2.2 – 2.6 L minute when using two taps at once. The required filling effort (and hence staffing requirements) can be estimated using the Takt Time tool that has been developed (available on request).
Storage of inventory	**Unquantified constraint**	It is likely that rigger storage will exceed the capacity within the shop chiller. No solution has been found to increase storage capacity.
Storage of raw materials	**No constraint identified**	At AMBO, peak rigger-filling time (December) will require approx. 1 pallet (1008 riggers per pallet) per day. This can be entirely managed through more frequent orders and rapid stock rotation.
Packaging: kegs		
Filling	**No constraint identified**	Peak kegging time (December) will require 87 x 50L kegs, and 9 x 30L kegs per working day at AMBO. This is entirely manageable through adequate staffing. The required filling effort (and hence staffing requirements) can be estimated using the Takt Time tool that has been developed (available on request).
Cleaning	**Manageable constraint**	The 'keg lane', where dirty kegs are stored, has a capacity of approximately 60 kegs. Increased production would necessitate a change to keg cleaning processes, i.e. keg cleaning may become a full-time job. A small scale automated keg cleaner is unlikely to improve keg cleaning throughput rates, but will allow staff to multi-task, thereby improving overall productivity.

Storage of inventory	**Manageable constraint**	The keg chiller can hold a maximum of approximately 240 x 50 L kegs, 40 x 30 L kegs, and 30 x 25 L kegs. Increased production output can be managed through changes to work processes, i.e. by kegging more often, and reducing the stock at hand.
Empty keg stock	**Manageable constraint**	The number of empty kegs required will depend on current sales demand. At AMBO, it is estimated that the Brewery will require an extra 400 x 50 L kegs, and 230 x 30 L kegs. Keg purchasing can be managed as required.
Supporting processes		
Refrigeration - Wort and fermenter cooling	**Significant constraint**	The same condenser is used to provide cold water for wort cooling and fermenter cooling. With double-brew days and increased fermenter use, it is likely that both processes will suffer, resulting in product quality issues.
Refrigeration - Cold room refrigeration	**Significant constraint**	During summer, the cold room refrigeration is overworked [21, 31]. Adding extra product will cause the cold room to operate above the maximum temperature and affect product quality.
Electricity - power draw capacity	**Significant constraint**	Currently have 200 A fuses which are nearly fully loaded [32]. These can be upgraded to a maximum of 250 A, and any further power draw increases will require new mains lines and a new switchboard.
Water mains - Pressure and volume	**Risk**	Possible water shortages during drought, depending on the course of action taken by the Tasman District Council. See Appendix 8 – Water supply.
Water heating	**Manageable constraint** **Risk**	Previous double brew trials have shown that the hot water can be managed adequately to allow for brewing and CIPs. However, as the production volume increases, the risk of running out of hot water through error increases, which would put significant constraint on key brewery processes.
Cold water for product dilutions	**Risk**	Cold water tank has limited capacity, and takes several days to cool. By increasing production volume, water will have less time to cool, which will increase the delay in carbonating some products and cause a constraint.
Logistics	**No constraint identified**	This can be easily managed by workflow changes, and more frequent logistics scheduling.
Material and ingredient availability	**No constraint identified**	There have been occasional hops shortages, but hop import is an option if local supply falls short.
Operations staff	**Manageable constraint**	It is likely that operations staff roles will become more defined to increase productivity, and more staff will be needed. This can be managed as required.

Water supply:

Waimea Community Dam (Lee Valley Dam) – water resources are currently over-allocated by 22% in drought conditions. With continued growth of the Tasman region, there is an increasing demand for irrigation. If it goes ahead, it is expected to be built in 2017/2018 [69].

Potential impacts to the Sprig and Fern Brewery [70]:

- Assume a scenario with no dam, as this is looking likely;
- Future business development will be curtailed, with no new consents for big water users given;
- Water rates are likely to go up significantly;
- Supply may be affected – the Water Act states that water is to be provided to residential areas in preference to businesses;
- Water flow may be reduced to a minimum during summer months, and come at a lower pressure – this will significantly impact production capabilities, especially at a time when production demand is highest.

Calculation for heat loss into the cold room during a CIP:

$q = m \times C_g \times (T_f - T_i)$

Where q is the energy loss from the change in heat of a substance

m is the mass of the substance

C_g is the specific heat capacity of the substance

T_i is the initial temperature of the substance

T_f is the initial temperature of the substance

$C_g(H_2O) = 4.18\ Jg^{-1}C^{-1}$

$C_g(steel) = 0.42\ Jg^{-1}C^{-1}$

$m(H_2O) \sim 100\ kg$

$m(steel\ T_S) \sim 100\ kg$

$T_i(steel\ T_S) \sim 70°C$

$T_f(steel\ T_S) \sim 4°C$

$T_f(H_2O) \sim 35°C$

$q_{total} = q_{steelTs} + q_{H2O}$

$q_{total} = (100{,}000 \times 0.42 \times -66) + (100{,}000 \times 4.18 \times -40)$

$q_{total} = -19492\ kJ$

So

the energy loss from CIPing a small T tank under normal conditions is approximately 20,000 kJ.

Calculation for ventilator requirements in Brewery:

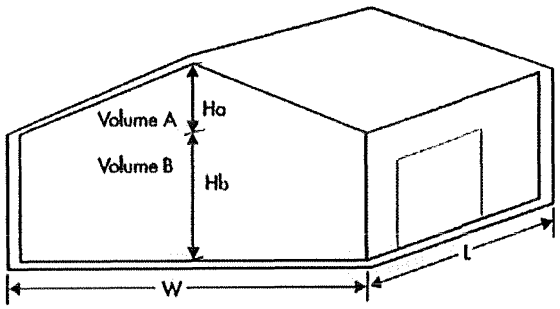
Total brewery volume:

Ha = 2.3 m

Hb = 5 m

W = 15 m

L = 30 m



Cold room volume (internal, excluded from ventilator calculations):

H = 5 m

W = 12 m

L = 15 m

Volume to be ventilated:

$Vol_{(External)} - Vol_{(Cold\ room)}$

= 1867.5 m^3

Recommended changes per hour = 10

= 18675 m^3/hr

= 5.19 m^3/s

Stack height = 7.5 m

Temperature difference between ambient and max = 12°C(as measured by VK during January 2015)

Wind speed (approx. summer average) = 12km/hr

600 mm throat diameter ventilators will move approx. 0.7 - 0.8 m^3/s under above conditions

= 7 x 600mm throat diameter ventilators needed, minus 2 for existing openings (front free spinning fan, back brewery door)

= 5 ventilators needed

Appendix 10. CAPITAL EXPENDITURE SUMMARY

Table 16. Summary of capital expenditure options given throughout report.

CapEx summary includes all possible CapEx options, so the actual total cost of options chosen will be less than given in the Total cell.

Adjustments: Kegs – price is in USD, so is adjusted to NZD based on the exchange rate of 1.35 NZD to 1 USD at 05-02-2015.
HADEN quotes – quotes were given to the S&F Brewery in October 2013, and have been increased by 10% (overestimate).

Category	Item	Units	Price	GST	Adjustment	Total cost
Food safety	FSP registration (Option A with FSP audit report)	1	$ 561.20	$ -		$ 561.20
	FSP external audit	1	$ 1,400.00	$ 210.00		$ 1610.00
	FSP audit follow-up costs	1	$ 420.00	$ 63.00		$ 483.00
						$ 2,654.20
Health & safety	Loop-bolt safety lugs	6	$ 15.00	$ -		$ 90.00
	Safety lug installation	1	$ 500.00	$ 75.00		$ 575.00
	Guiding and safety ropes	1	$ 220.00	$ 33.00		$ 253.00
	Safety harness	1	$ 159.85	$ 23.98		$ 183.83
	Safety helmet	1	$ 80.86	$ 12.13		$ 92.99
	Aliquot pump	1	$ 50.00	$ -		$ 50.00
	Manual keg trolley	1	$ 200.00	$ -		$ 200.00
	Modification to existing trolley	1	$ 50.00	$ 7.50		$ 57.50
						$ 1,582.98
Conditioning	5500L stainless steel tank	4	$ 12,500.00	$ 1,875.00		$ 57,500.00
	Cold store work to install	1	$ 8,900.00	$ 1,335.00		$ 10,235.00
						$ 67,735.00
Bright beer	5500L stainless steel tank	4	$ 12,500.00	$ 1,875.00		$ 5,980.00
	Second take-off points for 2500L BB tanks	5	$ 375.00	$ 56.25		$ 2,156.25
						$ 59,656.25
Kegs	KegCo 30L keg	230	$ 120.00	$ 18.00	1.35	$ 42,891.89
	KegCo 50L keg	440	$ 130.00	$ 19.50	1.35	$ 88,891.89
	Shipping costs		$ 2,780.00	$ -		$ 2,780.00
						$ 134,563.78

Refrigeration	HADEN 1 - condenser	1	$ 36,974.00	$ 5,546.10	1.10	$	46,772.11
	HADEN 2 - pump and fittings	1	$ 5,174.00	$ 776.10	1.10	$	6,545.11
	Installation costs	1	$ 10,449.00	$ 1,567.35	1.10	$	13,217.99
	HADEN 3 - pump, fittings and controller	1	$ 7,994.00	$ 1,199.10	1.10	$	10,112.41
	Installation costs	1	$ 15,665.00	$ 2,349.75	1.10	$	19,816.23
	HADEN 4 - relocate condenser	1	$ 5,718.00	$ 857.70	1.10	$	7,233.27
	Installation costs	1	$ 5,743.00	$ 861.45	1.10	$	7,264.90
	HADEN 5 - evaporator	1	$ 30,135.00	$ 4,520.25	1.10	$	38,120.78
	HADEN 6 - commissioning	1	$ 2,075.00	$ 311.25	1.10	$	2,624.88
	Concrete pad and housing	1	$ 15,000.00	$ 2,250.00		$	17,250.00
	Council approval	1	$ 20,000.00	$ 3,000.00		$	23,000.00
						$	**191,957.66**
Ventilation	Self-propelled ventilators (number of options)	5	$ 400.00	$ 60.00		$	2,300.00
	Installation costs	5	$ 650.00	$ 97.50		$	3,737.50
						$	**6,037.50**
Insulation	Formaflex roll (8m x 25mm) for fermenters	15	$ 318.98	$ 47.85		$	5,502.41
	Formaflex tube (42mm x 25mm) for copper pipe	7	$ 14.75	$ 2.21		$	118.74
	Formaflex tube (51mm x 25mm) for PVC pipework	25	$ 17.77	$ 2.67		$	510.89
	Flexcover UV paint (4L tin)	1	$ 105.78	$ 15.87		$	121.65
	ADOS adhesive (1L tin)	1	$ 31.76	$ 4.76		$	36.52
	Shipping costs	1	$ 300.00	$ -		$	300.00
	Internal labour and overheads	1	$ 420.00	$ -		$	420.00
						$	**7,010.20**
Electrical	250 amp fuse	1	$ 100.00	$ 15.00		$	115.00
	Labour	1	$ 100.00	$ 15.00		$	115.00
						$	**230.00**
	Installation of new mains lines from transformer	1	$ 2500.00	$ 375.00		$	2875.00
	Switchboard fabrication	1	$ 15000.00	$ 2250.00		$	17250.00
	Commission switchboard	1	$ 3000.00	$ 450.00		$	3450.00
						$	**23575.00**
Total			**$ 430,366.88**	**$ 64,555.03**		**$**	**494,921.91**

Appendix 11. SENSITIVITY ANALYSES FOR KEY ASSUMPTIONS

Sensitivity analyses were done on key assumptions to determine what effects they would have on production capacity constraints.

Removing product types:

The Brewery produces 17 core products and at least 1 limited release product at most times. The sheer number of products makes scheduling a significant challenge. Therefore, this analysis looked at the effect of removing one product from the range.

Ginger Lager or Doppelbock would be the most likely products to remove, due to their low sales volumes and tendency to "hold up" tank space for a long time. The challenge here is that these products are provided strategically to offer a diverse range of beverages.

Each of these product types would not take up more than approximately 1.5 conditioning tanks during Oct/Nov (2.1% of 66 brews required, Table 3). This would not free up sufficient space in the conditioning tanks to warrant the consequences of removing the product from the range. The corollary of this is that low-sales products, such as Ginger Lager and Doppelbock, should not actually add significant constraint on the conditioning process. If they do, this is a function of poor scheduling. These brews should be scheduled so that they only condition for the minimum length of time, and do not hold up any tanks.

However, they may cause a constraint in bright beer tanks due to the length of time they take to sell one complete brew. An alternative solution, as provided by Tracy Banner, is to have the products contract bottled and sold at S&F taverns by the bottle, rather than the tap. The value of this is to be evaluated.

Change in sales proportions:

With the exception of several products, the ratio of sales of all 17 core products has largely remained constant (see Figure 8). For the purposes of production modelling, it has been assumed that these sales ratios will remain constant in the future. Even if incorrect, this assumption would not have a significant effect on the production capacity, because:

- Most of the core product range takes approximately the same length to ferment and condition;
- Conditioning capacity was modelled on number of brews, rather than product types, and so the capacity would remain the same for a different proportion of products.

Change in conditioning time:

Conditioning capacity was modelled as a function of the number of brews that could be conditioned at one time, multiplied by the number of conditioning cycles in one year. With a 28 day conditioning cycle, the number of conditioning tank turnovers is approximately 12. By Reducing the conditioning cycle to 14 days, the number of turnovers doubles, effectively doubling conditioning capacity. Therefore, conditioning cycle time has a significant effect on conditioning capacity.