Wine Monitoring

Kandidatgrupp 10
TEIO47

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1 Background

A challenge in the wine and beer making process is to maintain high quality throughout the whole manufacturing process of the beverage. Both beer and wine are made using biological processes dependent on many factors and inputs, and these factors needs constant monitoring and control. This can be achieved, for example, by measuring particles, PH value and carbon dioxide levels, which serve as an indicator of where the process is heading.

The project aims to identify potential issues in the process, and ensure the quality of the wine or beer despite varying inputs. It also involves finding a way to mitigate deviations and create a solution that could be time- or resource-saving for the winemaker. Our client, ATTRACT, has provided two early stage technologies to the project, named Unicorn DX and PiPe4.0. The task is to adapt these technologies to the wine or beer making process, and develop the surrounding systems.

This chapter provides a background to the project, beginning with a description of the overarching process of wine and beer making and the two technologies in focus, namely Unicorn DX and PiPe4.0. Current products and potential competitors are also identified.

1.1 Wine and beer making process

The wine making process is a process that has been used for over 6000 years. Different kinds of wine have slight differences in the production process. Identifying potential errors in the process can be made evident by mapping the production processes for red and white wine.

1.1.1 Red wine making

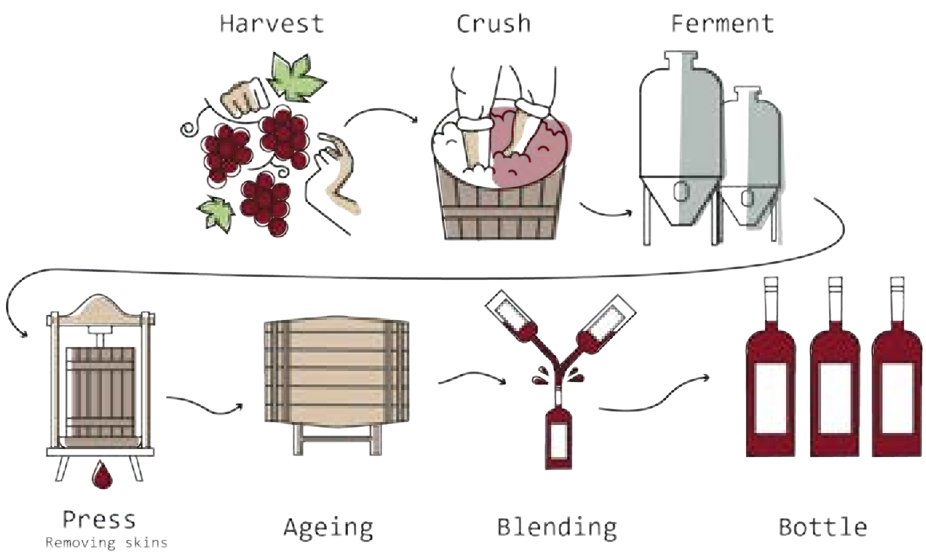

Figure 1: Steps of producing red wine

Harvesting and crushing
Red wine is made by first harvesting ripe grapes, either by hand or machine. Then the clusters of grapes go through a destemmer/crusher that removes whole grape berries from the stems and squeeze them to release the juices. This mixture of juice, skins and seeds is known as must. Sulphur dioxide is often added at this stage to kill unwanted microbes and preserve the must.

Alcoholic fermentation
After crushing, the must is fermented to convert sugars into alcohol. This can be done by adding commercial yeast or letting the native yeast that already occur in the grapes start the fermentation. Not removing the grape skins from the must during fermentation is what leads to the deep red colour in red wine. Depending on what kind of vessel that is used, different kinds of characteristics can be added to the wine. At the end of the alcoholic fermentation the wine is transferred to wine presses which separate the liquid from the skins and seeds.

Maturing
After fermentation, red wine is typically matured in oak barrels before being bottled, but can also be matured in clay amphorae and concrete eggs. Usually a second fermentation, called malolactic fermentation, occurs during the maturing of the wine. During this process, malic bacteria converts the wine's tart malic acid to softer lactic acid, creating a more pleasant mouthfeel to the wine.

Blending
Since wine making is a natural process, each barrel of wine will not develop completely identically, meaning that wine from the same batch can taste differently depending on factors such as acidity and sugar levels. Therefore, blending is a crucial step to balance and harmonise the aromas of the different barrels. By selecting and blending specific components, winemakers create their own balanced wine.

Filtration/Clarification
Red wine undergoes clarification through racking, fining and filtering during maturation. Remaining sediments such as seeds and grape shells settle at the bottom and are removed through racking. Fining of the wine is done by using substances like egg whites and certain clay, products that addresses tannins and tends to remove cloudiness in the wine.

Bottle
Before bottling, final adjustments involving sulphur dioxide takes place. Before filling, corking and labelling the wine, it is important to minimize the exposure of oxygen to the wine in order to prolong its lifespan and protect its characteristics.[Jim Gordon, 2023b]

1.1.2 White wine making

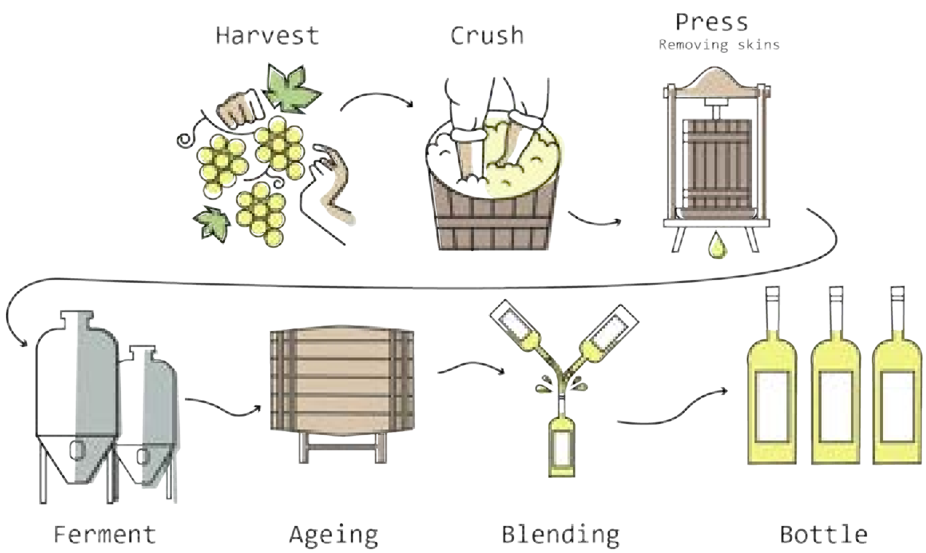

Figure 2: Steps of producing white wine

Harvesting and pressing
The grapes are harvested early in the morning at cool temperatures to keep

freshness at optimal ripeness. The grapes are then pressed directly when they arrive to the winery. Winemakers may be inclined to add sulfur dioxide or potassium metabisulfite at this stage to prevent spoilage and oxygen absorption. The skins are then separated from the must and the remaining juice is left to settle in a chilled tank, followed by racking, removing the majority to sediments.

Alcoholic fermentation
Once yeast is added to the grape juice, a biochemical process unfolds, converting sugar to alcohol, releasing carbon dioxide, and generating heat. Winemakers regulate this by manipulating temperature, stirring, aerating, and feeding the yeast nutrients. Various yeast strains are available depending on which style of wine is aimed to be achieved. While commercial yeast is an option, the native yeast present in the grapes are enough initiate fermentation. The majority of white wines ferment in stainless steel tanks, with some, like Chardonnay, fermenting in oak barrels.

Maturing
Malolactic fermentation is chosen for richness in Chardonnay or Viognier but avoided in crisp wines like Sauvignon Blanc. Maturation can range from four months for light whites to over two years for reserve-style white Burgundies.
Another choice presented to the winemaker is whether to keep or discard lees in the wine. Lees is a layer consisting of dead yeast and various sediments at the bottom, the right amount of lees can add aroma, protect from oxidation, and generally contribute to a richer mouthfeel with periodic stirring.

Blending
Just like when blending red wine, winemakers are blending their white wines in order to better control the taste characteristics of their final product, enabling more stable wines. The blending is done by trial and error in small batches, and the final composition is determined based on what the winemaker deems to taste the best. This process heavily relies on the taste, experience and preferences of the winemaker. [Sean P. Sullivan, 2023]

Filtering
During this phase, winemakers clarify wine through processes like racking to remove sediment and fining using substances like egg whites and clay. Membrane filtration is used to eliminate microbes, sulphur dioxide levels can also be tweaked during this phase to hinder the growth of microbes. [Jim Gordon, 2023a]

Bottling
When bottling still wine, it is ready for consumption immediately and further ageing does not necessarily improve its characteristics . TPO, short for Total Packaged Oxygen, is a measurement of the oxygen levels present in wine after bottling. TPO has a direct effect on quality, lifespan and stability of the wine. Thus, it is generally considered preferable to keep the TPO as low as possi-

ble during bottling since higher TPO increases the risk of the wine to oxidise, leading to a loss of favlour, color and essentially causing the wine to spoil.[Pete Brissenden, 2023]

1.1.3 Beer brewing process

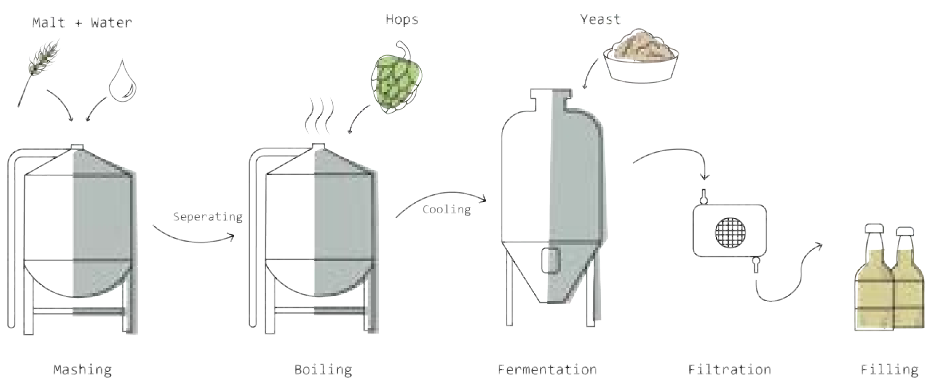

Figure 3: Steps of producing beer

Mashing
The first step in beer brewing is to combine hot water, typically between 60 to 80 degrees celsius depending on what style of beer is being made, with crushed grain in a vessel called a "Mash tun". The grains are typically left to soak in the hot water for 60 to 90 minutes, again varying depending on which type of beer is being brewed. During this process enzymes in the malt convert starches into sugars, resulting in a sugar rich liquid called wort.

Separation
The mash tun is equipped with a false bottom which enables the brewer to separate the wort from the malt solids. By using gravity or a pump, the brewer transfers the wort to the boil kettle. Hot water is often used to rinse the malt, ensuring that all sugars are extracted and collected.

Boiling
Once all the wort is gathered, the boiling stage begins, which serves several crucial purposes for the brewer. Boiling sterilises the wort, allowing only selected yeast to ferment. Additionally, hops are added which contributes to flavouring profile and bitterness. When the wort is finished boiling it is rapidly cooled to a temperature lower than 38 degrees celsius, allowing yeast to survive in the liquid.

Fermentation
In the fermentation stage, yeast is added to convert the sugars from the wort into alcohol, it is encouraged to aerate the liquid at this point. Furthermore, it is crucial for the liquid to be at the right temperature at this point not to kill the yeast. Yeast flavor can be influenced by factors such as fermenting temperature, yeast quantity, yeast type and oxygen levels. For instance, Hefeweizens showcase yeast-derived flavors like banana and clove, achieved by carefully managing fermentation conditions to stress the yeast and enhance these characteristics.

Filtration
Filtering stabilises beer flavour, preventing further yeast development and removing haze for a clear appearance. Various filter types, such as sheet or powder filters are used. Sheet filters trap particles based on size, while powder filters are more complex but efficient.

Filling
The final product is filled into bottles or cans using counter pressure, causing the carbon dioxide produced during fermentation does not escape [Editorial Dept., 2016]. Additional carbon dioxide can be added artificially or by introducing a small amount of sugar in the bottle, which the small amount of remaining yeast consume, in turn creating carbon dioxide and ethanol.

1.1.4 Possible faults

In some cases, errors are made when making beer and wine, which can lead to the beverages having an unpleasant smell, taste or being completely undrinkable.

Wine faults
A few examples of what can go wrong is that the wine can turn into vinegar, smell like rotten eggs or have yeastier characteristics than wanted.

A vinegary smell and taste means that the wine has been exposed to air, causing an interaction with acetobacter organisms, effectively converting ethanol into acetic acid in the presence of oxygen. This can be prevented by adding enough sulphides which inhibits the growth of unwanted organisms. If the wine has converted into vinegar, there is no way to revert the mistake and turn it into wine. The wine may still be drinkable and sellable if the taste is tolerable, if not the batch may be turned into vinegar and sold as such.

If the wine smells like rotten eggs it is likely due to an excessive use of sulphide or lack of nutrients. If the grape juice is lacking in nitrogen, hydrogen sulphide is released in to the wine by the yeast. This can also happen if the yeast is shocked by temperature changes. However, this fault can be corrected in most cases by simply racking the wine followed by aerating it. In more serious cases the wine can be treated with copper sulphate or activated carbon which inhibits the rotten egg sensation.

A yeasty smell is caused by the wine being in contact with lees for too long. Lees are deposits of dead yeast or residual yeast and other particles that precipitate to the bottom of a vat of wine after fermentation and ageing. When wine is left in contact with the lees for an extended period, autolysis of yeast cells can occur, releasing compounds that contribute to a yeasty or bready aroma. This process is intentional in some winemaking styles, as it can add complexity and richness to the wine. However, if the wine has been in contact with the lees for too long or if the winemaking process was not well-managed, it may result in off-putting aromas.[Northeast Winemaking, n.d.]

Beer faults
In beer brewing, faults can be divided in to two categories; those that occur during the brewing process and those that occur post packaging. One example from each category is presented below.

Bacterial spoilage is a fault that can happen during the brewing process. Lactobacillus, pediococcus, and acetobacter are common spoilage organisms that can impart sour, tart, buttery, and vinegar- like notes. To prevent this, it is crucial to sanitise during the entire process, especially after wort cooling, when the wort and beer is at a temperature ideal for bacterial growth.

Primary causes of faults in packaged beer are sunlight, heat and oxygen. It is important that the beer is sealed properly and stored cool to prevent oxygen from seeping in. It is also important to store the beer cool and dark since light exposure may result in breakdown of the beer, resulting in a skunky flavour. [Jeff S. Nickel, n.d]

1.2 The technology

The project works with two separate early-stage technologies that are partnering with ATTRACT.

1.2.1 Unicorn Dx

Unicorn Dx is an electrochemical nanosensor designed for diagnostic applications. It operates as a lab-on-a-chip system, integrating one or several laboratory functions onto a single integrated circuit. The chip is capable of detecting pathogens such as viruses and bacteria, as well as smaller biomarkers like infection markers at the single-particle level (e.g., proteins). The detection range spans from 10 to 100 nanometres.

To analyse a sample, a droplet of the substance to be measured is deposited onto the chip, which is then inserted into a readout device. The sample undergoes analysis by nanosensors within microfluidic channels, capable of detecting the presence of biomarkers, for example. The integration of microfluidic technology with nanosensors makes this system a versatile tool for point-of-care (POC) bioanalysis at a nanoscale. Initially developed for medical use, with a focus on prevention rather than treating existing diseases, the technology faces challenges in obtaining medical applications approval. In the meantime, the chip technology could find applications in the wine-making industry. For example, it can be used during the fermentation process, but that is our aim to investigate in this project.

The uniqueness of this technology lies in its capability to detect individual particles [Attract, 2023a].

1.2.2 PiPe4.0

PiPe4.0 is a system containing two connected units. It is developed with the main purpose of monitoring the chemical composition in bio gas, bio methane and hydrogen-enriched natural gas.

The main unit is called gas monitoring unit, GMU for short, and is able to do measurements in so called injection cabins to a low price. It is ready for Internet of Things (IoT) and the hardware does not need any reconfiguration.

GMU measures the gas composition and the heating value of the gas according to the standard ISO 6976:2016 which is used for natural gas. It is fully automatic and suitable for many types of gasses with a broad set of compositions.

IoT refers to the interconnection of devices embedded with electronics, software, sensors, and network connectivity, enabling data exchange over the Internet.

The second unit consists of a network of strategically distributed sensors. These self-powered sensors can measure secondary parameters such as calorific values and pressure. This distribution allows for the detection of leakage and changes in flow. The fact that the sensors are self powered by the gas flow it self, makes the system suitable for harsh environments.

The GMU unit uses something called gasraman, optical Raman spectroscopy. Raman spectroscopy is a technology that uses laser light and the spread of scattered light for measurements. Since the scattered light has different energy compared to the incoming light (shorter wavelength), this information can be used to determine the chemical compositions.

Optical Raman spectroscopy is used to measure the composition and calorific value of natural gas (also in mixture with hydrogen), bio gas and bio methane. Because this method is completely optical it is possible to measure these thing without contact with the gas. [Attract, 2023b]

1.3 Mapping of current products

In the following section, a rough outlining of the typical products currently in use by wineries are presented.

1.3.1 Brewing equipment

Fermentation tanks:
Fermentation tanks are used during the alcoholic fermentation of the wine. The

most common type of tank is made out of stainless steel. They make temperature regulations fairly easy and are also the most sanitary option since they are easy to clean. A stainless steel tank is also a solid investment as it holds its value after being used.

Another common type is wood tanks. They are not as sanitary since wood is a porous material and therefore not as easy to clean. However, the wood adds tannin to the wine which stainless steel does not, which is something some winemakers may prefer.

There are also less common types of tanks such as concrete or amphorae which also has their own pros and cons. [Gravity Wine House, 2019]

Ageing barrels:
Barrels used for ageing are typically made from oak wood. New barrels enhance flavour and texture, while used barrels contribute a smoother texture.

Bottles:
All bottles are not the same. When producing wine the properties of its containment are essential for the wines shelf life. Especially when dealing with sparkling wine, it is essential that the bottle can withstand the internal pressure, often reaching 6 bars.[Fick, n.d.] The colour of the bottle also plays a big role to ensure light does not deteriorate the wine.[Vogadori, 2021]

1.3.2 Measuring equipment

Carbodoseur
A carbodoseur measures the dissolved CO_2 concentration by grams per liter wine. A measuring cylinder is filled with wine and by shaking the cylinder the dissolved gas is evaporated, building up enough pressure to push wine out through a hole in the cylinders cap when opened. The remaining volume of wine determines the CO_2 concentration.

Indicator Strip
A thin piece of paper coated in a chemical that reacts with acids in the wine when dipped. The strip assumes a different colour, which is observed to determine pH. Dedicated wine pH indicator strips often span a range of acidity that is likely to occur in the wine, commonly pH 2.8 - 4.4.

pH-meter
A device typically in the shape of a large pen or rod, that gives a relatively precise reading of a liquids pH level. The meter is held partly submerged in the wine, measuring the pH level over the coarse of a couple of seconds, displaying the final value on a small screen. The method gives more accurate readings than indicator strips. In combination with a titration stand and a reactive additive the pH meter can also be used to assess total acidity, TA.

Hydrometer
A hydrometer is a thin graded glass tube with a small bulb at one end. When submerged in a liquid the bulb sinks beneath the surface, leaving a portion of the tube exposed above the surface. The density of the liquid can then be determined by how much the hydrometer sinks. The specific density is measured by reading the hydrometers grading at the liquids surface.

Vinometer
A vinometer is a graded glass tube used for determining alcohol content in wine. The tube open in both ends, with one opeing being wider than the other. Wine is pored into the wide end, letting the wine seep through the vinometer until a droplet appears in the thin end, upon which the vinometer is turned upside down in order to let the wine run back out through the wide opening. The alcohol content is determined by the amount of wine that remains in the thin part of the tube.

Sulphur Dioxide Analyser
A Sulphur dioxide, SO_2, analyser is an electrical device, which measures the concentration of SO_2 dissolved in the wine. The device consists of a measuring unit, reading the signals and displaying the result, and a probe, which is held in the sample, connected via wire to the measuring unit. The sample has to be mixed with precise amounts of certain reactive chemicals in order for the analyser to give a reading.

Combined Analyser
A combined analyser is an electrical device, which has the ability to measure multiple chemical characteristics of a sample, commonly total acidity, SO_2 concentration and pH. The different modes require different preparations and additives, therefore creating the need for multiple samples to be taken.

Thermometer
A common thermometer is the preferred method to monitor temperature in wine. The sensing probe itself usually consists of a stainless steel rod which is placed in the wine.

Refractometer
A handheld device that measures the refractive index of the measured content. It is appropriate to use when measuring sugar levels in grapes to determine their ripeness, it can also be used to determine alcohol levels in wine must. The measured results are brix units, which is calibrated to grams of sugar contained in 100 ml water.

Aphrometer
An aphrometer, or barometer, is an instrument used to measure barometric pressure inside a bottle [Andrew Turgeon, National Geographic, 2023]. A typ-

ical aphrometer for wine production utilises a needle that punctures the bottle cap, giving a reading of the pressure inside the bottle on an attached pressure gauge. The bottle is considered ruined or consumed after being subjected to such a device. Some modern aphrometers uses a tunable diode laser absorption spectroscopy (TDLAS) technique, shining a laser through the bottle and analysing the light spectrum passing through the liquid, that does not spoil the wine. [Randy Frank, Sensor tips, 2018]

1.4 Competitors

In any development of a new product or service it is relevant to take the influence of competing brands into account.

1.4.1 Manual measuring equipment

Several companies around the world produce measuring equipment used in wine making. Some equipment is primarily intended for wine use, whereas other is targeted towards general chemical analysis. The equipment offered by these companies are typically cheap, widely available, easily understood and pose less of a challenge to implement into current facilities, compared to more advanced purpose built monitoring systems.

Given the nature of the project, trying to find a use for two cutting edge technologies, the traditional manual equipment manufacturers are not to be viewed as primary competitors. Rather these should be regarded as a substitute for the product category this project is reaching into. [Tim Patterson, 2011]

1.4.2 Automated measuring equipment

In the last couple of years a market for more advanced, fully or semi-automated and interconnected monitoring systems has emerged. Companies like Vinpilot and Winegrid are major actors in the market.

The Winegrid fermentation monitoring system consists of a fibre optic sensor that can be placed inside a barrel or vat to give real time analytics of critical parameters [Watgrid Solutions, n.d.]. The data is sent via antennas to a local router, where the data is uploaded to a web service where it is stored and compiled. The user connects to the system via their smartphone and can monitor the different batches individually through a centralised visualisation platform, receiving information either through graphs or directly as numerical values. The company offers monitors for first fermentation, second fermentation, pressing, maturation and environmental control. [Winegrid, n.d.]

VinPilot offers an array of separate sensors and monitoring systems that interact with one another in order to provide users with a highly customisable amount of information on their batches. Unlike their competitors Vinpilot has incorporated devices, such as pumps, aerators and oxygenators, that can directly make adjustments to the wine it is monitoring. Data is collected by the individual sensors, which report back to a local node via wire. The data is encrypted and uploaded to either a web service or local server where it is stored, from which the user can access current and historical information on each barrel and tank. [VinePilot, n.d.]

Although these competing products offer an improvement in testing frequency and a decreased workload for the winemaker, the actual values that are tested for are very much the same as with traditional methods. Furthermore some key indicators still have to be tested for manually. Another issue is the pricing of the equipment, which through a bulk order mentality disincentivises smaller wineries from adopting the new technology.

1.5 Sales

Throughout this document the main objective is to find a way to implement these technologies in a beneficial way to either wine or beer making processes. Because of the project's openness a concrete solution for the implementation of the technologies is not yet fully in reach, therefore it is challenging to package a product for sale.

Diving into the potential economics at this point would be very difficult. Neither exact details on production nor real market applications have been produced. It is worth mentioning, on a more casual note, that the clients for this project have not been reachable thus making it more difficult to figure out exact price points and costs, the technology is not currently out on the market, and information regarding what the technologies actually are through a material perspective, which has a significant role in sales and cost, is yet to be found out.

1.6 Distribution

The product/s will most likely fall under the industrial goods sector. Providing consumers, with larger scale vineyards the potential product in hopes of simplifying or streamlining the process. Due to Attracts broad spectrum of products and innovations a producer to agent to business customer distribution chain will be relevant.

1.7 Customers

At the products current development stage, the potential customers may either be the wine makers themselves who intend to be the direct users of the product. Alternatively, depending on if the scope of the product shifts, the customers may turn out to be laboratory workers at wine testing facilities.

Potential customers in the future may also be beer breweries where the line of work shares similarities with that in the wine industry and thus pose the possibility of incorporating the product.

2 Target

The target chapter tries to define a vision of where the project is heading. Presented here is a preliminary definition of what the project is trying to accomplish, what should not be included in the project and some ideas on what might be suitable topics for the future bachelor theses.

2.1 Goals

In the following section, the goals of the project are outlined. The precise hierarchy of the goals within each category is visualised in Figure 4. Due to the nature of this project finding one singular goal is quite difficult.

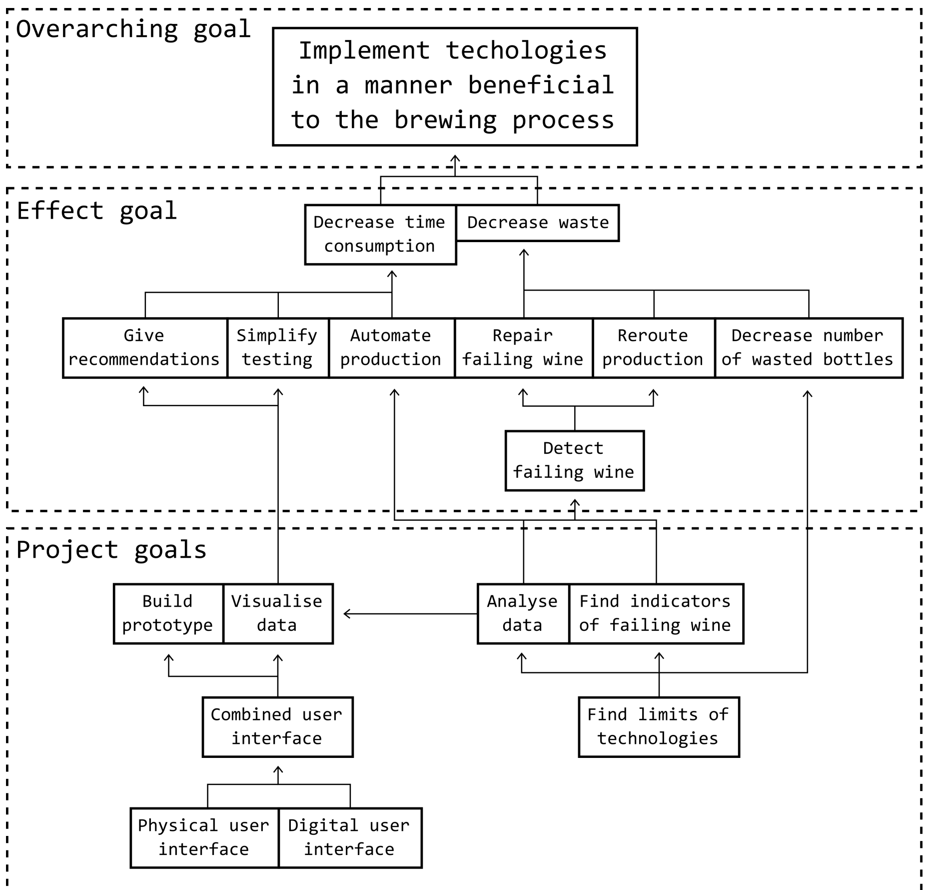

Figure 4: Hierarchy of goals

2.1.1 Overarching goal

The overarching objective is to find a way to implement the two provided technologies in a manner that is beneficial to the wine or beer making processes. Because of the limiting frames that surround the two technologies a physical solution is not granted.

2.1.2 Effect goals

Listed below are the general effect goals of the project. The effect goals will not be addressed directly, rather acting as motivation for the project goals.

Decrease time consumption:
Improve the efficiency of the wine making process by decreasing the time consumption of individual elements, allowing the wine maker to either expand operations or maintain the same with lessened workload.

Decrease waste:
Decrease the amount of wasted product and material. Large amounts of perfectly good wine is currently wasted in the testing process and on occasion entire batches have to be thrown out due to it failing.

Give recommendations:
Provide the wine maker with recommendations on how to improve the development of the wine throughout the process. These recommendations might include temperature changes, additives, time of bottling and much more.

Automate production:
Provide the possibility for an automated process, where measurements made by the end product is the decisions basis for alterations in the production process.

Simplify testing:
Make the testing process simpler, requiring less manual input and making each test less time consuming.

Detect failing wine:
Identify early stages of a wine developing in an undesirable direction.

Repair failing wine:
Allow winemaker to make an informed decision about how to repair a failing wine before it is permanently ruined.

Reroute production:
Avoid wasting resources on a ruined product by rerouting the wine to vinager production at an earlier stage.

Decrease number of wasted bottles in testing:
Provide wine makers with a method of making necessary measurements of a bottled wine without opening and wasting a bottle each time.

2.1.3 Project goals

Listed below are the general capability goals the group is aiming to accomplish at the end of the project. The project goals should aim to create preferable conditions for the effect goals to be achieved in the future.

Visualise data:
Find a way to visualise the collected data in order for the user to find it useful in the wine making process.

Analyse data:
Analyse the collected data in order to make predictions of the wines short and long term development, especially of it failing.

Find indicators of failing wine:
Identify chemical and biological indicators of a failing wine. Mainly, indicators that can be detected by the technologies, are of interest.

Find limits of technologies:
Identify which kinds of indicators can be found with the two technologies.

Combined user interface:
Make sure that the digital and physical user interfaces interact in a way, which offers the user the smoothest experience possible.

Digital user interface:
Create a digital user interface, that offers a low enough barrier for new users to adopt the product and to understand its main functions.

Physical user interface:
Create a physical user interface, that allows the product to be adapted to pre-existing wineries and for the user to interact with it without discomfort.

Build prototype:
Build a physical, at least partly functional, prototype. The prototype should showcase the intended user interface to the customer, giving a clearer insight to the projects' results.

2.2 Boundaries

The primary scope of the project is currently wine making, with the eventual possibility for beer brewing.

The project is time based and is set to end may 17th. The required man hours are estimated to be 5120 hours. The project is budgeted for 3 000 SEK and is the standard budget for bachelor projects at Linköping University, with an additional sponsorship of 10 000 SEK. Due to the time constraint, the project is delimited to only European wine making.

3 Business justification

In this chapter, the business justification of the project is discussed in terms of needs, expected utility, ethics, and sustainability aspects.

3.1 Needs

There are many types of demands this project needs to face. Directly linked to the chosen goals, one demand would be reducing waste during the winemaking process as well as making this process more effective.

Seen from an economic perspective, one relevant need for the product and/or solution is to be economically profitable and sustainable. During the study visit made at a small winemaker outside Väderstad in Östergötland, it was discovered that in addition to the economic need, there is also a need for smoothness. The winemaker in question needs to be able to easily and lightly perform his measurements.

Another need the winemaker brought up is that wine making is often seen as a craft and a sort of art form. Vineyards and recipes are inherited within families along with a deeply rooted tradition of wine making. The quality and taste of the wine are very subjective and adjustments in manufacturing and blending are simply made after what the winemaker tastes and likes. Therefore, there could be a need to maintain that aspect of the manufacturing that makes it a craft and keeping the actual pleasure for the winemaker. In the end, winemakers typically engage in wine making due to their genuine interest and passion for the craft. [**?**]

3.2 Expected utility

The expected utility can be described as how much value, primarily monetary, the project is expected to create. The expected utility is the basis for determining wether or not the project is profitable.[Hallin and Gustavsson, 2018]

Halling and Gustavssons model, PENG can be used to define the profit to more than just economic revenue that can in turn be used to determine the expected utility. It consists of three groups: "direct utility", "indirect utility" and "uncertain utility"[Hallin and Gustavsson, 2018]

Direct utility:

- Revenue from customers purchasing the product.
- Improve the brewing process in different stages.
  - Making the brewing process more consistent

  - Automating certain procedures and lessening work load and work time.

Indirect utility:

- Future potential for incorporation and adaptation of new technology.
- Implementing the product in similar areas of use, such as beer brewing.

Uncertain utility:

- Introducing a new product that allows the possibility to set new industry standard.
- The introduction of this product in turn makes wine producers more susceptible and accepting of future technology.

3.3 Ethics and sustainability aspects

In the product development process it is relevant to take into account different ethics and sustainability aspects. When it comes to product development, it may be more relevant from a sustainability perspective to develop a product or system that can be implemented together with the equipment already in use. In the case of wine making, avoiding having to replace all of the vessels or measuring equipment in order to use the new product, is thus a point of interest.

Given the previously formulated needs, it is also important that the work environment for the winemaker is sustainable.

Minimising the physical product and instead using the existing equipment can also mean that you take advantage of the functions that already exist in a modern smartphone, something that the winemaker at Särtshöga Vingård strongly advised.

It is also important to choose materials and design carefully to facilitate recycling.

Ethical aspects of the project may include issues such as how the product possibly relates to aiding the production of alcohol and the following effects of that.

4 Stakeholder Analysis

The project involves several stakeholders, each with varying degrees of impact and engagement. They have different levels of interest and varying degrees of influence on the final outcome. Below, the key stakeholders are presented, and their respective influence on the project is discussed.

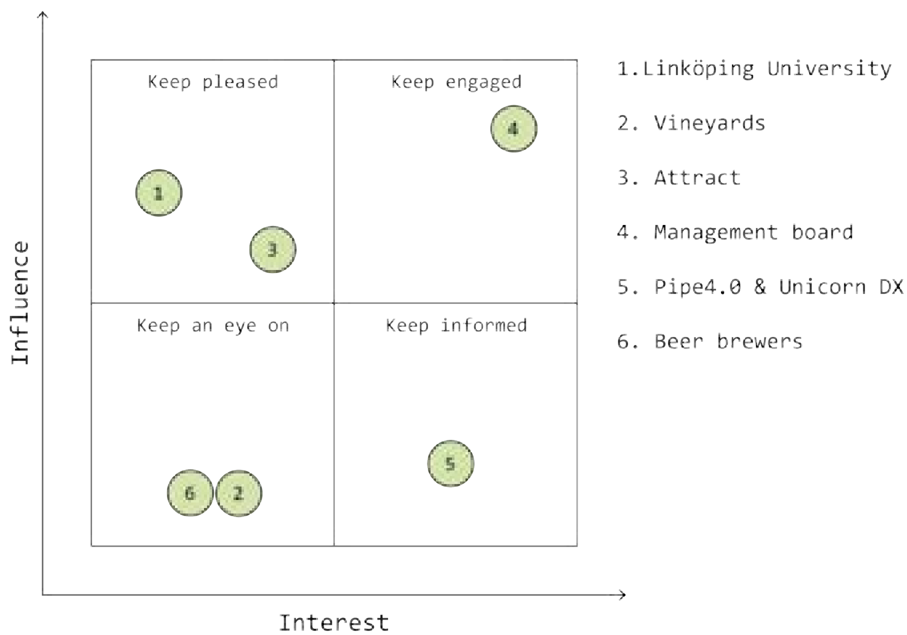

Figure 5: Visualitation of interest and influence of stakeholders

4.1 Project owner

The project owner is Marie Bengtsson at Linköping University and she is a key member in the management board.

4.2 Decisions

Critical decisions regarding the project are done by the management board consisting of the project owner Marie Bengtsson and examinators Mikael Axin and Anna Yström. The board regularly reviews the project and decides if the work is satisfactory, needs adjustments or should be stopped upon presentation. Major decisions are made by the group members in cooperation with the project owner and minor decisions are made internally within the group.

4.3 Clients and users

The client is ATTRACT, a company whose goal is to gather Europe's fundamental research and industrial communities in order to develop detection and imaging technologies. Attract offers two potentially usable technologies to the project, those being PiPe4.0 and Unicorn DX.

Primary users are wine producers. Possible secondary users are laboratories responsible for testing wine parameters and quality control, and breweries.

4.4 Key people and competences

Project owner Marie Bengtsson brings years of experience about design thinking from her work as program director at Linköping University. Bengtsson is scheduled to meet with the group on a weekly basis in order to consult and follow up on the project.

The management group is considered key to the project since they will steer the projects direction by denying or allowing certain ideas and methods, thus directly effecting the project orientation and final result.

Employees in the workshop at Linköping University offer key experience and high quality equipment which are useful when building the product prototype. Meetings with personnel can be arranged in order to receive consultation about construction, drawing parameters et cetera.

If needed, the group are able to contact a large selection of other professors at Linköping University with relevant experience. Furthermore, student contact persons at Attract for the two technologies are considered to be key people in learning about and understanding the technologies we are working with and contact with them is important to be informed and updated on the latest information about the technologies.

4.5 Other stakeholders

Stakeholders apart from Linköping University and ATTRACT could be:

- Universities with ongoing similar projects, about either wine making or similar technologies
- Aalto University in Finland is an example of an external stakeholder who currently is working with ATTRACT's technology, thus having an indirect part of the project
- Wine making researchers
- Companies developing or researching similar technologies

- Vineyards and beer breweries

When visiting Särtshöga vineyard, the owner Niclas, showed interest in a possible prototype or product we develop during our project.

4.6 Stakeholder mapping

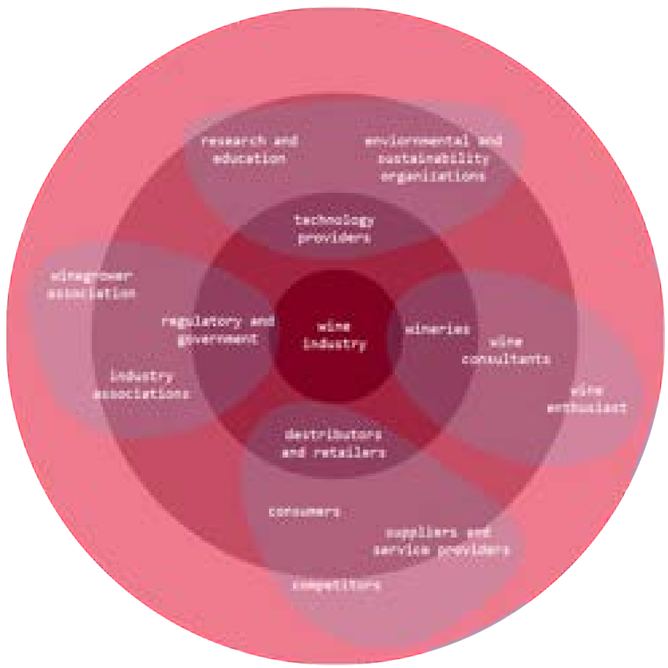

Figure 6: Map depicting stakeholders

With the main goal in mind; to ensure consistent wine, or increase efficiency in production, results with the main users of the potential product also being a major stakeholder, that is the wine farmers. For similar reasons, other actors, such as distributors and retailers retain great interest in the product. Other stakeholders may also be regulatory or governmental organs who may wish to ensure legitimate production. This may be especially prominent in areas where legality of production is of high importance, for example Champagne.

5 Conditions

In this chapter, the prerequisites and conditions for the project are discussed.

5.1 Current situation analysis

Below, a SWOT analysis is presented, examining the project´s strengths, weaknesses, opportunities and threats.

Figure 7: SWOT-analysis

5.2 Available resources

The project group has a total of 5120 working hours which translates to 640 working hours per group member. During period one the members are expected to log 30 work hours per week, this is increased to 40 work hours per week during period 2.

At Linköping University the group has a wide range of personnel, machines, manufacturing techniques and materials at their disposal. This includes workshop personnel, management board, assistants and supervisors. There are no production or material costs added when using the workshop at the university.

The project has a budget of 3000 kr which can be used to acquire materials that are not available in the workshop and to cover travelling costs. There is also a possibility to apply for a wider budget and resources from the client and earlier projects connected to this project. The project owner has mentioned the possibility for an excursion to visit the universities where the technologies have been developed as well as a vineyard in Italy.

5.3 Responsibilities of the project group and owner

The project group has the responsibility to maintain good contact with the management group, attending meetings with the project owner and to deliver a physical prototype for the solution that is developed. Furthermore the group needs to deliver status reports for the four gates and lastly a complete project report.

The project owners responsibility is to act as a support tool and to help the group with ideas, delegating decisions to the management board et cetera. The project owner also has the responsibility to keep an ongoing communication and discussion with the group, especially during the weekly meetings.

6 Preliminary requirement specifications

A preliminary requirement list regarding the prototype has been established, see Table 3. Because the project is in its early stages and as to not hinder any possible solutions, the requirement list has been fashioned with requirements that have been deemed essential or uniform for all possible approaches of the problem. R stands for ”requirements” and P for ”preferred”.

Table 1: Requirement specification

Number	Requirement	Type
1.0	**Function**	**R/P**
1.1	Be able to implement at least one of the technologies.	R
1.2	Be able to deliver measurable values with the help of a sensor.	R
2.0	**Function-Determining Properties**	
2.1	Does not contaminate existing product.	R
2.2	Potential for symbiosis/collaboration with other existing products or possible software.	P
3.0	**Service Properties**	
3.1	Does not diminish job satisfaction.	P
3.2	Easy to clean and maintain.	P
3.3	Lifespan of at least three (3) years	P
4.0	**Manufacturing Properties**	
4.1	Replaceable components for easy repair.	P
5.0	**Safety/ Ergonomic Properties**	
5.1	Oblige to health regulations.	R
6.0	**Aesthetic Properties**	
6.1	Designed in such a way as to not promote reluctance of usage.	P
6.2	The design must be adapted to its intended environment.	P
6.3	Express certainty that it does not contaminate the preexisting product (wine).	P
7.0	**Scrapping and Recycling Properties**	
7.1	Can be disassembled into sub-components to facilitate recycling.	P

7 Planning

This section outlines the overall plan for how the project is to be conducted, with regards to time and budgetary limitations.

7.1 Work Breakdown Structure

The work breakdown structure, WBS for short, is an account of all the tasks that need to be completed in order to finish the project as a whole. The tasks are divided into different work packages, shown in pink in Figure 8, which in turn is further divided into more specific tasks when applicable. The work packages are not necessarily presented in chronological order.

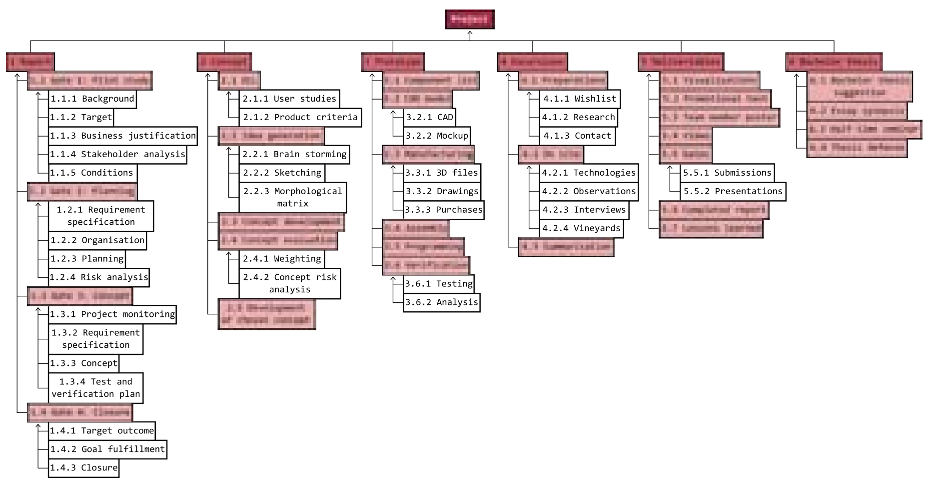

Figure 8: Project WBS

7.2 Activity list

Here, the activity list of the project is presented. The list outlines and describes various activities performed in the project. It provides a comprehensive overview of the planned and finished activities along with start end end weeks.

Activity description	Time (h)	Start (week)	End (week)	Status	Responsible
Gate 0	**157**	3	3	Finished	
Gate 1	**398**	4	5	Finished	
Gate 2	**123**	6	7	Finished	
1.2 Report					
1.2.1 Preliminary requirement spec.	8	6	7	Finished	C
1.2.2 Organisation	10	6	7	Finished	G & E
1.2.3 Planning	20	6	7	Finished	O & H
1.2.4 Deliverables	50	6	7	Finished	Everyone
1.2.5 Risk analysis	10	6	7	Finished	C & L
5. Deliverables					
5.1.2 PPT	25	5	6	Finished	C & G
Gate 3	**943**	8	13		
1.3 Report					
1.3.1 Project Monitoring	8	7	8	Finished	O
1.3.2 Test & Verification plan	20	7	8	Finished	M & S & G
2. Excursions					
2.1 Contacting vinyards	10	7	13	Finished	M
2.2 Planning trips	10	7	14	Finished	E
2.3 Booking cars	1	8	8	Finished	H
2.4 Execution Skåne	210	9	9	Finished	Everyone
2.5 Execution Padova	360	15	15	Finished	Everyone
3. Concept					
3.1 CCL	30	7	8	Finished	S
3.1.1 User studies	60	8	9	Finished	M & L
3.1.2 Requirement spec.	2	8	9	Finished	S
3.2.1 Brain Storming	16	8	9	Finished	E
3.2.2 Sketching	16	8	9	Finished	H
3.2.3 Morphological matrix	8	8	9	Finished	H
3.3 Concept development	100	8	12	Finished	Everyone
3.4.1 Weighing	8	12	13	Finished	G
3.4.2 Concept risk analysis	8	12	13	Finished	C
3.5 Final concept development	40	12	13	Finished	O
5. Deliverables				Finished	
5.5.2 PPT and presentation	32	12	13	Finished	E & S
5.7 Lessons learned	4	12	13	Finished	S
Gate 4	**564**				
1.4 Report					
1.4.1 Target outcome	30	13	14	Finished	G
1.4.2 Goal fulfillment	30	13	14	Finished	O
1.4.3 Closure	30	13	14	Initiated	M
3. Prototype					
3.1 Component list	50	13	14	Finished	M
3.2.1 CAD	50	14	15	Finished	C & S
3.2.2 Mockup	40	15	16	Finished	L
3.3.1 3D-files	40	15	16	Finished	C & O
3.3.2 Drawings	20	15	16	Finished	E
3.3.3 Purchases	40	15	17	Finished	H
3.4 Assembly	60	17	19	Finished	S
3.5 Programming	50	17	19	Finished	O
3.6.1 Testing	90	17	19		
5. Deliverables					
5.6 Completed report	2	20	20	Initiated	S
5.7 PPT and presentation	32	20	20	Finished	H + O
5.8 Preparation California	64	21	23	Initiated	Everyone
5.9 Participation California	128	22	23		Everyone
6. Bachelor thesis	2497				
6.1 Bachelor thesis suggestion	32	6	7	Finished	Everyone
6.2 Essay synopsis	32	7	8	Finished	Everyone
6.3 Half time seminar	913	8	15	Finished	Everyone
6.4 Thesis defense	1520	15	22	Initiated	Everyone
Tot	4682				

Figure 9: Activity list with appreciated time.

7.3 Preliminary estimate

As the project group works on unpaid time, vehicles for research excursions are provided by the university and materials for the prototype are paid for by ATTRACT, monetary limitations are not deemed to be the main limiting factor in the project. Instead the time available to the project group, measured in work hours, is considered the main resource.

7.3.1 Appreciated workload

In the first study period the schedule is shared with another course, absorbing 20 percent of the available time. Between the 15th of January and the 8th of March, it is therefore estimated that up to six work hours per weekday will be put into the project by each group member.

In the second study period all available time will be put into the project. Between the 25th of March and the 22nd of May, this means up to eight work hours per weekday and group member. The project will be concluded on the 31st of May. Four public holidays in the second study period means that several weeks will consist of only four work days.

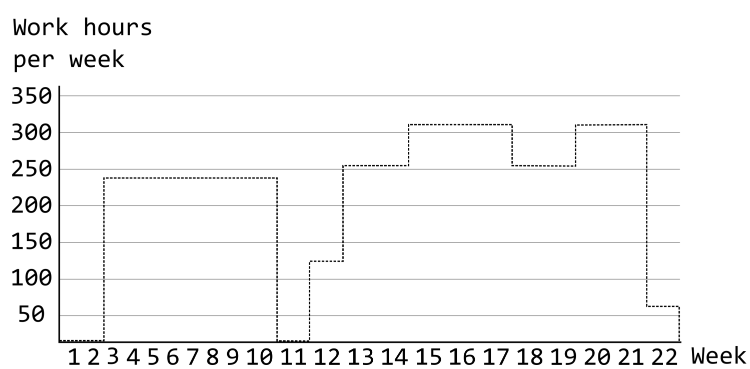

Figure 10: Estimated workload per week throughout the project

In reality, work hours will likely not be expended as steadily during the study periods, in particular study period 1, due to illness absence and other preoccupations. Similarly, expenditure might also not be completely static during the exam periods, with a possibility of making up for the loss of hours during the study periods.

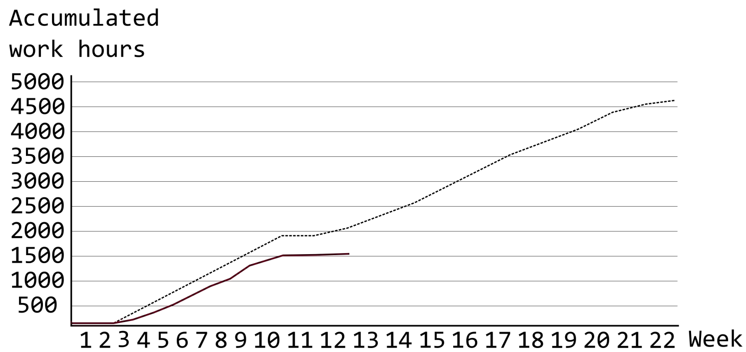

Figure 11: Accumulated resource expenditure as of 2024-03-22

7.4 Project timetable

The general timetable of the project is visualised in a Gantt chart seen in Figure 12. Direct dependencies between activities are shown with arrows. Due to major uncertainties around time consumption of each work package activity lengths are kept to whole weeks.

The chart shows an unbalanced distribution of work packages, leaning towards a more intense second study period with many tasks supposed to be done in a short time frame. This is a direct result of set dates for the project gates and bachelor thesis deadlines. Where possible, work packages will be initiated early in order to combat this imbalance.

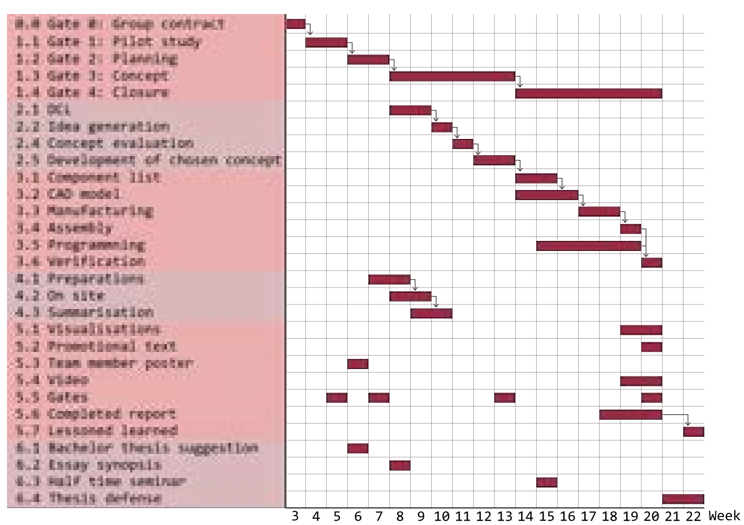

Figure 12: Gantt chart

7.5 Milestones

In this chapter, the project's overarching milestones are presented. The project is goal seeking, meaning that the goals and milestones are flexible and might change over time as the project's ultimate goal may change or evolve over time based on new information or changing circumstances. The recommended time span for setting milestones in goal- seeking projects is one to two weeks. This makes it difficult to estimate milestones past gate 3. [Hallin and Gustavsson, 2018]

The milestones are crucial for determining the project's continuation. The dates were chosen based of the provided gate deadlines, planned study visits, and the tasks that need to be completed beforehand.

- 2/2 Gate 1 - Prestudies.
- 16/2 Gate 2 - Plan.
- 19/2 Project monitoring.
- 29/2 Choice of application in process.
- 8/3 Preliminary choice of 3 concepts.
- 21/3 Test and verification plan.
- 28/3 Gate 3 - Concept
- 17/5 Gate 4 - Finish and submission of report.

8 Organisation

The following section aims to clarify the internal structure of the project.

8.1 Roles, responsibilities and staffing

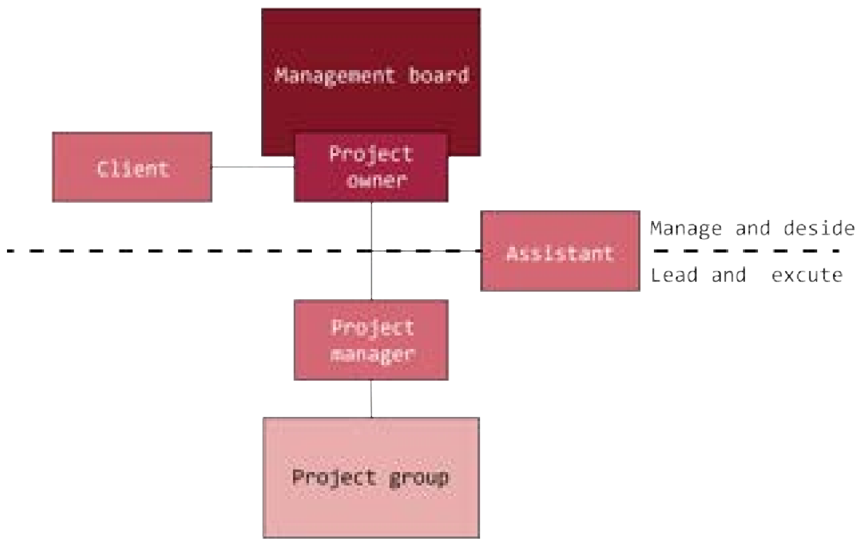

Figure 13: Visualisation of the organisation hierarchy

Beyond or within the main goal of our thesis specific roles have been established, presented and described below:

Management Board:

- Marie Bengtsson - Project owner
- Mikael Axin - Project assistant
- Anna Yström - Project office
- Elinor Särner - Project office

Assistant:

- Emma Walters - Assistant

Project group:

- Oscar Hägg - Project manager
  As project manager Oscar oversees the structure and what steps are necessary to move forward. Furthermore the responsibilities of the project manager include creating a common digital workspace, delegating and sending out surveys.

- Chris Thoring - Vice Project manager
  As vice project manager Chris assists the project manager with various assignments, as well as supports other members in their work.

- Hanna Jonsson - Financial manager
  As financial manager Hanna is responsible for looking over the monetary budget, the projects' finances and execute purchases.

- Ebba Johannisson - Logistics manager
  As logistics manager Ebba is responsible for different reservations of rooms for the group to work in. General overseer of the groups schedule is also apart of her responsibilities.

- Martin Håkanson - Communication manager
  As communication manager Martin is responsible for all external and internal communication and being the groups contact person.

- Gunnar Berg - LateX manager
  As LateX manager Gunnar is responsible for the common latex in which the group writes in. If a problem with code or formatting occurs, Gunnar is the first responder.

- Linus Frostell - Mood manager
  As mood manager Linus is responsible for everybody's well being by having continuous check ups with the group and also planning fun events.

- Sigrid Åkerskog - Overseer
  As overseer Sigrid double checks and reads through everything that will be submitted.

Beyond the established roles, everyone in the project group has common responsibilities. It is especially important to respect each other by contributing to the project and being on time. Even though we have a project manager whose main responsibility is to delegate work and ensure that the project moves forward, it is still important that each individual takes initiatives. Ever member should put in the time that was agreed upon; around 25 hours per week in study period one, and 40 hour per week during study period two.

8.2 In-depth Bachelor thesis

The project group is divided into three bachelor thesis groups. The three theses will approach the main problem of inefficiencies and uncertainties in the wine making process from different angles. In the end, all theses should contribute to the overarching goal of implementing the technologies in a manner beneficial to the wine making process.

8.2.1 Design of the sensor containing product

This bachelor essay is written by Chris Thoring and Oscar Hägg. The supervisor is Renee Wever.

The thesis will concentrate on researching important mechanical properties in the physical product. In particular details that interact with the wine itself, the tank and the immediate environment, will be in focus.

Research questions:

- What are the requirements and limitations for the product to successfully be incorporated into existing products?
- What mechanical principles could be utilised to achieve these requirements, and how does this affect the choice of materials?

The thesis should result in an in-depth design criteria list for the product. This list should be of use to the product developer assigned to a future project, should this project indicate substantial potential for the technologies to be used in wine production.

8.2.2 Designing a User Interface intended for Winemaking

This bachelor essay is written by Hanna Jonsson, Sigrid Åkerskog and Linus Frostell. The supervisor is Rene Wever.

The purpose of this thesis is to study how UX and UI can be used when developing technology for winemaking, while both keeping traditions and meaningfulnes. Winemakers tend to have deeply rooted traditions and methods which have passed through generations, meaning that there might be missed areas of improvement due to sceptism of changes to the winemaking process.

Research questions:

- Which traditions are widely valued as meaningful in winemaking?
- What is the most suitable UX/UI design in a product aimed towards a target group who has deeply rooted traditions?

UX and UI will be central in the project when shaping the product, from conceptualization to prototyping. Information gathering begins early in the process through observation and interviews, persisting throughout the project. The study's results will serve as a valuable resource for future product development initiatives targeting winemakers.

8.2.3 Business acceptability and viability

This bachelor essay is written by Ebba Johannisson, Gunnar Berg and Martin Håkanson. The supervisor is Renee Wever.

The thesis will investigate the viability of implementing the new technologies PiPe4.0 and/or Unicorn DX in the wine/beer industry from a business and market perspective.

During the pilot study, we observed that the acceptability to new technologies in the wine industry differs between types of production scales. Traditional vineyards, in particular, seem to be quite critical to change their way of wine making, while newer vineyards to some degree have already adopted technologies. Additionally, smaller wine and beer producers face resource constraints and cannot afford to invest heavily in individual measuring tools. Therefore, the economical aspect of producing a new product using the technologies is quite important. We also noted the presence of numerous existing measuring tools on the market already, contributing to significant competition within the industry.

Research questions:

- What is the perceived value proposition of implementing PiPe4.0 and/or Unicorn DX among wine/beer producers, and how does it compare to existing measurement methods in terms of accuracy, efficiency, and cost-effectiveness?
- What are the potential market dynamics, including demand, competition, and regulatory considerations, that could impact the adoption and commercial success of PiPe4.0 and/or Unicorn DX within the wine/beer production industry?

The result should be a mapping of the plausible future customers and if there is a business big enough to be profitable by answering the questions above. The questions will be answered by conducting a comprehensive market analysis and benchmarking research.

9 Deliverables

This section briefly describes the content of each of the projects deliverables. The final result especially, is likely subject to future changes and clarifications.

9.1 Gate 3: Concept

The concept delivered at gate 3 should outline a general idea for the final product. A decision will be made on what sensors should be included in the data gathering unit and how the collected data is to be displayed. Examples of possible display solutions might be to attach a screen directly to the product, relay the information to a phone or computer, or to save the gathered data to a local file which is the accessed via a spread sheet. Examples of sensors might be the PiPe4.0, Unicorn DX or a combination of sensors already on the market.

The concept should be the basis for the prototype development. Although the prototype should preferably somewhat reflect the concept in its choice of sensor, it is likely that the absence of the technologies in focus will call for a substitute sensor to be used. The user interface element of the product, however, should strive to be as close to the concept as possible. The idea for how the user is to interact with the product should therefore be presented in greater detail in the concept delivery.

9.2 Final result

The client has requested that the following material be included in the final delivery. More details on what these requests should contain may be made available at a later point in the process.

9.2.1 Physical prototype

A conceptual prototype proving a technical concept or explaining a design vision. The prototype should ideally include at least one data collecting unit and one displaying unit. Preferably the data collecting unit should contain one or more sensors that are capable of making useful measurements in wine.

9.2.2 Short video

A short video showcasing the result of the project, as well as possibly giving an insight to the process. The video should be one to two minutes long. Production value of the video does not matter.

9.2.3 Promotional text

A short text promoting the use of the technologies in the wine industry.

9.2.4 Visualisations

5 or more visualisations of the final result. These might include renderings of CAD models, photographs of the prototype or schematics explaining the results. The visualisations should be suitable for promotional or educational use.

9.2.5 Report

A project report going into depth on the process by which the result was achieved. The report should make it clear to the reader how conclusions were reached and why the design choices made were necessary. Future research on the topic should benefit from the content in the report.

9.2.6 Team member poster

A poster displaying each team member, as well as his or her role in the group. The poster may have a less serious tone and high production value is not a requirement.

10 Risk analysis

This section presents identified risks that may affect the project.

10.1 Mini risk matrix

A mini risk matrix is made in order to identify and evaluate risks directly involving the project with the aim of eliminating them as soon as possible [Hallin and Gustavsson, 2018].

First the group identified relevant risks that may affect the project, rated them from 1-5 based on probability and potential damage they could inflict on the project. The potential damage multiplied with the probability results with a damage product. A damage product of 25 represents a highly probable risk with severe consequences for the project while a 1 represents a low probable and low consequence risk [Hallin and Gustavsson, 2018]. Risks with a product of less than 8 will not be evaluated for solutions.

In order to clarify each risk a short description of precautionary actions and possible solutions are presented, see Table 2. Certain team members holds main responsibility for the risks that fall into the category of their role, for example, the finance manager holds main responsibility that the prototype budget is followed.

Table 2: Mini risk analysis

Risk	**Probabilit 1-5**	**Damage 1-5**	**Damage product 1-25**	**Preventive measure**	**Possible solutions**
The prototype is not realizable	3	5	15	Thorough research regarding avalible tech, wine making process etc.	Present the prototype as a potential product
Unicorn DX and PiPe4.0 is not appropriate to use in wine making or beer brewing	3	3	9	Acquire the technical limits early	Present the conclusion in the report with valid arguments
Poor work distrobution between the bachelor's theses	2	4	8	Map out the main subjects of each thesis before starting	Rethink the limits of each theses
Conflicts within the group begins to halt progress	2	4	8	Keep good group-spirit by arranging activites, keep good communication, follow the group contract etc.	Try to solve the conflict internally, lift with project owner if not possible
Contact with ATTRACT is underwhelming	2	4	8	Establish contact with relevant stakeholders early	Base the work on similar tech
The prototype is not finished on time	2	4	8	Create a separate riskanalysis for the prototype	Limit features and quality in order to have something to present
There is no time to test the prototype	3	2	6	Finish the prototype as early as possible	
The bachelor's thesis becomes too similar	2	3	6	Roughly map out the main subject and headers within the group before starting	
No relevant company is willing to accept study visits	2	3	6	Contact companies early	
LaTeX and teams documents ceases to exist	1	5	5	Save back-up documents regularly	
A group member decides to leave the project	1	5	5	Create and maintain a good group atmosphere	
The group fails to pass gate or misses the submission date	1	5	5	Make sure to follow the requirements for each gate	
The prototype budget is exceeded	1	4	4	Proper economic budget planning	

11 Field studies

This chapter provides a brief discussion on the conducted field studies, along with their purposes and lessons learned. The most active stages of winemaking occur during summer and autumn but the visits took place in February. This means the visits had to rely heavily on descriptions and interviews rather than the observations that otherwise would have been ideal.

11.1 Vineyards in Sweden

Four vineyards were visited in total and are presented in chronological order. The first vineyard Särtshöga Vineyard was visited early on in the project during January 2024, the last one in the end of February 2024.

Vineyard in Östergötland

To gain an early understanding of how a vineyard operates, a study visit was conducted to a vineyard in Östergötland, Sweden. There, the group had the opportunity to meet the wine maker and observe and learn about the wine making process, the tools and instruments used. Given the group's relatively low level of knowledge at the time of the visit, the main goal was to obtain an overview and identify any clear problems and needs. At the vineyard, the owner showed a smaller device that was used to measure alcohol level, but all analysing of the wine was outsourced to Brattås Winegarden. Other than this, the owner had a device to measure pressure in the wine after bottling, an afrometer. This device pierced the bottle which means that the sampled bottle is "destroyed". This was something that caught attention early on and further researched.

After the wine maker had gone through his work process and technologies, the group asked questions to gain knowledge and information. It was to the groups understanding that they was rather happy with his situation, and since his vineyard wasn't very large, funds for a highly technological device was not the main focus.

However, they said that if they was able to monitor the fermentation without manual testing, it could be interesting. They had looked into products such as Winescan, but said that it would take them 100 years to come to the break even point in comparison to using Brattås Winegarden's services. Price was definitely their main concern in investing in products.

Skåne

Later in the project, when it was time to develop concepts, a two-day trip to Skåne was made where three different vineyards were visited. By this time, the level of knowledge was higher, and the group was better prepared with interviews and a clear objective. The purpose of the visits, in addition to studying the current technology more thoroughly, was also to observe the winemakers at work.

The vineyards visited varied greatly in organisation, size, and the owner's attitude toward the project and responses to the questions. Furthermore the personality and lifestyles of the winemakers were vastly different. At the three vineyards visited, the winemakers used different equipment for monitoring and analysing the wine. This gave a wide perspective on the different methods of winemaking and attitude towards using technologies in the process. During the visits, the winemakers started with freely describing their work process and the tools used. Questions about technology, needs, problems and difficulties were asked as fit during the visit. After touring the vineyard and winery, semi-structured interviews were held, and worked well in the manner that the group could tailor the interview according to the winemakers objective and individual work process.

First vineyard in Skåne

Located in eastern Skåne. This vineyard operates as a collective, with its primary focus not being profit but rather serving as a recreational pursuit. It stands as one of the oldest and largest vineyards in Sweden. The group had the opportunity to meet the winemaker who is a retiree and formerly an agronomist. Their prior professional experience includes a role as a marketing manager at a company. They predominantly oversee the vineyard for the communal enjoyment it offers and as a fulfilling pastime. As previously mentioned, the vineyard worked as a collective in the way that individuals that had interest, pay for rows of vines and decide what grape they want to work with. When the time comes for managing the vines and harvesting, all members that had their vine rows joined and helped with the harvest.

The owners, a married couple, did not buy the land first hand to run a vineyard, the previous owner was selling and the land was leased. They thought it would be a shame if the vineyard and capital were to be destroyed if no one purchased the land, so it was a very spontaneous happening. Because of this, there was not much knowledge about wine making and they had to learn on the go. In the winery, no advanced technologies are used. In the steel tanks they measured pressure only. Just like the previous wine maker, this wine maker also outsourced all her analysing of wine to Brattås Winegarden, who they spoke very highly of. They mentioned that there was absolutely more to learn from analysing the wine on their own, but then one would need to be able to act on this, and neither of the owners were into the analytic part of wine making. They also mentioned that the contact and relationship with Sveneric, the owner of Brattås Winegarden, is meaningful and is more important than being able to do her own analysis.

Second vineyard in Skåne

Located right by the sea on the western side of Skåne the group met two younger-generation winemakers from France. Both individuals had backgrounds in the winemaking industry and had studied winemaking at master level in France. They had a positive attitude towards technology and used several instruments and technologies that the group had not seen during the previous visits. Their main scanning device was from FOSS which gave them almost all needed values. When purchasing this particular scanner, the customer is able to choose which functions should be included. One of these functions, is a sulphate analyser. However, since the accuracy of the sulphate scanner is not precise enough for their needs, it was deemed not economically worth it for them. In order to analyse sulphate, they use manual process called the Ripper method. According to them, the process is easy but time consuming. Another new aspect discovered in the winemaking process was the usage of microscopes. At this vineyard, microscopes were used to inspect smaller test batches during fermentation, with the purpose of analysing the yeast in the must. The goal of the method is to identify both wanted and unwanted yeasts as soon as possible. This information sparked ideas for what issue the concept could aim to solve.

During the tour in both the winery and lab the group had an ongoing dialogue with questions and after they had presented their work process and equipment. A shorter semi-structured interview was then held. One was interviewed about UI and UX while the other was interviewed about construction and technical questions.

Third vineyard in Skåne

Located south-western part of Bjäre peninsula, the group met another wine maker, a former architect with a love for wine making as an art form. Their view on wine making was as mentioned focused on art and letting nature, weather and soil be the important factors. They were not advanced in using technologies and had ties to Georgian wine making, using Qvevri wells buried in the ground to age the wine.

This winemaker was not interested in our nor any other technologies, however he was very committed in political questions. They wanted to break the Swedish alcohol monopoly, which would result in them being able to sell their wine on their own. That would allow them to gain a much higher profit from their products, and it was important to them to be in direct contact with their customers. When asked about the new law from EU that forces winemakers to display the ingredients and contents on their labels, they answered that they thought it was a very good thing. This was because they did not use any additives what so ever, except a little sulphur, thereby looking good in comparison to others. When asked about how they would gather information on the values of their wine in order to complete their labels, they responded that they would probably send it of to a lab instead of buying a measuring product themselves.

11.2 Vineyards in Italy

In mid April 2024 the group travelled to Padova, Italy where two vineyards were visited. At this point in the project the group were considering two product concepts, Pump on the tank and Distillation unknown, seeking confirmation or disapproval from winemakers during the trip.

First vineyard in Padova

Located in the Euganean Hills south of Padova, the vineyard is a family owned, organic vineyard with 25 hectares of vines. The group met the winemaker who together with their family and seasonal employees ran the vineyard. Today the winemaker used a manual hydrometer to measure density, calculate sugar as well as alcohol levels in his wine. For further analysis of the wine they sent samples to a local laboratory. The winemaker described that they were in the thought process of purchasing a microscope for analysis in the winery in order to detect *Saccharomyces* (a type of yeast that is used in wine making) and *acetobacter* (bacteria used to convert malic acid into lactic acid). Since they created their wine by not adding any yeast, it was important to know if the right cultures were present in the must. After similar dialogue as the other visits, they told us that a product of our nature would be worth four times the price of a microscope, which was in the 1500€ range, as long as it was easy to use, did not need regulating and measured values precisely and accurate. When asked about if there had been any problems related to climate change they responded: "If the grass is yellow in the end of the summer, you know that there is going to be problem with the fermentation." Further impact of climate change on wine making can be read about in [Johannisson et al., 2024].

After the tour of the winery, the UX/UI group hosted a workshop with the owner regarding general UI preferences. The workshop explored how they, as a winemaker, prefers to interact with the concept product. Topics raised for discussion were which format information should be presented in, which hardware should be used to display said information, how one should be notified when parameters of the wine are deviates from normality and the importance of portability of the product.

Second vineyard in Padova

Located at the bottom of the Euganean Hills, this vineyard is also a family owned vineyard with over 70 000 vines. In the winery, the family used the same kind of simple manual density meter as the previous vineyard. They seemed rather pleased with their current situation, and main concern for a product was as the other winemakers, pricing. However, they had noticed the impact of warmer weather. They discussed about how their latest wines had a lot of residual sugars left after fermentation, that the pH was to high and that their wine that is supposed to be around 12% alcohol instead came all the way up to 15%. This, in their opinion, contributed to a less enjoyable drinking experience.

11.3 Conclusion field studies

As all vineyards visited were in the small to medium range, the main concern for a technological product was pricing. Takeaways from these visits was that if a precise and accurate product within a reasonable price range i.e below 10 000 euros could be developed, it would be of interest. Unfortunately the group did not get a chance to visit or get in contact with a larger scale winery which would provide another perspective. These larger, mass scale wine production wineries with a budget for technology could be the main target group and is something that should be further studied.

Figure 14: Used wineglasses in a winery in Italy.

12 Requirements specification

The requirements specification presented in table 3 has been developed based on the users needs identified during conducted excursions and preliminary studies.

Table 3: Requirement specification

Number	Requirement	Type
1.0	**Function**	**R/P**
1.1	Be able to use Unicorn DX chip together with the product.	R
1.2	Measure pH.	R
1.3	Measure specific gravity.	R
1.4	Measure density.	R
1.5	Measure temperature.	P
1.6	Measure SO2.	P
1.7	Measure NH3.	P
1.8	Detect yeast strains.	R
1.9	Detect lactic bacterias	P
1.10	The user can take remote samples/track the progress of the wine	R
1.11	The product can perform continuous sampling	R
1.12	Samples taken represent the entirety of the wine	R
2.0	**Function-Determining Properties**	
2.1	Does not contaminate wine.	R
2.2	The tank should not have to be adjusted in order to implement the product.	R
2.3	The user can still taste the wine from the fermentation tank.	R
2.4	Should tolerate temperatures up to 80 C.	R
2.5	Have an external energy source.	R
2.6	The wine should not crystallise inside the sensor unit.	P
2.7	The device should be movable	P
2.8	Possibility to turn on/off	R
2.9	Structural strength for a pressure difference of at least 72 kPa	R
2.10	Leak-proof at a pressure difference of at least 72 kPa	R
3.0	**Service Properties**	
3.1	Does not diminish job satisfaction.	P
3.2	Easy to clean and maintain.	P
3.3	Do not exceed 70 db	P
3.4	Minimum lifespan of 5 years.	P
4.0	**Manufacturing Properties**	
4.1	Replaceable components to ease repairs.	P
4.2	Prototype friendly.	R
4.3	Modular.	P

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Table 3 – continued from previous page

Number	Requirement	Type
5.0	**Safety/ Ergonomic Properties**	
5.1	Oblige to health regulations.	R
5.2	Inert to chemicals in wine and cleaning agents	R
6.0	**Aesthetic Properties**	
6.1	Designed in such a way as to not promote reluctance of usage.	P
6.2	The design must be adapted to its intended environment.	P
6.3	Express certainty that it does not contaminate the preexisting product (wine).	P
7.0	**Scrapping and Recycling Properties**	
7.1	Can be disassembled into sub-components to facilitate recycling.	P

13 Concepts

In this chapter, the concepts generated from field studies and idea generation workshops are presented, along with an explanation of how the workshops were conducted. The study visits provided insights into wine production and contributed to an understanding of winemakers' needs and desires. The information and insights gathered during the visits served as input to the concept generation process.

13.1 Idea generation workshops

Idea generation is used in this project as a systematic process to explore the entire solution space to the given problem. Several workshops are held to generate an inspirational list of solutions to each partial measuring problem.

13.1.1 Workshop A

The main product is divided into four different functional categories:

- Measurable value:
  What could the product measure? Which values could be of interest to the wine maker?
- Input to the product:
  How could the user communicate instructions to the product?
- Output from the product:
  How could the product communicate its results to the user?
- Sensing unit:
  What could the sensing unit look like? What physical principles could be implemented?

For each category the group is given a set time to come up with as many possible solutions as possible. Emphasis is on speed, in order to stimulate free thinking and discourage self censoring. One participant at a time writes down a suggestion on a sticky note, sticks it on a board and hands the pen over to the next participant. When the time is up duplicates are eliminated and the team members vote on the most promising ideas by distributing a set number of dots on their favourites. Multiple dots were allowed to be placed on the same idea.

13.1.2 Results from workshop A

The results from workshop A are visualized in figure 15. The number within parentheses represents the number of votes each item got. Suggestions with one or no votes are grouped together, and is not represented in the figure, but in text down below. Some words, which does not fit the description, are eliminated.

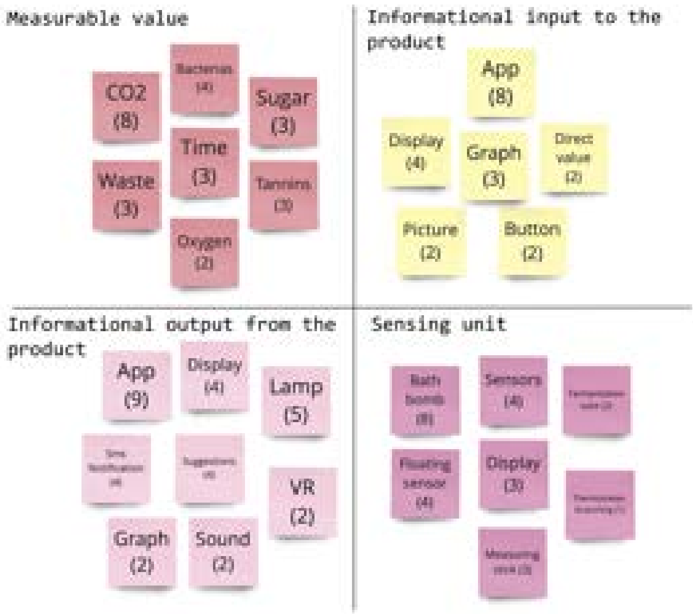


Figure 15: Results from workshop A.

Measurable value:

- Aldehydes, pH, Temperature, Volume, Alcohol, Bacteria and Yeast on grapes, Interactions, Transparancy, Profit, Volume of grapes, Transport (1)
- Sulfides, Sulphur, Weight, Number of bottles, Grape value, Water content, Lactic acid, Pressure, Work hours (0)

Informational input to the product:

- Knob, Seamless, Sensors, Voice, Handle (1)
- Touch, Lid/Cork, Unicorn in product, Signal, Vibrations (0)

13.1.3 Workshop B

Workshop B was a storyboard session where each group member had to propose a solution to a specific problem within our project, presented in sketch format. Certain criteria were given to each member, and they then had to apply these criteria to their idea and sketch. The workshop served as a spontaneous practice to pause and rethink the available options.

13.1.4 Results from workshop B

Despite the enjoyable and creative nature of the workshop, none of the concepts generated in this exercise were ultimately incorporated. While the sessions may have inadvertently nudged us towards fruitful ideas, the brainstorming process tended to yield unconventional and "wacky" concepts. However, upon reflection, this outcome was precisely what we had hoped to achieve. The workshop provided an opportunity for free thinking and exploration without the constraints of immediate practicality, allowing us to stretch our creative muscles and consider possibilities outside the box. Although the specific ideas may not have been directly utilised, the exercise served as a valuable means of sparking new perspectives and potentially inspiring future innovations within our project.

13.2 Basic concepts

The most promising ideas from the idea generation workshops are combined into 16 rough concepts, denoted A to Q.

Table 4: Basic concepts

Den.	Process	Technology	Value	Description
A	Fermentation	PiPe4.0	Gases	Pipes or tubes from tank to sensor station. Pump and gas switch
B	Fermentation, Ageing	Already in use	CO_2, pH, temperature	Sensor in lid. Modular design, ability to add more capabilities
C	Fermentation	Unicorn DX	Particles	Stationary sensor. Collect droplets from tanks
D	Fermentation	Unicorn DX	Yeast	Sensor on tank
E	Fermentation	Unicorn DX, EasyDens	Sugar, alcohol, density	Pump on tank pumping out liquid. Measuring unit mounted on the tank
F	Crushing, fermentation, ageing	Liquid raman	Sugar, alcohol	Handheld or stationary unit. Measure through glass
G	Ageing	Unicorn DX	Thiols, bacteria	Take sample with argon syringe after bottling or pipette. Determine when wine should be sold
H	Ageing in bottle	Liquid raman	pH, Tannins, Alcohol etc	Smart bottle. Representative for batch being continuously monitored

Continued on next page

Table 4 – continued from previous page

Den.	Process	Technology	Value	Description
I	Preparation	Unicorn DX	Bacteria, fungi	Scrape inside of barrels and test for contaminants between batches
J	Crushing, soaking	Liquid raman	Tannins, sugar, yeast	Determine when to stop soaking for desired taste. Monitor yeast presence
K	Bottling	Unicorn DX, PiPe4.0, Liquid raman	Sugar, CO_2, yeast	Determine fermentation time. Anticipate bottle pressure
L	Every stage	Unicorn DX, Liquid raman	All chemical and biological markers	Universal machine able to test for all values in all stages. Stationary measuring unit, with a test tube dispenser on each tank. Insert test tube into measuring unit. Self cleaning chips for multiple uses
M	After fermentation	PiPe4.0	Alcohol, CO_2	Evaporate sample to measure gases
N	Replace microscope	Unicorn DX	Identify yeasts	Additional attachment to fermentation tank outlet
O	Fermentation, ageing	Unicorn DX, Already in use	Already measured, bacteria	Stationary measuring unit with built-in receipt printer
P	Fermentation	PiPe4.0	Sulphur and free sulphur	Automatises sulphur distillation
Q	Before bottling	PiPe4.0	CO_2	Sample is extracted from tank and shaken to release CO_2. Sensor measures concentration of gas

13.3 Concept description

In the following text the concepts listed in table 4 are described in more detail.

Concept A
This was originally an idea from the researchers at PiPe4.0. Their vision was of pipes or hoses connecting the fermentation tanks to a stationary GMU. The gases would be pumped from the top of the tank through a gas switch to the GMU, where CO_2, oxygen and various other gases would be measured in order to monitor the fermentation process. The concept would probably work from a technical perspective, but likely has very limited use within the current industry, especially seen as many wine makers use float lids. Thus far, none of the wine makers participating in the study has indicated that the gases produced during fermentation would be a suitable indicator of fermentation progress.

Concept B
Concept B is intended to lay a foundation for future technologies and implementations of instruments. The concept replaces existing float lids on the wine tanks, and incorporates existing in-use instruments such as, thermometer, pH-meter, and other instruments of interest.

Concept C
This concept intends to use Unicorn DX as it was presented in the Tech cards provided by ATTRACT. In other words as a stationary sensor that can measure one desired particle at the time, in the sizes between 1-100 nm. This does not improve the wine but harmful particles can be detected in time to solve the problem. This concept could be combined with both I and O.

Concept D
A device with sensors, preferably Unicorn DX, is attached to the nozzle of the tank using a garden hose connection. The concept is quite similar to concept C but more complicated, and is therefore rejected.

Concept E
This concept intends to continuously monitor the density, and thereby simultaneously, also the alcohol levels. This is done by providing a continuous flow through a machine, similar to an EasyDense, powered by a small pump. The data is then redirected to software that plots and presents the data in a fashionable manner. This concept also has the possibility to insert a Unicorn DX chip in the side to easily take samples of the wine. The flow that passes through the machine ensures that the sample that is taken, is representative of the entire tank, in contrast to if the wine had been still.

Concept F
A liquid raman sensor can measure molecules in liquids without being in contact with the fluid. Therefore it could be suitable to measure alcohol, sugar and other interesting molecules in different stages of the wine; crushing, fermentation and ageing.

Concept G
This concept does not intent to improve the wine in any way, but rather help the wine maker determine the ideal time to sell or discard the wine. This could help maximise

the wine makers profits more than other concepts, but seen as the initial cost of the product is rather high the Unicorn DX might as well be used in other stages of the process too.

Concept H

Concept H intends to use any technology implemented in a wine bottle. During bottling, the bottles are filled as usual with wine, but one of the bottles is a special bottle with built-in sensors that measure pressure, pH, thiols, and tannins. This bottle allows you to track the development of the wine's character during the aging process.

Concept I

A crucial part in winemaking is hygien. Therefore we saw the opportunity to use Unicorn DX to test for contaminations in barrels or tanks before use. This would be done by scraping the inside of a container and disolve the test to be able to drop it on a chip and detect particels. This concept could be combined with both concept C and O.

Concept J

This concept relies on using a liquid raman during soaking, which is when the must is in contact with the flesh and skins. The liquid raman could measure when to stop soaking to have relevant levels of tannins and end up with a desired taste.

Concept K

With the use of both Unicorn DX and PiPe4.0, an estimate of the amount of residual sugar and yeast can be calculated. This can be used to determine the fermentation time, and anticipate the final bottle pressure. This is useful to ensure a complete fermentation or to determine the level of carbonation which in turn determines which tax bracket it may land in.

Concept L

L is similar to concept C where the technology is used in a fixed measurement station. A Unicorn DX sensor is combined with a liquid raman sensor to cover essentially all chemical and biological measuring requirements. One drawback of the concept is that it heavily relies on the condition that the chips are able to be cleaned within the machine. Given that this requirement is met, however, the concept is deemed very realistic, although not as interesting as other solutions and probably much more expensive.

Concept M

PiPe4.0 could be useful to determine different gases in samples. Since PiPe4.0 is a gas raman, it means that the sample has to be in gas form in order to measure. Therefore, the sample has to be heated up. Our idea is that this could measure small molecules such as alcohol and CO_2 accurately.

Concept N

The goal of concept N is to replace the microscope with an extension to the tank outlet containing Unicorn DX. The microscope is currently being used by certain winemakers to identify different strains of yeast while running smaller test batches. The created extension should be able to identify and measure bacteria while reducing the risk of human error by misidentifying biomarkers, as well as hopefully minimising the total steps to identify yeasts.

Concept O
This concept involves implementing Unicorn DX into a measurement station along with other measurement technologies to measure values both before and during the fermenting and ageing process. The design of this concept would be in the form of a stationary unit that can print out slips with tables of information, but also be able to transfer information digitally. This is due to the discovery made during the excursions, that many of the winemakers use post-it notes or similar items on their tanks. It therefore seems apparent that analogue methods are appreciated by the users. The printing would resemble a receipt printer/label printer and therefore not be something that needs to be specially ordered. This concept could be combined with both C and I.

Concept P
This concept aims to automatise the sulphur distillation process. This is done by implementing PiPe4.0 in a contraption that monitors the gas that is boiled during distillation. PiPe4.0 should successfully monitor and count the flow of sulphur thus eliminating the next step in the traditional distillation process, where the amount of sulphur is calculated manually with solutions and colouring liquids. Resulting in the amount of sulphur being know without major interaction with the process, and no additives.

Concept Q
This concept aims to automatise and remove possible human errors when measuring CO_2 , in a similar way as an already existing product, the Carbodoseur, does. This is done by shaking a cylinder which brings dissolved CO_2 out of the wine, this forces liquid out of the container and the lost liquid can be cross referenced by a supplied chart to calculate CO_2 i mg/l. [Winequip, 2024] The idea is to, create a nozzle which could simulate the shaking to get the dissolved CO_2 . This would then be analysed by the pipe which could be attached on the nozzle. A pre installed software where values are entered in advance would act as an indicator if there is too little, good or too high levels of CO_2 .

13.4 Initial evaluation

The concepts D, F, I, J, K, M, and Q have been eliminated. Through group discussion, the different concepts were color-coded red, yellow, and green. Green represented a concept we wanted to move forward with, yellow indicated one that needed some adjustments, and red signified when the concept felt irrelevant. There were no definitive requirements when the concepts were produced, except that the technologies had to be included and needed to be implemented in one or more stages of the winemaking process. Some qualities from the concepts are however noted for future development of the other concepts. Much the same, the concepts A, B, G, N and O are not considered promising enough on their own, but might be combined with other concepts into suitable contestants in the future. Considered most promising are therefore the concepts C, E, H, L and P.

13.5 Concept sorting

By combining and evaluating the concepts that were not eliminated in earlier stages, four concepts were created and will be described and presented with both text and separate sketches below.

13.5.1 Pump on the tank

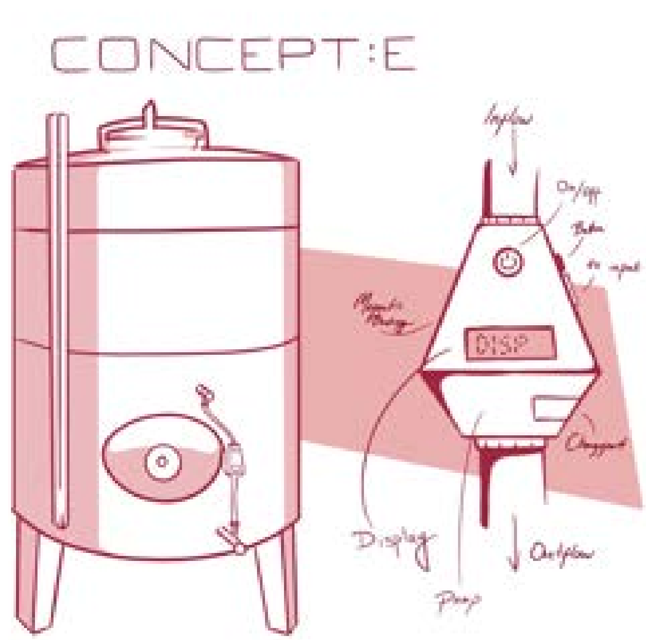
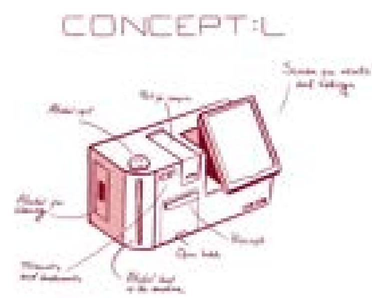


Figure 16: Concept:E

After reviewing the remaining concepts it was apparent that concept E could be used to satisfy what N was aiming to achieve, thus they are combined into one. The concept "Pump on the Tank" utilises an attachable extension which is able to connect to the fermentation tank outlet. Once connected, the winemaker can command the product to present a sample to the technique used in Unicorn DX via a pump, combined with other already existing techniques. The concept is supposed to be swiftly moveable between different tanks depending on which one is more interesting to measure at a given moment. This method would offer the winemaker continuous monitoring of the wine in order to measure biomarkers and alcohol levels. The winemaker does not necessarily have to be present when doing the tests depending on how the UI is designed.

13.5.2 DXpacito

(a) Concept: C



(b) Concept: L

Figure 17: DXpacitos original concepts

This concept is a combination of of the original concepts C and L. It's main focus is to implement Unicorn DX in wineries as a measuring unit for winemakers and/or wine-analysers. It would be designed as a stationary unit that the user could place on a preferred surface. The technologies in the unit would be Unicorn DX combined with a liquid raman. This would theoretically be able to measure all essential chemical and biological requirements, even those that was found to be hard to measure such as bacteria and sulphur in different forms. Drawbacks on this concept however is that it would be quite expensive and also in need of single use chips in order to use Unicorn DX, or to find a way to clean and re-use the chips.

13.5.3 Distillation unknown

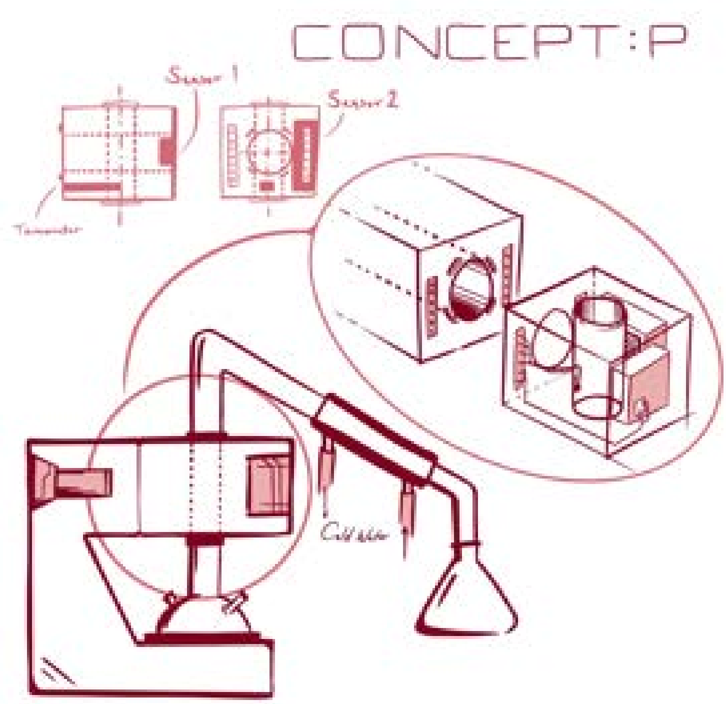


Figure 18: Concept:P

This concept intends to automatise the sulphur distillation process by removing a large amount of the human labour in this process. A sample of the wine is placed in the round beaker which is then heated with the use of a heating mantle, controlled by internal software. The unit contains two thermometers, one which ensures that the heating mantle maintains the correct temperatures and one positioned higher in the pipes that measures the temperature of the gas. The units internal software will ensure that the temperature is maintained and not exceeded so that unwanted substances are distilled. Once the gas from the sample starts rising, it passes the PiPe4.0 unit that measures and analyses the gas that is passed. PiPe4.0 will then document the amount of sulphur that has been extracted from the sample, and once PiPe4.0 indicates that there is no sulphur left residing in the sample, the main connection will be cut off and the heating will stop. The gas follows the turn and is then condensed back to a liquid with the help of water cooling.

13.5.4 Argon will pierce the wine

Figure 19: Argon will pierce the wine

The concept is a custom made wine bottle with three windows on its sides. The windows are to be transparent and flat which allows raman spectral methods to be used, a technique that can analyse gases and liquids molecular composition. A custom cork could also be implemented and contain measuring equipment to monitor parameters during bottle aging.

The concept is aimed towards winemakers and restaurants. The winemaker could use it to gain information about the wine during aging without opening the product and thus wasting an entire bottle of wine. Vinyards could market the special bottles as "the first batch of the year" which potentially could interest wine collectors and increase revenue while wasting less wine.

Restaurants and bars would benefit from the product by transferring wine from opened bottles into the concept bottle and resealing it with argon, effectively pushing out unwanted oxygen and creating a vacuum. When resealed, restaurant staff can monitor the health of the wine and determine whether it is sellable or not. The concept bottle at restaurants would come in a smaller size compared to the one used by the winemaker, and is mainly aimed towards more expensive wines worth conserving.

13.6 Concept choice

The four sorted concepts were once again put against each other. This was done by writing up pros and cons in an excel sheet. A post construction of the sheet is presented in table 5 below:
It was decided that the number of pros and cons was not decisive, but rather the

Pump on the tank	**DXpacito**	**Distillation unknown**	**Argon will pierce the wine**
		Pros	
Fun to prototype Modular Replaces microscope	Useful in all stages	Interesting measured value Fulfills a need	Gap in the market
		Cons	
Similar products are on the market One unit per tank Unclear how to implement UnicornDX	Boring to prototype Very expensive technology	Unclear if it is better than competitors Unnecessary to vaporise in order to use PiPe4.0	Does not work with any technology in theory No time for more research

Table 5: Pros and cons of the sorted concepts

groups value of them. The group was united in removing *DXpacito* and *Argon will pierce the wine* immediately. Mostly due to prototyping reasons, the need of further research which requires time that is not available in this project. However, there was a split opinion weather to go forward with *Pump on the tank* or *Distillation unknown*. This choice would be vital in order to know what product to develop as well as which of the two technologies to implement.

A discussion was held and the discussed points were mostly around the pros and cons presented in table 5. The decision was finally made by a simple voting. The result was to continue with *Pump on the tank*. Further arguments on why PiPe4.0 was found to be hard to implement in the wine industry is written in section 15.2.

13.7 Concept development

After settling on the final concept being *Pump on the tank*, a multitude of design choices remained to be made in order to create a finished concept and prototype.

The first step was to decide on the general design of the prototype. A brief workshop was performed where the group members sketched ideas on general design principles such as attachment to the tank, how pumping of wine should work and how the user could interact with the product. The resulting conclusion was that there should be a small display on the device as well as buttons for on/off as well as a mode button, changing the shown parameter on the display when clicked, for example from pH-value to temperature. In addition to using already known sensor technology for monitoring parameters, an outlet for the Unicorn DX technology is to be added to the device for further yeast bacterial analysis. In order to be able to store and view historically measured data, it was deemed that the concept should have an external application avalible on phones and tablets.

At first, the general idea was to use plastic pipes to carry the wine from the racking valve down to the bottom valve with the goal of having a constant flow of wine through the device. To easily read measurements from the device, movable tubes inspired from flexible hoses were suggested to be implemented, see Figure 19 and Figure 20.

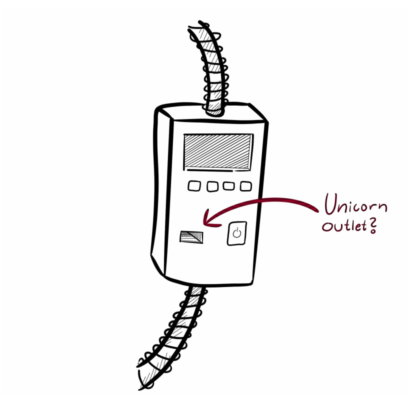


Figure 20: Plastic pipe 1

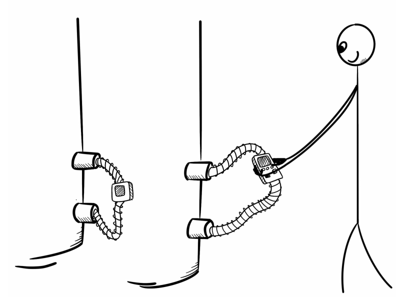


Figure 21: Plastic pipe 2

After further discussion, it was decided that the a constant flow was unnecessary viewed from an energy perspective, since the pump would have to be running constantly. It was then determined that plastic pipes would not be needed and the device should instead be attached via a ball valve to the racking outlet. This enables the possibility to detach the device while wine is in the tank as well as making it more ergonomic and easy to read of the display. This solution also allows the winemaker to use the tap freely, for example to taste the wine. To circulate wine from tank into the product a pump system is considered, in the prototypes case, this could be done with a dc-motor inside the product, see Figure 21 and Figure 22.

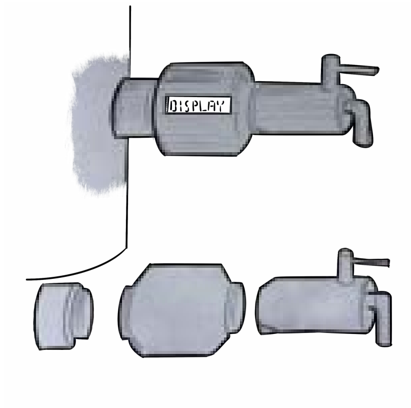


Figure 22: Attachment to tank

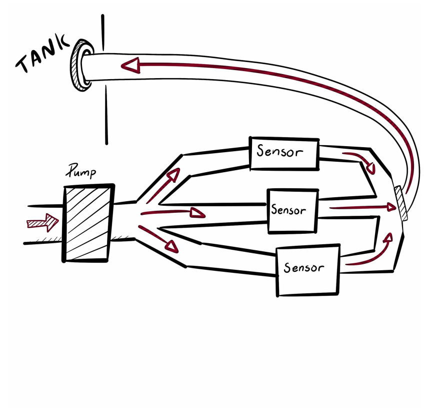


Figure 23: Pumps

At this point the general design was considered done, and more detailed iterations were made in the CAD program Fusion 360 to decide a potential final design of the prototype. Six different versions were made, as well as a suggestion for construction with internal parts, see Figure 23. It is important to note that all of the iterations utilises the same general concept function, it is merely the shape of the shell that differs.

Figure 24: Prototypes 1-6

After reviewing the six iterations based on user friendliness, number two and four were deemed not good enough since the placement of displays combined with the prototype being close to the floor, forces the user to operate non ergonomically when reading the screen. Among the remaining iterations, number one and five seemed suitable based on function, but did not aesthetically suit the common shapes found in wineries during study visits. The circular shape found in version three was appealing, but not optimal since products used to build physical prototypes often are rectangular, meaning that room within the prototype would be hard to use efficiently.

With this in mind, version six was picked as the most satisfactory model. However, since the screen and button layout found in version three was appreciated, it was decided to continue with similar features in the final CAD model.

14 Test and verification plan

In this chapter, a plan is presented for how to test and verify the requirements set for the prototype.

14.1 Execution

The execution of the verification and constructions requirements is presented in table 6. Some requirements require a specific verification plan, and are evaluated separately. The verification plan only tests requirements that applies to the prototype, some requirements can not be tested because the prototype will not be able to be built to it's fullest. To summarise, some verification points will be theoretical.

Table 6: Verification execution

Test execution	**Requirement tested**
Visual inspection	1.1, 1.10, 2.2, 2.3, 2.7, 2.8, 6.3.
Disassemble and assemble	1.12, 2.5,3.2, 4.1, 4.2, 4.3, 7.1
Run prototype	1.2 - 1.11, 1.13, 2.4, 2.6, 2.9, 3.3
User testing and interview	3.1, 6.1, 6.2, 6.3

Visual Inspection
Visual inspections involve confirming specific criteria through visual observation, as the name suggests. However, the requirements extend beyond mere visual confirmation, as exemplified by Requirement 1.2: "be able to deliver measurable values with the help of a sensor." This requirement underscores the importance of integrating sensor technology to complement visual inspections.

Essentially, the approach combines the intuitive nature of visual inspections with the analytical capabilities of sensor technology. By doing so, it ensures that the inspection process not only meets visual standards but also adheres to predetermined quantitative criteria. In essence, the goal is to ensure that what is seen visually aligns with measurable values obtained through sensor assistance, thereby validating the acceptability of the inspected criteria.

Disassemble and Assemble
The primary objective is to design a prototype that facilitates easy disassembly and assembly, for example, cleaning purposes, and the physical test for this is self explanatory. Requirement 3.2 emphasises the importance ease of cleaning, with assembly being a critical aspect of achieving this goal.

The rationale behind this requirement is twofold. First, easy disassembly enables thorough cleaning of the prototype's components, ensuring that any dirt, residue, or contaminants are effectively removed. By simplifying the disassembly process, maintenance personnel can access all areas of the prototype, enhancing cleanliness and hygiene standards.

Secondly, seamless assembly is essential for ensuring operational efficiency and minimising downtime during cleaning procedures. A prototype that can be quickly and effortlessly reassembled enables swift turnaround times between cleaning cycles, maximising productivity and minimising disruptions to workflow.

Run prototype
The verification run prototype functions as an observation method, akin to visual inspection but with a focus on senses beyond sight. Requirement 3.4 emphasises the importance of minimising noise levels during the prototype's operation. The test procedure involves observing the prototype while it runs, evaluating its performance and noise output.

User testing and interview
When conducting a usability test, a commonly used method is the System Usability Scale (SUS). The method is a question-based test, where ten statements are presented to the user on how the system was experienced. The user can then chose on a scale of one to five how strongly they agree, with one being "strongly disagree" and five being "strongly agree".

Another important method is to ask many follow-up questions and inquire about the user's thoughts, reasons, preferences, or why they consider a specific feature good.

14.2 Specific technical performance evaluation

Tests performed on the prototype should indicate, whether the principles discussed and eventually put in use on the prototype are suitable for the real product. A testing system will be set up, with a test tank attached to the prototype via a ball valve, similar to those in use in the wineries of the target group.

14.2.1 Sealing ability

In order to ensure a long term seal between the wine in the system and the air and contaminants in the outside world, it is of importance to test the sealing components for longer periods of time. Given the time frame of the project, it is not likely that the one to two month use cycles the product is intended for can be replicated properly. In order to make up for this discrepancy as much as possible, the prototype should be attached to the full test tank at all possible times.

When service needs to be conducted, changes made to the prototype or tests taken, the prototype should be temporarily removed and then put back on the tank to continue the sealing test. Much the same, unless necessary, the tank should not be emptied of liquid. Visual inspection will be used in order to confirm that the prototype is either sealed or leaking.

A value that is harder to measure is the leakage of oxygen into the tank through the prototype. Although measures should be taken to ensure that the sensor containing unit does not become a source of unwanted oxidation on the final product, doing so for the prototype will be of lower concern. If there is the time to do so at the end of the project, a testing method for ensuring complete separation from the outside atmosphere will be developed and tested.

14.2.2 Pressure capacity

Seen as the liquid pressure is proportional to the height differential from the top of the tank to the measuring point, the pressure that the prototype will be subjected to will be negligible during testing [Hägg, 2024]. This concerns requirement 2.9 and 2.10, but in order to carry out proper tests on pressure capabilities, the prototype would need to be connected to a pressure chamber suitable for liquids. Although possible, the extra work needed to provide such data for a prototype, which does not perfectly resemble the final product, is not deemed a worthwhile endeavour.

14.2.3 Fluid mixing and particle build up

A hot topic of discussion during the development of the concept, figure 16, was whether the chosen solution would mix the fluids properly, guaranteeing a sampling pool representative of the whole batch, or lead to a micro climate closest to the intake and in the sensor containing unit, being unique to that part of the system and delivering skewed results. This point is in regards to requirement 1.12, and in order to test this aspect of the prototype two methods are proposed.

The easiest and most intuitive testing method involves dying the liquid using common dyes, such as food colouring. By adding different dies in different parts of the tank and observing the spread and mixture of the colours an image can be created of how fluids behave in and around interesting components. This method has mainly two issues. Firstly observing the spread of colouring throughout the tank is fairly hard considering neither the tank nor the prototype is designed with visibility of the liquid in mind. Samples could be taken and compared side to side outside of the tank, but how clear the differences would be to the eye is unclear. Secondly, food colouring is dependant on stirring or other mechanical mixing in order to properly mix in water, and without the natural circulation created by the active yeast during fermentation the food colouring might spread much slower throughout the liquid, delivering an unrealistically pessimistic result.

The second method involves adding salt to the liquid. Unlike food colouring, salt is expected to spread through the system in a more desirable way, however, testing can only be done by extracting samples from different points. The samples are then evaluated by running an electrical current through the liquid and measuring the resistance. Lower electrical resistance should equate to higher concentrations of salt. It is yet unclear how effective this method is and whether the use of consumer grade measuring equipment will yield any meaningful results.

In order to combat the flaws of each method, both methods might be used. If both tests point towards the same conclusion, this indicates that something might. On the contrary, if the two tests indicate different results, the verdict might be that the testing methods are too flawed to provide any meaningful information. Unfortunately, both tests cannot be carried out at the same time. Food colouring relies on the similar density of the water and colouring in order to mix properly. When salt is added to the solution the density of the fluid increases, which forces the food colouring to gather at the top of the tank, not combining properly with the rest of the solution even after violent stirring.

Another concern was whether putting the intake close to the bottom of the tank would lead to a disproportional build up of sediment as larger residual particles from the grapes and dead yeast cells sink to the bottom. A rough simulation of this phenomenon could be created by adding substances such as crushed grapes, bentonite or some other arbitrary form of clay and other organic contaminants to the system. After running the prototype for a longer period of time without a mesh covering its intake, letting the sediment gather at the bottom of the tank, the prototype should be removed in order to monitor whether a higher concentration of particles is present in the liquid previously in the prototype compared to the rest of the tank.

14.3 Requirement Fulfilment

At the time of achieving a completed prototype, some requirements are able to be verified. Though due to it only being a prototype and lacking all proper components, a complete and comprehensive verification can not be made.

The following requirements are made evident by the construction of the prototype: 1.5 and 1.10 through 1.12. Along with 2.2, 2.3, 2.5, 2.7, 2.8, 4.2. Further structural and health governing requirements such as 2.1, 2.5, 2.9, 2.10, 3.3, 5.1, 5.2 can be achieved by adhering to the proposed guidelines from thesis *Design of the Sensor Containing Product* [Hägg, 2024].

15 Product design

The current unit is designed in such a way as to fit a DIN 40 thread and accommodated its components in a space efficient manner, whilst maintaining accessibility to its components and controls.

The device is comprised of two compartments, an inner part where the sensors and wine is contained and an outer shell containing the electronics. This is done for the sole reason to mitigate wine leakage in case the device is damaged. This is to ensure that the primary damage receiver is the outer shell and not the containment where whine is kept to avoid leakage and loss of wine.

The main focus when designing the casing was retaining a pleasing aesthetic and producing a product that attempts to suit its surrounding.

15.1 Mounting position

The mounting position of the device came down to two alternatives. Either through the standard taps used for tasting the wine, or through the racking port. After evaluating the mounting alternatives, it was concluded that mounting on the racking port was preferred. This decision was motivated by the desire to not occupy or remove the tasting tap, being that it is frequently in use. Producing a substitute solution for the occupied tap was possible, but deemed too cumbersome to be viable.

15.2 Why not PiPe4.0?

Throughout the project, as previously mentioned, two technologies have been under discussion. The challenge has been to identify which parameters in the winemaking process are not already being monitored and how these technologies could assist in addressing those aspects. After research and discussions, the technology PiPe4.0 was determined not to be relevant for further developments in regards to the project.

The primary challenge with the PiPe4.0 technology stemmed from its measurement of irrelevant parameters, while the relevant ones were not present in high enough concentrations for the technology to detect. This includes alcohol and sulphur levels. PiPe4.0 functions as a Gas Measurement Unit (GMU) utilizing Raman spectroscopy. Consequently, the concepts involved necessitate passing through several unnecessary stages, like distillation, to facilitate monitoring. This would be a difficult and unnecessary manoeuvre.

15.3 Design language

The design language of the product has been investigated in many ways. Through user studies it has been noted that wine makers are more like artists and not lab workers. Therefore, the group wants the design to be a bit playful and create an easy interpretation of the device for the user. To differentiate the product and make it more appealing than existing products, a cheaper monitoring system is very important as well as a new and sleek design of the device. The remote and continuous measuring system is uncommon and only few other competitors uses something similar [Johannisson et al., 2024].

To design a device that is appealing the group compared existing products and steered clear of similar designs. With a different design composition and modularity, our device gets its own identity which is important for marketing and to attract new customers. Requirements for the device to be small and easy to use are met and as learned from user studies, smaller to medium range wineries do not have the budget for many devices, which our product eliminates with the possibility to easily attach to the tank.

Figure 25: The final product.

16 Ethical aspects

One aspect when talking about ethics concerning the product developed, is that the product may decrease job opportunities. Since the final concept would be implemented in the fermenting process, the person performing tests on the wine is not longer needed to the same extent as before. On the other hand, the final concept makes it possible to perform more testing in-house, instead of sending samples to an external laboratory. Anyhow, the measurements made with the final concept still has to be analysed.

Another aspect could be regarding alcohol and alcoholic consumption. The final concept aims to monitor the quality of the wine, making it easier to ferment the win. This might lead to an increased production of wine, which can lead to negative health consequences for individuals and society.

Developing a product aimed for food production entails a responsibilities. If the product doesn't work correctly or in some way could be manipulated, it can lead to an inaccurate fermentation process or bad wine. This, in turn, can result in a product that contains more alcohol than predicted, which can be harmful.

The final concept is beneficial for fermenting wine with natural yeast, as the Unicorn Dx likely can detect yeast strains. In other words, the final concept might facilitate and simplify the use of wild yeast, which can be seen as advantageous. Normally, using wild yeast can result in an unpredictable process, but with the final concept, the process can be more easily controlled. The final concept also makes it easier for the winemaker to produce wine that keeps the same consistency year-to-year, as the yeast can be analyzed with ease.

When interviewing winemakers that used wild yeast, it was found that they viewed using wild yeast as a method to preserve the micro flora of the vineyard, and produce a more diverse wine. Using wild yeast also means that no lab yeast has to be produced for fermenting the wine. Due to this, the final concept might be beneficial for a more sustainable wine production. However, the yeast question is considered complex and divides winemakers as well as consumers into two opposing groups.

17 Prototype

The prototype consists of one physical prototype and one application prototype made in Figma.

17.1 Physical Prototype

The physical prototype consists of a cube-like 3D-printed casing with a LCD screen accompanied with 2 buttons and a rotary encoder. For demonstration purposes, the device is connected to a ball valve sized DIN 32. This is in turn attached to a 25L stainless steel tank.

The casing is constructed by FDM printing the housing and threaded coupling. The unit is divided into two main compartments in order to separate the liquid from the electronics. The inner compartment is connected to the outlet of the tank and allows fluid to be pumped through itself and past the thermal sensor. The outer compartment contains the electronics.

The prototype is attached to the test setup just like the real product would be to a real wine tank, by holding the casing at the desirable angle and screwing the attachment ring onto the valve on the tank. The battery is inserted through a front lid, attached to the casing with magnets. To turn the device on, one of the two buttons is pressed. The other button allows the user to switch between different metrics and to turn the display back on if it has gone into stand-by mode in order to preserve battery life. Unlike the real product would, the prototype has a rotary encoder to alter the frequency of measurements. This is done in order not to have to reprogram the device every time different tests are going to be performed.

The electronic components consist of:

- Arduino Uno board
- Arduino LCD display
- Arduino LCD display interface
- Liquid thermal sensor
- Peristaltic pump DC
- Buttons
- Rotary encoder
- Resistors and transistors
- Relay
- Battery housing
- 1,5 V batteries AA
- Cables and electrical connectors

The relay protects the Arduino Uno board from excessive current surges during operation of the peristaltic pump, which might otherwise damage the board. In order to provide power to both the relay and the arduino board the power supply is spliced into two parallel power supplying cables.

Figure 26: Physical prototype

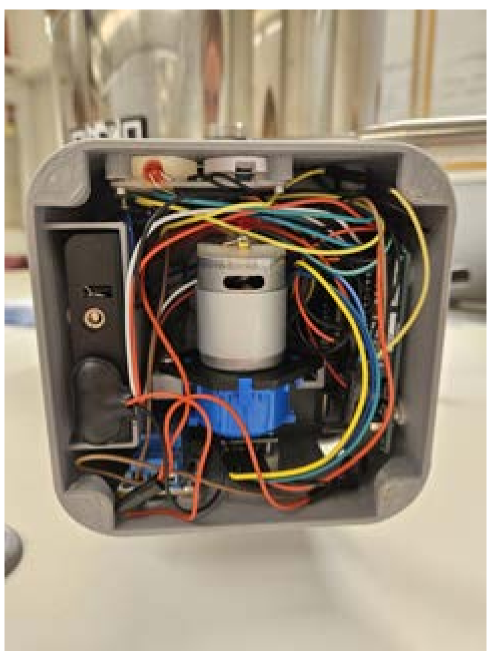


Figure 27: Inside of physical prototype

17.2 Application Prototype

The application prototype is an interactive prototype, created in Figma, aiming to mimic a functioning application connected to the physical prototype. Users interact with the application prototype via a tablet, placed near the physical prototype, and are able to navigate through fictional measurements, graphs, reports and more.

The digital user interface is designed based on results and information gathered from existing theory, study visits, interviews and workshops, more about the design process can be found in the thesis *Designing a User Interface intended for Winemaking* Frostell et al. [2024], which is connected to the project.

The application prototype allows the user to view and simulate the following actions digitally:

- View home screen.
- View current wine parameters: pH, alcohol level and specific gravity.
- View historical graphs of the measured parameters.
- Navigate between different WineOT units on other tanks.
- Generate wine reports in pdf format.
- Dispense yeast samples.
- View and adjust a selection of general and tank settings.
- Simulate the scanning of a QR code on a tank, redirecting the user to a corresponding measurement page.

Figure 28: Parts of the app prototype.

Figure 29: Overview dashboard

Figure 30: pH level dashboard

Figure 31: Alcohol level dashboard

18 Target fulfilment

This chapter follows up on the targets set in chapter 2.1. Table 7 displays a summary of which objectives were met and which were not.

"A": *Achieved*, "SA": *Somewhat Achieved*, "NA": *Not Achieved*

Table 7: Target fulfilment

Goal	**Fulfilment**
Overarching goal	
Overarching goal	SA
Effect goals	
Decrease time consumption	A
Decrease waste	SA
Give recommendations	NA
Automate production	A
Simplify testing	A
Detect failing wine	SA
Repair failing wine	NA
Reroute production	NA
Decrease number of wasted bottles in testing	NA
Project goals	
Visualise data	SA
Analyse data	NA
Find indicators of failing wine	A
Find limits of technologies	A
Combined user interface	A
Digital use interface	A
Physical user interface	A

18.1 Overarching goal

The overarching objective of implementing both the PiPe4.0 and Unicorn DX systems into the wine making process was not reached. Research has concluded that the technology used in PiPe4.0 at this point in time has no suitable application in wine making. Unicorn DX shows potential, being able to measure several desirable values previously unavailable to the common wine maker, however, the system has not been developed far enough to be properly evaluated in this specific application and must therefore be analysed further in order to reach a meaningful conclusion.

18.2 Effect goals

Seen as no product has been developed far enough to perform accurate tests on its effect on the wine making process, this section is somewhat speculative. The conclusions drawn are based on the indicative performance of the prototype and the theoretical effects of the concept.

Decrease time consumption:
Wine makers spend a considerable amount of time collecting samples and performing measurements during the fermentation stage, sometimes up to one hour per day during prolonged periods of time. A product developed from the chosen concept could likely decrease the time consumption of the work required to monitor the fermentation. This could allow wine makers to expand their business, or dedicate their time to tasks that they experience as more meaningful.

Decrease waste:
Once wine is extracted from the fermentation tank, it is considered consumed or wasted, being that it cannot be returned to the tank due to contamination risks. Thus by sampling the wine that is in circulation in contrast to extracting samples regularly, the product successfully decreases the quantity of wine that does not amount to the end product. This gain, however, is very small compared to the potential savings from decreasing the number of wasted bottles during ageing, and should therefore not be considered a major success.

Give recommendations:
In its current state, the product is not supposed to make any type of measurements that wine makers currently cannot make by hand. Due to this fact, recommendations given by the product would likely be as good as or inferior to an experienced wine makers verdict. Giving recommendations on how to develop the wine would be possible, but currently unnecessary, and has not been investigated further.

Automate production:
The concept successfully automates and simplifies the testing of daily collected data which in turn lessens the workload and time consumed in-house for the winemaker. This is done by continuous measurements collected by the device that then provides accumulated and processed data to the winemaker, elevating them from conducting the repetitive daily tasks of testing for pH, alcohol/sugar level and temperature.

Simplify testing:
Compared to manually collecting samples and making measurements with analogue equipment, taking notes on paper and calculating the progress with tables, attaching a measuring device to the tank at the start of fermentation, monitoring the progress via a mobile application and cleaning the equipment after use seems less complicated. Although not realised yet, the concept shows great promise when it comes to simplifying the testing process.

Detect failing wine:
Through continuous sampling and testing, the concept can detect an early decline in the health of the wine, being the pH, alcohol, sugar or temperature levels deviating from its expected path. Primarily the health of the yeast can be monitored. By notifying before irreversible damage occurs preemptive and reactive measures can be taken do ensure that the wine ferments in a desirable way. *Repair failing wine:*

The chosen concept does not directly contribute to the wine makers ability to repair a failing wine. Apart from possibly giving the wine maker a few hours earlier warning, which would likely not make a large difference seen as changes during fermentation usually takes up to several days, the concepts benefits mainly relates to the decreased time consumption of testing.

Reroute production:
The chosen concept is primarily intended to be used in the fermentation stage. Rerouting production to either vinegar, a different type of wine or gin, however, does not occur in this stage of the process. The concept would therefore not decrease the amount of unnecessary resources put into a product that is going to be turned into something else at a later point.

Decrease number of wasted bottles in testing:
The chosen concepts approaches the problem of waste in a stage before bottling. This goal has therefore not been achieved.

18.3 Project goals

Unlike the effect goals, evaluating whether the project goals were met is a more straight forward process.

Visualise data:
The collected data should be processed and presented in an intuitive way in the corresponding mobile application. The UI for this application has been created based on research performed on how to best convey the information of importance. The absence of a realistic data set has however hindered testing the usefulness of the UI and it is therefore unclear whether the data visualisation is satisfactory.

Analyse data:
The vision is for collected data to be processed and subjected to algorithms that plot and predict near future developments of the wine. This should then be presented to the winemaker through a mobile application where the winemaker can asses each tank individually and conduct their decision making based on the aforementioned predictions. However, seen as no meaningful measurements have been performed and no relevant reference data has been found, no actual analysis has been performed and no algorithms developed.

Find indicators of failing wine:
Through the conducted excursions, it was discovered that certain bacteria and yeast strains were undesirable and may lead to wine failing. These biomarkers can be identified in early stages of the wine thanks to Unicorn DX. Aiding in the decision to continue with the batch or divert it to other use. Additionally, by monitoring the state of the wine, with indicators such as yeast ceasing to produce alcohol or the temperature reaching sub-optimal levels, can be vital for ensuring that the wine does not fail.

Find limits of technologies:
From the excursions made it was concluded that PiPe4.0 is not viable for the projects intentions, due to lacking measuring accuracy at low concentrations and difficulties

to measure in a liquid medium. Unicorn DX was not investigated as thoroughly, but seems promising in certain applications within wine making, as it could replace some measurements usually performed with a microscope to assess bacteria and yeast presence.

Combined user interface:
The physical interface (the final product) interacts with the app prototype through QR codes and bluetooth. Additionally, the final product has a small screen, offering several options for displaying current measurements to the user. While designing the interfaces, this objective has been considered. For example, the amount of clicks required within the app and on the product display has been minimised to enhance usability, as users often prefer the easiest path. Due to time constraints, this goal hasn't been tested on the user. Further user tests would be necessary to validate if the objective has been achieved. The test and verification plan for the user interface is outlined in [Frostell et al., 2024].

Digital user interface:
The digital user interface is designed using established principles commonly used for smartphone and tablet applications, meaning that new users are likely to swiftly learn how to navigate within the application. Clear icons and describing texts connected to majority of the functions is believed to help the user quickly adopt and understand the main functions of the product.

Physical user interface:
The concepts main attachment point, the coupling thread, intentionally uses Deutsches Institut Fur Normung (DIN) standard threads to allow for wide application on the most common tanks within the EU. These threads consist of very few varieties and are easily fit with adaptors if needed. Mounting the device is done similarly to mounting hoses or other tank accessories, using a standard spanner for DIN fittings, eliminating the need for special tools.

Build prototype:
The prototype intends to simulate the usage of the product, providing an representative experience of its size and interactive elements. This is done by creating a scale model that pumps and circulates wine and measures the temperature. The act of measuring the temperature represents how further sampled data such as pH, alcohol and sugar levels will be collected in the final product. The prototype further indicates the implementation of Unicorn DX.

19 Project follow-up

This section will evaluate how well the project group has lived up to the time plan, budget, milestones etc.

19.1 Resource expenditure

As of the 17th of May a total of 3791 hours have been spent on the project. This is 561 hours less than anticipated. In gate 3 there was a difference of 495. This means that even though it still has been hard to fulfil the time plan, the difference between planned time and actual time has been almost the same since last time, as seen in figure 32. The deficit depends primarily on Swedish holidays such as Valborg, Ascension Day and Easter. Group members have taken a bit more vacation than given in the public calendar.

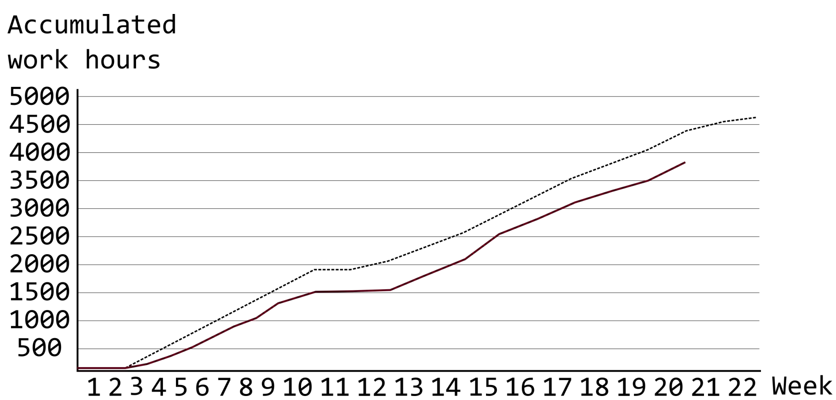


Figure 32: Accumulated resource expenditure as of 2024-05-16

19.2 Milestone completion

Since Gate 3 the milestones ”Concept” and ”Test and verification plan” have been completed. However, it has been decided that the test and verification plan can not be done in this project due to lack of time. It is instead included so it can be used in eventual future projects. The final report will be finished in time for submission.

19.3 Preliminary estimate

As the project group works on unpaid time, vehicles for research excursions are provided by the university and materials for the prototype are paid for by ATTRACT, monetary limitations are not deemed to be the main limiting factor in the project. Instead the time available to the project group, measured in work hours, is considered the main resource.

19.3.1 Appreciated workload

In the first study period the schedule was shared with another course, absorbing 20 percent of the available time. Between the 15th of January and the 8th of March, it was therefore estimated that up to six work hours per weekday will be put into the project by each group member.

In the second study period all available time is put into the project. Between the 25th of March and the 22nd of May, this means up to eight work hours per weekday and group member. The project will be concluded on the 31st of May. Four public holidays in the second study period means that several weeks will consist of only three or four work days.

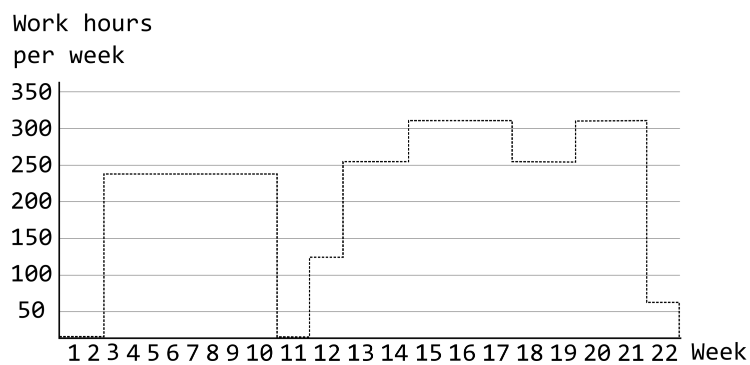


Figure 33: Estimated workload per week throughout the project

19.3.2 Accumulated resource expenditure

Based on the credit valuation of the courses, the project and attached bachelor thesis's as a whole should correspond to 640 work hours per group member, or 5120 hours combined. With a planned expenditure of six hours per day in the first study period and eight hours per day in the second, it is estimated that each group member will put 240 hours, in the first study period, and 336 hours, in the second study period, into the project. This amounts to a grand total of 576 hours per person, or 4608 hours combined.

19.4 Budget

Linköping University has allocated 3,000 SEK to the project, which have been used for the prototype. Costs for vehicle booking and study trips are covered by Marie Bengtsson's project budget, outside of the budget shown below. Furthermore AT-TRACT have sponsored the prototype budget with 10,000 SEK, some of which has been utilised.

Purchase	**Expenses [SEK]**
Electrokit, arduino compontents	1521
Bygghemma, water tank	1086
Polisinelli, ball valve stainless steel	1286
Sum:	3893
Remaining budget:	9107

Table 8: Prototype budget

19.5 Risk Analysis

This subsection integrates the developed risk analysis from Gate 2, focusing on existing risks and their development since then. No new risks has been identified since Gate 2.

Table 9: Mini risk analysis from gate 2

Risk	**Probability 1-5**	**Damage 1-5**	**Damage product 1-25**	**Preventive measure**	**Possible solutions**
The prototype is not realizable	3	5	15	Thorough research regarding avalible tech, wine making process etc.	Present the prototype as a potential product
Unicorn DX and PiPe4.0 is not appropriate to use in wine making or beer brewing	3	3	9	Acquire the technical limits early	Present the conclusion in the report with valid arguments
Poor work distribution between the bachelor's theses	2	4	8	Map out the main subjects of each thesis before starting	Rethink the limits of each theses
Conflicts within the group begins to halt progress	2	4	8	Keep good group-spirit by arranging activites, keep good communication, follow the group contract etc.	Try to solve the conflict internally, lift with project owner if not possible
Contact with ATTRACT is underwhelming	2	4	8	Establish contact with relevant stakeholders early	Base the work on similar tech
The prototype is not finished on time	2	4	8	Create a separate riskanalysis for the prototype	Limit features and quality in order to have something to present
There is no time to test the prototype	3	2	6	Finish the prototype as early as possible	
The bachelor's thesis becomes too similar	2	3	6	Roughly map out the main subject and headers within the group before starting	
No relevant company is willing to accept study visits	2	3	6	Contact companies early	
LaTeX and teams documents ceases to exist	1	5	5	Save back-up documents regularly	
A group member decides to leave the project	1	5	5	Create and maintain a good group atmosphere	
The group fails to pass gate or misses the submission date	1	5	5	Make sure to follow the requirements for each gate	
The prototype budget is exceeded	1	4	4	Proper economic budget planning	

The prototype is not realizable
In essence, a prototype will be crafted to visually showcase the project's outcomes, prioritising intuitive presentation. However, it's crucial to note that this prototype won't encompass all previously discussed functionalities due to constraints like missing technology, expertise, budget, and time.

Unicorn DX and PiPe4.0 is not appropriate to use in wine making or beer brewing
This risk loomed over our project from the outset and stood as a pivotal factor in determining the project's trajectory. Through thorough research and discussions, it became evident that PiPe4.0 was not pertinent to our objectives, whereas Unicorn DX emerged as a more relevant avenue for our pursuits.

Poor work distribution between the bachelor's theses
This risk remains pertinent at present, with impending deadlines looming for both the group project and individual bachelor theses. Balancing time between these commitments has been crucial, and efforts have been evenly distributed accordingly. Notably, progress made in individual bachelor theses has served as a reference framework for developments within the group project, highlighting the interconnected nature of these endeavours.

Conflicts within the group begins to halt the progress
Luckily, this has not been a problem for our project. Of course disputes and dissatisfaction have occurred. But is has not affected the progress of the project.

Contact with ATTRACT is underwhelming
This risk has proven to be entirely accurate. Despite the lack of contact with ATTRACT, it has not posed any significant issues. At the time of identifying this risk, we lacked clarity on who our stakeholders were and which ones necessitated communication. However, our interactions with the technology owners have emerged as more pertinent, and the communication in this regard has been effective and fruitful.

The prototype is not finished on time
The prototype is unlikely to be fully developed and finalized in time for the "vernissage," which is scheduled shortly before the project deadline. This delay is primarily attributed to logistical issues such as shipping delays and challenges in communication within the chain of command.

There is no time to test the prototype
This risk is quite high now, at least in time for the vernissage and Gate 4 presentation on the 15th and 17th of May. However, the plan is to have a semi functioning and tested prototype for the eventual trip to California during the first week of June.

The bachelor's theses becomes too similar
Early on in the project this eventual problem was solved and there is no risk anymore that the thesis's are too much alike.

No relevant company is willing to accept study visits
Now with the answer given, there has been many interesting study trips during this project. It was quite difficult to get accepted by vineyards but by contacting an extensive number of people the problem was solved.

LaTeX and teams documents ceases to exist
This is a risk with a very small chance of happening and has not happened thus far. Everything is saved and downloaded throughout the work to prevent this.

A group member decides to leave the project
This has not been a problem.

The group fails to pass gate or misses the submission date
This has not been a big problem. The group has set up deadlines all the time in order to get all the work done over time. There has also been clear directions on what to do thanks to the governing documents.

The prototype budget is exceeded
The budget given by Linkoping University has been used, but the group attained a larger budget for prototyping, there has not been any need to utilize this budget as much so far, as 9000 SEK out of 10 0000 is still left. Therefore, the risk of exceeding budget hasn't impacted the project at all.

20 Closing

This chapter presents the residual-list of the project, how the result is to be submitted and recommendations for possible future projects or research.

20.1 Residual-list

The residual list is a description of the backlog of activities not yet finished, along with the approximated number of hours left in the budget. As of May 20th, the activity list is depicted in Figure 9. Most tasks have been completed at this stage, however, some remain. Chiefly, the project should be summed up and concluded in a finished report, necessary tests and verifications performed in order to evaluate the result and the three bachelor theses finished and presented. In Table 10 the remaining activities from Figure 9 are presented with a remaining time estimate.

Activity description	Time (h)	Status	Responsible
1.4.3 Closure	160	Initiated	Everyone
5.6 Completed Report	200	Initiated	Everyone
5.8 Preparation California	64	Initiated	Everyone
5.9 Participation California	128		Everyone
6.4 Thesis defence	600	Initiated	Everyone

Table 10: Rest list

20.2 Delivery

The result will be submitted in the form of a final report, a physical prototype, an application prototype, posters, a promotional text and visualisations, consisting of two short videos and a brochure describing the project.

Since this project is goal seeking, a full solution will not be delivered, but rather a suggestion.

20.3 Further Recommendations

Following up on the effect goals, it is clear that the prototype successfully decreases wasted wine and automating parts of the wine making process. At the current stage, the concept is capable of plotting parts of the fermentation process and give adequately predictions. With further development, the unit will be able to predict and produce well informed forecast of the fermentation.

The next steps in development would be to explore ways to perhaps compartmentalise components of the product and to further develop a product in a way that eases sanitation and repairs. With the focus of maintaining a clean product without contamination and simultaneously retaining strength and wear resistance.

Further incorporation of new technologies and further developed technologies is of importance to investigate. This is an important aspect dedicated to the development of the physical product. Making the device susceptible to updates in developments in regards to advancing technologies, notably Unicorn DX, will lead to further reaching the overarching goals, which is to implement new technologies in a manner beneficial to the brewing process. This however can only be done with close cooperation of the Unicorn DX developers.

The user interface prototype is currently at an early-stage proof of concept. It visualises the idea of how the data should be presented, but further user studies and other types of research are needed to make the interface more closely fitted to winemakers needs. To achieve this, a clearer understanding of the technology's capabilities is required. For instance, it's unclear exactly what Unicorn DX can measure, making it difficult to determine which data should be presented to the user and how it should be presented. At present, the prototype offers an idea of how the interface could appear and function. For the prototype, the human-computer interaction could be further developed by connecting the app concept to the measuring device. That would make the whole system more understandable and realistic.

References

Andrew Turgeon, National Geographic. Barometer. https://education.nationalgeographic.org/resource/barometer/, 2023. Accessed: 2024-01-29.

Attract. Attract phase 2. https://attract-eu.com/attract-phase-2/, 2023a. Accessed: 2024-06-01.

Attract. PiPe4.0. https://attract-eu.com/wp-content/uploads/2022/07/ATTRACT-RDI_PiPe4.0-project.pdf, 2023b. Accessed: 2024-01-26.

Editorial Dept. Beer 101: The Fundamental Steps of Brewing. https://beerconnoisseur.com/articles/beer-101-fundamental-steps-brewing, 2016. Accessed: 2024-02-06.

Karen Fick. Sparkling wine, n.d. URL https://www.diffordsguide.com/beer-wine-spirits/category/599/wine-sparkling#:~:text=Most%20fully%20sparkling%20wines%2C%20including,generated%20during%20the%20production%20proces.

Linus Frostell, Hanna Jonsson, and Sigrid Åkerskog. Designing a user interface intended for winemaking. Not published, 2024. Accessed 2024-05-03.

Gravity Wine House. Fermentation Tanks. https://gravitywinehouse.com/blog/wine-production-fermentation-vessels/, 2019. Accessed 2024-01-24.

Anette Hallin and Tina Karrbom Gustavsson. *Projektledning*. Liber, 2018.

Chris Thoring Oscar Hägg. Design of the sensor containing product. Not published, 2024. Accessed 2024-04-22.

Jeff S. Nickel. Faults in beer. https://beerandbrewing.com/dictionary/S8DPF4ntWs/, n.d. Accessed: 2024-02-06.

Jim Gordon. How White Wine Is Made. https://www.wineenthusiast.com/basics/how-white-wine-is-made/, 2023a. Accessed: 2024-01-26.

Jim Gordon. How Red Wine Is Made. https://www.wineenthusiast.com/basics/how-red-wine-is-made/, 2023b. Accessed: 2024-01-26.

Ebba Johannisson, Gunnar Berg, and Martin Håkanson. Business value for wine monitoring devices. Not Published, 2024. Accessed 2024-05-03.

Northeast Winemaking. Troubleshooting Common Winemaking Problems. https://northeastwinemaking.com/pages/troubleshooting-common-winemaking-problems, n.d. Accessed: 2024-01-26.

Pete Brissenden. Everything you need to know about bottling wine. https://www.fruitandvine.co.uk/everything-you-need-to-know-about-bottling-wine/, 2023. Accessed: 2024-01-26.

Randy Frank, Sensor tips. What is an aphrometer? https://www.sensortips.com/featured/what-is-an-aphrometer/, 2018. Accessed: 2024-02-02.

Sean P. Sullivan. The Why, When and How of Wine Blending. https://www.wineenthusiast.com/culture/wine/wine-blending/, 2023. Accessed: 2024-01-26.

Tim Patterson. All the Numbers You Need, and Then Some. https://winebusinessanalytics.com/columns/section/24/article/93769/

All-the-Numbers-You-Need-and-Then-Some, 2011. Accessed: 2024-02-01.

VinePilot. Our solutions. https://www.vinpilot.com/home, n.d. Accessed: 2024-01-26.

Alberto Vogadori. Wine bottles: shapes, sizes and characteristics. https://gravitywinehouse.com/blog/wine-production-fermentation-vessels/, 2021. Accessed: 2024-01-26.

Watgrid Solutions. Winegrid SME Instrument Phase 1. https://www.watgrid.com/wg-smac-ip1/, n.d. Accessed: 2024-01-26.

Winegrid. Solutions. https://www.winegrid.com/en/#solutions, n.d. Accessed: 2024-01-26.

Winequip. Carbodoseur. https://winequip.com.au/equipment/carbodoseur/, 2024.