Project Deliverable H

Prototype III and Customer Feedback

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Abstract

This document contains Project Deliverable H. This document outlines our third and final prototype of the product. This prototype was created according to the client's needs/requests, and through user/technical benchmarking. Moreover, this document contains the customer feedback we got during our third meeting with the client .

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1.0 Introduction

Robert Ritchie has tasked our design team to create a product that displays the specific conveyor speeds that optimize the yield of beer from his manufacturing line. Following the initial client meeting, our team developed the following problem statement.

“A need exists for Robert Ritchie and his fellow supervisors to find the optimal speeds of their beer packaging process to ensure it is “always at top efficiency (Project Background, Brightspace)”. The solution must have an attractive and straightforward interface that uses a flexible algorithm based on the V-Curve Theory to report optimized speeds of each unit and make recommendations on how to achieve them.”

From this problem, we developed design criteria and metrics that will be used to measure our design’s ability to solve our client’s problem. With research, benchmarking, and brainstorming, the first conceptual design was developed and it was presented during the second client meeting.

After we presented our presentation to the client in our second meeting and he expressed interest in our conceptual design, our team developed the first prototype of the product. This prototype was created based on the feedback that we got from the client meeting, following the client’s needs, and meeting the design criteria.

In our third meeting with the client, we presented our first prototype. After this presentation, we received positive feedback and the client expressed great interest.

In the previous deliverable, we created our test plan based on the client’s specific feedback and it helped us establish our goals for testing different aspects of our second prototype. Thus we improved our second prototype and overall design.

This deliverable will be our third and last prototype of our product. We developed our third prototype based on all the client's needs, design criteria, and his feedback on our first and second prototypes.

2.0 Feedback of First Prototype

The client expressed interest in our first prototype during the recent meeting. This allows us to move on to the next stage and improve our designs.

2.1 Feedback of Second Prototype

Thankfully, the client showed interest in our second prototype and expressed no concerns regarding our design. For some time now, we have been asking the client for information regarding the quality and performance of the machines, so as to know the maximum output. His response was that their yield loss calculations are established by their bill of materials, meaning that when they make a can, they predict a yield loss of about 5%.

3.0 Objectives of Prototype III

We have updated the third and final prototype of our product based on both the plan outlined in the previous deliverable and the client's feedback.

The following updates were made:

1. Conveyor algorithm was developed
2. Editable list (This component only works on iPhone, but not the iPad. This will be fixed in the future)

The Objective of the third prototype was to finalize the algorithm and work on some of the finicky parts of the UI.

3.1 Prototype III UI

The UI was able to integrate the following functions:

- Text input
- Update button (updates a corresponding table with text input)
- Table view of data
- Tabs for each unit of measurement for display (Cpm Hz OEE)

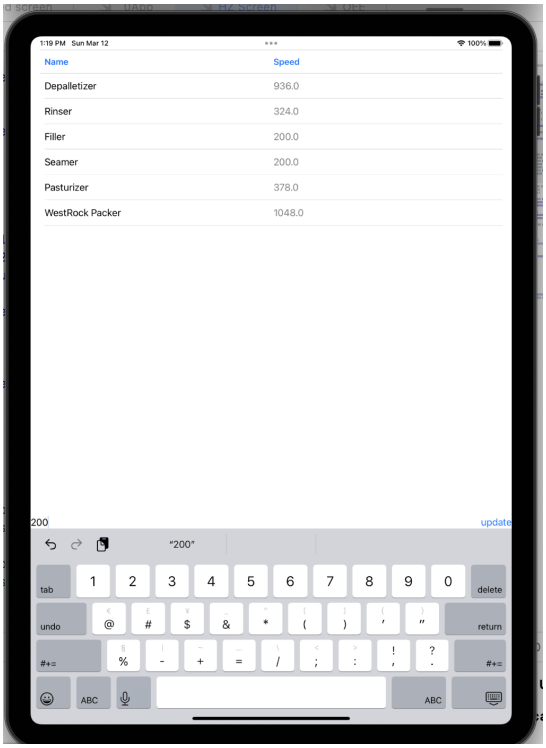
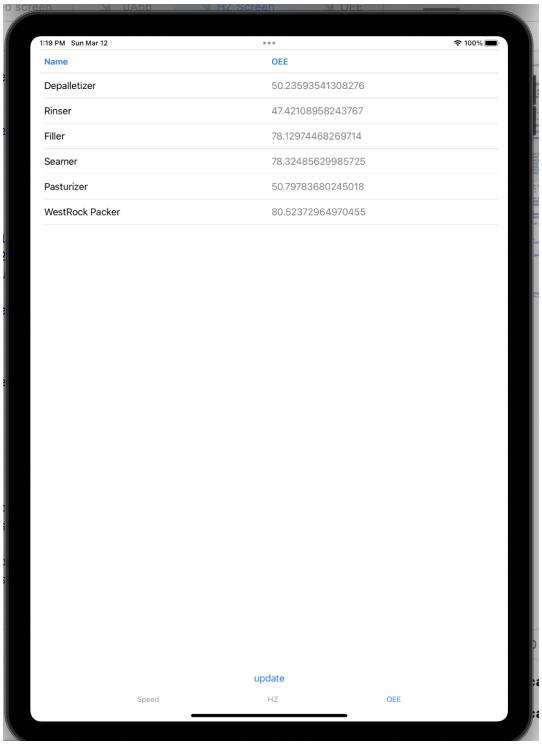


Figure 1 Screenshot of prototype (Speed Tab)



Graph 2 Screenshot of OEE windows

Updated: Editable conveyor list:

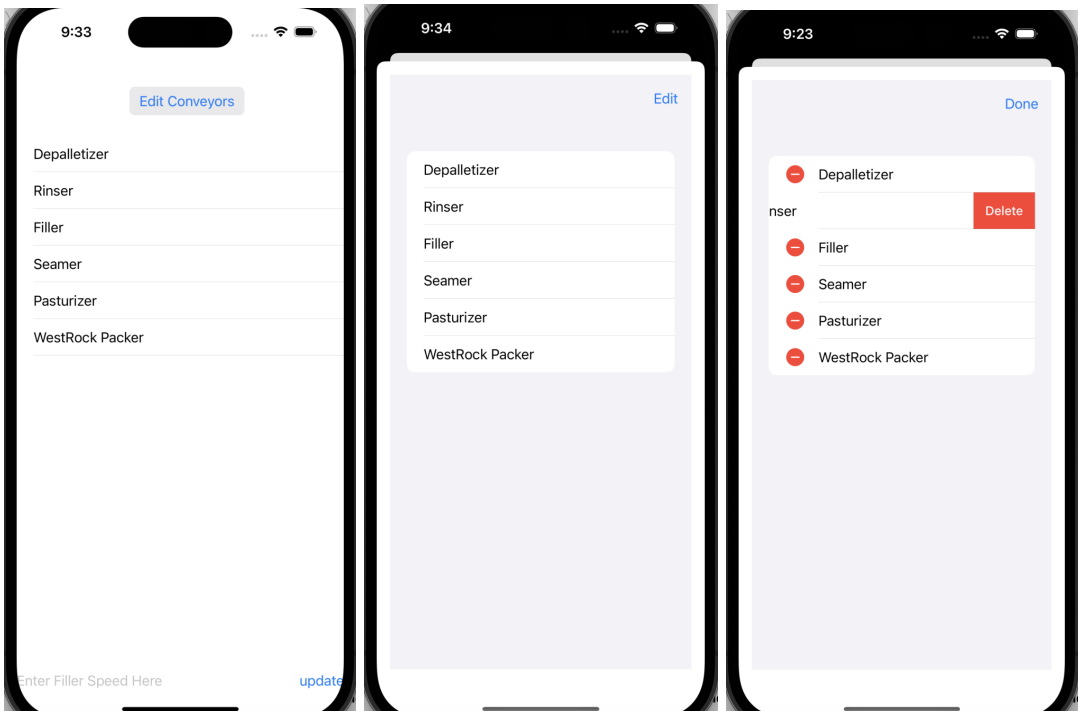


Figure 3 Screenshots of the editable conveyor list

According to the client, an editable table that can freely add or delete the conveyor units is needed. Therefore, a button that connects to a list was used.

```
    var body: some View {
        VStack {

            Spacer().frame(width: 0, height: 20.0, alignment: .topLeading)

            Button("Edit Conveyors"){
                self.isShowingPopover = true
            }
            .buttonStyle(.bordered)
            .padding(.leading)
            .popover(isPresented: $isShowingPopover) {
                //editabel poplist
                NavigationStack{
                    List{

                        ForEach(Us,id:\.self) {uSers in
                            Text(uSers)
                        }.onDelete(perform: delete)
                    }
                    .toolbar{
                        EditButton()
                    }
                    //f***ing working on iphone but not the ipad
                    //frame is extra for iphone app but necessary for ipad app
                   // .frame(width: 900, height:900)

                    Spacer()
                }.padding()

```

Figure 4 Screenshot of the code

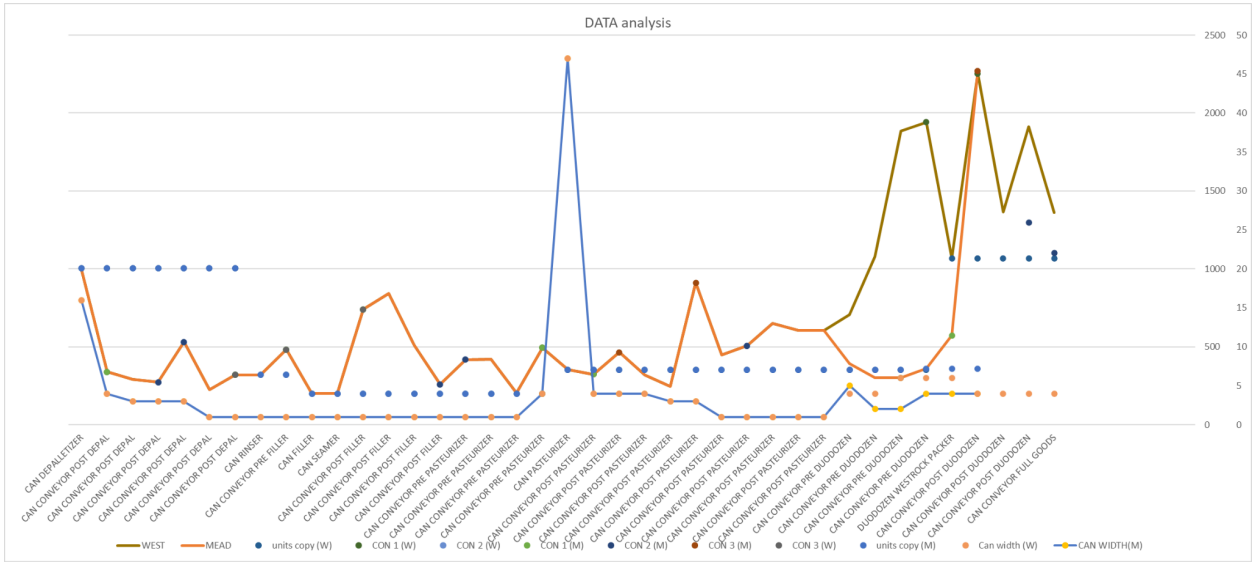
3.2 Prototype 2 Algorithm

Formula for calculating Units from V-curve theory:

$$Speed\ Of\ Desired\ Unit = \begin{cases} fillerSpeed\left(1+\frac{n}{10}\right)\times 2^{\frac{n^2}{2}} & :Before\ Filler \\ fillerSpeed\left(1+\frac{n}{10}\right)\times 2^{\frac{n^2}{2}} + 0.4 & :After\ Filler \end{cases}$$

In previous prototypes, we have estimated the speed of all units in a production line. This prototype aims to re-create this process to predict the speed of the conveyors in the production line.

The first stage of the prototype began with analyzing all the data as a whole and seeing if there was any correlation with the data. We created a graph of both the MEAD and WESTROCK line set up with the conveyor widths. We also added scatter plots of the change of the unit speed, and highlighted different conveyors we thought had patterns.



From this graph, we found that there was a correlation between the change in conveyor width and their speeds. This is evident in the graph, as seen at the start when looking at the

depalletizer, and the four conveyors after it, following a similar path as the can widths. In addition, is seen before both of the packers. These conveyors were grouped as TRANSITIONAL conveyors which have the main function of transitioning the cans from big areas to smaller ones or vise versa. These conveyors are slow to avoid damaging the cans. The rest of the data seemed to have minor relationships, such as a few seem that to follow a linear rise in speed and others form trapezoidal bumps or indents in the process. In order to see the relationships of the conveyors that aren't reliant on the conveyor widths, we divided the conveyor speeds with the width of each conveyor to see the line as if all conveyors only had one can in the process.

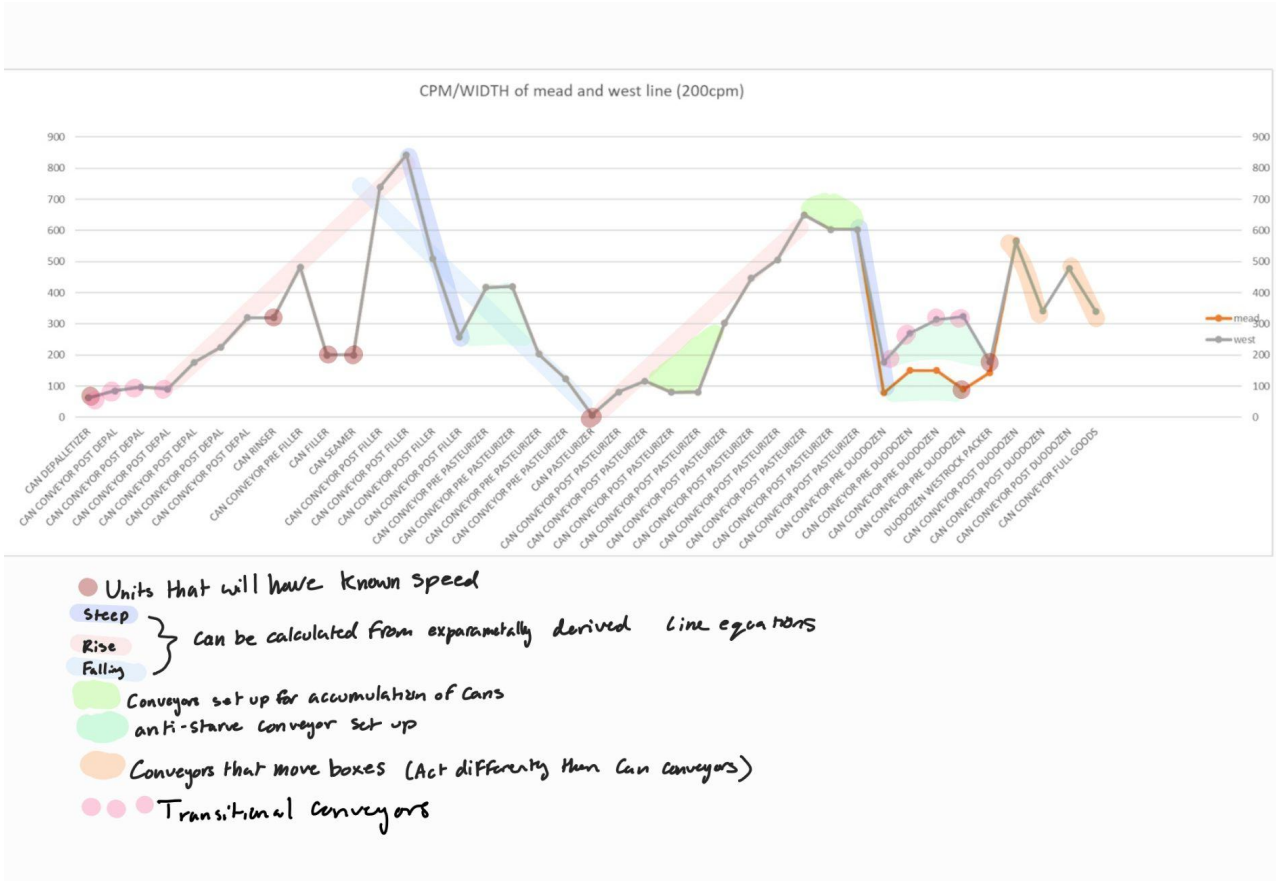
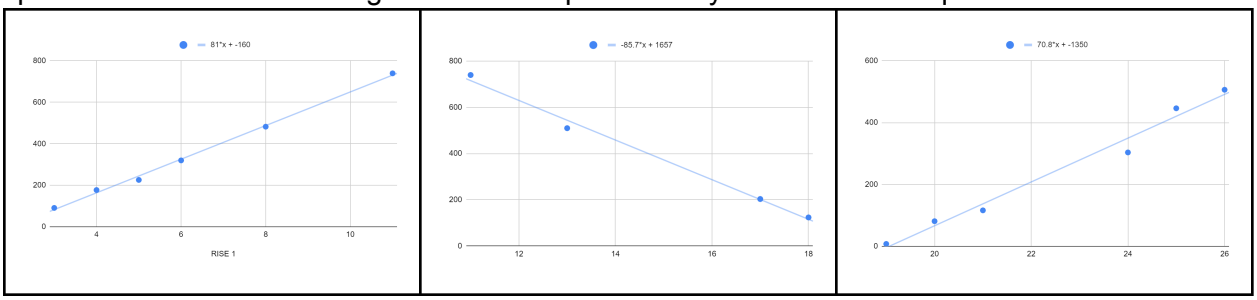


Figure 2. Graph of Correlations

The graph above shows the speed of the production line divided by the width of each conveyor. Here there are more obvious correlations. In previous research on optimizing production lines, we came across a document that talked about dynamic accumulation which optimizes the conveyors within a production line. Dynamic accumulation means that some conveyors are set as BUFFERS that act to either prevent the starvation of a unit or act as an accumulator to prevent blockages in the production line. (Härte, F.L. 1997). Otherwise conveyors are simply just meant to transition the cans from one unit to the next.

The patterns in the graph correlate to these ideas.

The highlighted lines show the characteristic of conveyors whose function is to move the cans from unit to unit incrementing linearly up or down to prepare for the next unit. These conveyor speeds were estimated using a series of experimentally derived linear equations.



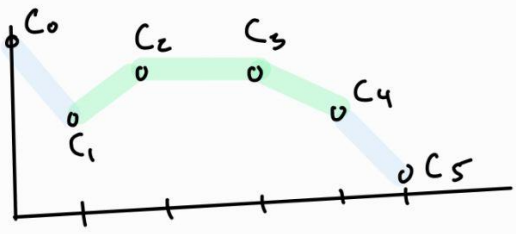
Counting from zero at the depalletizer and graphing the conveyor speeds of the conveyors that have a linear correlation between them. These conveyors were grouped as LINEAR conveyors.

The pale blue highlighted areas in the graph are areas where the conveyors break from the linear correlation to abruptly increase the can speed with for usually 2 conveyors and then continue the linear correlation. This happens close to the start of the pasteurizer and both packers. To increase the speed before the units is a characteristic of an ANTI STARVE buffer, that works to keep the cans flowing into the units.
The configuration is much like a trapezoidal shape that stems from a point off the line and has a set height. This can be modeled as a condition if you want to add an anti starve buffer two conveyors (C2,C3) will be set to (C1+h) and C1 = C4 and C5 continues the slope from C0-C1.

$$C_0 = C_4$$

$$\text{slope}(C_0 \sim C_1) = \text{slope}(C_4 \sim C_5)$$

$$C_2 = C_3 = C_1 + h$$



h - is an arbitrary value set by the user or found with historical data.

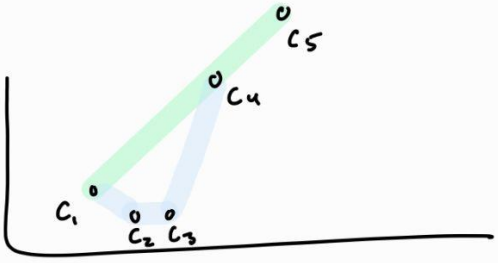
The anti starve buffer near the WESTROCK parker is not a trapezoid rather it looks similar to the conveyors at the start after the depalletizer. These conveyors are part of the

TRANSITIONAL conveyors that act to transition the cans from large spaces to tiny ones or vice versa. These conveyors create a curve to transition from two different speeds which can be determined by the equation:

$$\text{Speed of conveyor } i = \underset{\text{lowest speed}}{low} + (\underset{\text{highest speed}}{high} - low) \times \left(1 - \frac{10^{\frac{n-1}{n-i}} - 1}{9}\right)$$

(n: number of conveyors in group; i: position of conveyor)

The last group of conveyors is highlighted in light green. These conveyors break away from the linear correlation and slow down rather than speed up around 2 conveyors in the production line. By slowing down the conveyors, the cans would accumulate at these spots and thus these conveyors work as accumulators that prevent blockages further down the line by having space to accumulate before blocking occurs at a unit. These conveyors speeds can be determined by the conditions:

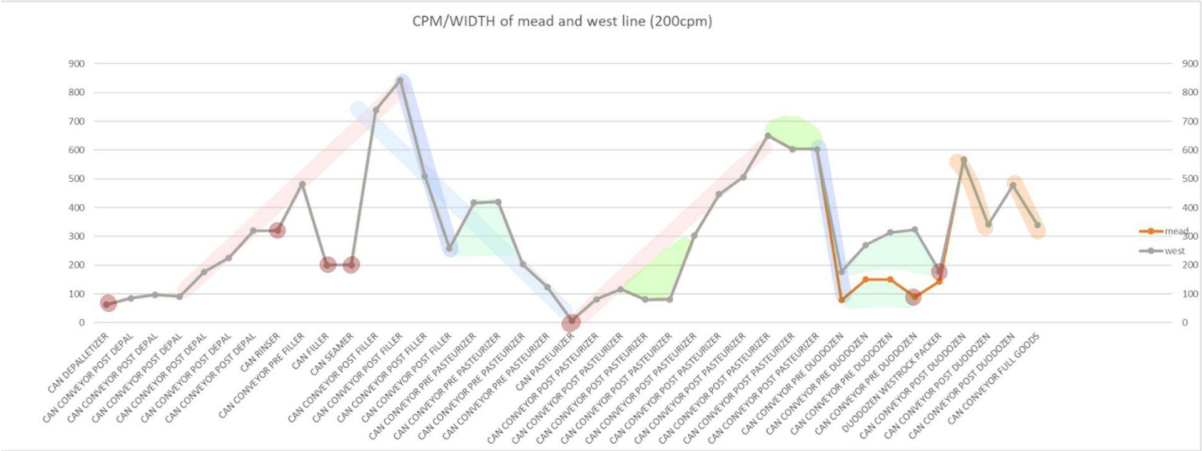


$$\text{Slope}(C_1, C_u) = \text{Slope}(C_u, C_5)$$

$$C_2 = C_3 = C_1 - a$$

a is the cpm that the user would like the accumulator to run at.

From this analysis there are 4 different groups a conveyor can be in, which determines how their speed is set. By using this method accumulators and anti-starve buffers can be moved to desired locations and the conveyor line set up becomes highly adjustable to allow for easy experimentation using the simulation. The configuration of the different groups of conveyors can be changed to match historical data or even create an original line set up.
Upon calculating the speeds for each group of conveyors all the conveyors are multiplied by their width to convert the speeds back into their proper value.



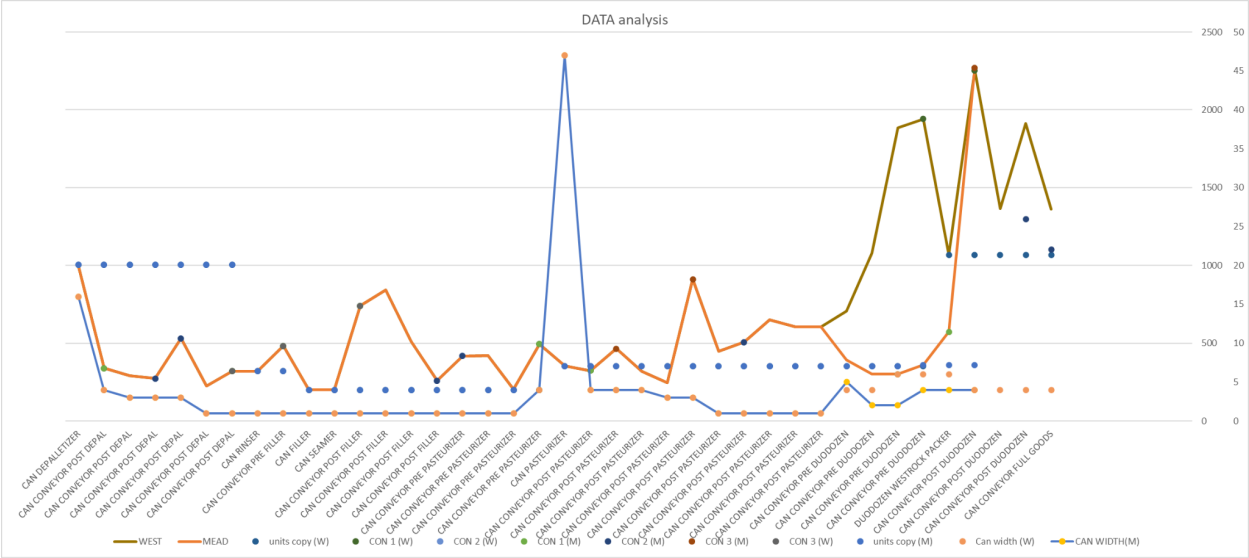
Units that will have known speed

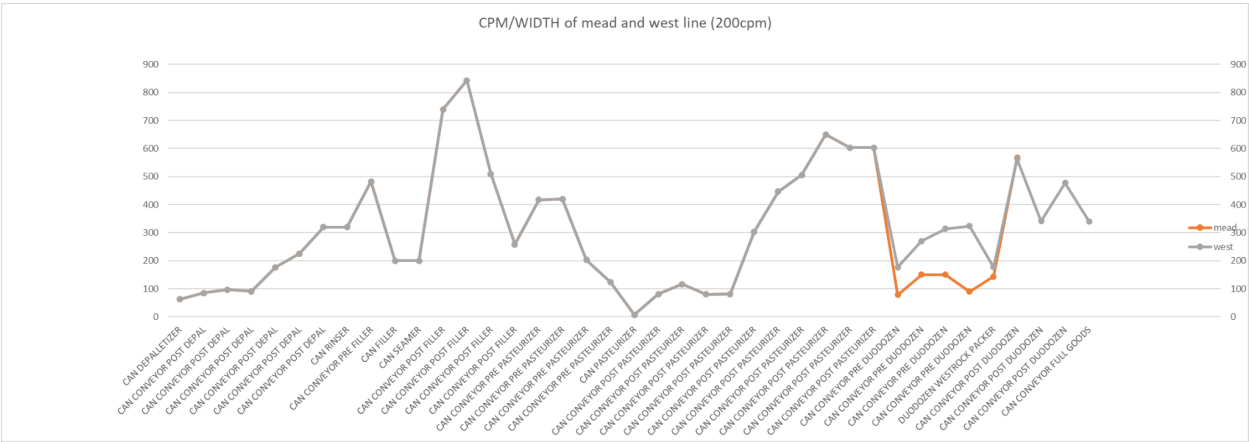
Steep
Rise
Falling
} can be calculated from experimentally derived line equations

Conveyors set up for accumulation of cans

anti-starve conveyor set up

Conveyors that move boxes (Act differently than can conveyors)





4. 0 Prototyping Test Plan

Test ID	*Test Objective* *(Why)*	*Description of Prototype used and of Basic Test Method* *(What)*	*Description of Results to be Recorded and how these results will be used (How)*	*Estimated Test duration and planned start date* *(When)*
1	[Deploy Test] The objective is to test if we need to buy a developer account to deploy	Prototype Xcode tut will be used. An application that will most likely be a tutorial of how to use/get started	**Recorded:** Fail **Response:** If the test fails then a developer account	26-27th Feb

Test ID	*Test Objective* *(Why)*	*Description of Prototype used and of Basic Test Method* *(What)*	*Description of Results to be Recorded and how these results will be used (How)*	*Estimated Test duration and planned start date* *(When)*
	an application for our client. And test the feasibility of using Xcode.	with Xcode will be attempted to be downloaded on an Ipad without a developer account.	will be used to deploy the real thing. **developer account will be bought when the application is fully ready**	
2	[Pure UI Test] The objective of the test is to make sure the program can be interacted with without issue before focusing on its ability to perform its task.	Test the functionality and ease of use of the UI.(refer to 5.1) Prototype UI Shell will be used. A prototype of the UI that does not perform any real calculations or simulations.	**Recorded:** Score 5/5 students: pass **Response:** Some suggestions have been given and will be taken into account for final UI design (see 5.1) UIkit will continue to be used	4 - 7th March
3	[UI aesthetics Test] The objective is to test the aesthetics of the UI with the user.	Test the aesthetics of the UI with client feedback. Prototype UI Shell will be used. A picture of the UI will be sent to the client for feedback.	**Record:** A number from one to ten will be recorded on the client's likability of the UI colour scheme, Formatting and Aesthetics. Score > 8/10: pass Score <8/10: fail **Response:** Ask for feedback and fix the UI. Iterate until it passes.	6-10th March Need time for the Client to respond.
4	[Algorithm Test] The objective of this Test is to prove	Test of the algorithm that predicts the optimal speeds.	**Record:** Margin of Error: 13% Within 15% error for conveyor speed Pass.	20- 26 march

Test ID	*Test Objective* *(Why)*	*Description of Prototype used and of Basic Test Method* *(What)*	*Description of Results to be Recorded and how these results will be used (How)*	*Estimated Test duration and planned start date* *(When)*
	our ability to calculate the optimal speeds before implementing it into the application.	Prototype ExcelA will be used. An excel spreadsheet, that displays all the elements and functions of the algorithm and when given the historical data it is able to replicate the optimal speeds within a small percentage of error.	**Response:** Algorithm is finalized and is working to be integrated into the UI	
5	[Integration Test] The objective of this test is to make sure that the display of the input and output is well formatted on the UI.	Tests of the algorithm's integration into the UI. Prototype R1 will be used. A first rendition of the application will be created that includes the UI and the algorithm working together, the focus will be on the formatting of the input and output numbers and other variables on the UI and the ability of the user to change aspects of the production line and the algorithm still calculates things accordingly to test cases made from Excel prototype.	**Record:** The Pass or Fail of the application's ability to correctly format the UI and output correct speeds of three test cases derived from the Excel prototype. 3 Passes = Pass **Response:** Reference working Excel algorithms and find out what is different or causing problems. Iterate until 3 passes.	9-10th March

Test ID	*Test Objective* *(Why)*	*Description of Prototype used and of Basic Test Method* *(What)*	*Description of Results to be Recorded and how these results will be used (How)*	*Estimated Test duration and planned start date* *(When)*
6	[Input Error Test] The objective of testing wrong inputs is to make sure that the inputs cannot exceed the max speeds of the conveyors.	Test of the UI's ability to catch error inputs. Prototype R2 will be used. On the second rendition of the application where invalid errors are caught, a comprehensive collection of bad inputs will be tested on each possible place where the user can do something wrong.	**Record:** Number of invalid inputs that were stopped Number of invalid inputs that were accepted The ratio between invalid inputs caught and accepted must be 90% caught to pass. **Response**: catch invalid inputs that were accepted and iterate until pass	13-14th March
7	[Multiple Tab Test] The objective of this test would be to make sure that the program is able to handle multiple sets of inputs and display each accordingly.	Test the application's ability to simulate multiple production lines and save and load the user's edits to each production line. Prototype R3 will be used. On the third rendition of the application where multiple lines can be added. Multiple production lines will be added to the application. They will be edited, saved and loaded at selected points throughout a simulated use of the application.	**Record:** Based on the information of different production lines. Three production lines will be tested to run multiple simulations at once. If they can be created, saved and loaded in the right places during regular usage of the application then the test is passed. **Response:** Figure out what went wrong and fix the code and iterate the test until it passes.	13-14th March

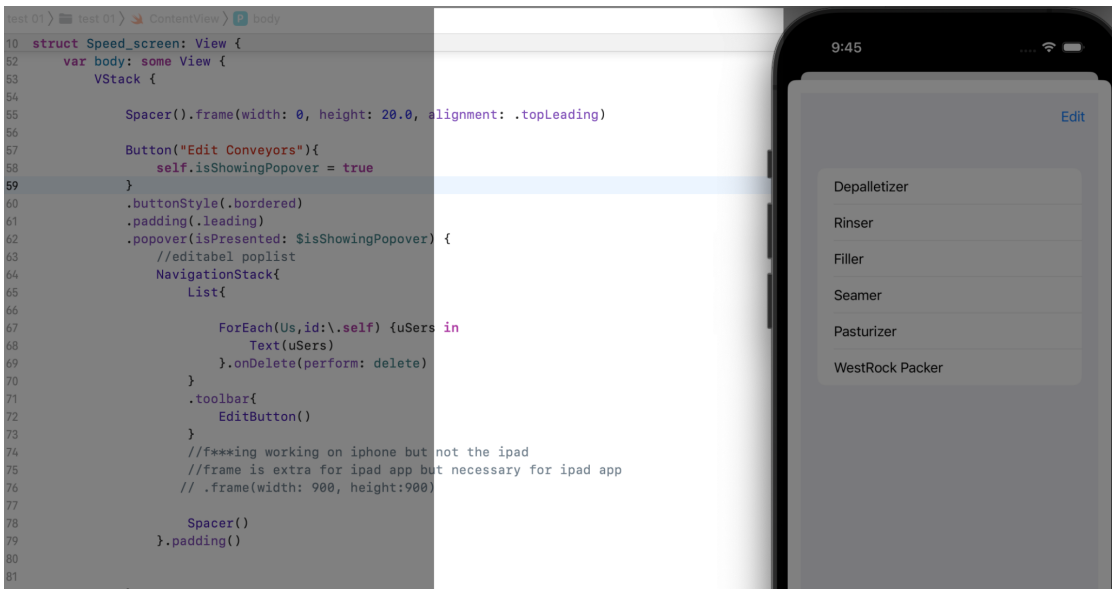
Test ID	***Test Objective*** ***(Why)***	***Description of Prototype used and of Basic Test Method*** ***(What)***	***Description of Results to be Recorded and how these results will be used (How)***	***Estimated Test duration and planned start date*** ***(When)***
8	[Stress Test] The objective of the test would be to figure out and test the limits of the application so measures can be put in place to make sure that the user knows the limit of the application	A stress test on the amount of data can be added to the program before it loses functionality or UI formatting. Prototype 3 will be used. On the Third rendition of the application. Production lines will continuously be added to the application until it crashes. Conveyors and Units will continuously be added to a single line until the UI formatting becomes illegible or the program crashes. Extremely large numbers will be added to the filler speed or other inputs until the application crashes or the UI formatting becomes illegible.	**Record:** The limit to the number of production lines, conveyors and units and numbers that can be inputted into the system before the UI gets messed up or the application crashes. If the limits < the theoretical values that would be needed to run the application under normal conditions (determined from the information we gathered for multiple tab tests) then it fails. **Response:** Find the source of the data storage limit and work around or buy more storage. Fix how data is saved and loaded if there is a formatting issue. Iterate until pass.	15-16th March
9	[Random Person Ease of Use Test] The objective would be to make sure that the program and final user manual is	A test on the ease of use of random person's ability to follow an instruction manual and the application. Prototype R3 will be used. The application and a user manual will be sent to a person with no knowledge of beer production. They will be	**Record:** The feedback and the percentage of tasks that the person was able to complete will be recorded.	March 18-20th.

Test ID	*Test Objective* *(Why)*	*Description of Prototype used and of Basic Test Method* *(What)*	*Description of Results to be Recorded and how these results will be used (How)*	*Estimated Test duration and planned start date* *(When)*
	comprehensive for the client.	required to complete a set of instructions from the user manual. They will be asked to give feedback on the ease of use.	**Response:** Use feedback to improve the user manual and UI if failed. Iterate until pass.	

4.1 UI aesthetics Test

Prototype II was not the complete version, thus the interface was updated for Prototype III.

- An editable list was added into the system.



Potential users showed interest in our application.

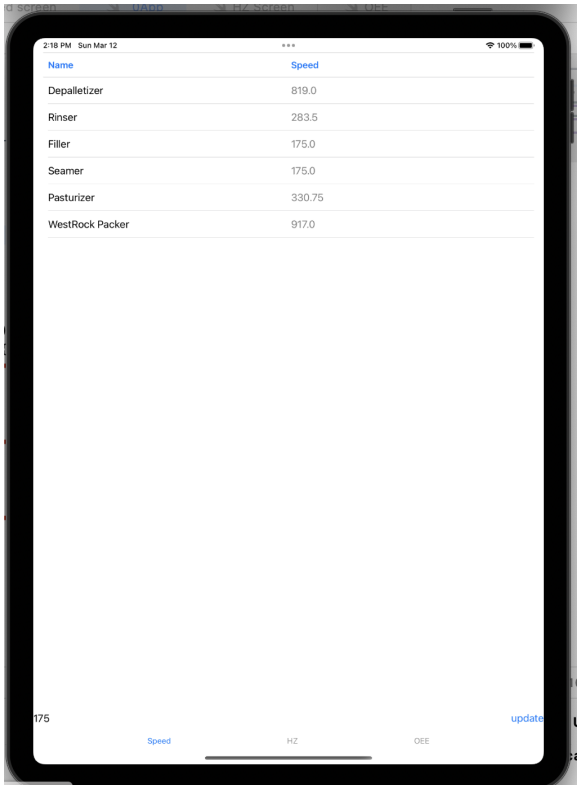
However, the editable list is not completed.

- Current system is only capable of deleting the list item within the pop-up window.
- Can not update the final-edited conveyor sets into the desired-data displaying page.
- Current editable list is only working on Iphone, but not the Ipad.

The above issues will be fixed before the deadline.

4.2 Integration Test

This test is to show the program is able to handle the inputs and display each corresponding desired data.



Unit	Speed (cpm)
CAN DEPALLETIZER	760.9
CAN RINSER	265.0
CAN FILLER	175
CAN SEAMER	175
CAN PASTEURIZER	265.0
DUODOZEN PACKER	760.9

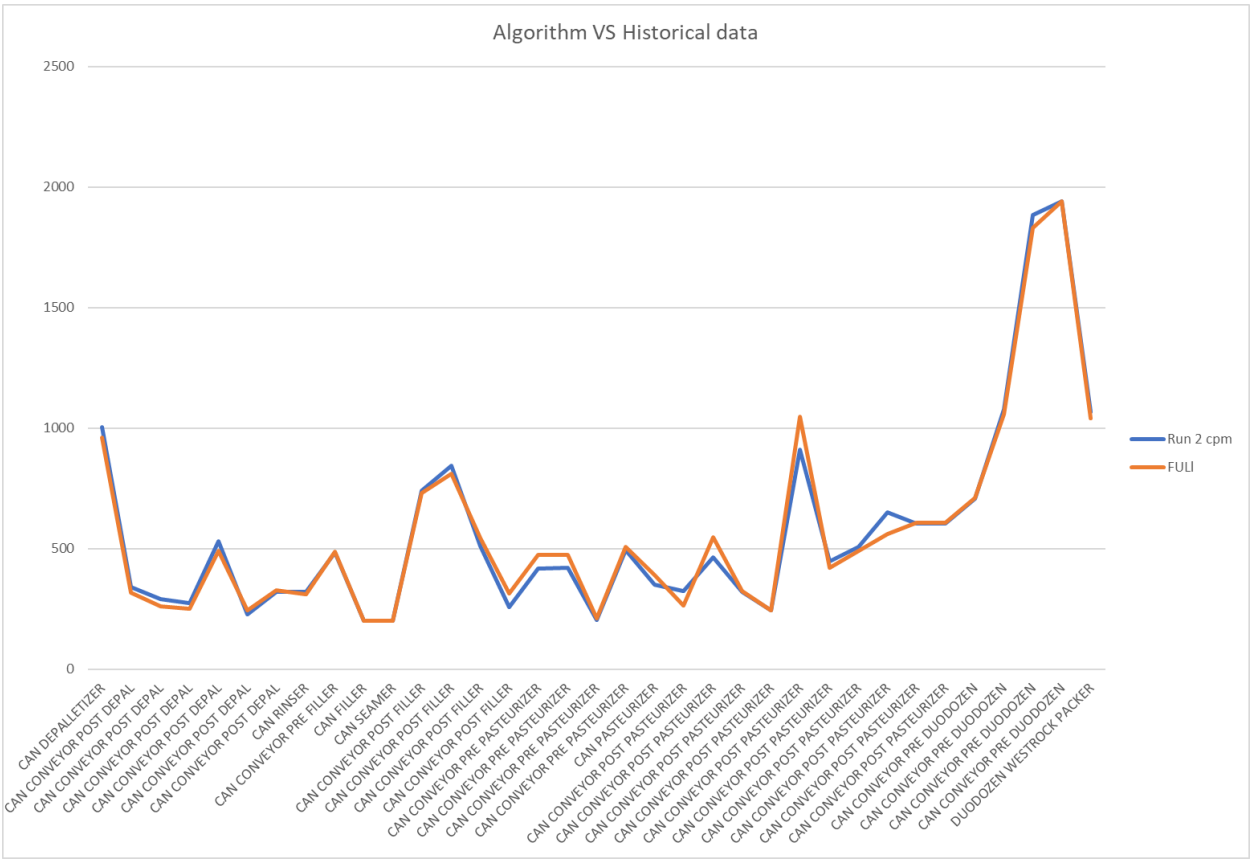
Figure 5 the predicting data and Historical data

The data perfectly matched.

4.3 Random Person Ease of Use Test

The application was shown to 4 random students.
Please See the feedback in 5.0 part.

4.4 Algorithm Test



Graph 4. A comparison between the algorithm's predicted speeds and the historical data
This graph shows the test between the historical data and the new algorithm. Visually, it is clear that the algorithm closely resembles the historical data. There are a few areas where the algorithm deviates from the data due to the fact that theoretical calculations assume some estimations that are not exact. The most that the algorithm deviated by was 13%. Which is within our margin of error. Therefore it passes the algorithm test for the conveyors.

5.0 Feedback and Comments

The following table outlines the collected feedback and comments on the prototypes.
Same students (Student 2, 3) were interviewed for Prototype III as who was interviewed for prototype II.

	Student 1	Student 2	Student 3	Student 4	Student 5
Are you able to access and use the app smoothly?	Student 1 thought the app is intuitive and smooth.	Student 2 wants to have a unit shown on the windows (speed -> cpm). Note: will be added if possible	Yes, Beside it. Student 3 was wondering how to update the data directly after changing the conveyors. Note: What we need to figure out.	Student 4 was able to access it.	Student 5 wishes us to figure out how to run the editable list on Ipad.
Is the interface logic appropriate and intuitive accessible?	Yes	Yes, really intuitive if regardless of the unknown unit for speed.	Yes. Really intuitive. The OEE part was kind of confusing for her since there was only an update button on the page.	Yes. Love the clean design.	Student 4 loves it.
Does the Algorithm make sense?	Yes. Perfectly match the historical data.	Yes, speed was corresponding to the historical data. But the OEE part was kind of unique. Note: Because for the Hz part, there was no max speed provided to us. Clients are able to fill in the max speed on their own.	Yes, everything makes sense after explaining.	Yes	Yes, student 4 was impressed by the Algorithm.
Do you like the integration of the UI and the algorithm?	Yes, looking forward of the final product	Beside the incompetent editable-list, everything was perfect.	Student 3 thought it was better to add a button to directly switch from Speed to Hz without any extra retyping in	Yes.	Yes.

			data.		

6.0 Updated Bill of Materials

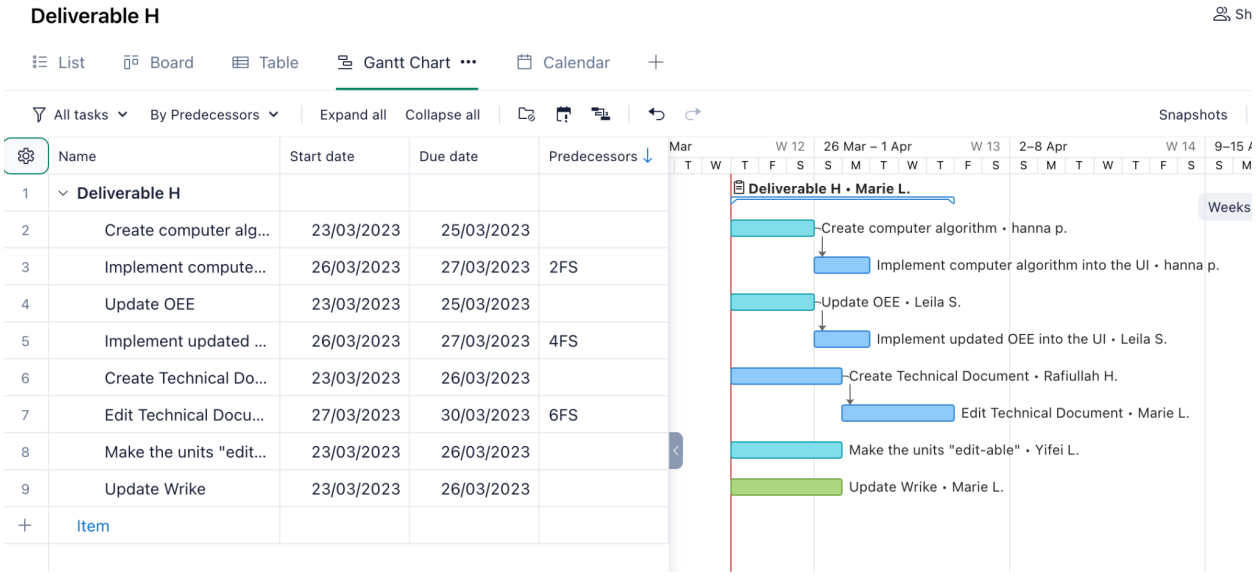
The following table outlines the updated bill of materials. The changes made include

1. We no longer need a paid developer account.
2. The swift UI we needed for XCode is free.
3. We are no longer using UI kit.
4. We will not be using test flight because XCode can simulate it instead.

No	Item name		Description	Units of measure	Quantity	Unit Cost ($)	Extended Cost ($)	Link
1	Apple ID account		To use Xcode	Account	1	0	None	N/A
2	Xcode		IDE for native ios application	Software application	1	0	0	https://developer.apple.com/xcode/
3	Xcode Object Libraries	Swift UI	UI libraries for personalizing and customizing UI	Additional software download	1	0 ($99 to deploy)	0 (annually if deployed)	https://developer.apple.com/xcode/swiftui/
4	Excel		Application used to create an algorithm and compute test cases	Software application	1	0	0	https://www.microsoft.com/en-us/microsoft-365/excel
5	Ipad		Device used to run application software	Equipment	1	0	0	https://www.apple.com/ca/ipad-air/

							- personal devices for testing - Client also has devices available for deploying
7	Mac	Device used to use Xcode	Equipment	5	0	0	https://www.uottawa.ca/faculty-arts/facilities-resources
Total product cost (without deploying it)						$0	
Total product cost (if we deploy it)						$99	

Wrike snapshot:



https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=gm4KxDrvVrDVj7yvAwMuywFQ3mmU9e7i%7CIE2DSNZVHA2DELSTGIYA

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