UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Capstone Design Project: Waste Vegetable Oil Pick-up System Conceptual Alternatives Report

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MECH 457 – Capstone Design Project

Waste Vegetable Oil Pick-up System

Conceptual Alternatives Report

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PURPOSE OF CONCEPTUAL ALTERNATIVES REPORT

This document is written through the collaboration of the MECH 457 Waste Vegetable Oil (WVO) Pick-up System team. The purpose of this report is to illustrate and report, to the clients and project supervisor, the concepts generated for implementing the main functions of the WVO Pick-Up System. These concepts were evaluated against the pre-determined evaluation criteria. Subsequently, the best concept is chosen for its ability to implement the determinant functions while giving the highest perceived value, through the evaluation criteria. In the report, the best concept will be the team's recommendation for the client and through the validation process, the client provided feedback that he prefers the recommended concept to the other concepts generated. Reasons are stated in the validation portion of the report. Subsequent stages of the project will now commence where the team goes forward to design the selected concept in detail and prepare for prototyping in 2009.

ABSTRACT

The Bio-diesel Initiative wishes to develop a small-scale facility in UBC, turning WVO into bio-diesel to partially fuel UBC Plant Operation vehicles. The purpose of the MECH 457 project is to develop a WVO Pick-up System that will perform the primary function of collecting WVO from various locations on campus to the processing plant.

During the conceptualization phase, the team identified various concepts to implement the key function of collecting WVO. After preliminary analysis, these concepts were narrowed down to those that are more feasible. After evaluation, the best three concepts are the small buckets, manual crane (to move large containers) and the small buckets with crane (crane facilitates drop-off of multiple small buckets) concepts.

These concepts were presented to the client and he prefers the small buckets with crane concept. The reasons were that this concept has the benefits of the small buckets concept (clean, inexpensive, etc.) while reducing physical and time requirements during drop-off. More importantly, since the drop-off location is uncertain, using this concept makes the drop-off process adaptable to any drop-off requirements (moving WVO to the 5th floor of CHBE Building).

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1.0 INTRODUCTION

The primary purpose of the MECH 457 WVO Pick-up System Project is to develop a system that will perform the tasks of collecting, transporting and dropping-off WVO from campus locations to a bio-diesel processing facility. To identify the determinant high-level functions, we created a function structure diagram (see Figure 1).

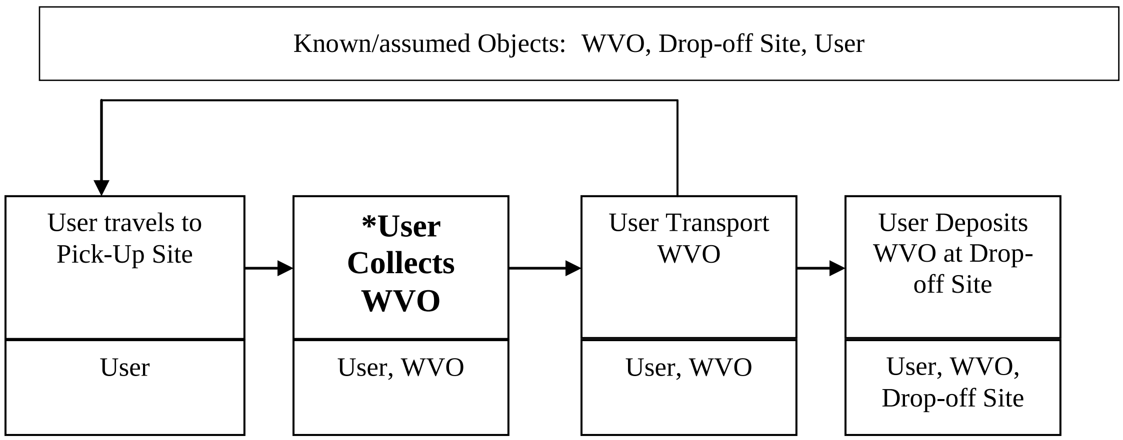


Figure 1 – Function Structure Diagram

The primary, high-level function we have identified from our function structure diagram is WVO collection. This function is chosen as the high-level function because all other aspects of the collection process will depend on the collection method used. For example, if a pump is used to collect WVO, then an additional storage unit will be needed to store the WVO on the transportation device. The transportation device will also have to accommodate the specified storage unit. If the solution involves moving small containers of WVO onto a truck, then no additional storage unit is needed. This effectively changes the attributes of the transportation device/vehicle.

In addition, the concepts generated for this function will potentially provide the client with the highest satisfaction. Based on the evaluation criteria, the client cares about the operating cost, physical exertion and cleanliness of the process. The collection of WVO will ultimately determine these factors. For example, moving large barrels of WVO will be more physically demanding than moving small buckets of WVO, thus giving less satisfaction to the client based on his needs. Also, each concept requires different amounts of time during operation. Low operation time translates to lower operation cost spent on wages. Lastly, the collecting method will also determine the cleanliness. Methods using pumps may require the user to use a suction hose dipped in WVO. This hose can potentially come in contact with the user, dirtying the user and thus giving less satisfaction to the client.

Seeing that the function of WVO collection affects the rest of the system and the client's satisfaction the most, it is the key function for this project.

2.0 BENCHMARKING

Currently, West Coast Reductions collects the campus WVO using an industrial sized vacuum truck (see Figure 2). Typical vacuum trucks have a storage tank of approximately 7500 litres and the collection devices on the vacuum trucks have flow rates of approximately 245 litres per minute. Please refer to appendix A for specifications.

Figure 2 – Vacuum Truck

(http://www.vacallindustries.com/downloads/av_vacuum_truck.pdf)

As shown on the picture above, the collection device utilized by the vacuum truck is mounted on a 20 Ton tandem axel diesel rig. For the transport function, the system should be able to transport the user, collection device, and the WVO. Thus, a vacuum truck satisfies the transport function. Also, the collection method of the vacuum truck utilizes the vacuum pressure. With either a large size vacuum tank or a large compressor in a vacuum system, it is capable of creating large suction force to move sludge, broken up solid, and/or fluid into the storage tank. With the capability of pumping bits of solid, the vacuum pump is very desirable for WVO collection, since WVO solidifies in cold weather conditions. Therefore, the vacuum truck satisfies all of the top-level functions in the functional diagram described in the earlier section.

2.1 Evaluation of the Benchmark Competition

The evaluation criteria consist of ergonomics and operational cost, where the ergonomics is separated into two criterions: cleanliness and physical exertion. The vacuum truck will be evaluated against these three evaluation criterions below. A score from 0 to 10 is assigned to each of the evaluation criteria where the value is based on the satisfaction curve. The slope of the satisfaction curve will be further discussed in the evaluation criteria section of the report.

Cleanliness:

The suction hose/wand on a typical industrial sized vacuum truck has a diameter of 0.2 meter. When the operator moves the hose/wand between storage containers, the user will stain his/her glove, shoe, pants, and, possibly, shirt with WVO. From the slope of the satisfaction curve, the vacuum truck scored a value of 1.5 in the WDM.

Physical exertion:

Typical vacuum hose with a diameter of 0.2m weights approximately 8.41 kg/m, see appendix for specification of the hose. In scenario where the vacuum truck is parked a considerate distance away from the WVO storage container, longer hose are required and it can be quite heavy. Therefore, the vacuum truck scored a value of 4 on the WDM.

Operational cost:

Fuel consumption for a semi truck is heavily influence by the total weight of the vehicle for highway/freeway speed. However, for a delivery/collection type service where the vehicle makes frequent stop and traveling at low speed, the weight of the vehicle does not significantly affect the fuel consumption. The fuel consumption of a semi truck that is used in delivery/collection type service is approximately 25-42 L/ 100km. This wide range in fuel consumption depends on the drivers' decision to keep the engine running or turn it off in between stops. The total distance travel is approximately 5km. Also the vacuum truck is equipped with air brakes; therefore, the driver must have a class 1 driving license. As a result, the labour cost is approximately $18.00 per hour. The estimated hours required to complete the process is 2.3 hours; 1 hour for travel time, 10 minutes at each pick-up locations, and a half hour for setup and cleanup per shift. Total operation cost is approximately $18.00/h X 2.3h + 42L X (100km/5km) X $1.30/L = $44.13. Therefore, the vacuum scored a value of 8 on the WDM.

Given the weight assigned to the evaluation criteria, the vacuum truck scored a value of 4.725 in the WDM, making vacuum truck ranked 4th overall. The result from the WDM has shown that the vacuum truck is not the best solution for small-scale community like UBC. However, if the vacuum truck is to be utilized in municipal like in the Lower Main Land, the Vacuum truck would most likely rank first. With the vacuum truck costing approximately $120 000, the vacuum truck does not meet our cost requirement of $2500.

3.0 CONCEPT GENERATION

We have identified from the work sequence that the collection process is the determinant function. Concepts were generated for implementing that function. These concepts are classified based on the fundamental way of implementation.

Concept group 1 – Collecting the WVO with the original container

- Includes bucket, crane, and truck with lift methods.

Concept group 2 – Collection that involves the removal of WVO from original containers

- Includes manual, diaphragm, and vacuum pump methods.

Bucket Method:

Several 5 gallon buckets will be available for each restaurant to store their WVO. These buckets would be designed with easily sealable lids so the restaurant staff can fill the buckets with WVO directly from the fryers without the chance of spilling. The buckets will be stackable, minimizing the amount of space required at each restaurant loading bay. The buckets would be manually loaded onto the transportation vehicle, replaced with an equivalent number of empty buckets, taken to the remaining restaurants for collection, transported to the designated biodiesel processing plant, and finally manually unloaded.

This concept was inspired by the recent success of Summit Grease Cycling, a small Colorado based company, who have implemented a similar system and have received a considerable amount of positive feedback from all parties involved.

Figure 3 – Small Buckets

Crane Method:

Each restaurant would store their WVO in a transportable container such as a tote or drum. There would be a manual crane mounted to the WVO transportation vehicle. This crane would acquire these transportable containers and load them onto the available storage space of the transportation vehicle, and then replace them with empty storage containers. These steps would be repeated at each restaurant location, and finally all WVO would be transported to the biodiesel processing plant, where the crane would unload these containers.

Figure 4 – Transportation Vehicle with Mounted Crane

Truck with Lift Method:

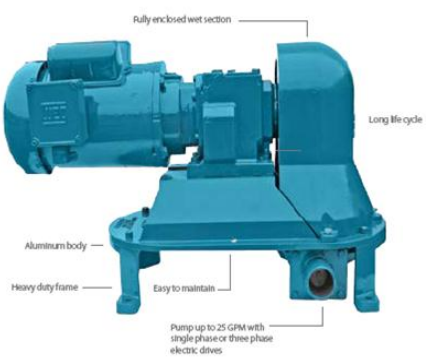
Each restaurant would store their WVO in transportable barrels or drums. There would be some type of mechanical lift (manual, electric, hydraulic, etc.) attached to the transportation device. The transportation vehicle would park itself next to the loading dock so that this lift could allow itself to match perfectly with the dock elevation. A dolley would be used to move the barrels/drums onto this lift and into the correct position on the transportation vehicle. The loaded barrels would be swapped out with empty barrels. These steps would be repeated at other restaurants until the transportation vehicle is at maximum capacity, and then all these containers would be taken to the processing plant, where the lift would unload them. This method would require two round trips to collect all of the WVO from the five UBC restaurants involved.

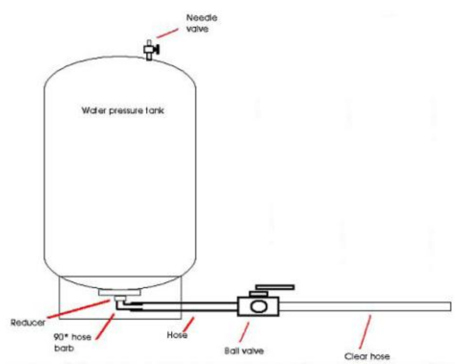
Figure 5 – Truck with Lift

Pump Method:

WVO storage containers would be permanently placed at each restaurant location, and another storage container would be mounted to the transportation vehicle that will travel from site to site. The pump and vehicle mounted storage container would travel to each restaurant pumping all the WVO from its storage container, proceed to the biodiesel processing plant, and the WVO would be pumped into a storage container at this drop-off location.

All proposed pumps would required the same collection and transportation method, with the only difference being that the manual pump would require manual labour to operate. The major differences in pump characteristics include: The vacuum pump is potentially the least expensive, and it can suck up solids. The manual pump needs at least 46 strokes per minute to satisfy the pumping speed requirements, which is much more labour intensive than the pump alternatives.





Top Left: *Diaphragm*
Top Right: *Vacuum*
Bottom Left: *Manual*

Figure 6: Pumps

After some basic concept generation, the crane method became recognized as possibly being a very valuable addition to the more promising concepts. The following two concepts were generated to improve specific functions of the previously stated concepts.

Buckets with Crane Method:

There are two distinct variations of this method. The first variation has a similar method to the bucket method. Instead of manually unloading all the buckets at the processing plant, a crane would perform the unloading. The other variation would also be similar to the bucket method, the difference being that the transportation vehicle would have a portable container temporarily mounted on it. The buckets at each restaurant location would dump their WVO into this portable storage container, and no replacement buckets would be necessary. A crane, located at the processing plant, would unload this portable storage container.

Pump with Crane Method:

The pump was combined with the crane concept because it was evident that the crane would potentially benefit the unloading process at the biodiesel processing plant. This method is similar to the general pump method, but instead of leaving the storage container on the transportation vehicle and pumping the WVO at drop-off, this container would be unloaded by a crane at the processing plant. This would lower the operational costs by decreasing the set up time associated with the pump.

4.0 CONCEPT SELECTION

In order to have unbiased concept selection we utilized our well established evaluation criteria that was based on our clients needs assessment, including the desire to improve upon previously made attempts. However, concepts must always satisfy our primary requirements set out in the Project Proposal. Throughout the screening process, new concepts would be evaluated, but if they did not meet our requirements then they would not make it to the evaluation criteria stage.

In order to accurately judge our potential concepts by our evaluation criteria we positioned them on satisfaction curves that represent our evaluation criteria of cleanliness, physical exertion, and operational cost. However, before we could rank our concepts based on the satisfaction curves, we first had to justify how the concepts fulfilled each evaluation criteria. The original concept justifications are described below.

Small Buckets

<u>Cleanliness:</u> With proper storage and transfer techniques, and locking lids, there will be no spilled WVO. The user can thus transport the full buckets and replace them with empty buckets with only slight contamination to their gloves and shoes.

<u>Operating Cost:</u> 50 20L buckets are to be collected around campus based on ~750L per month. The maximum bucket exchange rate is 1 per minute = 50 minutes for collection time. Additional travel time is calculated to be 1 hour based on a total collection loop of 6.2 km at a traveling rate of 10 km/hr. Drop off of buckets at the collection center is a similar 1 bucket per minute rate for an additional 50 min. 50 clean buckets must be

picked up from depot and exchanged each collection round adding an additional 50 minutes (assuming exchange and collection can happen in one trip). Total time = 3.5 hr @ $12/hr = $42.

Physical Exertion: The metal buckets will be filled with 20L of WVO at a density of 0.92kg/l at a weight of 18.4kg plus the bucket weight of 1.5kg for a total of 20 kg and can be carried with one hand by use of a handle. This corresponds to 100% of the acceptable physical impact for males under 50 (Pheasant 1986).

Manual Crane

Cleanliness: The user will not have any direct contact with any WVO, as it is sealed inside containers. When attaching the crane hooks, there will be some contamination of gloves and shoes.

Operating Cost: A manually operated crane will require 15 minutes changing out each of the three 250L totes (Vanier, Totem, and the SUB), and 10 minutes to change out each of the 55 gallon barrels (99 Chairs, Barn). The capacity to collect only one large tote per trip increase travel time to 3 hours. This capacity could potentially be increased with the use of a much larger trailer system, however, this will increase initial costs, making this concept too expensive. We are evaluating all concepts on a level playing field by assuming the use of a 8 foot truck bed or trailer. Total time = 5.2 hours x $12/hr = $62. Manual cranes are maintenance free aside from the occasional greasing.

Physical Exertion: With a proper gear system, manually cranking up the large totes will have a low labour requirement of 10 Nm torque. A single operator will be able to raise the WVO containers with a single hand turning the crank within 15 minutes. This corresponds to a physical impact of 60% of the maximum (Pheasant 1986).

Diaphragm Pump

Cleanliness: The user will experience some WVO contamination in handling the hose and messy suction wand. Moving between barrels, handling the suction wand, and end-of-collection clean up will cause oil to contaminate gloves, shoes and pants (WVO Sucker 2008).

Operating Cost: A setup time of 30 minutes is required in addition to 15 minutes of collection time at each of the 5 locations. 1 hour is required to drop the WVO off at the storage site and 45 minutes are needed for final cleanup and maintenance. As described earlier, the single round collection travel time is 1 hour. There will also be a $2 fuel cost for idling the engine to produce the power required to run the compressor, estimated at a maximum of 1 litre of fuel for the 1.25 hours of idle time. Total time = 4.5 hours x $12/hr + $2 extra fuel = $56.

Physical Exertion: Handling of the wand and hose will require lifting of 10 kg (WVO Sucker 2008). This corresponds to 50% of the physical impact for males under 50 years old (Pheasant 1986).

Vacuum Pump

Cleanliness: Similar to the diaphragm pump, the user will experience some WVO contamination in handling the hose and messy suction wand. Thus contamination is the same with gloves, shoes and pants being contaminated (WVO Sucker 2008).

Operating Cost: A vacuum pump will require 30 minutes to decompress per pickup location using a refrigerator compressor. 15 minutes for collection and another 30 minutes to discharge is also required for each location. Note that discharge time is longer than suction time because a positive vacuum can be accumulated before the collection process begins. This accumulation will require 2.5 hours to decompress per collection trip, which is not included in labour time as it can be done at the WVO storage depot. 1 hour is required for travel time, and a half hour is required for setup and cleanup per shift. There will also be a $2 fuel cost for idling the engine to produce the power required to run the compressor, estimated at a maximum of 1 litre of fuel for the 1.25 hours of idle time. Total cost = 8.25hr x $12/hr + $2= $102.

Physical Exertion: Similar to other pumping methods, handling of the wand and hose will require lifting of 10 kg (WVO Sucker 2008). This corresponds to 50% of the physical impact for males under 50 years old (Pheasant 1986).

Manual Pump

Cleanliness: Similar to the diaphragm pump, the user will experience some WVO contamination in handling the hose and messy suction wand. Thus contamination is the same with gloves, shoes and pants being contaminated (WVO Sucker 2008).

Operating Cost: Manual pumps can achieve flow rates of 130L per hour based on acceptable physical impact of 300N repetitive pushing and pulling force. 1000L must be pumped onto the transport device and again off the device at the depot. 2000L/130L = 15 hours of pumping, plus an hour of transport time between sites is also required. Total cost = 16 hours x $12/hr = $192

Physical Exertions: Continuous leverage force of 300N is equivalent to 100% of the maximum limit for males under 50 (Pheasant 1986).

Truck with Lift

Cleanliness: With barrels on wheels, the user will only have WVO contact with their gloves and shoes while pushing the barrel onto the lift.

Operating Cost: Collection of the WVO will take 10 minutes per each of the 11 necessary 55 gallon barrels. Also, only four barrels may be collected per trip due to space constraint, so three trips will be necessary at a rate of 1 hour per trip as described earlier. No set up or clean up will be required for the lift. Offloading at the depot and replacing with new empty barrels will take 10 minutes per barrel swap. There will also be a $6 fuel cost for idling the engine to produce the power required to operate the lift, as well as the extra 2 trips. Total time = 6.5 hours x $12/hr + $2 = $84

Physical Exertion: The operator is required to manually push the barrels onto the truck lift. The force requirement is 450N, equivalent to 100 percent of the acceptable male limit(Pheasant 1986).

After comparison using the Pugh chart (Appendix C), the Truck with lift and manual pump concept were eliminated from further consideration based on extremely poor performance when compared to other methods. However, it was discovered that the strengths of the manual crane could be utilized by both the vacuum pump method as well as the bucket method. These new methods were judged based on the same evaluation criteria as before, and are justified below.

Vacuum Pump with Crane

Cleanliness: As justified for the vacuum pump method previously, the user will still experience glove, shoe, and pant WVO contamination in handling the hose and suction wand.

Operating Cost: This vacuum pump setup will still require approximately 2.5 hours to decompress per collection trip, which can be done during storage. Similar to the previous vacuum pump method, 15 minutes is required for collection at each of the 5 sites, 1 hour is required for travel time, and a half hour is required for setup and cleanup per shift. The addition of a crane in the storage area allows for the full storage/suction tank to be offloaded at once, rather than pumping it out. This exchange will take 30 minutes to offload the full tank, in order to maintain low physical impact. Total operator time = 3.75hr x $12/hr = $45.

Physical Exertion: As this method is a combination of the vacuum pump with 50% physical exertion due to hose/wand lifting and the manual crane method which requires 60% physical exertion, it is rated at 55% total physical exertion. This is less than the 60% of the pure manual crane method as it only requires the use of the manual crane for 1 tank exchange for 30 minutes.

Small Buckets with Crane

Cleanliness: As with the standard bucket method, with proper storage and transfer techniques, and locking lids, there will be no spilled WVO. The user can thus transport the full buckets and replace them with empty buckets with only slight contamination to their gloves and shoes.

Operating Cost: 50 20L buckets are to be collected around campus based on ~750L per month. The maximum bucket exchange rate is 1 per minute = 50 minutes for collection time, plus travel time which as calculated before is 1 hour. The addition of a crane in the storage area allows for all of the full buckets to be unloaded simultaneously and a new supply of empty buckets to be loaded for the next collection. This exchange will take 15 minutes for offloading and 15 minutes for on loading for a total of 30 minutes. Total time = 2.5 hr @ $12/hr = $30.

Labour Requirements: The metal buckets will be filled with 20L of WVO at a density of 0.92kg/l at a weight of 18.4kg plus the bucket weight of 1.5kg for a total of 20 kg and can be carried with one hand by use of a handle. This corresponds to 100% of the acceptable physical impact for males under 50 (Pheasant 1986). The crane method only requires 60% physical impact as mentioned before, but the impact is ultimately rated at 100% due to the bucket transfer.

Satisfaction Curves for ranking Evaluation Criteria:

Below are the three satisfaction curves used to rate each of the concepts according to the evaluation criteria. We used the above justification conclusions to position each concept on each of the cleanliness, physical impact, and operating cost curves. From here we were able to accurately measure how satisfying each of the final concepts were so that we could assign them unbiased scores in the weighted decision matrix.

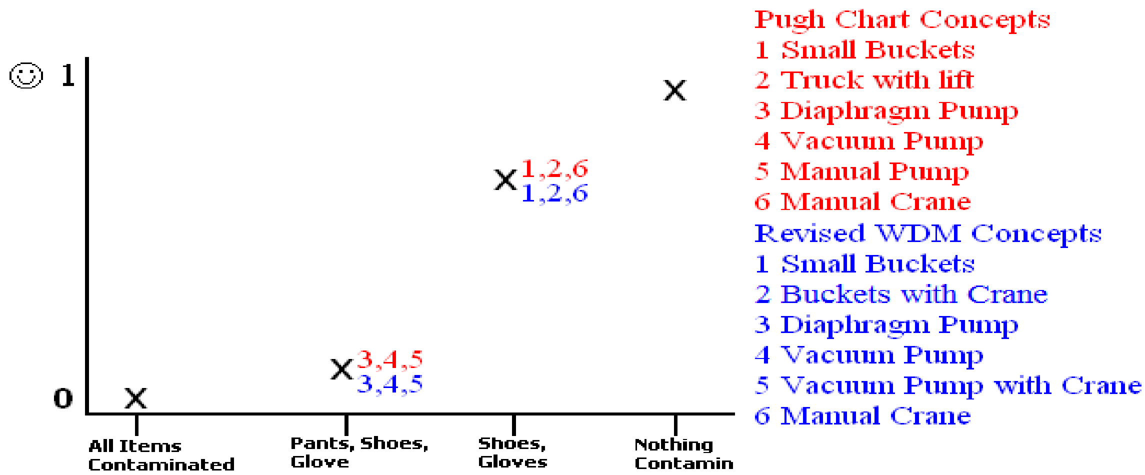


Figure 7: Cleanliness

As seen in the figure above, the bucket, buckets with crane, and manual crane methods scored the highest in terms of cleanliness. In contrast, all of the pumping methods scored poorly.

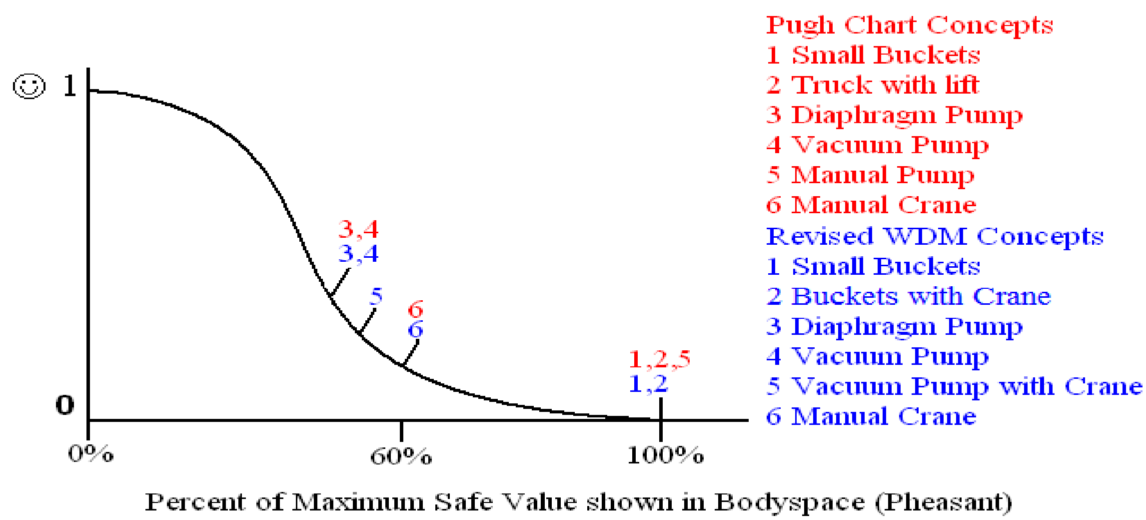


Figure 8: Physical Impact

Based on the above figure, diaphragm pump and vacuum pump have the least physical impact. On the other hand, both of the bucket methods scored very poorly.

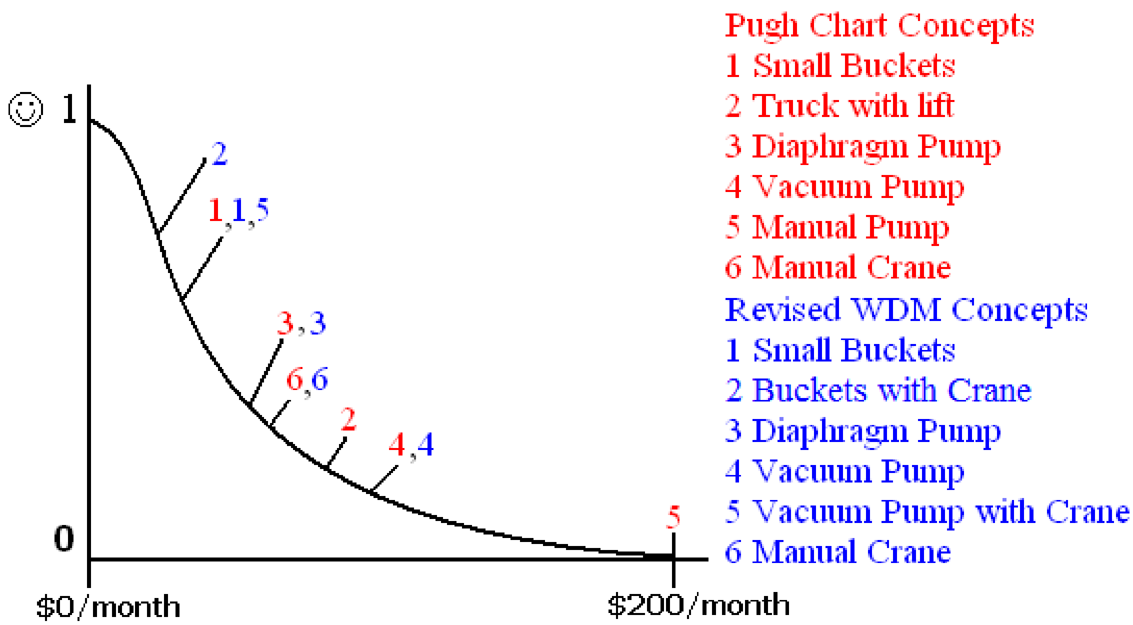


Figure 9: Operating Costs

As made clear by the above figure, the bucket method with crane assisted off loading has the cheapest operating costs. However, the vacuum pump has a very high operating cost due to the lengthy collection time required.

Weighted Decision Matrix

Weights Justification

1) Operating cost was rated at 40% since the project is still in preliminary stages and will not have a steady income until full scale operations occur. Because of this, the UBCBI has stated that low operating cost, which is primarily based on operating hours, is very important to minimize for the success of the entire UBCBI (Dan Khan Email).
2) Cleanliness was rated at 35% since past experience has shown that dirty labour is extremely undesirable for the operator. In fact, this was a leading reason why previous attempts were unsuccessful.
3) Physical Exertion was rated at 25%, since it is important to enable any average citizen to perform the collection duty without extensive physical requirements, although this is not the primary objective.

Based on these weights and the scores based on concept justification and satisfaction curves for our evaluation criteria, the following WDM was formed. Furthermore, there is very little uncertainty in the scores obtained in the WDM. The low uncertainty is a result of well established technology and thorough research of how similar concepts are already utilized in this industry. Furthermore, the evaluation criterion is well defined and the satisfaction curves are properly justified. All these factors lead to very accurate scores used in the weighted decision matrix.

Table 1: Weighted Decision Matrix

WDM		Evaluation Criteria				
		Cleanliness	Operating Costs	labour requirments	**Total Score**	**Rank**
	Weight	0.35	0.4	0.25		
Concepts						
Small Buckets	Rating	7.5	6	0		
	Score	2.625	2.4	0	**5.025**	**2**
Small Buckets w/ Crane	Rating	7.5	7.5	0		
	Score	2.625	3	0	**5.625**	**1**
Diaphragm Pump	Rating	2.5	3.5	5		
	Score	0.875	1.4	1.25	**3.525**	**5**
Vacuum Pump	Rating	2.5	1.5	5		
	Score	0.875	0.6	1.25	**2.725**	**6**
Vacuum Pump w/ Crane	Rating	2.5	6	4.5		
	Score	0.875	2.4	1.125	**4.4**	**4**
Manual Crane	Rating	7.5	3	4		
	Score	2.625	1.2	1	**4.825**	**3**

From the above table, it is clear that the top three scoring concepts in order are the 20L bucket method with crane assisted off loading, the standard 20L bucket method, and finally the manual crane method. The bucket method scored very high because it is a clean process in which only the gloves and shoes get contaminated. Also, it has the lowest operating costs at $42 per collection round. However, it has the highest physical exertion and therefore scored the lowest score in this area. The crane method also scored very high because it is also a clean method, and has lower physical impact at 60%. Furthermore, it scored relatively well in operating costs at $62 per collection round. However, the top ranking concept turned out to be a combination of these two high scoring methods. The buckets with crane assisted offloading scored just as well as the bucket method in cleanliness, but has a much higher score for operating costs at $30 per collection round. Even though this still has low performance in terms of physical exertion, the low operational cost far outweighed this downfall.

5.0 CONCEPT VALIDATION

As mentioned earlier, there was very low uncertainty in our weighted decision matrix. We identified the top three concepts as the bucket method, bucket method with crane assisted offloading, and the manual crane method. We then presented our top three concepts with justifications to the UBC Biodiesel Initiative (Appendix D). We described each concepts strength and weaknesses, as well as exactly why and how they scored with respect to each evaluation criteria.

Upon further inspection, it was identified that the bucket method is beneficial for all parties involved. Although it is a labour intensive task to collect the full WVO containers, the relatively low volume of oil generated by the UBC eateries allows the buckets to be collected very quickly. Draining the deep fryers, collecting the WVO containers and using these at the processing facility will be spill free, keeping all the buckets clean and free from oil contamination. Having a set of clean, empty buckets will allow the restaurant workers to quickly and easily change out their oil and store it. The buckets are an inexpensive investment with very low operating costs. Even if a bucket is damaged, the replacement cost is low at $8 per bucket. The versatility of having small buckets is one of the primary benefits favored by our client, and the UBC eateries. With the current biodiesel reactor on the fifth floor of the CHBE building, buckets will allow for simple transportation for processing. The addition of a crane for unloading will greatly reduce the time and work requirements during the WVO drop off.

The manual crane method is another versatile and easily adaptable way of collecting WVO in its storage container. The crane can be used to pick up drums, if they are designed with hook-up locations such as eyelets, or if they are skid mounted. The crane can also be used to pick up the larger totes, such as the one being utilized at the SUB. Similar to the automotive cranes used to remove engines, a manual crane will be mobile, and operable by a single worker. Since the worker will not come in contact with the WVO container itself, no oil should come in contact with clothing. If the WVO containers are mounted on wheels, the crane will only be required to lift them onto the vehicle for transport, but if not, the crane can be used to move the containers around their storage location, as well as into the processing facility. Depending on the method used at the production facility, the crane may also require a pump to extract the oil from its storage container for refining.

The response provided by the UBC Biodiesel Initiative indicated that they also preferred the bucket method with crane assisted offloading for the similar reasons as we previously stated (Appendix E). They were only interested in the first variation of this concept because they thought that dumping the buckets of WVO into the transportable storage container would more time consuming and dirty. The UBCBI also mentioned that keeping the WVO in these small portable buckets throughout the whole process would be very helpful for their current situation of having the reactor on the 5^{th} floor of the CHBE building.

After confirmation that the bucket method with crane assistance was the best concept, our attention will now be turned to improving this chosen concept to even further satisfy the customer's needs. The largest flaw with the chosen concept is that the amount of labour required to lift the buckets repeatedly throughout the entire process is quite high. The steps involved and the ergonomic features that will eventually be chosen in our final design can still potentially increase the user satisfaction. Ways of improving this concept to further satisfy the customer's request and needs will be of the largest consideration during the remainder of the design process.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Once a winnowing process was used to eliminate unfeasible concepts, a Pugh chart was used for preliminary evaluation. As a commonly used and trusted technology, the diaphragm pump was chosen as our datum. By talking to our client, examining the failures of the first biodiesel initiative, and understanding the financial requirements of the project, our evaluation criteria were developed. Originally, operators had to physically move 15 gallon drums of WVO. Two major issues were seen with this. Skin and clothing contamination was a common occurrence, which should be avoided. Also, the labour required was higher than what is safely recommended. Using guidelines from the book "Bodyspace" by Steven Pheasant, maximum lifting forces were chosen for an operator to be male and under the age of 50. These values range depending on proximity to body, awkwardness of lifting, single- or two-handed, and other factors. Our last evaluation criterion came from operational costs. With diesel fuel displaced as the revenue generated in the biodiesel initiative, the cost of collection and refining cannot exceed the price of diesel per liter. The collection phase is allowed approximately 30 cents per liter of fuel displaced (or of WVO collected) which is equivalent to approximately $200 per month under the average monthly collection rate of 725 liters of WVO. The top three concepts of buckets, buckets with crane and manual crane best satisfied the evaluation criteria.

Through identifying functional requirements, as well as analyzing the previous Biodiesel Initiative at UBC, many different methods of WVO collection were identified. Collecting the WVO was our determinative function that drove the conceptualization process. Two primary methods of collection were identified; picking up the WVO from its storage site, and picking up the WVO storage container and exchanging it for an empty one.

Cleanliness, physical exertion and operating costs were the evaluation criteria. During the winnowing down phase, if a concept was not feasible or did not meat a system requirement, such as initial cost, then the concept was eliminated. Once concepts were evaluated in a Pugh chart, benefits of a crane were evident, and the concept was combined with the vacuum pump and bucket methods. Satisfaction curves were used to help justify values for the weighted decision matrix. The top 3 concepts became the small bucket method, the bucket method with a crane for unloading, and the manual crane method. These methods best met our evaluation criteria, and were considered acceptable by our client (Appendix E).

The bucket method was favoured by our client as well as UBC food services. Having a sealed bucket to empty used vegetable oil into is cleaner and safer than the current method of disposing of used oil. With the buckets falling within the acceptable physical limits noted in *Bodyspace*, and being easily stacked, food service employees can store WVO in a clean and stable manner. Although collection will be a physically demanding job, the benefits of cleanliness and low operating cost greatly outweigh the work required. Furthermore, the addition of a crane at the processing facility will reduce the physical impact and collection time. Now that we can focus primarily on this concept, further work can be done to make the bucket method with crane assisted off loading less physically demanding, as well as cleaner and cheaper to operate.

7.0 REFERENCES

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Pheasant, Stephen. Bodyspace: Anthropometry, Ergonomics and Design. Philadelphia: Taylor and Francis Inc. 1986.

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APPENDIX A: SPECIFICATIONS OF VACUUM TRUCK

MC 2008 Vacuum Truck

Basic Specifications

- 8 cubic yards of debris capacity
- 2,000 gallon stainless steel water tank
- Tandem axle system
- 65 Gpm and 2,000 Psi direct-drive Water Pump
- 3,500 Cfm- 15" Hg positive displacement vacuum pump
- Front-mounted Boom with twin lift cylinders, 1,000 lb. lift and 26' reach
- Front-mounted articulating direct-drive reel with 800'x 1" hose capacity
- Hydraulic rear Door locks & Door open/close cylinders
- High capacity Cyclone between debris tank and vacuum pump
- Galvanized steel tube trays on both sides of tank

Basic Options

- Vacuum pumps up to 5,000 Cfm and up to 27" Hg
- Water pumps to 100 Gpm and to 3,000 Psi
- Hydro Excavation package
- Remote Vacuum relief
- Pump-off systems
- Safety lighting
- Storage compartments
- Variable flow water system
- Wireless remote control
- Tube racks
- Decants
- Body flush-out
- Hydraulic tool circuitry
- Extend or Stainless steel debris tank

Standard Equipment

- Field adjustable baghouse doors, easy-open, no power assist required
- Stainless steel "sure seal" sealing surface on tailgate and dump chutes
- Full bearing body pivot pin
- Blower hourmeter and temperature gauge
- Custom engineered, stainless steel, micro safety screen
- Full length aluminum fenders
- Super heavy duty rear splash plate
- Electric vibrator
- Two adjustable sealed-beam work lights on tailgate
- Debris backed collector body inlet-long life design resists abrasion

- Heavy duty isolator mounts for transfer case and blower
- Porthouse rotation flange
- All clean-outs adjustable
- Full-width rear debris guard
- Super heavy duty porthouse
- Body and Tailgate safety prop
- Stainless steel tube sheet resists corrosion and simplifies bag replacement

APPENDIX B: MORE SPECIFICATIONS OF VACUUM TRUCK

Spec 1100 Hose

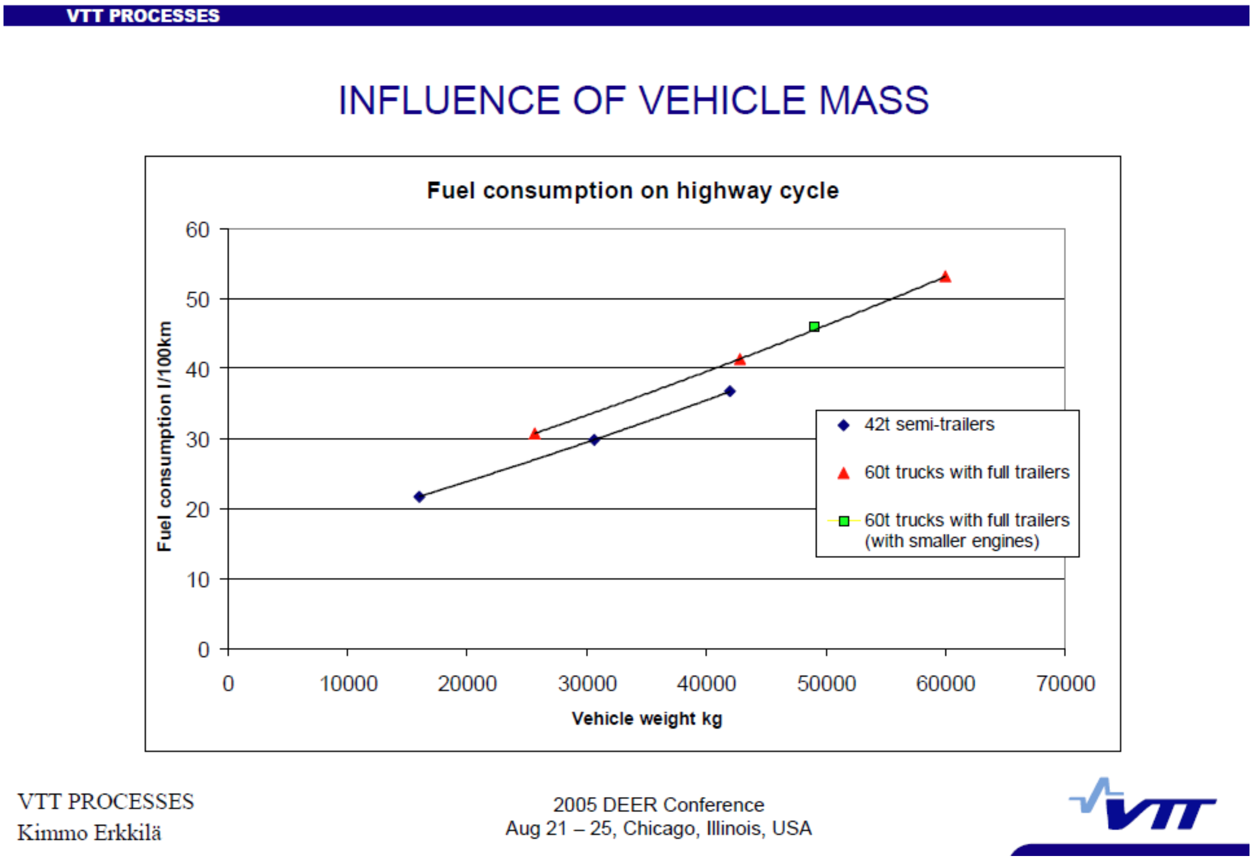
Temp. Range:
-40°F to 158°F
Applications:
Heavy duty abrasion resistant suction hose for vacuum trucks or handling abrasives such as crushed rock, sand, pea gravel, cement powder, dry fertilizer, iron ore and grains
Construction: SBR rubber blended with static carbon black, rigid PVC helix, smooth bore, corrugated O.D.

Features:
¥ Lightweight and flexible
¥ Static dissipating with no grounding wire
¥ Extremely abrasion resistant

Note: This hose was not designed for bulk handling such as unloading of rail cars.

I.D. (Inches)	1-1/4	1-1/12	2	2-1/2	3	3-1/2	4	5	6	7	8	10	12
O.D. (Inches)	1.57	1.82	2.35	2.87	3.50	4.11	4.68	5.63	6.73	7.83	9.04	11.26	13.39
Pitch (Inches)	0.33	0.35	0.39	0.56	0.59	0.64	0.65	0.87	0.87	0.87	0.91	1.00	1.18
Min. Bending Radius 72°F (Inches)	2.00	2.00	2.50	2.50	3.00	4.00	4.50	5.00	9.20	14.00	15.00	30.00	40.00
Working Pressure 72°F, PSI	45.00	45.00	40.00	35.00	35.00	30.00	30.00	30.00	30.00	30.00	30.00	28.00	25.00
Bursting Pressure 72°F, PSI	150.00	150.00	130.00	115.00	115.00	100.00	100.00	100.00	100.00	100.00	100.00	80.00	80.00
Vacuum Rating 72°, In/Hg	29.80	29.80	29.80	29.80	29.80	29.80	29.80	28.00	28.00	27.00	27.00	25.00	25.00
Weight, Lbs/Ft	0.31	0.37	0.50	0.88	1.10	1.35	1.77	2.47	3.08	4.10	5.65	8.88	10.43

http://www.cat-vacuum-collectors.com/vacuum-hose-and-tools/spec1100.html



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la.pdf

Appendix C: Pugh Chart

PUGH CHART	Evaluation Criteria			Scoreing			
CONCEPTS	**Cleanliness**	**Operating Costs**	**Physical Exertion**	**Total +**	**Total -**	**Balance**	**Rank**
Small Buckets	+	+	-	**2**	**1**	**1**	**1**
Truck w/lift	+	-	-	**1**	**2**	**-1**	**3**
Diaphragm Pump	**D**	**A**	**T**	**U**	**M**	**0**	**2**
Vacuum Pump	0	-	0	**0**	**1**	**-1**	**3**
Manual Crane	+	0	-	**1**	**1**	**0**	**2**
Manual Pump	-	-	-	**0**	**3**	**-3**	**4**

APPENDIX D: Email to Dan Kahn for Validation

We have selected our best overall concepts and would like you to provide us with some formal feedback regarding each one. Our top three ideas, from best to worst, are small buckets with a manual off-loading crane, small buckets where you off-load one at a time, and drums/totes with manual mobile crane to load and unload from a trailer. These concepts are explained in our presentation and justification document, but here is a quick summary of each one.

Small Buckets: 2nd

This system would be very similar the current operation Dara is trialing. Basically, there would be a bunch of sealable 5 gallon buckets at each WVO location that would be swapped out on a monthly basis and brought to the reactor for processing. The restaurant would fill the buckets directly from the fryers.

Small Buckets w/ Crane: 1st

This system would the same as the previous one, but would also have a manual crane at the reactor drop-off location. There are a couple of variations for this concept in that we could either place the buckets on a skid on the transportation vehicle and then leave the WVO in the buckets, OR we could have a transportable tote that the small buckets will dump into at each collection site and which can also be unloaded with a crane at the reactor site.

Manual Crane: 3rd

This system would contain 3 totes and 2 drums (one container at each collection site) that can be swapped out at each site. The transportation vehicle will have a mounted manual crane that will unload/load the totes and drums at each site, and will also unload them at the reactor for processing.

Attached is the Weighted Decision Matrix (WDM), our 'Rough' Presentation, and our justifications for each concept. The WDM shows the ranking for all the concepts. Please be as honest and critical as possible because once we choose our final concept there will be no turning back. This is the stage in our design process where, if necessary, we can make new requirements based on other needs you provide us. In your reply, please be as formal as possible because we will be referencing your email in our report and presentation.

If you have any questions regarding the concepts, please don't hesitate to contact us. Our presentation is on Monday, so it would me much appreciated if you completed a review by Sunday night.

Thanks,
Andrew Field

APPENDIX E: Dan Kahn Email

Hey everyone,

I have reviewed the documents you sent me and I am impressed. The presentation looks good, and I like the concepts you have looked into. Here are my thoughts based upon the following requirements:

It is imperative for this project that the system achieves each of the following:

1) The system must be operable by a single person
2) The system must be operated in a way which will not result in a net loss for the UBC Biodiesel Initiative.
3) The system must be clean and WVO shall not touch the operators skin.
4) The initial prototype must cost less than $2500 CAD

It is extremely important to that we work to reduce the operating costs, create a system that is easy to use, and that can be operated in cold weather.

Small bucket concept:

This looks like a great idea because it is not only easier for restaurants to fill the buckets (and we want them to support this idea), but it is clean and inexpensive. In the cold we would not have to worry about oil being too thick to pump and could heat the buckets at the production site. One drawback is that the operator will have to offload each bucket one-by-one which will be very time consuming.

Small bucket w/crane:

This has all the pros of the above concept plus eliminates the problem of having to manually off load each one. This would make the work of the operator a little easier and help to facilitate the transfer of WVO to the production facility holding tank.

Manual Crane:

This concept is good because it would require the pickup of less barrels, but the operator would have to perform a variety of manual operations. The large drums would also difficult to manage for the time being, however this may be useful as production capacity increases.

Pumps:

Although initially I though this would be the best method, after looking at the numbers you have produced and the reduced capacity of our system, it seems that all of the pump ideas would be too expensive to operate. They may also be too dirty and more difficult for the operator to do his/her job.

Overall I think that for us, the small bucket idea is the best, especially with the addition of a crane off loading system. The portable (emphasis on portable) tote system sounds great especially because currently, the pilot reactor is located on the 5th floor of the CHBE building. However, again, for cold weather application these buckets may not be able to be "dumped" and they may have to be stored inside and thawed.

I am a little concerend with the operator having to dump each bucket one-by-one into a larger holding tank wheather it is on the trailer or at the facility. For the time being the capacity is only about 50-60 L / batch, but even still dumping of 10 buckets into a storage tank would be time consuming (and dirty). Some sort of easy transfer system would usefull to avoid this bottleneck, however I know you are on a tight budget and this may be asking for too much.

Anyways you guys are really doing good work and I am excited to see what happens. What time is your presentation tomorrow? If possible I would like to attend it.

Once again the work you all are doing is really helpful to our little project and it is much appreciated. If you need any other information or clarifications don't hesitate to email or call me whenever you need.

Thank you all so much and I wish you the best of luck,

-Dan