Designing an Integrated Supply Chain for Biodiesel Production in the UAE

Afra Najeeb Safar, Fatima Ghubar Alshamsi, Mouza Ojail Alketbi, Nada Abdulhakeem Bushlaibi and Safeya Saeed AlMaazmi
Industrial Engineering Technology Department, Higher Colleges of Technology, UAE
H00388587@hct.ac.ae, H00390845@hct.ac.ae, H00417293@hct.ac.ae, H00417219@hct.ac.ae
H00392342@hct.ac.ae

Yousef Abu Nahleh
Assistant Professors
Industrial Engineering Technology Department, Higher Colleges of Technology, UAE
Yabunahleh@hct.ac.ae

Abstract

As the world's greenhouse emissions increase, there is a worry about the need to address the role of development in the transportation industry responsible for the majority of emissions. The sector consumes vast quantities of fuels forcing nations to enact guides on regulating the use of fossil fuels. One measure includes diversification of energy sources for transportation through consideration of biodiesel. The choice is motivated by the simplicity of integration of the supply chain for a resource that relies on raw material links with other core components. In UAE, biodiesel consideration demands the enactment of a collaborative institutional approach in developing a biodiesel supply chain. As part of the proposal to develop an integrated supply chain, this text describes measures and tactics for developing the integrated supply chain for biodiesel in the UAE. The process will connect users of cooking oil, with the manufacturers of biodiesel, and consumers of biodiesel in the transportation industry. The analysis for evaluating the violability of the supply chain involves the use of Structural Equation Modelling (SEM), and Supply Chain Management Globe software. The process will help access the prospects and the potential of the raw material Used Cooking Oil (UCO), which is an essential component in determining stakeholder's willingness to supply their use coil cooking oil for the manufacture of biodiesel. Part of the research involves data collection using questionnaires disseminated to the UAE society, afterward, the analysis of the same using the structural equation modelling technique follows. As per the SEM results, there is a prospectus of people championing recycling due to awareness of UCO recycling that eases the donation of household waste for biodiesel manufacture. The study conducted using SEM revealed a lack of public awareness regarding UCO recycling in the United Arab Emirates but highlighted a willingness to participate, particularly among larger households. It is equally promising that the Supply Chain Management Globe software is facilitating optimization of UCO collection bin placement, and simplification of the UCO donation by inspiration communal participation in biodiesel production.

Keywords
Biofuel, Biodiesel, UCO: Used cooking oil, (SEM)Structural Equation Modelling and (SCM)Supply Chain Management Globe.

1. Introduction
The changing times are witnessing the consideration of biofuels as alternative sources for fossil fuels responsible for increasing greenhouse emissions. The prospectus for the energy source is ignited by the urge to address the challenges of urbanization. The viability for the biofuels which will likely transform the energy sector is also arising due to transformation in perceptions of the rising costs, (Maxime Merheb, 2018). There is awareness of the ecological risks of carbon-intensive fuels ignited by global demand for clean energy sources. Part of the transformative advances in the United Arab Emirates (UAE) is driven by the urge for maximization of the potential benefits of biofuels. As part of the nation's agenda, the UAE aspires to lead advances and technologies for renewable energy through sustainable global energy production initiatives. The action aligns with the aims of improving air quality in the nation as part of the 2021 National Agenda, (Environment, 2019)

Biodiesel is renewable and biodegradable, made from 100% pure soy, vegetable oil, non-food grade animal fats or even restaurant waste grease (Alternative Fuels Data Center: Biodiesel Fuel Basics, n.d.). What is significant about biodiesel is that it helps ensure a more energy independent future by reducing the dependency on imported oil thus, increasing national security. Its flexibility and complementarity to current diesel engines create an offer suitable for many uses (transportation, industrial, etc.), thus responding to the needs of this market (Biodiesel Technocrats, n.d.).

Biodiesel is critically important to the UAE, for it fits seamlessly into its forward-thinking goals. The UAE dreamt of a green future, sustainable, innovative, and environment-considerate future. In this context, biodiesel plays an important role as a renewable and clear energy which decreases CO2 emissions, improves the energy security and drives economic growth. and represents the UAE’s vision to lead globally as a sustainability pioneer in clean energy. Incorporating the United Nations Sustainable Development Goals (SDGs) with biodiesel in the UAE forms strong co-relation. Production and use of biodiesel make direct contributions to many fundamental SDG’s. Biodiesel helps Goal 13 (Climate Action) by reducing carbon emissions and mitigating climate change. Also, it is consistent with Goal 7: Affordable and Clean Energy by encouraging clean and renewable energy options. That the biodiesel industry could create economic opportunities and job creation that would contribute to Goal 8 (Decent Work and Economic Growth). Plus, using localized feed stock for biodiesel manufacturing helps to improve Goal 12 (Sustainable Consumption and Production) as it minimizes waste (Internet, n.d.).

In investigating the viability of the prospects of reducing air pollution in the UAE, this paper examines the extent of awareness of the environmental impact of transportation with a focus on diesel-powered vehicles while being intended to map out the road towards developing an integrated supply chain for biodiesel in UAE. This paper’s goal is to pull together an integrated system that connects the key stakeholders involved in regional, renewable energy-based biodiesel production. These interests include the collectors of used cooking oil (UCO), biodiesel producers and customers. The inquiry explores the development of an efficient biodiesel supply chain that motivates the consideration of sustainable alternative fuel sources for transportation firms and people who utilize diesel as their energy source. The paper aspires to enhance the adoption of green fuels as a sustainable action in the transportation sector. The process involves communicating the cost-effectiveness and ecological gains of considering biodiesel as an alternative energy source. This endeavor promises not only to fortify the UAE's energy security but also to emerge as a potent instrument in the concerted effort to curtail greenhouse gas emissions within the transportation sector. In the long term, the action will align with the UAE's overarching goals of balancing economic growth with sustainable practices like environmental preservation to lead the globe as the model for sustainable development.

1.1 Objective

This paper aims to introduce a new generation of an integrated supply chain by developing the existing deficient processes to enable the expansion of the scope of producing and utilizing biodiesel as an alternative source in UAE's transportation.

The objectives are:

- Design and demonstrate the biodiesel supply chain in the UAE.
- Investigate the effects of people's awareness of UCO recycling in the production of Biodiesel.
- Replace portion of the public bus fleet's conventional fuel with biodiesel.

2. Literature Review

2.1 Biofuel and Biodiesel

A fuel made from organic resources, such as plants and animals, is known as biofuel. Biofuel usually refers to liquid fuels used as replacements for or additives to petroleum-based liquid fuel. A distinctive quality of biofuel is that it can be produced using raw materials that can be developed or grown. Many different types of biofuels could be produced, but biodiesel and bioethanol are the two that are most frequently discussed globally, (Khani, 2021)

Biofuel has been developed over three generations and is made from renewable resources. Food products including sugar cane, corn grains, and animal fats are used to make the first generation of biofuels. The second generation uses non-edible items such as biomass, switchgrass, and agricultural residue. While the third generation uses algae, a single-cell organism. Generally, algae are categorized based on their habitat, such as freshwater, (Khani, 2021).

The production and use of biofuels have fewer negative effects on the environment compared to fossil-fuel-derived fuels. Burning biofuels does result in emissions of carbon dioxide (CO2), which is a greenhouse gas. However, according to international convention, CO2 emissions from biofuel combustion are excluded from national greenhouse

gas emissions inventories because growing the biomass feedstocks used for biofuel production may offset the CO2 produced when biofuels are burned.
Biodiesel is an alternative fuel to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow, and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. The resources of biodiesel are Straight vegetable oils, both edible and not, recycled waste vegetable oils, and animal fat, (what is bioethanol, n.d.).

2.2. Generation of Biodiesel from households UCO

According to a report by the international council on clean transportation, the study estimates how much UCO is likely to be available from the six countries in Asia that currently export the most UCO to Europe and the United States: China, India, Indonesia, Japan, Malaysia, and the Republic of Korea. As a result, the amount of UCO produced from the households collected from major Asian exporting countries presents 50% of the biodiesel production, (Tenny Kristiana, 2022). The amount of biodiesel produced compared to the collected UCO can be seen in table 1.

Table 1. Estimates of UCO Collection Potential From Urban Households, Urban Restaurants, And Food Processing In Kilotons Per Year, (Tenny Kristiana, 2022).

Country	Household, 50%	Restaurant, 100%	Food processing, 100%	Total potential	Fuels potential	
					FAME	Renewable diesel
China	84	4.461	586	5,131	4.669	4,361
India	117	1,164	416	1,697	1,544	1,442
Indonesia	255	332	128	715	651	608
Japan	54	217	60	331	301	281
Malaysia	88	54	16	158	144	134
Rep. of Korea	7	78	31	116	106	99

An example, BioKT, a preeminent environmental program in Turkey, has made tremendous progress in gathering spent cooking oil. BioKT has made it simple and accessible for people to dispose of their spent cooking oil responsibly through a network of collection locations and collaborations with neighborhood eateries and homes. In addition to preventing incorrect cooking oil disposal, which may clog drains and damage ecosystems, this effort also makes sure that the collected oil is used to make biodiesel, a step toward Turkey's transition to cleaner and more sustainable energy sources (Used Cooking Oil UCO, 2022).

Additionally, BioKT has actively engaged with local communities to spread knowledge about the environmental risks associated with inappropriately discarding leftover cooking oil. Their educational initiatives and community outreach work have been essential in inspiring people to take part in the used cooking oil collection program, cultivating a feeling of environmental stewardship, and facilitating Turkey's transition to a greener economy.

2.3. Structural Equation Modeling

Structural equation modeling (SEM) is a collection of statistical techniques that allow a set of relationships between one or more independent variables, either continuous or discrete, and one or more dependent variables, either continuous or discrete, to be examined (BENTLER, 2013).
For instance, there is study in Malaysia that used the SEM, Suhaiza Zailani's case study from 2019 looked into the variables that affect Malaysian drivers' willingness to pay for biofuels. The study indicated that drivers' willingness to pay for biofuels was positively influenced by functional value, emotional value, conditional value, and epistemic value, (Suhaiza Zailani, 2019). Biofuels may see greater usage if governments and businesses highlight their practical, emotional, hypothetical, and cognitive advantages, according to the study. Companies may educate buyers on the positive aspects of biofuels while governments offer economic motivation via subsidies or other financial rewards.
Overall, Suhaiza Zailani's case study from 2019 offers insightful information on the variables that affect drivers' willingness to pay for biofuels. Governments and businesses may promote the use of biofuels and lessen their reliance on fossil fuels by using the study's conclusions, (Suhaiza Zailani, 2019).

Furthermore, in a Finnish study, participants filled a questionnaire. The questionnaire has four parts. Basic participant information including age, education, and gender was requested first. The aim was to have a diverse group. The next section addressed Finnish issues. Most individuals worried about global warming, population increase, and waste disposal. Many didn't care about food security. Interestingly, many believed tackling overpopulation could assist other environmental challenges, (Md. Munjur E. Moula a, 2017). The third portion asked participants why they might switch to biofuels and what the government should do. Some thought reducing biofuel prices would be an effective government reaction and encourage their use. People were additionally concerned about gas station availability, (Md. Munjur E. Moula a, 2017).

Finally, the questionnaire examined the market. Most respondents had hybrid or standard fuel vehicles, not hydrogen or electricity. Electricity was the most preferred fuel. No one thought biofuels were better, but others said hydrogen or electricity weren't accessible yet. They might switch to those fuels as technology improves. (Md. Munjur E. Moula a, 2017).

3. Methodology

The case study approach was chosen as the form of research for this paper in order to generate a detailed article about creating an integrated biodiesel supply chain in the United Arab Emirates. This research uses a questionnaire experimental design, which explores the relationship between society's awareness of UCO recycling and willingness to donate their UCO to produce biodiesel. Then, the research uses the simulation tool for the distribution of UCO collection bins at specific points to ease the sourcing of UCO. Figure 1 illustrates the method overview to develop the integrated biodiesel supply chain.

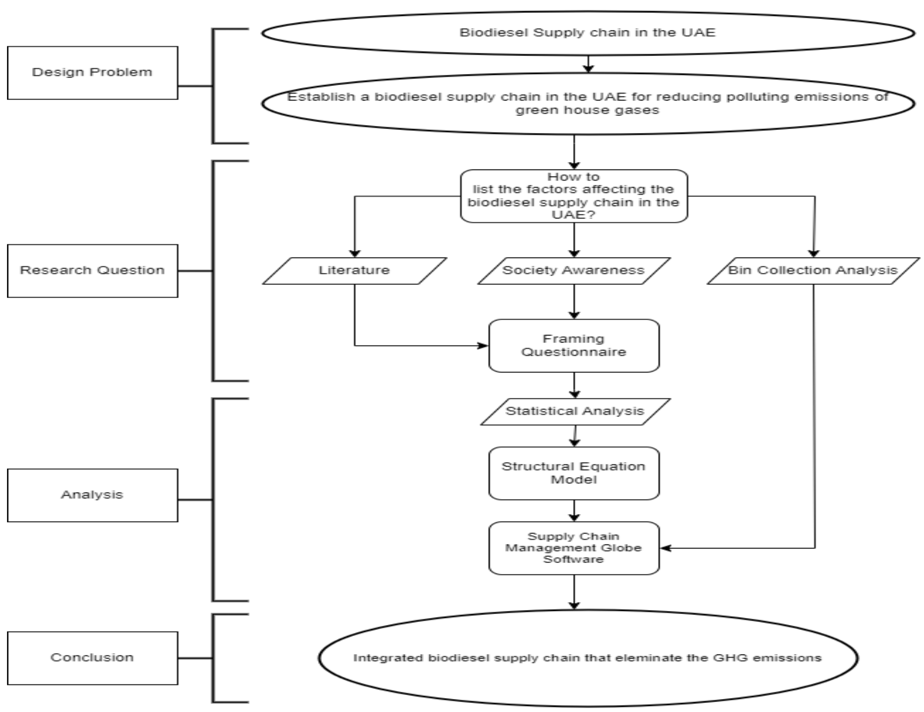


Figure 1. Flow chart of the paper

4. Data Collection and analysis

4.1 Households Awareness Questionnaire

This part presents information on the survey questionnaire's design and the process of selecting sample respondents. Additionally, the section outlines the methods employed for data collection and the procedures adopted for data analysis in research. Moreover, the survey involved interaction with the United Arab Emirates (UAE) residents. The goal was to access their knowledge concerning the usage of cooking oil and recycling of the energy source. The investigation sought to source a representative sample on the extent of cognition of the critical disposal methods for used cooking oil in the UAE.

4.2 Data Analysis

After the collection of the survey data, the information was subjected to quantitative analysis. The research process entailed the collection of data and the determination of the corresponding proportion of the response for each question. The researchers deployed Structural Equation Modelling (SEM), which is a statistical technique used for analysis of the correlation between independent and dependent variables. Structural equation modeling (SEM) was integral in the identification of the important elements to produce biodiesel in the United Arab Emirates (UAE). The analysis of the element's importance relies on the data from a household survey.

5. Results and Discussion

This part goes in-depth with the findings and results reached after a thorough analysis of the UCO (Used Cooking Oil) supply chain. The scope of the study includes the main suppliers, householders, who will donate the UCO in order to dispose the waste in a proper manner rather than pouring it into sinks. Secondly, the production of biodiesel will be manufactured by Lootah BioFuels, and Neutral Fuels, which are cooking-oil-to-biodiesel refineries that started up in 2010, in the UAE (ABRAHAM, 2015). Thirdly, the considered customers, Road and Transport Authority (RTA) in Dubai and Emirates Transport. Have large fleets of transportation buses, that could run on biodiesel made from UCO. Where RTA have large fleet of 1,518 public transportation buses in Dubai. (About Dubai Bus, 2023) And Emirates transport have a fleet of transporting government schools students using 4,161 buses, and private schools students through 2,256 buses (Staff Writer, 2022) Moreover, universities, colleges and other educational institutions students for more than 800 buses (Staff Writer, 2022). Finally, the potential partners are Beeah and Hotels, where Beeah Tandeef has launched machine that collects UCO deposits in Sharjah (BEEAH Tandeef Launches Used Cooking Oil Deposit Machines To Reduce Waste And Produce Biodiesel, n.d.). On the other hand, hotels are identified as partners to provide discounts and promotions to the suppliers, households, that donate their UCO. Both partners are crucial to this dynamic network, as illustrated in figure 2.

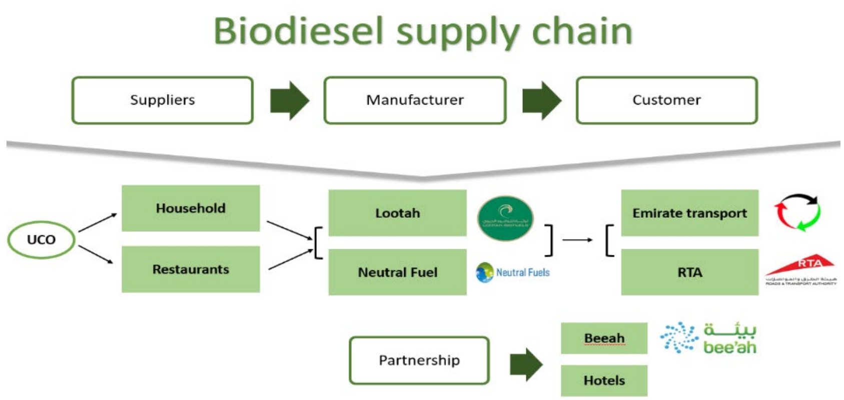


Figure 2. Biodiesel supply chain components

5.1.1 Sample Characteristics

153 collected responses from residents of the UAE. Most of the participants sampled lived in households with 5-9 people. The representation reflects the prevalence of extended families in the UAE. The data is critical for contextualizing cooking oil consumption patterns because larger households are prone to use vast amounts of the resource (cooking oil). As illustrated in Table 2.

Table 2. Analysis Of UCO Consumption Amount In Households With 5-9 Members

Consumption amount	1-2 liters	3-5 liters	5-9 liters	10 or more liters
5-9 living in a household	32.95%	37.5 %	25%	4.45%
Reuse their Cooking oil	27.58%	24.2%	40.9%	25%
Throw it garbage	72.4%	87.87%	72.72%	100%
Pour it in sink	24.137%	6.06%	22.72%	0%

Recycle it	3.44827%	6.06%	4.54%	0%
Doesn't know about Recycling UCO	100%	69.6%	95.45%	75%
Willing to donate UCO for free	100%	87.87%	81.8%	50%
Willing to donate UCO for volunteering hours	100%	75.75%	81.8%	50%

5.1.2 Social Perspective

To begin, Figure 3 depicts respondents' awareness of used cooking oil (UCO) recycling and reveals that 79% of respondents were not aware of used cooking oil recycling. Continuing with Figure 4, which illustrates respondents' ways of disposal, indicates that 65.2% of respondents dispose of their UCO in the garbage, while 29.1% pour it in sinks, with a representation of 3.2% recycles their oil. Moving on to Figure 5, which represents respondents' willingness to donate their UCO in return for volunteering hours, depicts that 70.7% of respondents were willing to donate their used cooking oils in return for volunteering hours. It was found that consumers were willing to donate but were unaware of the proper disposal methods for used cooking oil, which pointed to an immense potential for incentivizing UCO recycling in the UAE.

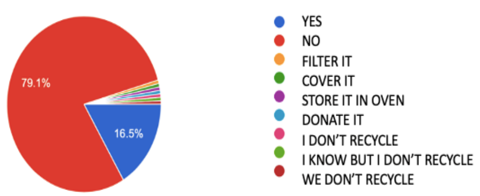


Figure 3. Awareness Of Recycling UCO

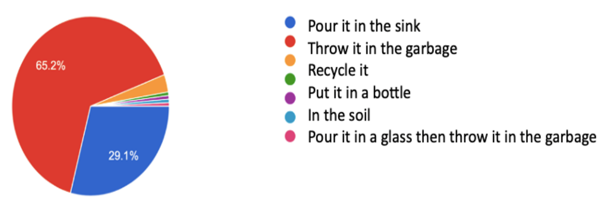


Figure 4. Ways Of Disposing UCO

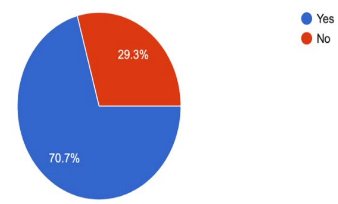


Figure 5. Donating UCO In Return Of Volunteering Hours

5.1.3 Structural Equation Modeling: Households Analysis

Figure 6 shows the framework that is proposed for the investigation into the relationship between UAE society's awareness of UCO recycling ways and their willingness to donate UCO to the production of biodiesel. The next sub-sections will provide the subsequently developed hypotheses.

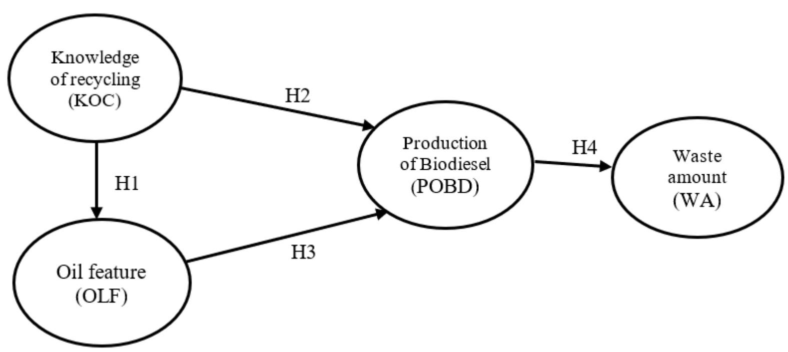


Figure 6. Proposed model

H1: Knowledge of recycling used cooking oil has a significant effect on the features of oil.
H2: Knowledge of recycling used cooking oil has a direct positive effect on the production of biodiesel.
H3: Oil feature has a direct positive effect on the production of biodiesel.
H4: Biodiesel production has a significant impact on the reduction of the waste amount of UCO.

5.1.4 Testing Hypotheses

The hypotheses evaluated to contextualize the relationships between variables:

- Hypothesis 1 (H1) insinuated that the awareness of recycling described as Knowledge of Recycling (KOC) affects the production of biodiesel (POBD). The analysis showed a significant relationship (p-value = 0.654), supporting H1.
- Hypothesis 2 (H2) suggested that knowledge of recycling (KOC) influences oil features (OLF). The results highlighted a significant relationship (p-value = 0.568), supporting H2.
- Hypothesis 3 (H3) proposed that oil feature (OLF) affects the production of biodiesel (POBD). The analysis highlighted a significant relationship (p-value = 0.804), supporting H3.
- Hypothesis 4 (H4) suggested that the production of biodiesel (POBD) affects waste amount (WA). The results highlighted a significant relationship (p-value = 0.139), supporting H4 (Table 3).

Table 3. Hypothesis testing.

	Relationship	**P – value**	**Decision**
Hypothesis 1	KOC >> POBD	0.654	Supported
Hypothesis 2	KOC >> OLF	0.568	Supported
Hypothesis 3	OLF >> POBD	0.804	Supported
Hypothesis 4	POBD >> WA	0.139	Supported

The research validates the hypotheses suggested proving that there is a critical relationship between knowledge of recycling, biodiesel production, oil features, and waste reduction in the UAE. The findings serve as a foundation for further research and actions that seek to encourage UCO recycling and biodiesel production in the United Arab Emirates.

5.2.1 Number of UCO

In the proceeding section, a critical task is discussed regarding the number and location of the UCO bins. In that stage, a heavy reliance on population density data was needed to determine the right number of bins. In order to adequately meet Dubai's population demand. Based on the population density of the UAE, especially in the Dubai Emirate, a study was conducted to estimate the number of bins required to simplify the UCO donation process by inspiring communal participation in biodiesel production. Table 4 illustrates the number of bins in each area in Dubai.

Table 4. Number Of Bins

Community code	**Sector and Community**	**Total population**	**consumption amount in ml/ daily**	**consumption amount in L/daily**	**consumption amount in L/weekly**	**actual consumption amount in L/weekly**	**Leftover oil from frying process**	**number of bins with 200 L capacity**
112	AL RASS	8,067	320,201.0	320.2	2,241.4	1,584.7	1,362.8	7
113	AL DHAGAYA	16,723	663,781.0	663.8	4,646.5	3,285.1	2,825.1	14
116	AYAL NASIR	19,820	786,709.3	786.7	5,507.0	3,893.4	3,348.3	17
117	AL MURAR	40,105	1,591,875.7	1,591.9	11,143.1	7,878.2	6,775.2	34
118	NAIF	53,075	2,106,690.1	2,106.7	14,746.8	10,426.0	8,966.4	45
119	AL REGA	11,097	440,469.9	440.5	3,083.3	2,179.9	1,874.7	9
122	AL BARAHA	25,839	1,025,619.7	1,025.6	7,179.3	5,075.8	4,365.2	22
123	AL MUTEENA	48,739	1,934,582.5	1,934.6	13,542.1	9,574.2	8,233.9	41
124	AL MURQABAT	73,087	2,901,020.4	2,901.0	20,307.1	14,357.1	12,347.1	62
125	REGA AL BUTEEN	7,538	299,203.6	299.2	2,094.4	1,480.8	1,273.5	6
126	ABU HAIL	18,043	716,175.4	716.2	5,013.2	3,544.4	3,048.1	15
127	HOR AL ANZ	84,661	3,360,423.7	3,360.4	23,523.0	16,630.7	14,302.4	72
129	PORT SAEED	14,241	565,263.7	565.3	3,956.8	2,797.5	2,405.8	12
132	AL WAHEDA	21,608	857,679.9	857.7	6,003.8	4,244.7	3,650.4	18
133	HOR AL ANZ EAST	22,026	874,271.4	874.3	6,119.9	4,326.8	3,721.0	19
134	AL MAMZER	16,534	656,279.1	656.3	4,594.0	3,247.9	2,793.2	14

For example, Calculating the Number of Bins Required in Al Mamzer:

- $Applying\ Consumption\ amount\ in \frac{ml}{daily} = population\ of\ area \times consumption\ amount\ per\ person$ (1)
  - $Consumption\ amount\ in \frac{ml}{daily} = 16{,}534 \times 39.6927 = 656{,}279.1\ \frac{l}{daily}$
- $Applying\ Consumption\ amount\ in \frac{l}{daily} = \frac{Consumption\ amount\ in \frac{ml}{daily}}{1000}$ (2)

- $Consumption\ amount\ in \frac{l}{daily} = \frac{656{,}279.1}{1000} = 656.3\ \frac{l}{daily}$

- $Applying\ Consumption\ amount\ in \frac{l}{weekly} = Consumption\ amount\ in \frac{l}{daily} \times 7\ days$ (3)
  - $Consumption\ amount\ in \frac{l}{weekly} = 656.3 \times 7 = 4{,}594.0 \frac{l}{weekly}$

- $Applying\ Actual\ consumption\ amount\ in \frac{l}{weekly} = Consumption\ amount\ in \frac{l}{weekly} \times$ $the\ percentage\ of\ people\ who\ are\ donating\ their\ UCO$ (4)
  - $Actual\ consumption\ amount\ in \frac{l}{weekly} = 4{,}594.0 \times 0.707 = 3{,}247.9\ \frac{l}{weekly}$

- $Applying\ Leftover\ oil\ from\ frying\ process = Actual\ consumption\ amount\ in \frac{l}{weekly} \times$ $percentage\ of\ oil\ is\ left\ from\ the\ frying\ process$ (5)
  - $Leftover\ oil\ from\ frying\ process = 3{,}247.9 \times 0.86 = 2{,}793.2\ \frac{l}{weekly}$

- $Applying\ Number\ of\ Bins\ with\ 200\ l\ capacity = \frac{Leftiver\ oil\ from\ frying\ process}{200}$ (6)
  - $Nubmer\ of\ bins\ with\ 200\ l\ capacity = \frac{2{,}793.2}{200} = 14\ bins$

5.2.2 Determination of the UCO bin's location

In order to accommodate Dubai's expected population of 3,355,900 people, a total of 2,957 bins are needed. The bin's placement is determined using the Center of Gravity approach (Russell and Taylor, 2014), which utilizes a mathematical model to identify the optimal location for a facility based on factors like population density, existing facility locations (such as bins), and demand distribution, including the quantity of UCO (Used Cooking Oil). The equations and Table 5 below illustrate the Center-of-Gravity Method's calculations for a specific section in Dubai.

Center–of–gravity equation:

$$X = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i}\quad , y = \frac{\sum_{i=1}^{n} y_i w_i}{\sum_{i=1}^{n} w_i}\ (7)$$

$x, y =\ coordinates\ of\ new\ facility\ at\ center\ of\ gravity\ (new\ hub)$
$x_i, y_i =\ coordinates\ of\ existing\ facility\ i$
$w_i = weekly\ amount\ of\ UCO\ from\ facility\ i$

Table 5. Calculation of Center-of-Gravity Method of section one.

Community Code	Sector and Community	UCO amount (volume)	x_i	y_i	$x_i w_i$	$y_i w_i$
112	AL RASS	1362.8	25.26807	55.29583	34435.8436	75358.27587
114	AL BUTEEN	509.5	25.26865	55.29973	12874.78471	28176.10046
116	AYAL NASIR	3348.3	25.27405	55.30453	84626.22839	185178.6286
117	AL MURAR	6775.2	25.27677	55.31029	171256.3006	374740.8067
118	NAIF	8966.4	25.27176	55.31004	226595.8772	495930.1975
119	AL REGA	1874.7	25.26766	55.3085	47369.3245	103686.935
122	AL BARAHA	4365.2	25.27961	55.32227	110350.0626	241491.7221
123	AL MUTEENA	8233.9	25.27251	55.32274	208090.1654	455519.3467
124	AL MURQABAT	12347.1	25.26419	55.32212	311940.7383	683070.4238
125	REGA AL BUTEEN	1273.5	25.26136	55.31582	32169.13301	70442.06167
126	ABU HAIL	3048.1	25.28487	55.32942	77071.9043	168651.9559
127	HOR AL ANZ	14302.4	25.27784	55.33672	361534.6	791449.7788
129	PORT SAEED	2405.8	25.25749	55.33016	60765.51097	133115.5992

132	AL WAHEDA	3650.4	25.29108	55.33661	92322.70651	202001.0838		
133	HOR AL ANZ EAST	3721.0	25.28321	55.34775	94079.37594	205950.1502		
134	AL MAMZER	2793.2	25.29824	55.35166	70663.45045	154609.1361		
TOTAL		**83377.2**			**25.27468475**	**55.32305569**	**25.275111**	**55.323296**

$$X = \frac{2107331.655}{83377.2} = 25.27468475 \;, y = \frac{4612679.75}{83377.2} = 55.32305569$$

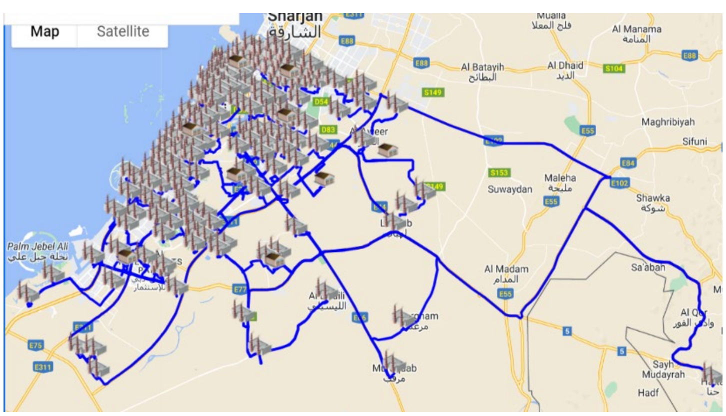
So , the selected location is (25.275111 , 55.323296).

After calculation, a new facility (Hub) is generated at the designated site, where the UCO quantity will be gathered and stored in warehouses prior to production. The effectiveness of the location as a location to store massive volumes of UCO is then examined by this method. According to this assessment, the location picked was unsuitable as a storage space. Therefore, manual consideration is taken to determine the new location.

5.2.3 UCO collection network structure

To effectively manage the collection and transportation of used cooking oil (UCO) in Dubai, a total of 9 hubs have been established across the 9 sectors. Additionally, a tenth hub has been established in Hatta, which is located further away from sector 8, to ensure efficient collection and transportation of UCO from this area.

In order to carry out the weekly collection of UCO from the bins and store it in the hubs, a total of 18 trucks have been allocated for this purpose. These trucks are responsible for collecting UCO from various collection points in Dubai and transporting it to the designated hubs. Once the UCO has been collected and stored in the hubs, it is then transported to the manufacturer in neutral fuel. For this purpose, 2 additional trucks are utilized to ensure the safe and efficient delivery of the UCO to the manufacturer. This network ensures the proper collection, storage, and transportation of UCO to be recycled into neutral fuel, reducing waste, and contributing to a more sustainable environment. The structure of the UCO collection network is shown in the Figure 7 below.



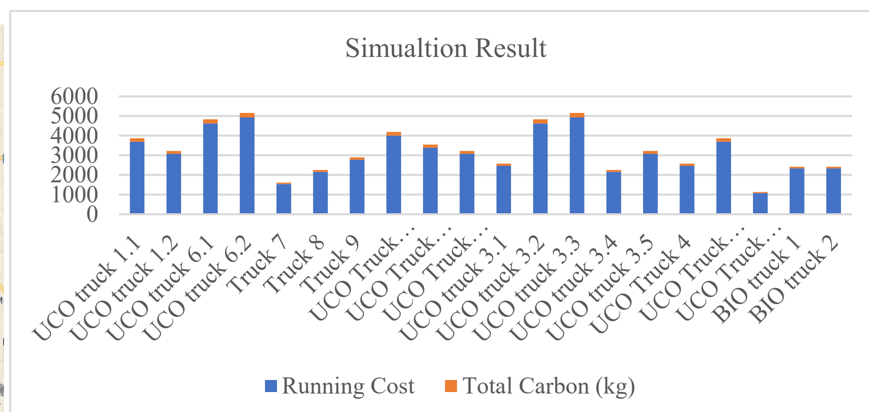


Figure 7. Structure of UCO collection network.

Figure 8. Simulation result of UCO collection network.

Simulation results involve using B100 in the network trucks, which is a 100% biodiesel blend, and it effectively reduces truck carbon emissions to 0.07644 kg CO2/km. However, B100 is more expensive than regular diesel, with costs of $0.589/km for large trucks and $0.465/km for medium trucks. Figure 8 illustrates cost and emissions data for B100. B100 indeed significantly reduces emissions but comes at a higher fuel cost.

5.3 Proposed improvements

Integrate a supply chain in the UAE: This study recommends the Implementation of a supply chain in the UAE to increase the production of biodiesel. Consumer Education: It is established that the UAE population needs awareness about UCO recycling and suitable/ proper disposal methods for used oil. The process of sensitization can be initialized through public campaigns and educational initiatives.

Incentivization: There exists viability in encouraging the donation of UCO in exchange for volunteering hours. As noted, the incentive-based approach is critical in boosting recycling rates. In the proceeding section a critical task is discussed regarding the location of the UCO bins. In that stage, a heavy reliance on population density data was needed to determine the right number of bins. In order to adequately meet Dubai's population demand.

6. Conclusion

In summary, the study shed light on the UAE's consumption patterns, emphasizing the prevalence of larger households and the limited awareness about Used Cooking Oil (UCO) recycling. These findings underscore the immediate need for targeted sensitization and educational programs that promote sustainable practices among residents.

The SEM analysis validated the critical link between recycling awareness and biodiesel production, emphasizing the pivotal role of education and incentivization. Additionally, the integration of Supply Chain Globe software, coupled with the Center-of-Gravity Method, revolutionized the UCO collection process. Through strategic placement of ten hubs and optimized routes, the supply chain achieved heightened productivity and reduced transportation costs. This strategic approach not only ensured operational excellence but also seamlessly aligned with the sustainability goals.

Therefore, the outcomes from utilizing SCM Globe in this paper are substantial. This advanced supply chain modeling tool enabled the comprehensive planning of the UCO collection network. The strategic placement of bins, optimized collection routes, and detailed analyses of costs and emissions significantly reduced transportation costs and minimized emissions, validating the efficacy of this approach. Beyond affirming the feasibility of the biodiesel supply chain, SCM Globe provided invaluable insights crucial for shaping future sustainable initiatives.

This study underscores the urgency of integrating cutting-edge tools like SCM Globe into environmental projects. Through education, meticulous planning, and innovative technologies, this can pave the way for a greener UAE. By fostering recycling awareness and enhancing biodiesel production, it is not just addressing immediate challenges but also building a sustainable future for generations to come.

References

About Dubai Bus. (2023, September 28). Retrieved from RTA: https://www.rta.ae/wps/portal/rta/ae/public-transport/dubaibus?lang=en. Seprtember 28,2023.

ABRAHAM, S, UAE backs use of biofuels. *MEED*, 2015

BEEAH Tandeef Launches Used Cooking Oil Deposit Machines To Reduce Waste And Produce Biodiesel, Retrieved from BEEAH Tandeef: https://beeahtandeef.com/our-announcements/beeah-tandeef-launches-used-cooking-oil-deposit-machines-to-reduce-waste-and-produce-biodiesel/. (n.d.)

BENTLER, J. B, *Structural Equation Modeling.* John Wiley & Sons, 2013

Environment, M. o, *UAE National Air Emissions Inventory Project.* Dubai: Ministry of Climate Change & Environment, 2019

Khani, N. Z, *Designing a sustainable biofuel supply chain by considering carbon policies: a case study in Iran, 2021*

Maxime Merheb, R. M, *Alternative Energy in the UAE: The Potential of Biofuels Sourced from Ras Al Khaimah Mangroves.* Ras Al Khaimah: American University of Ras Al Khaimah (AURAK), 2018

Md. Munjur E. Moula a, J. N, *Public acceptance of biofuels in the transport sector in Finland.* Helsinki and Aalto: Gulf Organisation for Research and Development, 2017

Reimer, D. a, *3rd International Conference on Industrial Engineering and Operations Management*, (p. Engineering education and the entrepreneurial mindset at Lawrence Tech). Istanbul, Turkey. Retrieved from http://ieomsociety.org/ieom2012program.pdf. July 3-6, 2012

Staff Writer, K. T, Back to school in UAE: Emirates Transport adds 490 buses to fleet, improves safety features. *Zawaya*, 2022

Suhaiza Zailani, M. I, Applying the Theory of Consumption Values to Explain Drivers' Willingness to Pay for Biofuels. *Creative Commons*, 13, 2019

Tenny Kristiana, C. B, *An estimate of current collection and potential collection of used cooking oil from major Asian exporting countries.* INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATIO, 2022

Used Cooking Oil UCO, Retrieved from bio-kt: https://bio-kt.com/en/maslo/. 2022 *what is bioethanol*, Retrieved from esru.strath: https://www.esru.strath.ac.uk/EandE/Web_sites/02-03/biofuels/what_bioethanol.htm. (n.d)

Biographies

Afra Najeeb Safar is a graduate of the Higher College of Technology in Sharjah, where she obtained her degree in Industrial Engineering. During her time at the college, Afra displayed a strong commitment to her field of study and a passion for sustainability. Her graduation highlights the institution's dedication to providing quality education. As she begins her professional career, Afra will undoubtedly bring the knowledge and experiences she gained at the Higher College of Technology, reflecting the college's reputation for producing dedicated and knowledgeable graduates.

Fatima Ghubar Alshamsi is an enthusiastic industrial engineer that is dedicated to sustainability. She graduated with a Bachelor of Science in Industrial Engineering from the Higher Colleges of Technology in Sharjah, and she is strongly committed to sustainable business methods. Fatima is well-positioned to become a future leader in her industry because to her remarkable track record in sustainability-related competitions and her commitment to excellence.

Mouza Ojail AlKetbi is a dedicated senior industrial engineering student at the Higher Colleges of Technology. She has participated in many initiatives during her studies and has had success. Her passion for creating a cleaner, more sustainable environment guided her to work on her graduation project. She has discovered a startup that focuses on sustainability due to this inspiration

Nada Abdulhakeem Bushlaibi - a senior student at HCT Sharjah majoring in Industrial Engineering. Passionate about sustainability and have actively participated in various competitions. Committed to forging a more sustainable future and have learned valuable entrepreneurial skills through these endeavors. Willing to contribute positively to both the industrial engineering field and the global sustainability movement.

Safeya Saeed AlMaazmi is a Senior Industrial Engineering student at the Higher Colleges of Technology, Sharjah. During her study years she have participated in several sustainability hackathons held in the UAE prior to COP28 Event. Working on her graduation project “Biodiesel Supply Chain in UAE”, she implemented tools learnt that aims to waste reduction leading to circular economy startup and an environmental conscious society. She seeks to leave a mark in sustainability field both on national and global level.

Dr. Yousef Abu Nahleh is an accomplished industrial engineer with a PhD from Royal Melbourne Institute of Technology (RMIT) University in Australia. He is currently working as Assistant Professor at Higher Colleges of Technology (HCT) in the United Arab Emirates. Yousef's research interests include operations management, quality control, and supply chain management. During his PhD studies, he conducted groundbreaking research in the field of industrial engineering, making significant contributions to the knowledge base of the field.