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Use of cashew nut as a source of bio-diesel for a circular economic approach with reduced carbon footprint in the system of production of processed cashew: - A novel study

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Abstract

One of the biggest question in today's world is how we can save non-renewable sources of energy?. Apart from that India faces a big problem to estimate the carbon footprint in a supply chain. This paper takes into consideration of a supply chain for the production of cashew nuts and estimates the time till it reaches the customer. This time is used to calculate the minimum carbon content in a process and plan accordingly to inculcate a circular economy within the process of production. Here, we have come up with a novel approach where we can manufacture bio-diesel from the cashew nuts and include that bio-diesel as a source of energy for the process of production. Thus, we propose to achieve a green supply chain with the inclusion of bio-diesel from cashew nut as a source of energy for the supply chain of production of cashew. Here, we have estimated the reduction of carbon footprint within the planned production supply chain with the inclusion of bio-diesel and imbibed circular economy in the process.

Introduction: -

We know that India faces a big problem due to the wastage of food which could have been provided to the needy people and could have been used elsewhere. This turns out to be because we many a times not plan properly using several supply chain optimization techniques. This not only increases food scarcity in the country but also causes a lot of harm to the environment. Hence, it is very essential to estimate the time within a supply chain so that we can plan accordingly to reduce the emission within a supply chain.

Several theories have been proposed in previous literature to reduce the wastage of food, some focusing on perishable food whereas a few throw lights on how overproduction results in a significant amount of food waste [15, 16]. We know that less the price and more the demand and more the supply more is the profit as per the demand and supply curve. This is all done in order to cover the excess demand for food that we have in India. However, due to the price and profitability it turns out to be very difficult to cover the entire nation. However, even if it reaches specific community of users, we can estimate the time and hence we can say that it should be reaching the consumer community in order to reduce the extensive reduction in the expiration of the products that we have. Hence a transportation optimization is required in order to estimate the maximum time within the process and from here we can come to a conclusion of by the optimization process we can estimate the min carbon foot print within a supply chain and this amount of carbon footprint will definitely be present within the chain.

In order to estimate the time we have taken into consideration of PERTwhich stands for Program Evaluation Review Technique. By using this technique we can estimate the maximum time required for the process. From here with the maximum time taken into consideration we will calculate the definite amount of carbon footprint present within the process. We will then find out different processes that can be used for the reduction in the carbon footprint within the process. The Program Evaluation and Review Technique is a statistical tool used in project management and is used to analyse and represent the tasks involved in the completion of a given project. This technique is used to get the Critical Path within a supply chain. This critical path will take into consideration of the maximum time and this maximum time will help us estimate the definite carbon footprint within the process. Here, by taking the PERT we have nullified the Queuing time or the waiting time which we have given an uncertainty mark and as in the pessimistic time is taken into consideration which takes into consideration the queuingtime or the waiting time of the process.

Carbon Footprint is a very important part in every supply chain. Carbon emission in India is also a great problem and this problem should be reduced in the process. We have used design optimization technique from different references and this in turn helps is the estimation of a carbon footprint in the process. This estimate is the minimum carbon content that will be present or the definite carbon footprint in the entire process. Carbon footprint is the total amount of greenhouse gases that is generated by our actions. We are going to estimate the carbon footprint in the process and then we are going to propose a solution that will be used for the reduction in the carbon footprint and this will take place with the advent of circular economy in the process.

This will take place where we will use Cashew nut shells to produce bio diesel or bio fuel and this bio fuel will be used to suffice the energy requirement in the entire process. We have discussed various processes within the supply chain of the production of the biofuel as well.

Resource limitations, environmental concerns and unstable petroleum costs in India have led to an increased effort to develop alternative liquid fuels that will suffice the energy requirements within the process. Cashew nuts are an excellent source for good potential low-cost feedstock. We have seen the combustion potential of the biofuel produced from Cashew nut are good enough to suffice the energy requirements for transportation of raw materials to the storehouse of the product in our case this is a product of cashew, milk, sugar and placed in a paper cut cup and this recycling of cashew nut shells in the form of biofuel will lead us to a conclusion that the use of spent cashew nut grounds will lead to circular economy in the process which is essential to get a green supplychain.

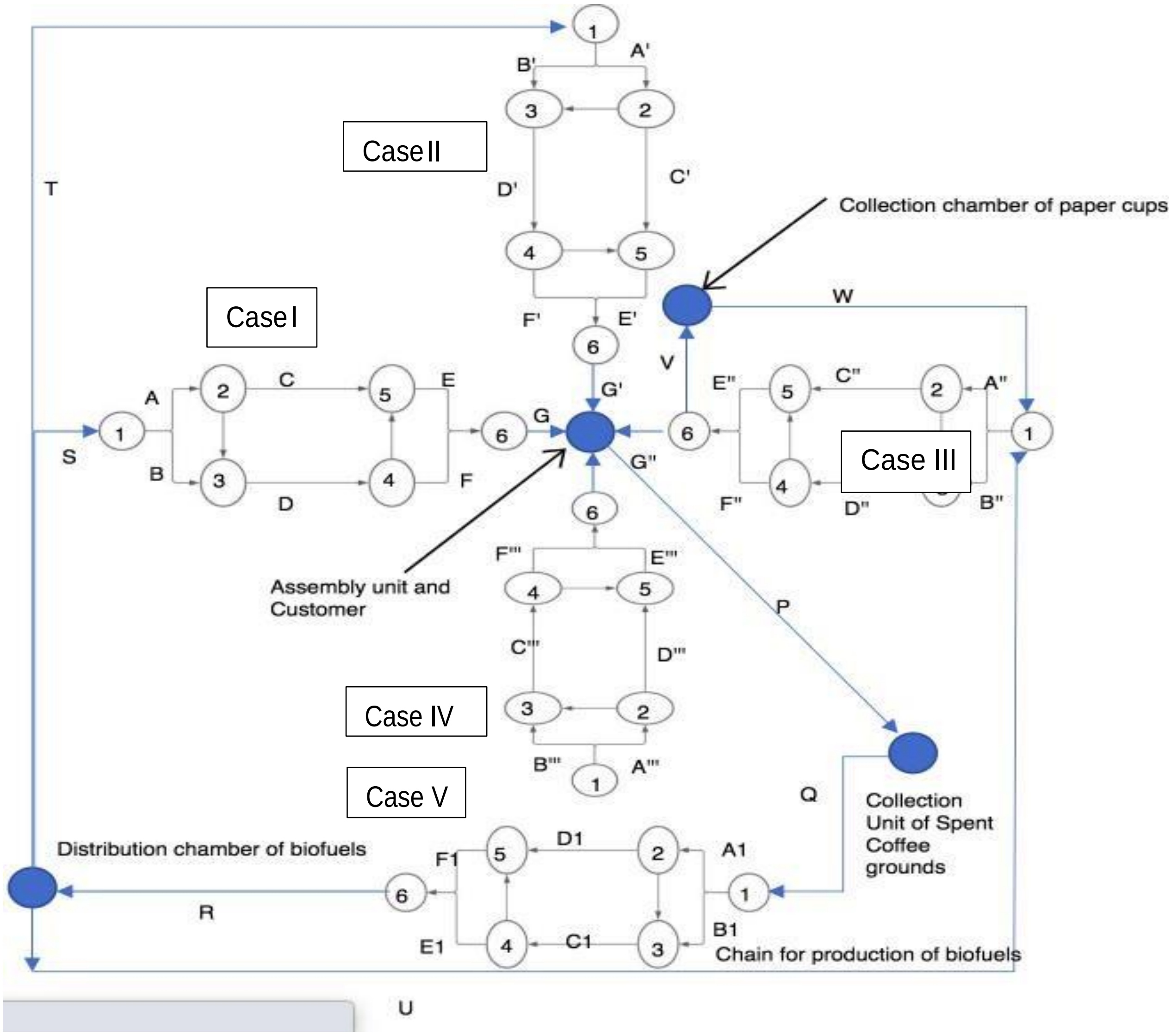
Paper cups or plastic cups are definitely reusable cups that can be reused again and again in order to reduce the use of plastic oruseofpaper.Ifwecantakealookatthe big picture, we can see that paper is manufactured from Tree which leads to deforestation and we all know the environmental degradation that is led to by the advent of plastic in our day to day lives. We know that if we can reuse paper of plastic cups or any of them in particular then we can definitely somehow reduce the manufacturing of plastics or paper which in turn will definitely beneficial as it in turn reduces environmental degradation. This also falls under circular economyasthistakesintoaccountofthe reusability of paper cups or plastic cups that leads to circular economy in the process.

Now, the question comes that what is circular economy. A circular economy is an alternative to a traditional economy (Make, use, Dispose) in which we keep the resources in use for as long as possible reduce, and recycle them extract the maximum value from them whilst in use and then recover and regenerate products and materials at the end of each service life. Here, we have used two circular chains. Firstly, the cashew nut have been used which helps in the manufacture of the bio diesel and this biodiesel have been definitely been important as it helps in the recycling of the waste that we have in the form of cashew nut used grounds. This CNSL is then used in the production of biofuel and it in turns reduces the amount of carbon footprint in the process. The next important process that reduces waste content in the process is the reuse of paper cups or plastic cups that are used in drinking. We have detailed each procedure in the cases to follow through.

As we have all the data which we have assumed are distributed in the distribution

Methodology:

Wecandividetheentiresupplychainthat



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consumer consume the readymade Cashew from the consumer unit. The unit G is the consumer unit or the assembly unit where the sugar, Cashew and milk are put inside a paper cup or a plastic cup and provided to the consumers to consume the Cashew. So, we have divided the supply chain into four parts and they are: -

1. Supply Chain forcashew
2. Supply chain forSugar
3. Supply chain for Paper Cup.
4. Supply chain forMilk.

Next what we do is analyze each supply chain and describe what each of them are and say how those times are important for the supply chain.

Part 1. Supply Chain for cashew nuts

Here, we have taken into consideration of the production of the cashew nut. The production of the Cashew starts from the harvesting unit and we have marked each of the unit numerically. First the harvesting of the Cashew is done then the harvested Cashew goes to the processing unit and then after processing we require the Cashew to be dried up and this requires the Cashew to be taken up to the drying unit and from the drying unit we have the processed Cashew and then the Cashew is taken to the packaging unit and from the packaging unit the Cashew is then taken to the assembly unit which we have here as the assembly unit.

Part 1: Cashew nut production	
Stations	Description
1	Harvesting unit
2,3	Processing unit
4,5	Drying unit
6	Packaging unit
7	Assembly Unit

We won't go into the details of the Cashew production process and is described in several references provided. The main purpose of the research is to consider the time and estimate the related variables in the process.

Part 2. Supply Chain for Sugar

The sugar is first harvested from sugarcane in the harvesting unit and then the sugar is taken to the crushing unit and the cane sugar is then crushed and then the made sugar is taken to the crystallizing unit and then after crystallizing the sugar is taken to the packaging unit and after packaging the sugar is taken to the assembly unit and this is the consumer unit and from here the Cashew is manufactured and provided to the consumer.

Part 2: Sugar	
Stations	Description
1	Harvesting unit
2,3	Crushing unit
4,5	Crystallizing unit
6	Packaging unit
7	Assembly Unit

We are not going deep into the process of manufacturing of the Cashew as the project deals with the proposition of estimating the time within a simplified supply chain and hence we are not going deep in details of each processes.

Part 3. Supply chain for Paper Cup.

We are taking into consideration of recyclable paper cup or plastic cup and we take into consideration of different units within the supply chain of each of them, namely, the manufacturing unit, where the manufacturing of the paper cups is done and are taken into consideration. The next step that comes up is the processing unit where the papers are processed for scaling of the cups and are then manufacturing. Next comes the packaging unit where the packaging of the paper cups is done and made ready for distribution and then comes the distribution unit from where we will distribute the cups respectively.

Part 3: Paper Cups	
Stations	Description
1	Manufacturing unit
2,3	Processing unit
4,5	Packaging unit
6	Distribution unit
7	Assembly Unit

We are not going deep into the process of manufacturing of the Cashew as the project deals with the proposition of estimating the time within a simplified supply chain and hence we are not going deep in details of each processes.

Part 4. Supply chain for Milk.

The milk is first collected from the farm and then it is taken to the separation and collection chamber and then the milk is taken to the pasteurizing chamber which is also the pasteurizing unknit and then to the packaging unit also the distribution unit here and then to the assembly unit where the milk is mixed with Cashew to produce the readymade Cashew for the consumer. Here, the unit is also the consumer unit where the distribution is made to the consumers.

Part 4: Milk	
Stations	Description
1	Farm
2,3	Separation and collection chamber
4,5	Pasteurizing Chamber
6	Packaging Unit
7	Assembly Unit

We won’t go into the details of the Cashew production process and is described in several references provided. The main purpose of the research is to consider the time and estimate the related variables in the process.

Now, we will analyze each of the parts of the supply chain or the part supply chains and we will estimate the definite carbon content in the process which is also the minimum carbon footprint that will be present within the supply chain and hence we go further.

Part 1. Supply Chain for Cashew nuts

Activity	Optimistic time (to)	Pessimistic time (tp)	Most likely (tm)	Immediate Predecessor
A	2	3	3	-
B	1	3	2	-
C	3	5	4	A
D	5	8	6	A, B
E	10	10	10	C, D
F	3	4	4	D
G	9	9	9	E, F

Activity	to	tp	tm	Mean	$\sigma 2$
A	2	3	3	3	0.33
B	1	3	2	1	0.66
C	3	5	4	4	0.66
D	5	8	6	7	2
E	10	10	10	10	0
F	3	4	4	4	0.33
G	9	9	9	9	0

Here,

to= Optimistic Time tp= Pessimistic Time tm= Most likelyTime
Te= Expected Time (Time in which process is to be executed)

σ^2= Variance
σ=StandardDeviation
Ts=ScheduledTime

Critical path: A, D, E, G.

Value of Optimistic time(to) along the Critical path: 26

Value of Pessimistic time(tp) along the Critical path: 30

Value of most likely time(tm)along the Critical path: 28

Te= (to+4tm)/6 +tp
= (26 + 4*28)/6+30 = 52.33~53 days.

Total Variance (σ^2) = 3.98
Standarddeviation(σ)=√3.98=1.99 P(Z≤ (Ts-Te)/

σ)=0.95

From Normal Distribution Chart, Z(0.95) =1.64

(Ts-Te)/ σ ≥1.64

So, in order to have the minimum Scheduled Time for 95% accuracy, we have

$$\frac{Ts-Te}{\sigma} = 1.64$$

We have Te= 53 days

So on Calculating Ts = 56days

Therefore, with the help of CPM and PERT Technique, we can select the most optimal path and for 95% of time Sugar will reach in 56days.

Part2.SupplyChainforSugar

Activity	Optimistic time (to)	Pessimistic time (tp)	Most likely (tm)	Immediate Predecessor
A'	2	2	2	-
B'	1	2	2	-
C'	2	4	3	A'
D'	3	4	4	A', B'
E'	3	5	3	C', D'
F'	1	2	2	D'
G'	4	4	4	E', F'

Activity	to	tp	tm	Mean	$\sigma 2$
A'	2	2	2	2	0
B'	1	2	2	2	0.33
C'	2	4	3	3	0.66
D'	3	4	4	4	0.33
E'	3	5	3	4	1
F'	1	2	2	2	0.33
G'	4	4	4	4	0
Total					2.65

Here,

to= Optimistic Time tp= Pessimistic Time tm= Most likelyTime

Te= Expected Time (Time in which process is to be executed)

σ^2= Variance

σ=StandardDeviation

Ts=ScheduledTime

Critical path: A', D', E', G'.

Value of Optimistic time(to) along the Critical path: 12

Value of Pessimistic time(tp) along the Critical path: 15

Value of most likely time(tm)along the Critical path: 13

Te= (to+4tm)/6 +tp
= (12+ 4*13)/6+15 = 25.66~26 days.

Total Variance (σ^2) = 2.65
Standard deviation (σ) = √2.65 =1.62

P(Z≤ (Ts-Te)/ σ)=0.95
From Probability Distribution Chart,
Z(0.95) =1.64
(Ts-Te)/ σ ≥1.64

So, in order to have the minimum Scheduled Time for 95% accuracy, we have

$$\frac{Ts-Te}{\sigma} = 1.64$$

We have Te= 26 days

So, on Calculating Ts = 29days

Therefore, with the help of CPM and PERT Technique, we can select the most optimal path and for 95% of Cashew nuts will reach in 29days.

Part 3. Supply chain for Paper Cup.

Activity	Optimistic time (to)	Pessimistic time (tp)	Most likely (tm)	Immediate predecessor
A''	2	4	3	-
B''	1	3	2	-
C''	3	3	3	A''
D''	4	8	6	A'',B''
E''	10	10	10	C'', D''
F''	8	12	10	D''
G''	7	7	7	E'', F''

Here,

to= Optimistic Time tp= Pessimistic Time tm= Most likelyTime

Te= Expected Time (Time in which process is to be executed)

σ^2= Variance
σ=Standard Deviation
Ts=ScheduledTime

Critical path: A’’, D’’, E’’, G’’ .
Value of Optimistic time(to) along the Critical path: 23

Value of Pessimistic time(tp) along the Critical path: 29

Value of most likely time(tm)along the Critical path: 26

Te= (to+4tm)/6 +tp

Te= (23+4*26)/6 + 29 =50.1 ~50days

Total Variance (σ^2) = 6.66

Standard deviation(σ)=√6.66=2.5 P(Z≤ (Ts-Te)/σ)=0.95

From Normal Distribution Chart, Z(0.95) =1.64

(Ts-Te)/ σ ≥1.64

So, in order to have the minimum Scheduled Time for 95% accuracy, we have

$$\frac{Ts-Te}{\sigma} = 1.64$$

We have Te= 50 days

So, on Calculating Ts = 54.2 ~55days

A’’	2	4	3	3	0.66
B’’	1	3	2	2	0.66
C’’	3	3	3	3	0
D’’	4	8	6	6	2.67
E’’	10	10	10	10	0
F’’	8	12	10	10	2.67
G’’	7	7	7	7	0
Total					6.66

Therefore, with the help of CPM and PERT Technique, we can select the most optimal path and for 95% of time Paper cup will reach in 55 days.

Part 3. Supply chain for Paper Cup.

Activity	Optimistic time (to)	Pessimistic time (tp)	Most likely (tm)	Immediate Predecessor
A’’’	3	3	3	-
B’’’	1	2	2	-
D’’’	2	4	3	A’’’
C’’’	4	4	4	A’’’, B’’’
E’’’	2	3	2	D’’’, C’’’
F’’’	1	1	1	C’’’
G’’’	5	5	5	E’’’, F’’’

Activity	to	tp	tm	Mean	σ2
A’’’	3	3	3	3	0
B’’’	1	2	2	2	0.33
D’’’	2	4	3	3	0.66
C’’’	4	4	4	4	0
E’’’	2	3	2	3	0.66
F’’’	1	1	1	1	0
G’’’	5	5	5	5	0
Total					1.65

Here,

to= Optimistic Time tp= Pessimistic Time tm= Most likelyTime

Te= Expected Time (Time in which process is to be executed)

σ^2= Variance
σ=Standard Deviation
Ts=Scheduled Time

Critical path: A''', C''', E''', G'''.

Value of Optimistic time(to) along the Critical path: 14

Value of Pessimistic time(tp) along the Critical path: 15

Value of most likely time(tm)along the Critical path: 14

Te= (to+4tm)/6 +tp

=(14+4*14)/6+15=52.33~53days.

Total Variance (σ^2) = 1.65

Standard deviation(σ)=√1.65=1.28 P(Z≤ (Ts-Te)/

σ)=0.95

From Probability Distribution Chart, Z(0.95) =1.64

(Ts-Te)/ σ ≥1.64

So, in order to have the minimum Scheduled Time for 95% accuracy, we have

$$\frac{Ts-Te}{\sigma} = 1.64$$

We have Te= 26.6~27 days

So, on Calculating Ts = 28.6 ~29days

Therefore, with the help of CPM and PERT Technique, we can select the most optimal path and for 95% of time Milk will reach in 29 days.

Analysis of time:

Now once we have received the time for each of the process, we will analyze the time so that we can take into consideration of the time of the process which in turn will help us in the identification of the estimation of the carbon footprint or carbon emission in the entire process.

First let us know what time each process is taking.

The table below shows the time taken for each process and hence, will be values as such.

Serial Number	Supply chains	Total time required in the process
1.	Cashew	56
2.	Sugar	29
3.	Paper Cup	55
4.	Milk	29

Now, in order to nullify the waiting time for each process we will start the process
which is having maximum time so that there is no wastage of the perishable products and the next processes starts henceforth in descending order.

Serial Number	Supply chains	Started after how many days
1.	Cashew	56
2.	Sugar	27
3.	Paper Cup	1
4.	Milk	27

In this way everything reaches within 56 days and we avoid the expiration of the products.

Now, we will use this time to estimate the carbon footprint in the process, however, first we require to optimize the carbon content in the process and it is as follows

Mathematical Formulation [28]

Some assumptions should be considered for modeling the queue:

1. The queue model is as M / M / S / ∞ /Pri.
2. Total number of transportation fleet as well as their capacity isspecified.
3. The number of servers in each center consists two parts of loading and unloading fleets, which queue systems operate separately.
4. Servers in each loading or unloading centers can be multipleparallelservers.
5. The distance between centers is specified.
6. The discharge rate in centers is directly related to the distancebetween thecenters.
7. The number of parallel servers is fixed and specified in the loading and unloadingcenters.
8. The quantity of waste which comes from the market to the recycling center isspecified.
9. The fleet movement rate between different centers is specified.
10. The production rate in factories centers isspecified.
11. The amount of waste isspecified.
12. The amount of the final product should be maintained in the factories in any order is specified in terms of order.
13. The withdrawal rate of discharge machines (unloaded) in each center is fixed.
14. The fleet movement between centers is reciprocating.
15. It is assumed that system is stable in eachcenter:

$$\boxed{p = \frac{Arrival\ rate}{(\ Arrival\ rate) \times (Service\ rates)} < 1}$$

L: Warehouse centers
J: Factories centers
K: Distribution centers
L: Recycling centers

The parameters considered in this model include:

Z: Traffic volume between the two centers

Z_0*:* Amount of waste that enters the waste storage from market

σ_j: Percentage of waste in the factory j

γ_j: Percentage of production rate at the factory j

H_j: Quantity of products entered into the warehouse after production at the factory j *TNV:* Total number of fleets in the entire chain

CV: Carrying capacity of the fleet

λ: Arrival rate of vehicles to discharge

μ: Rate of discharged vehicles outflow

S: The number of parallel servers in each center unloading section

λ: Fleet arrival rate for loading

μ: Rate of loaded vehicles withdrawal.

S: The number of parallel servers in each center loading sector

π_0: Idle percentage in state zero

LQ: Average length of queue

WQ: average waiting time in queue

W: The average waiting time in the system

P: The percentage of servers' or utilization agent's operating time

D: Distance in center (*m*)

T: Transportation time unit per distance unit

C: The percentage of pollutants

generated by the operation time of

transportation fleet The decision

variables in this model are as

follows:

NV: Number of fleets in the different centers between layers of the supply chain

NT: Number of fleet commutes between centers

For this purpose of the present study, the time function is used. C coefficient is used to calculate the consumption of contaminants over time. This means that the shorter the transit and waiting time, the lower the energy consumption.

MinC= this stands for minimum of emissions.

(1) $$\text{MinC}\ \left(\sum_i \sum_j 2T_{ij} d_{ij}\, NT_{ij} + \sum_j \sum_k 2T_{jk} d_{jk}\, NT_{jk} + \sum_j \sum_l 2T_{jl} d_{jl}\, NT_{jl} + \sum_l \sum_i 2T_{li} d_{li}\, NT_{li} + \sum_i \left(W_i LQ_i + \acute{W}_i L\acute{Q}_i\right) + \sum_j \left(W_j LQ_j + \acute{W}_j L\acute{Q}_j\right) + \sum_j (W_k LQ_k) + \sum_k \left(W_l LQ_l + \acute{W}_l L\acute{Q}_l\right)\right)$$

S.t.

(2) $$\sum_i \sum_j N\, V_{ij} + \sum_j \sum_k N\, V_{jk} + \sum_j \sum_l N\, V_{jl} + \sum_l \sum_i N\, V_{li} = \text{TNV}$$

(3)–(5) $$\begin{cases} Z_{ij} = c \\ Z_{jl} = \sigma_j \gamma_j \sum_i Z_{ij} \quad \forall j, l \\ Z_{jk} = \sum_i Z_{ij} - \sum_l Z_{jl} - H_j \quad \forall j, k \\ Z_{li} = \sum_j Z_{jl} + Z_0 \quad \forall l, i \end{cases}$$

(6)–(9) $$\begin{cases} NT_{ij}.NV_{ij} \geq \frac{Z_{ij}}{CV} \quad \forall i, j \\ NT_{jk}.NV_{jk} \geq \frac{Z_{ik}}{CV} \quad \forall i, k \\ NT_{jl}.NV_{jl} \geq \frac{Z_{jl}}{CV} \quad \forall j, l \\ NT_{li}.NV_{li} \geq \frac{Z_{li}}{CV} \quad \forall l, i \end{cases}$$

$$\lambda_i = \sum_l \frac{NV_{li}}{T_{li} d_{li}} \quad \forall i \tag{10}$$

$$\acute{\lambda}_l = \sum_i \frac{NV_{li}}{T_{li} d_{li}} \quad \forall l \tag{11}$$

$$\lambda_j = \sum_i \frac{NV_{ij}}{T_{ij} d_{ij}} \quad \forall j \tag{12}$$

(13 $$\acute{\lambda}_i = \sum_j \frac{NV_{ij}}{T_{ij} d_{ij}} \quad \forall i$$

(14) $$\lambda_k = \sum_j \frac{NV_{jk}}{T_{jk} d_{jk}} \quad \forall k$$

(15) $$\acute{\lambda}_j = \sum_k \frac{NV_{jk}}{T_{jk} d_{jk}} + \sum_l \frac{NV_{jl}}{T_{jl} d_{jl}} \quad \forall j$$

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(16) $$\lambda_l = \sum_j \frac{NV_{jl}}{T_{jl} d_{jl}} \ \forall l$$

(17) (18)
$$\begin{cases} P_i = \frac{\lambda_i}{s_i \mu_i} \ \forall i \\ \acute{P}_i = \frac{\acute{\lambda}_\iota}{\acute{s}_\iota \acute{\mu}_\iota} \ \forall i \end{cases}$$

(19) (20)
$$\begin{cases} P_j = \frac{\lambda_j}{s_j \mu_j} \ \forall j \\ \acute{P}_j = \frac{\acute{\lambda}_J}{\acute{s}_J \acute{\mu}_J} \ \forall j \end{cases}$$

$$P_k = \frac{\lambda_k}{s_k \mu_k} \ \forall k$$ (21)

(22)
$$\begin{cases} P_l = \frac{\lambda_l}{s_l \mu_l} \ \forall l \\ \acute{P}_l = \frac{\acute{\lambda}_l}{\acute{s}_l \acute{\mu}_l} \ \forall l \end{cases}$$

(24) (25)
$$\begin{cases} \pi_i^0 = \frac{1}{\left[\sum_{n=0}^{S_i-1} \frac{\left(\frac{\lambda_i}{\mu_i}\right)^n}{n!} + \frac{\left(\frac{\lambda_i}{\mu_i}\right)^{S_{i,j,l}}}{S_i!(1-P_i)}\right]} \ \forall i \\ \acute{\pi}_\iota^0 = \frac{1}{\left[\sum_{n=0}^{\acute{S}_\iota-1} \frac{\left(\frac{\acute{\lambda}_\iota}{\acute{\mu}_\iota}\right)^n}{n!} + \frac{\left(\frac{\acute{\lambda}_\iota}{\acute{\mu}_\iota}\right)^{\acute{S}_l}}{\acute{S}_\iota!(1-\acute{P}_\iota)}\right]} \ \forall i \end{cases}$$

(26) (27)
$$\begin{cases} \pi_j^0 = \frac{1}{\left[\sum_{n=0}^{S_j-1} \frac{\left(\frac{\lambda_j}{\mu_j}\right)^n}{n!} + \frac{\left(\frac{\lambda_j}{\mu_j}\right)^{S_j}}{S_j!(1-P_j)}\right]} \ \forall j \\ \acute{\pi}_J^0 = \frac{1}{\left[\sum_{n=0}^{\acute{S}_J-1} \frac{\left(\frac{\acute{\lambda}_J}{\acute{\mu}_J}\right)^n}{n!} + \frac{\left(\frac{\acute{\lambda}_J}{\acute{\mu}_J}\right)^{\acute{S}_J}}{\acute{S}_J!(1-\acute{P}_J)}\right]} \ \forall j \end{cases}$$

(28)
$$\pi_k^0 = \frac{1}{\left[\sum_{n=0}^{S_k-1} \frac{\left(\frac{\lambda_k}{\mu_k}\right)^n}{n!} + \frac{\left(\frac{\lambda_k}{\mu_k}\right)^{S_k}}{S_k!(1-P_k)}\right]} \ \forall k$$

(29)
$$\begin{cases} \pi_l^0 = \frac{1}{\left[\sum_{n=0}^{S_l-1} \frac{\left(\frac{\lambda_l}{\mu_l}\right)^n}{n!} + \frac{\left(\frac{\lambda_l}{\mu_l}\right)^{S_l}}{S_i!(1-P_l)}\right]} \ \forall l \\ \acute{\pi}_l^0 = \frac{1}{\left[\sum_{n=0}^{\acute{S}_l-1} \frac{\left(\frac{\acute{\lambda}_l}{\acute{\mu}_l}\right)^n}{n!} + \frac{\left(\frac{\acute{\lambda}_l}{\acute{\mu}_l}\right)^{\acute{S}_l}}{\acute{S}_l!(1-\acute{P}_l)}\right]} \ \forall l \end{cases}$$

(30)

$$\begin{cases} LQ_i = \frac{\left(\frac{\lambda_i}{\mu_i}\right)^{S_i} P_{i,j,l}}{S_i!(1-P_i)^2}\pi_i^0 \ \forall i \\ L\acute{Q}_\iota = \frac{\left(\frac{\acute{\lambda}_\iota}{\acute{\mu}_\iota}\right)^{\acute{S}_\iota} P_{\acute{\iota},j,l}}{} \acute{\pi}^0 \ \forall i \end{cases}$$

(31)

$$WQ_k = \frac{LQ}{\lambda}$$

$$\begin{cases} WQ_l = \frac{LQ_{i,j,l}}{\lambda_{i,j,l}} \ \forall l \\ W\acute{Q}_l = \frac{L\acute{Q}_l}{\acute{\lambda}_l} \ \forall l \end{cases}$$

(32)

$$\begin{cases} LQ_j = \frac{\left(\frac{\lambda_j}{\mu_j}\right)^{S_j} P_j}{S_j!(1-P_j)^2}\pi_j^0 \ \forall j \end{cases}$$

(33)

$$\begin{cases} W_i = WQ_i + \frac{1}{\mu_i} \ \forall i \\ \acute{W}_\iota = W\acute{Q}_\iota + \frac{1}{\acute{\mu}_\iota} \ \forall i \end{cases}$$

$$LQ_k = \frac{}{S_k!(1-P_k)^2}\pi_k^0 \ \forall k$$

(34)

$$\begin{cases} LQ_l = \frac{\left(\frac{\lambda_l}{\mu_l}\right)^{S_l} P_l}{S_l!(1-P_l)^2}\pi_l^0 \ \forall l \end{cases}$$

(35)

$$\begin{cases} W_j = WQ_j + \frac{1}{\mu_j} \ \forall j \\ \acute{W}_j = W\acute{Q}_j + \frac{1}{\acute{\mu}_j} \ \forall j \end{cases}$$

(36)

(37)

$$\begin{cases} WQ_i = \frac{LQ_i}{\lambda_i} \ \forall i \\ W\acute{Q}_\iota = \frac{L\acute{Q}_\iota}{\acute{\lambda}_\iota} \ \forall i \end{cases}$$

(38)

(39)

$$\begin{cases} WQ_j = \frac{LQ_j}{\lambda_j} \ \forall j \\ W\acute{Q}_j = \frac{L\acute{Q}_j}{\acute{\lambda}_j} \ \forall j \end{cases}$$

(

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$W_k = W($

(51)

(49)

NT, NV: Integer

(50)

$$\begin{cases} W_l = WQ_l + \frac{1}{\mu_l}\ \forall l \\ \acute{W}_l = \acute{W}Q_l + \frac{1}{\acute{\mu}_l}\ \forall l \end{cases}$$

Now let us consider that we have the waiting time to be zero as we have considered that the process that are taking place are simultaneous and the waiting time that is present is present within the process and hence taken into account and is not considered in the calculation for the minimum time that will cause the lowest carbon emission. Hence the formula comes up as: -

□i□j2TijDijNTij+□j□k2TjkDjkNTjk+□k□l2 TklDklNTkl+□m□n2TmnDmnNTmn

Now if we consider that the value for the number of fleets is that is commuting between the centers is 1 at time then we have the formula as: -

□i□j2TijDij+□j□k2TjkDjk+□k□l2TklDkl+□m □n2TmnDmnTmn

Therefore, the two factors on which the value is dependent are the time that is consumed per unit distance for the transportation time and the distance between the centers. The transportation time per unit distance takes in account distance travelled within the company as well. Now if we take the value of D to be 2, 3, 1 and 1 respectively as an assumption then we have the time for the entire process that will minimize the carbon emission. Which comes up as

56x2+29x3+55x1 +29x 1 = 283.

This is the estimated value of min C that we are taking into consideration and this is the definite amount of carbon that should be present within the supply chain

Circular Economy [29]:

Circular economy takes into account of the reduce, reuse and recycle processes within a supply chain. In order to have the circular economy in place we need to find spots within the supply chain where we can imbibe the process of circular economy so that we can have a sustainable process as well as a green supply chain. Here, we will optimize the supply chain while we propose to use the Cashew nut shells to produce bio fuel which has properties similar to that of petroleum and can be used to suffice the energy requirements in the supply chain.

Now, we will use this supply chain and we will then distribute the biodiesel produced in the entire supply chain including the parts of it. However, first we will require to know the basics of how biodiesel is produced from the Cashew. The process in listed below.

Detailed process of how to make biodiesel from Cashew may be summarized in following steps [30].

1. Firstly, the Cashew grounds are collected and dried at a temperature of 105degree C to remove the moisture. Then the oil was extracted applying a Soxhlet process, organic solvent n-hexane was used, the Soxhlet device temp is kept at 65-70degree C. Finally, at the end crude oil will be separated from the solvent using the rotatory vacuum evaporator to remove the moisture for 1 hr at 95-degree C.

   The yield crude oil = The weight of the extracted oil/ weight of the waste Cashew ground x 100
2. Then the crude oil obtained from the Step 1 passes through the esterification process, molar ratio of methanol to refined oil is maintained at 12:1 ratio.1% of H2so4 is added to the preheated oil at 60 degree C for 3hrs. under 300 rmp steering speed.
3. Then the product is poured into a separating tunnel to separate excess alcohol, H2SO4 AND the impurities present in the lower level. This lower level is separated and entered into a rotatory evaporator and heated at 95 degree C for 1 hr. to remove methanol and water from the esterified oil.
4. In the Transesterification process, crude waste Cashew oil is reacted with 25% of methanol and 1% of KOH at 60 degree C for 2 hrs. and 600 rpm steering speed. After this the produced biodiesel is deposited in a separation tunnel for 15 hrs. to separate glycerol from biodiesel. Therefore, the lower level which contain the impurities and glycerol was drawn off.
5. Now the unrefined biodiesels is wasted to remove the impurities and glycerol. In this process 50% of distilled water at 60 degree C is sprayed over the surface of ester stirred gently.
6. This process was repeated several times until the pH of the distilled water became neutral. The lower layer was discarded, and the upper layer was entered into a flask and dried using Na2SO4 and then further dried using a rotary evaporator to make sure that biodiesel is free from methanol and water.

The schematic diagram for the production of biodiesel is provided below and can be as such shown in the diagram.

Figure 2. Steps used in the production of Biofuel from Cashew

We have taken into consideration of the important steps from the biodiesel production process from the Cashew grounds and we have constructed a simplified supply chain as provided in figure 2. From figure 2 we can say that the biodiesel supply chain as in the case V or part 5 and can be designed as follows:-

Simplified steps according to the supply chain provided in Case V.

Events	Descriptions
1	Cashew grounds are dried, Crude oil is extractedusingn-hexane
2,3	Esterification process
4,5	Transesterification process
6	Washing

Unit V.

Activity	Optimistic time (to)	Pessimistic time (tp)	Most likely (tm)	Immediate predecessor
A1	2	2	2	-
B1	1	3	2	-
C1	2	3	3	B1, A1
D1	4	6	4	A1
E1	10	10	10	C1
F1	1	2	2	D1, C1
R	7	7	7	E1,F1

Here,
to= Optimistic Time tp=Pessimistic Time
tm= Most likely Time
Te=ExpectedTime(Time in which process is to be executed)

σ^2= Variance
σ = Standard Deviation Ts=ScheduledTime

Activities	to	tp	tm	Mean	σ2
A1	2	2	2	2	0
B1	1	3	2	2	0.66
C1	2	3	3	3	0.33
D1	4	6	4	5	1
E1	10	10	10	10	0
F1	1	2	2	2	0.33
R	7	7	7	7	0
Total					2.32

Critical path: A1, C1, F1, R.

Value of Optimistic time(to) along the Critical path:12

Value of Pessimistic time(tp) along the Critical path:14

Value of most likely time(tm)along the Critical path:14

Te= (to+4tm)/6+tp
Te= (12+4*14)/6 + 14 =25.33 ~26days

Total Variance (σ^2) = 2.32

Standarddeviation(σ)=√2.32=1.52 P(Z≤ (Ts-Te)/σ)=0.95

From Probability Distribution Chart,

Z(0.95) =1.64

(Ts-Te)/ σ≥1.64

So, in order to have the minimum Scheduled Time for 95% accuracy,we have

$$\frac{Ts-Te}{\sigma} = 1.64$$

We have Te= 26 days

So, on Calculating Ts = 28.4 ~29days

Therefore, with the help of CPM and PERT Technique, we can select the most optimal path and for 95% of time Paper cup will reach in 29 days.

Once we have calculated the supply chain till the distribution center for the bio diesel and from there the biodiesel is taken to different sub- supply chains and the process continues.

Another place where we have included the circular economy is in the supply chain of the paper cups and here, we recycle/reuse the paper cups or plastic cups to use the same in the process again.

Thus, we can say that circular economy has been attained in the process and the cost analysis of the entire process is required to be done which stands out to be a future prospect of the project.

Normal Distribution of Data:

It has been required that we distribute the entire data normally so that we can take into consideration of the rejection region of the time, which accounts to the uncertainty in the entire process. There can be accidents, there can be damages that might lead to uncertainty and the product may not reach in time and this is given a percentage of 5% which is the significance level of the project and the confidence level taken in the calculation is 95% which means that 95 percent of the time the product will reach in time to the consumer and before the expiration of the product.

For this, we have use Analysis of Variance and we have used SAS to form the ANOVA table and from here we have plotted the Q-Q curve which helps us to determine whether the data is normally distributed or not. The ANOVA Table and the Q-Q plot has been provided below:-

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	178.0000000	29.6666667	6.72	<.0001
Error	35	154.5000000	4.4142857		
Corrected Total	41	332.5000000			

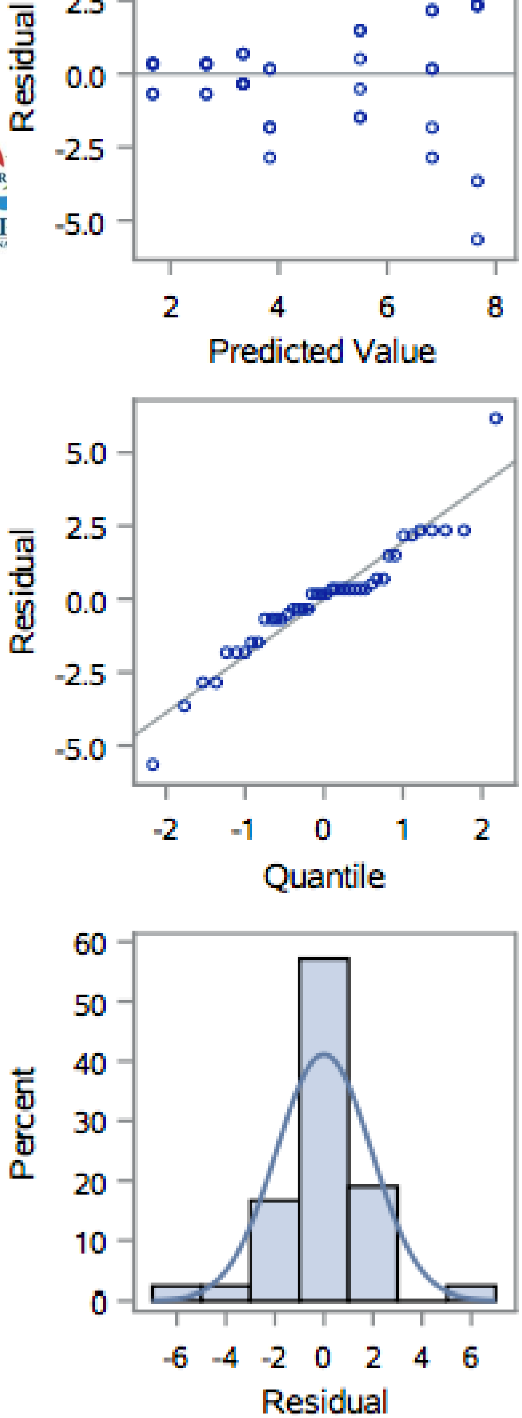

Fig3.A.Thefigureshowstheresidualvs predictedvaluesandwecan seethatthe points are well distributed and the funneling effect isnotprominent.
Fig 3. B. The Q-Q plot showing the residual vs quantile data.
Fig3.CPlotforPercentvsresiduals.

From here we can see that the data is normally distributed and hence we can consider the values that we have taken into consideration.

Results andDiscussion:

Firstlywehavedesignedasupplychain wherewehaveestimatedthe timethen we have taken the maximum time of an unit supply chain or sub-supply chain and from there we have calculated after how many days we should start the other supply chains so that we receive the products together which means that if all the product reaches together there will be no lapse of time for the supply chains that takes lesser time to complete. In this way we are reducing holding of expiration dated products.In our case wehavetakena sample supply chain of Cashew and we have estimated the time using PERT and then estimated from when we should start the supply chain in order to have minimum holding (in our case holding is nullified). Once, we have the estimation we can use the time that we have estimated using PERT to calculate the minimum carbon content in the process. Then, we have proposed a way by which we can reduce the carbon emission in the process. By our extensive search in literature we have found out that petroleum-based products that is used to suffice the energy requirements in the process can be replaced using Bio- fuel which is manufactured from Cashew as they are almost equivalent to petroleum. Cashew is obtained as a waste product in the preparation of Cashewandthisinturnbuildsacircular economy in the proposed supply chain. We have also proposed the use of Recyclable paper and plastic cups in the supply chain that also contributes to circular economy and hence reduces adverse environmental impacts thatis caused byplastic.

Wehavekeptinourmindthateverytime it will be difficult to have the product within time always. So, we have kept a rejection region where we have mentioned that 5% of the cases the product will not reach within time and will contribute to expiration and in order to calculate the scheduled time and the expected time, we have used the Normal Distribution function curve. In order to fit the data in such a curve we need to know whether the residuals of the curve fall in a straight line in the Q-Q plot and we have designed an ANOVA and we have plotted the Q-Q plot and we have seen that the data that we have taken into consideration is normally distributed

For 2778 carbon per gallons of diesel used: -

Carbon footprint = 2,778 g x 3.66 x 0.99 = 10,084 g.

For 1 gallon of the biodiesel we used taking into consideration of 12 percent of reduced combustion efficiency: 2661 x 3.66 x 0.99 = 9641 g.

For our supply chain gallons of diesel used:

Vehicle average speed = 40 km/ hour
Time taken = 6792 hours
Distance covered = 271680 km
Mileage = 10 km / liter for diesel and 9.6 km / liter for biodiesel
Liters used = 27168 liter (7177 gallons)for diesel and 28300 (7476) liter for biodiesel
Carbon footprint = 72372 kg for diesel and 72076 kg for biodiesel

Hence, the carbon footprint in the process is reduced.

We have also calculated the amount of carbon footprint that will be produced with both diesel and the proposed biodiesel and we have come to the conclusion that bio diesel will yield lesser amount of carbon footprint keeping in mind all types of design parameters and optimizations.[31-33].

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