Modeling of Biodiesel Plant Design: Data Estimation and Generation Based on Suppositions and Interpolation

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Abstract--- This paper presents the approach for the Biodiesel plant design data estimation and generation to support the mathematical formulation of the model. Presented approach is based on certain suppositions. Design data is estimated by using actual fundamentals involved in the design of the resources and equipments. Later, the sample space is increased by generating the design data. Design data is generated using the concept of linear interpolation, where the basic data fitting model is developed and then the intermediate design data values are obtained to increase the sample space. This facilitates the formulation of mathematical model. Experimental results are obtained through the MATLAB implementation.

Keywords- Biodiesel, Production Plant Design, Data Estimation and Generation, Data Fitting, Modeling

I. INTRODUCTION

Renewable energy sources become the need of today and Biodiesel is one of them. In India, research in the area of Biodiesel production and marketing are in development stage. Oilseeds are, in general, used as the base commodity for Biodiesel production. The most important reason for interest in Biodiesel production in India is that the India's climatic conditions are conducive for production of wide range of oil seeds such as: soybean, groundnut, safflower, mustard, castor and sunflower etc. which are easily available. Main issue in the Biodiesel production is the design of the plant and is one of the important challenges. The scope of research exists in this typical area for the industrial engineering researchers.

This paper addresses the issue of plant design from mathematical modeling point of view. For any mathematical modeling approach large data/sample space is required. This paper mainly focused on how to create large sample space. Firstly, typical cases of plant capacities are considered and accordingly the design data is estimated and later large sample space of design data is generated based on previously estimated design data. All this work carried out with certain suppositions which mainly include the manufacturing process, plant layout, maintenance schedule etc. Also, the mathematical modeling approach based on generated sample space is briefly described in this paper.

This paper is organized as follows: section II discusses the basic plant design issues. Section III presents the analysis of existing design related work. Proposed approach is summarized in section IV. Estimation and generation of the design data is presented in section V and experimental results are given in section VI. Section VII discusses the conclusion and future scope followed by references.

II. PLANT DESIGN ISSUES

Various issues have to be considered in designing of any Biodiesel plant. Here, some of the important issues are identified and briefly discussed.

Purity of the feedstock: Biodiesel processing and quality are closely related. The processes used to refine the feedstock and convert it to Biodiesel determine whether the fuel will meet the applicable specifications as per standard or not [1].

Type of production process: Different methodologies or processes [2], generally, used for production of Biodiesel are: Direct use / blending, Micro-emulsion, Pyrolysis and Transesterification.

Capacity of the plant: The first decision point for the design of a production unit is its capacity. Based on capacity of the plant, design of various equipments involved in production process can be specified, as well as other requirement such as total cost, land, power consumption, raw materials, and man-hours etc. can be estimated.

Production cost analysis: Production cost depends upon the prices of raw materials, the method of production, and utilization of by-products etc. The unit production cost can be obtained by taking into account the cost of oil, methanol, utilities and operating labor and all other costs directly related to production.

Equipment cost analysis: Capital cost estimation is one of the most critical elements in plant valuation, capital budgeting, feasibility studies and finance decisions. Investment (capital cost) for plant and equipment is important in establishing Biodiesel production capabilities. Cost estimation is used for proposal preparation, feasibility analysis and evaluation [3].

Land acquisition and infrastructure cost analysis: Land requirement and infrastructure cost are directly related to production capacity. Initial capital costs of the plants differ primarily based on feedstock needs and output. The physical requirements of a plant consist of a production facility, a tank yard allowing storage of manufactured Biodiesel and feedstock, offices, and loading/unloading facilities which adds the cost to initial capital cost.

Maintenance cost: To operate a safe plant is the first step, but maintaining a safe plant at safe working environment to handle any emergency is a full time job. For various plant capacities, the contributions of maintenance cost overhead become higher with bigger capacities. The maintenance cost of the plant is associated with the breakdown(s) or failure(s) of equipment(s).

Operating profit: Profitability of a Biodiesel plant can be used as the basic parameter for comparison of various plants. In general, the operating profit is related to the capacity of the plant. The capacity of the plant directly affects the operating profit and therefore the operating profit can be the base for comparison of various plant capacities.

Feasibility Analysis: The proximity of feedstock is a crucial component for the feasibility analysis of the Biodiesel plant. Apart from this, the others like equipment cost, Biodiesel selling price, human resources involved etc. also drive the feasibility analysis. The feasibility analysis of a plant can provide useful conclusions with respect to the unit production cost and various other technical and economical parameters.

Performance evaluation parameters: The cost of the plant installation according to the capacity of production; the profit as per the capacity of the plant; quality of the Biodiesel; maintenance cost required as per the maintenance schedule; risk analysis etc. are the general parameters can be used for the evaluation of any Biodiesel plant design.

TABLE I. PARAMETRIC ANALYSIS OF DESIGN RELATED WORK

Approach / **Parameter**	(Skarlis et al., 2008) [4] Feasibility analysis- Biodiesel plant in Greece	(Haas et al., 2006) [5] Simulation- Computer model to estimate the capital and operating costs based on changes in feedstock costs	(Van Kasteren & Nisworo, 2007) [6] Process model- Conceptual design to estimate the cost of Biodiesel production	(Al-Zuhair et al., 2011) [7] Pilot plant- Biodiesel from waste/used vegetable oil using enzymatic approach
Feedstocks to Biodiesel	1000 Kg of oil + 110 Kg of methanol → 1000 Kg of Biodiesel + 110 Kg of glycerol	Not Specified	Constant input of waste oil for whole production year	1138 kg per hour
Capacity of Plant	4000 tons per year	37,854,118 litre	125,000; 80,000 and 8000 tones Biodiesel/year	1 ton per hour
Capital Cost	Vegetable Oils, Methanol, Catalyst, Water, Electricity, Natural Gas, Equipment cost	Equipment cost	Fixed (plant location, prod. capacity, present status of Biodiesel)	Total capital investment of 620000 US$
Operating Cost	Chemical process cost, Operating cost	Soy oil, Methanol, HCL, NaOH, Electricity, Natural gas,	Fixed (plant location, prod. capacity, present status of Biodiesel)	Total capital investment of 620000 US$

The design and feasibility analysis of Biodiesel production plant is difficult to standardize the total investment and production cost, since its main characteristics (feedstock, final products, the equipment items cost, land acquisition) are subject to market price fluctuations. Also, the cost of conventional diesel fuel, which is directly related to the price of crude oil, is subject to similar fluctuations, creating uncertainty in targets for Biodiesel production cost/selling price [4].

As discussed previously, the important issues in the designing of any plant are the equipments, land availability, investment amount, capacity requirement etc. Therefore, the scope of optimization in plant designing exists with the imposed constraint of certain issues. One can design the Biodiesel plant with the consideration of all above mentioned important issues or can considered only selected issues.

III. RELATED WORK

Prominent work related to plant design is reported in [4-11], where most of the parameters, already discussed in previous section, are used in formulation of the problem. Summarized analysis of these existing works is presented in Table I and Table II. Skarlis et al. [4] focused on the profit analysis, while Hass et al. [5] has not carried out it. Van Kasteren and Nisworo [6] have designed the conceptual design to estimate the cost of Biodiesel production. Al-Zuhair et al. [7] have designed and installed a pilot plant for Biodiesel production. Kapilakam and Peugtong [8] and Marchetti and Errazu [9] worked on simulation of Biodiesel plant. Apostolakou et al. [10] and Myint and El-Halwagi carried out work of feasibility analysis and optimization of Biodiesel production respectively.

		Water, labor, others		
Profit Analysis	Depend on the raw material cost and Biodiesel cost	Not estimated	Not carried out (factors are capital cost, capacity, raw material and glycerol price	Total capital investment will be paid back within four years
Storage Tank Material	Not specified	Carbon steel	Not specified	Not specified

TABLE II. PARAMETRIC ANALYSIS OF DESIGN RELATED WORK

Approach / **Parameter**	(Kapilakarn & Peugtong, 2007) [8] Approach: Simulation for Optimality- Optimal operating condition for the Biodiesel production	(Marchetti & Errazu, 2008) [9] Approach: Simulation- to produce the conceptual design and simulate each technology	(Apostolakou et al., 2009) [10] Approach: Economic analysis- Biodiesel production from vegetable oils	(Myint & El-Halwagi, 2009) [11] Approach: Optimization -Biodiesel production from Soybean oil
Feedstocks to Biodiesel	50 litre and 100 litre	4550 kg per hour	Triolein + 3Methanol →3 Biodiesel + Glycerol	Soybean oil is used
Capacity of Plant	Not specified	36036 ton per year	50 kton per year	40 million gallons per year
Capital Cost	Total cost is evaluated for three processes	Evaluation is carried out	Evaluation is carried out (equipment cost, etc.)	Capital cost estimation was carried out using the ICARUS Process Evaluator computer-aided tool linked to the results of the ASPEN Plus simulation.
Operating Cost	reaction time, temperatures and molars ratios of alcohol to oil affects the operating cost	Evaluation is carried out	Evaluation is carried out (raw material cost, labor cost, etc.)	The operating cost of the process was estimated based on process operation such as raw materials, utilities, and labor.
Profit Analysis	Not carried out, *Quality of the Biodiesel for three processes is evaluated	Evaluation is carried out	Evaluation is carried out	A profitability analysis was carried out by examining the return on investment and the payback period.
Storage Tank Material	Not specified	Not specified	Stainless steel	Not specified

IV. PROPOSED APPROACH

A. Basic Idea

The cost related parameters can be used to evaluate the design of the Biodiesel plant with respect to the economics. These performance evaluation parameters are- Capacity (Production turnover); maintenance cost; operating profit. One can develop the approach to focus on these parameters when go for designing of the Biodiesel production plant. Biodiesel plant design basically concerned with the resource management, i.e. how optimally one can use the resources? Model based approach can be developed, where the relativity amongst the various resources can be used in model development. The cost evaluation of each individual resource can be the base in forming the relativity amongst the various resources.

The important issue at the formulation of model is that one should keep in mind the production process flow of the plant. As per the process flow and the specifications of the desired Biodiesel production plant design, the dependency and independency of the resources can be evaluated and accordingly the relation of the resources can be established. Once the relational model is prepared, the objectives of the desired mathematical model can be identified which make the concern problem as the single or multi-objective problem. Later it can be solved by the classical on non-classical methods. Different models can be possible as per the desires of the individual, perspectives of the engineer involved in designing of the plant, objectives in designing and the basic key parameters on which the design should get evaluated. Known area which can be explored in the Biodiesel production plant design is the optimal resource management.

An approximate model can be developed using the design data, where the design data can be related to- Feedstock cost, Equipment specification, Tank design, Land specification, Power consumption, Man hours, Production turnover, Maintenance cost, and Operating profit. Various symbols or the variables can be used for the identification of the above mentioned data parameters, and based on this, the mathematical model can be formulated using the generated data and later the developed model can be used to answer the specific questions concerned to the Biodiesel production plant design.

B. An Approach

This section discusses the suggested approach for design of Biodiesel manufacturing plant with cost and capacity perspective, and also the motivation behind it. After analyzing the available literature, it is found that the plant design is an open issue where the research scope exists. The gaps and the observations identified in literature are summarized as follows.

(a) No concrete results are reported in literature regarding the launching/installation of new Biodiesel plant with variety of objectives.
(b) Existing approaches which are suggested in the literature for the plant design move around the cost parameters and the chemical processes with the fixed plant capacity.
(c) No approach exists as per our knowledge which can address the problem of design of Biodiesel plant with variety of capacities.
(d) No approach exists as per our knowledge which can address the problem of design of Biodiesel plant with cost and capacity perspective.
(e) No mathematical model based approach exists for designing of Biodiesel plant.
(f) The capacity of plant, capital cost, operating cost, profit analysis and storage tank material are the important basic issues to be considered in designing of any Biodiesel plant.
(g) Any plant design move around the parameters related to these basic issues.

The above mentioned gaps and observations are the key motivation for the development of the mathematical model based approach for the Biodiesel manufacturing plant design. The suggested approach consists of the following steps.

Step-1: Estimation of the design data for various capacities.

Step-2: Generation of the design data for various capacities.

Step-3: Formulation of the mathematical model for the plant manufacturing Biodiesel

In section III, it is identified that the capacity of plant, capital cost, operating cost, profit analysis and storage tank material are the base parameters which plays very important role in Biodiesel plant design. In presented work, Biodiesel plant design related input and output parameters are identified with reference to these base parameters and following assumptions.

- Method of Biodiesel production is alkali catalytic methanol transesterification.
- Quality of raw material is as per the standard required to produce Biodiesel.
- Plant is operated for one batch per day.
- Plant is having integrated crushing (seeds) plant.
- Construction and site preparation cost is not considered in this study (it varies significantly from location to location).
- Specifications of process equipments can accommodate all types of oil (raw material) for biodiesel production.
- Quality of Biodiesel is as per the standard (EN 14214/IS 15607 biodiesel fuel standard).
- Plat layout design is developed at our own.

Presented work concern with the following input and output parameters. Input parameters and output parameters of the Biodiesel plant design are identified as the inputs and responses of the Biodiesel plant and the same nomenclature is used hereafter in the remaining text of this paper.

Inputs: Equipment Cost, Power Consumption, Water Requirement, Total Factory Area (Land Area), Oil Seeds, Methanol, Catalyst (KOH), Man-hours

Responses: Production Turnover, Maintenance Cost, and Operating Profit

V. DESIGN DATA: ESTIMATION AND GENERATION

A. Data Estimation

Various inputs and responses with their unit of measure and the estimation based on are summarized in Table III. The data related to the inputs and responses is generated based on the plant capacity and the estimated data of inputs respectively. Estimation of inputs and responses is carried out for Biodiesel production plant of different capacities (1, 2, 3, 5, 7, 9, and 10 ton per day) independently.

TABLE III. SUMMARY OF INPUTS AND RESPONSES

Specification	Unit	Parameter	Estimation Based On
Equipment Cost in Lacs	`	Input	Design and supplier Quotations
Power	*HP*	Input	Power rating of equipments
Water	*Litre*	Input	Estimated as per process requirement
Total Factory Area	m^2	Input	Layout of plant plotted in AutoCAD (*Appendix-A*)
Oil Seeds	*kg*	Input	Capacity of Biodiesel plant
Methanol	*Litre*	Input	Capacity of Biodiesel plant
Catalyst KOH	*kg*	Input	Capacity of Biodiesel plant
Man-hours	*Hours*	Input	Human resource required for operation of plant
Production Turnover (Kg. converted in Rupees)	`	Response	Expected output at each stage of production
Maintenance Cost in Lacs	`	Response	Expected failure causes and preventive maintenance scheduled for individual equipment
Operating Profit in Lacs	`	Response	Production cost and revenue generated

Estimation of all the inputs for the capacities (1, 2, 3, 5, 7, 9, and 10 ton) is carried out by referring the Biodiesel production plant layout designs which are prepared in AutoCAD for all the capacities with certain assumptions.

Basic requirements of the Biodiesel production plant may get changed as per the desired capacity. Estimation of some of the input parameters is also changed due to the varying requirement specification for different capacities of Biodiesel production plant. Shape of the oil tank for all capacity is same. Number of washing tanks and drier tanks considered for all capacities are 3 and 2 respectively, while single tank is considered for other type of tanks. Summary of inputs estimation for all capacities is shown in Table IV. Estimation of all the response variables for the capacities (1, 2, 3, 5, 7, 9, and 10 ton) is also carried out. Estimation of expected production turnover is based on production process and minimum output at each stage of the process. Capacity of oil expeller varies due to specification and number of units used for various capacities of Biodiesel production plant. Chemical composition as per the standard reaction for estimated oil, methanol and catalyst and expected quantities of Glycerol and Biodiesel for all capacity are given in Table V. Summary of responses estimation for all capacity Biodiesel plant is given in Table VI. Finally, summary of all inputs and responses for 1, 2, 3, 5, 7, 9, and 10 *ton* capacity Biodiesel plants is given in Table VII.

TABLE IV. SUMMARY OF INPUTS AND RESPONSES

Capacity of Plant *(ton)*	Inputs							
	Equipment Cost (` *In Lacs*)	**Power (*HP*)**	**Water (*Litre*)**	**Total Factory Area (m^2)**	**Oil Seeds (*Kg*)**	**Methanol (*Litre*)**	**Catalyst KOH (*Kg*)**	**Man-hours (*Hours*)**
1	14.58419	59.88	525	125	3333	139	15.00	80
2	23.89304	104.60	1050	152	6666	278	30.00	92
3	33.35492	162.26	1500	253	10000	471	45.00	92
5	50.2963	273.57	2550	464	16666	695	75.00	104
7	66.51348	380.85	3750	728	23333	973	105.00	116
9	81.78912	492.16	4500	1044	30000	1251	135.00	136
10	89.62276	545.80	5250	1141	33333	1390	150.00	148

TABLE V. CHEMICAL COMPOSITION AS PER STANDARD FOR ESTIMATED OIL, METHANOL AND CATALYST FOR 1, 2, 3, 5, 7, 9, AND 10 TON CAPACITY BIODIESEL PRODUCTION PLANT

Capacity of plant *(ton)*	Oil *(kg)*	Methanol *(kg)*	Catalyst (KOH) *(kg)*	Glycerol *(kg)*	Biodiesel *(kg)*
1	919.9	101.19	13.8	101.19	919.9
2	1839.8	202.38	27.6	202.38	1839.8
3	2760	303.6	41.4	303.6	2760
5	4599.8	505.98	69	505.98	4599.8
7	6439.9	708.39	96.6	708.39	6439.9
9	8280	910.8	124.2	910.8	8280
10	9199.9	1011.99	138	1011.99	9199.9

TABLE VI. SUMMARY OF RESPONSES ESTIMATION FOR ALL CAPACITY BIODIESEL PLANT

Capacity of Plant *(ton)*	Responses		
	Prod. Turnover (`)	**Maint. Cost (`)**	**Oper. Profit (`)**
1	34204	198784	3985785
2	68408.4	240193	8385327
3	102624	329754	11890881
5	171032	482296	21427497
7	239452	586113	30259377
9	307872	692989	39127014
10	342076	809622	43424184

TABLE VII. SUMMARY OF ALL INPUTS AND RESPONSES ESTIMATION FOR 1, 2, 3, 5, 7, 9, AND 10 TON CAPACITY BIODIESEL PLANTS

Capacity of Plant *(ton)*	Inputs								Responses		
	Equipment Cost (` *In Lacs*)	**Power (*HP*)**	**Water (*Litre*)**	**Total Factory Area (m^2)**	**Oil Seeds (*kg*)**	**Metha-nol (*Litre*)**	**Cata-lyst KOH (*kg*)**	**Man-hours (*Hours*)**	**Prod. Turnover (`*In Lacs*)**	**Maint. Cost (`*In Lacs*)**	**Oper. Profit (`*In Lacs*)**
1	14.58419	59.88	525	125	3333	139	15.00	80	0.34204	1.98784	39.85785
2	23.89304	104.60	1050	152	6666	278	30.00	92	0.68408	2.40193	83.85327
3	33.35492	162.26	1500	253	10000	471	45.00	92	1.02624	3.29754	118.90881
5	50.2963	273.57	2550	464	16666	695	75.00	104	1.71032	4.82296	214.27497
7	66.51348	380.85	3750	728	23333	973	105.00	116	2.39452	5.86113	302.59377
9	81.78912	492.16	4500	1044	30000	1251	135.00	136	3.07872	6.92989	391.27014
10	89.62276	545.80	5250	1141	33333	1390	150.00	148	3.42076	8.09622	434.24184

B. Data Generation

This section gives the details of the generated design data. Design data is generated using the estimated values of the inputs and responses. Intermediate values of the inputs and responses for various capacities are generated by using the MATLAB tool. This generated design data for inputs and responses will be used later for development of mathematical model.

Previously estimated design data values given in Table VII are used to generate design data. The flow of the approach to generate the design data consist of following two steps:

Step-1: Data fitting- For each input and responses, form the vector between the two consecutive capacity values.

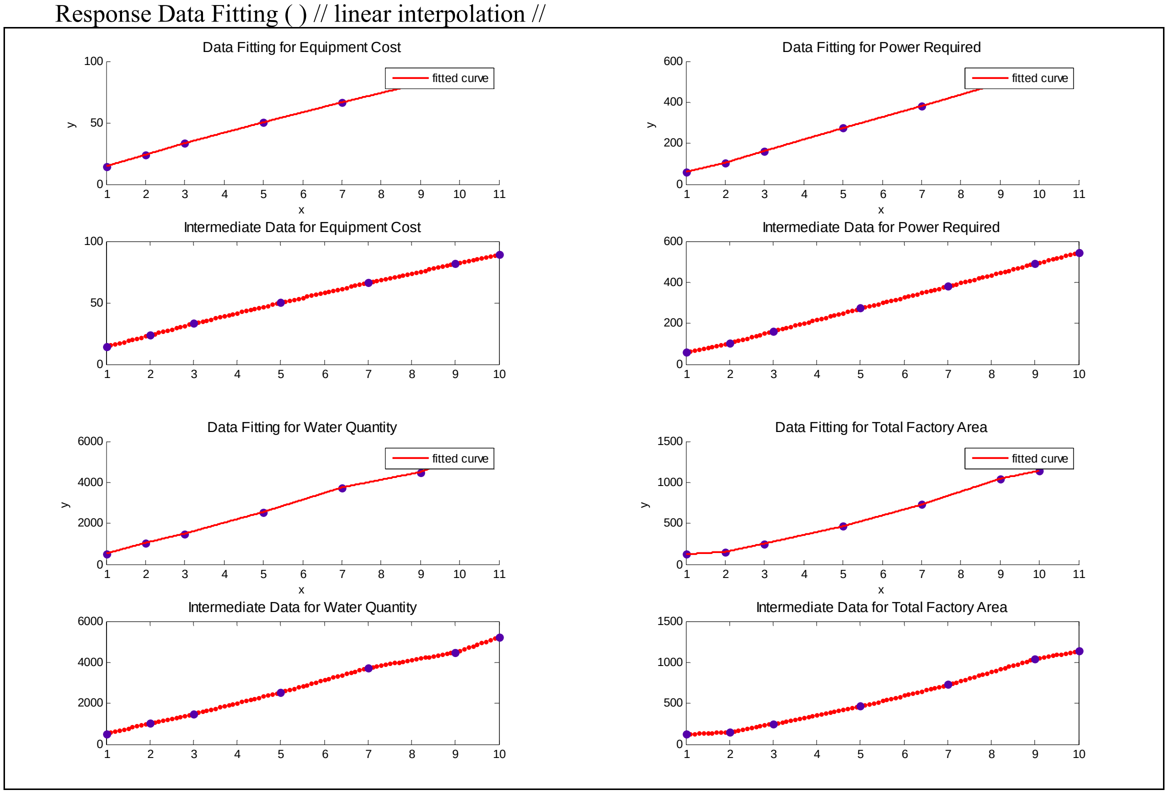
Step-2: Finding intermediate data- Increment the lowest value by 0.1 to the highest value of the two consecutive capacities which formed the vector to get the corresponding intermediate values of the inputs and responses by referring the vector formed in step 1.

The pseudo code for the implementation of above two steps is as follows:

Data Fitting and Generation ( )
{ Refer Input: matrix A;
Input Data Fitting ( ) // linear interpolation //
{ For each input parameter (Total 8)
{ Fit the corresponding capacity and input data values using linear interpolation; Obtain the fitting model for corresponding input parameter; Plot the data fitting for corresponding input parameter; } }
Intermediate Input Data Finding ( )
{ Find the lowest capacity value; Find the highest capacity value; Increment the lowest value by 0.1 to the highest value; Obtain the different capacity values;
For each input parameter (Total 8)
{ For each obtained capacity values
{ Use the corresponding fitting model to get the corresponding intermediate input value; Store these values in matrix B; } } }
Response Data Fitting ( ) // linear interpolation //
{ For each response parameter (Total 3)
{ Fit the corresponding capacity and response data values using linear interpolation; Obtain the fitting model for corresponding response parameter; Plot the data fitting for corresponding response parameter; } }
Intermediate Response Data Finding ( )
{ Find the lowest capacity value; Find the highest capacity value; Increment the lowest value by 0.1 to the highest value; Obtain the different capacity values;
For each response parameter (Total 3)
{ For each obtained capacity values
{ Use the corresponding fitting model to get the corresponding intermediate response value; Store these values in matrix B; } } }
Obtain Output: Matrix B;
}

VI. EXPERIMENTAL RESULTS

The pseudo code is implemented in MATLAB on a computer with the general configuration. Implementation screenshots are shown in Figure 1. Generated data for all input and responses is given in Table VIII and Table IX.



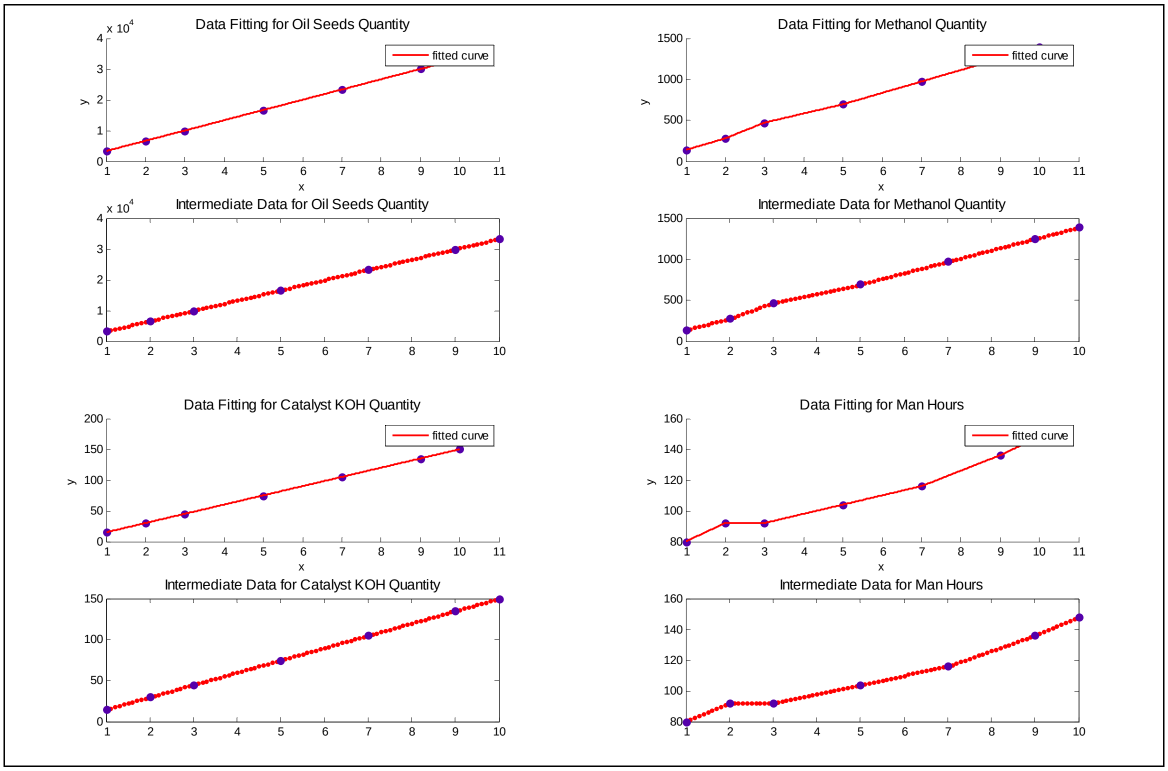


Figure 1. Implementation Screenshots for Inputs

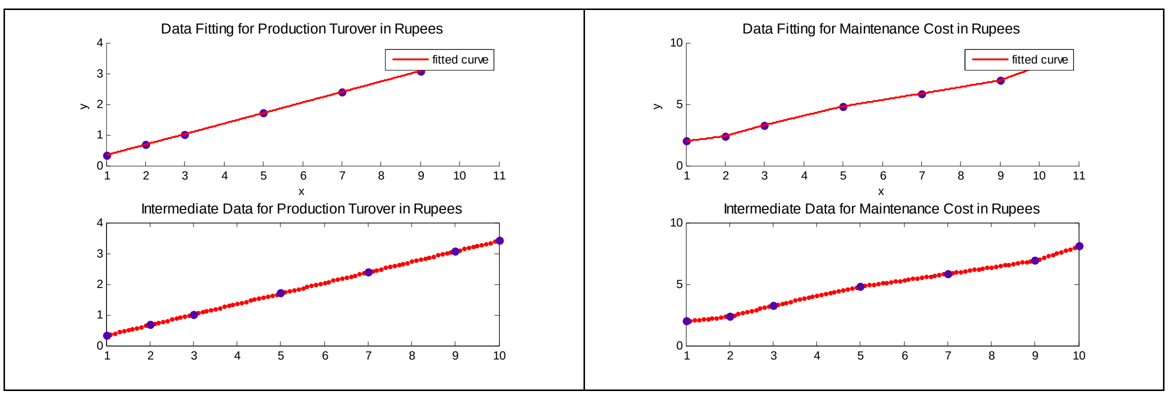


Figure 2. Implementation Screenshots for Two of the Responses

TABLE VIII. GENERATED DATA FOR ALL INPUT AND RESPONSES

Capacity of Plant *(ton)*	Inputs								Responses		
	Equipment Cost (` *In Lacs*)	Power (*HP*)	Water (*Litre*)	Total Factory Area (m^2)	Oil Seeds (*kg*)	Methanol (*Litre*)	Catalyst KOH (*kg*)	Man-hours (*Hours*)	Production Turnover (`*In Lacs*)	Maintenance Cost (`*In Lacs*)	Operating Profit (`*In Lacs*)
1	14.58419	59.88	525	125	3333	139	15	80	0.34204	1.98784	39.85785
1.1	15.51508	64.352	577.5	127.7	3666.3	152.9	16.5	81.2	0.376244	2.029249	44.25739
1.2	16.44596	68.824	630	130.4	3999.6	166.8	18	82.4	0.410448	2.070658	48.65693
1.3	17.37685	73.296	682.5	133.1	4332.9	180.7	19.5	83.6	0.444652	2.112067	53.05648
1.4	18.30773	77.768	735	135.8	4666.2	194.6	21	84.8	0.478856	2.153476	57.45602
1.5	19.23862	82.24	787.5	138.5	4999.5	208.5	22.5	86	0.51306	2.194885	61.85556
1.6	20.1695	86.712	840	141.2	5332.8	222.4	24	87.2	0.547264	2.236294	66.2551
1.7	21.10039	91.184	892.5	143.9	5666.1	236.3	25.5	88.4	0.581468	2.277703	70.65464
1.8	22.03127	95.656	945	146.6	5999.4	250.2	27	89.6	0.615672	2.319112	75.05419
1.9	22.96216	100.128	997.5	149.3	6332.7	264.1	28.5	90.8	0.649876	2.360521	79.45373
2	23.89304	104.6	1050	152	6666	278	30	92	0.68408	2.40193	83.85327
2.1	24.83923	110.366	1095	162.1	6999.4	297.3	31.5	92	0.718296	2.491491	87.35882
2.2	25.78542	116.132	1140	172.2	7332.8	316.6	33	92	0.752512	2.581052	90.86438
2.3	26.7316	121.898	1185	182.3	7666.2	335.9	34.5	92	0.786728	2.670613	94.36993
2.4	27.67779	127.664	1230	192.4	7999.6	355.2	36	92	0.820944	2.760174	97.87549
2.5	28.62398	133.43	1275	202.5	8333	374.5	37.5	92	0.85516	2.849735	101.381
2.6	29.57017	139.196	1320	212.6	8666.4	393.8	39	92	0.889376	2.939296	104.8866
2.7	30.51636	144.962	1365	222.7	8999.8	413.1	40.5	92	0.923592	3.028857	108.3921
2.8	31.46254	150.728	1410	232.8	9333.2	432.4	42	92	0.957808	3.118418	111.8977
2.9	32.40873	156.494	1455	242.9	9666.6	451.7	43.5	92	0.992024	3.207979	115.4033
3	33.35492	162.26	1500	253	10000	471	45	92	1.02624	3.29754	118.9088
3.1	34.20199	167.8255	1552.5	263.55	10333.3	482.2	46.5	92.6	1.060444	3.373811	123.6771
3.2	35.04906	173.391	1605	274.1	10666.6	493.4	48	93.2	1.094648	3.450082	128.4454
3.3	35.89613	178.9565	1657.5	284.65	10999.9	504.6	49.5	93.8	1.128852	3.526353	133.2137
3.4	36.7432	184.522	1710	295.2	11333.2	515.8	51	94.4	1.163056	3.602624	137.982
3.5	37.59027	190.0875	1762.5	305.75	11666.5	527	52.5	95	1.19726	3.678895	142.7504
3.6	38.43733	195.653	1815	316.3	11999.8	538.2	54	95.6	1.231464	3.755166	147.5187
3.7	39.2844	201.2185	1867.5	326.85	12333.1	549.4	55.5	96.2	1.265668	3.831437	152.287
3.8	40.13147	206.784	1920	337.4	12666.4	560.6	57	96.8	1.299872	3.907708	157.0553
3.9	40.97854	212.3495	1972.5	347.95	12999.7	571.8	58.5	97.4	1.334076	3.983979	161.8236
4	41.82561	217.915	2025	358.5	13333	583	60	98	1.36828	4.06025	166.5919
4.1	42.67268	223.4805	2077.5	369.05	13666.3	594.2	61.5	98.6	1.402484	4.136521	171.3602
4.2	43.51975	229.046	2130	379.6	13999.6	605.4	63	99.2	1.436688	4.212792	176.1285
4.3	44.36682	234.6115	2182.5	390.15	14332.9	616.6	64.5	99.8	1.470892	4.289063	180.8968
4.4	45.21389	240.177	2235	400.7	14666.2	627.8	66	100.4	1.505096	4.365334	185.6651
4.5	46.06096	245.7425	2287.5	411.25	14999.5	639	67.5	101	1.5393	4.441605	190.4334
4.6	46.90802	251.308	2340	421.8	15332.8	650.2	69	101.6	1.573504	4.517876	195.2017
4.7	47.75509	256.8735	2392.5	432.35	15666.1	661.4	70.5	102.2	1.607708	4.594147	199.97
4.8	48.60216	262.439	2445	442.9	15999.4	672.6	72	102.8	1.641912	4.670418	204.7384
4.9	49.44923	268.0045	2497.5	453.45	16332.7	683.8	73.5	103.4	1.676116	4.746689	209.5067
5	50.2963	273.57	2550	464	16666	695	75	104	1.71032	4.82296	214.275
5.1	51.10716	278.934	2610	477.2	16999.35	708.9	76.5	104.6	1.74453	4.874869	218.6909
5.2	51.91802	284.298	2670	490.4	17332.7	722.8	78	105.2	1.77874	4.926777	223.1069

TABLE IX. GENERATED DATA FOR ALL INPUT AND RESPONSES

Capacity of Plant *(ton)*	Inputs								Responses		
	Equipment Cost (` *In Lacs*)	Power (*HP*)	Water (*Litre*)	Total Factory Area (m^2)	Oil Seeds (*kg*)	Methanol (*Litre*)	Catalyst KOH (*kg*)	Man-hours (*Hours*)	Production Turnover (`*In Lacs*)	Maintenance Cost (`*In Lacs*)	Operating Profit (`*In Lacs*)
5.3	52.72888	289.662	2730	503.6	17666.05	736.7	79.5	105.8	1.81295	4.978686	227.5228
5.4	53.53974	295.026	2790	516.8	17999.4	750.6	81	106.4	1.84716	5.030594	231.9387
5.5	54.3506	300.39	2850	530	18332.75	764.5	82.5	107	1.88137	5.082503	236.3547
5.6	55.16145	305.754	2910	543.2	18666.1	778.4	84	107.6	1.91558	5.134411	240.7706
5.7	55.97231	311.118	2970	556.4	18999.45	792.3	85.5	108.2	1.94979	5.18632	245.1866
5.8	56.78317	316.482	3030	569.6	19332.8	806.2	87	108.8	1.984	5.238228	249.6025
5.9	57.59403	321.846	3090	582.8	19666.15	820.1	88.5	109.4	2.01821	5.290137	254.0184
6	58.40489	327.21	3150	596	19999.5	834	90	110	2.05242	5.342045	258.4344
6.1	59.21575	332.574	3210	609.2	20332.85	847.9	91.5	110.6	2.08663	5.393954	262.8503
6.2	60.02661	337.938	3270	622.4	20666.2	861.8	93	111.2	2.12084	5.445862	267.2663
6.3	60.83747	343.302	3330	635.6	20999.55	875.7	94.5	111.8	2.15505	5.497771	271.6822
6.4	61.64833	348.666	3390	648.8	21332.9	889.6	96	112.4	2.18926	5.549679	276.0981
6.5	62.45919	354.03	3450	662	21666.25	903.5	97.5	113	2.22347	5.601588	280.5141
6.6	63.27004	359.394	3510	675.2	21999.6	917.4	99	113.6	2.25768	5.653496	284.93
6.7	64.0809	364.758	3570	688.4	22332.95	931.3	100.5	114.2	2.29189	5.705405	289.346
6.8	64.89176	370.122	3630	701.6	22666.3	945.2	102	114.8	2.3261	5.757313	293.7619
6.9	65.70262	375.486	3690	714.8	22999.65	959.1	103.5	115.4	2.36031	5.809222	298.1778

7	66.51348	380.85	3750	728	23333	973	105	116	2.39452	5.86113	302.5938
7.1	67.27726	386.4155	3787.5	743.8	23666.35	986.9	106.5	117	2.42873	5.914568	307.0276
7.2	68.04104	391.981	3825	759.6	23999.7	1000.8	108	118	2.46294	5.968006	311.4614
7.3	68.80483	397.5465	3862.5	775.4	24333.05	1014.7	109.5	119	2.49715	6.021444	315.8952
7.4	69.56861	403.112	3900	791.2	24666.4	1028.6	111	120	2.53136	6.074882	320.329
7.5	70.33239	408.6775	3937.5	807	24999.75	1042.5	112.5	121	2.56557	6.12832	324.7629
7.6	71.09617	414.243	3975	822.8	25333.1	1056.4	114	122	2.59978	6.181758	329.1967
7.7	71.85995	419.8085	4012.5	838.6	25666.45	1070.3	115.5	123	2.63399	6.235196	333.6305
7.8	72.62374	425.374	4050	854.4	25999.8	1084.2	117	124	2.6682	6.288634	338.0643
7.9	73.38752	430.9395	4087.5	870.2	26333.15	1098.1	118.5	125	2.70241	6.342072	342.4981
8	74.1513	436.505	4125	886	26666.5	1112	120	126	2.73662	6.39551	346.932
8.1	74.91508	442.0705	4162.5	901.8	26999.85	1125.9	121.5	127	2.77083	6.448948	351.3658
8.2	75.67886	447.636	4200	917.6	27333.2	1139.8	123	128	2.80504	6.502386	355.7996
8.3	76.44265	453.2015	4237.5	933.4	27666.55	1153.7	124.5	129	2.83925	6.555824	360.2334
8.4	77.20643	458.767	4275	949.2	27999.9	1167.6	126	130	2.87346	6.609262	364.6672
8.5	77.97021	464.3325	4312.5	965	28333.25	1181.5	127.5	131	2.90767	6.6627	369.101
8.6	78.73399	469.898	4350	980.8	28666.6	1195.4	129	132	2.94188	6.716138	373.5349
8.7	79.49777	475.4635	4387.5	996.6	28999.95	1209.3	130.5	133	2.97609	6.769576	377.9687
8.8	80.26156	481.029	4425	1012.4	29333.3	1223.2	132	134	3.0103	6.823014	382.4025
8.9	81.02534	486.5945	4462.5	1028.2	29666.65	1237.1	133.5	135	3.04451	6.876452	386.8363
9	81.78912	492.16	4500	1044	30000	1251	135	136	3.07872	6.92989	391.2701
9.1	82.57248	497.524	4575	1053.7	30333.3	1264.9	136.5	137.2	3.112924	7.046523	395.5673
9.2	83.35585	502.888	4650	1063.4	30666.6	1278.8	138	138.4	3.147128	7.163156	399.8645
9.3	84.13921	508.252	4725	1073.1	30999.9	1292.7	139.5	139.6	3.181332	7.279789	404.1617
9.4	84.92258	513.616	4800	1082.8	31333.2	1306.6	141	140.8	3.215536	7.396422	408.4588
9.5	85.70594	518.98	4875	1092.5	31666.5	1320.5	142.5	142	3.24974	7.513055	412.756
9.6	86.4893	524.344	4950	1102.2	31999.8	1334.4	144	143.2	3.283944	7.629688	417.0532
9.7	87.27267	529.708	5025	1111.9	32333.1	1348.3	145.5	144.4	3.318148	7.746321	421.3503
9.8	88.05603	535.072	5100	1121.6	32666.4	1362.2	147	145.6	3.352352	7.862954	425.6475
9.9	88.8394	540.436	5175	1131.3	32999.7	1376.1	148.5	146.8	3.386556	7.979587	429.9447
10	89.62276	545.8	5250	1141	33333	1390	150	148	3.42076	8.09622	434.2418

VII. CONCLUSION AND FUTURE SCOPE

In presented work, the design data is generated based on the estimated design data which later can be used for the mathematical model formulation for the plant manufacturing Biodiesel. For estimation of the design data, certain assumptions have been made and the plant layout is created in AutoCAD. Based on these assumptions and the layout, different requirements of the plant are identified and accordingly the design of the various equipments and fixtures is carried out for required/desired specifications. Basic design data is estimated for the typical seven capacity values and later the linear interpolation is used to create the data fitting model. This model is then used to generate the intermediate data values of all the inputs and responses for identified different capacity values. The generated data in Table VIII and Table IX can be used to formulate the mathematical model. In future the mathematical model will be formulated based on this generated data. Mathematical formulation can be carried out by using different existing mechanisms and/or techniques. One of the possible ways to develop the mathematical model is through dimensional analysis and multiple regression analysis. This paper provides the new direction of work for the researchers to optimize the design of any plant by generating design data which then be used for the mathematical model.

An opportunity exists for the use of new advanced optimization techniques, for instance, one can go with neural network based approach for the estimation of the cost related parameters or the production capacity related parameters. Other possible approach may include the use of the genetic algorithm by which the mathematical model of the chemical process or the production process can be optimized and other lot more approaches can be possible by optimizing design model, production process, chemical process, cost model, simulation model (chemical process, production process, cost estimation) etc. using classical optimization techniques and non classical optimization techniques.

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