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Mathematical Model & Feasibility Study for Construction an Invested Refinery of 100,000 (bbl / Day) in AL-Nasiriya Governorate

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Abstract

A mathematical Model and feasibility study of construction an invested Refinery with 100,000 (Bbl/day) in AL-Nasiriya governorate was performed. The project is composed of three Units, Atmospheric Column Distillation Unit (CDU), Catalytic Reformer Unit (CRU) and Residue Fluidized Catalytic Cracking Unit (RFCC) that produce different products. Based on the Platts prices of petroleum products which was provided by State Organization for Marketing of Oil (SOMO) for May of this year and by standard specifications and technical information of Petroleum Research and Development Center (PRDC), Material balance for feed and products as well as optimization process using LINGO software for these three Units were calculated in order to determine influential financial parameters: (NPV), (IRR), (PI) and Payback period of the project. Different calculation scenarios were prepared taking into account discount of crude oil and products prices, inflation indicator of Capital expenditure (CAPEX) and operation expenditure (OPEX) in addition to extending the life of the project and increase in the cost of capital as well. These scenarios are illustrated as followings: -

1- The refinery was considered non-feasible in case of the crude feed price is taken (65$) and the products prices still constant. Discounted of oil feed was taken gradually by 10% and the products prices stay constant turns the project to be feasible at (50%) discounted oil price which gives positive financial parameters as can be seen in scenario (1), (2) but no longer feasible when increasing inflation by (3%) and (5%) as shown in scenario (3) and (4).

2- The price of crude oil feed was taken constant (65$) and the products prices were gradually increased by (10%) till (50%) with constant other parameters gives negative financial parameters means non feasibility as can be seen in scenario (5).

3- Increasing products prices by 10% and discount crude oil price by 10% together makes the project feasible at (25%) for both as shown in scenario (6). Conversely, when

inflation was taken into account for OPEX and cost of capital, the project shifted to be feasible at (40%) for both crude oil and products as seen in scenario (7, 8, 9). The crude oil feed price and products was increased gradually by (10%) and decreased by the same percent. Both scenarios give negative financial parameters as shown in (10) and (11).
4- Extending life of project from (4) to (6) years and let other parameters constant including CAPEX to study the impact on the financial parameters. It is noticed that the refinery gives negative income compared to previous period of project in scenarios (12), (13). The cost of capital was increased from 2,100 million to 3000 million with no change in the other parameters gives negative income as seen in scenario (14) and (15). On the other hand, cost of capital and life of project were changed together makes the project worse income due to decline in the financial parameters as illustrated in scenario (14) and (16).

Keywords: CAPEX, OPEX, Depreciation, NPV, IRR, PI.

1. Introduction

Mathematical model is set of equations that are connected to each other linearly or non-linearly to simulate specific process in plant or refinery and to give behavior of that process among different of parameters in environment. based on the goal of the model, maximization profit, minimization cost, effective time of maintenance and management planning can be applied to result different scenarios of output. In this model, a construction an invested refinery will be conducted technically and financially to gain maximum profit. Different scenarios of simulation for long term will pe presented.

2. Refinery Process Description

AL-Nasiriya Refinery is composed of different Units which are classified as simple in the degree of complexity such as Distillation column, Hydrodesulfurization Unit and more complex Unit such as Residue Fluid Catalytic Cracking (RFCC) as shown in the Figure (1). 100,000 (bbl /day) of Basra crude oil of 29.91 API is received to be fractionated in the distillation column to yield different cuts of light and intermediate that are required further processing. Light naphtha is treated in the desulfurization Unit to be sent to the gasoline pool and the extra amount would go to sale. The heavy Naphtha is also treated in the desulfurization Unit and then sent to the Reforming Unit. Reformate of high-octane number is then sent to the pool of gasoline for blending as

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marketed finished product. Middle distillates kerosene and light, heavy Gas Oil are also treated to be directed to the market according to the required Iraqi standard characterization. Residue from distillation column is charged to the (RFCC) as feed for conversion to the cracked gasoline. Light and heavy cycle oil are hydrotreated and then sent to market. Prices of products and feed in addition to related information of feasibility analysis are shown in Table (1). Product specifications for sale in market are shown in Tables (2) and (3).

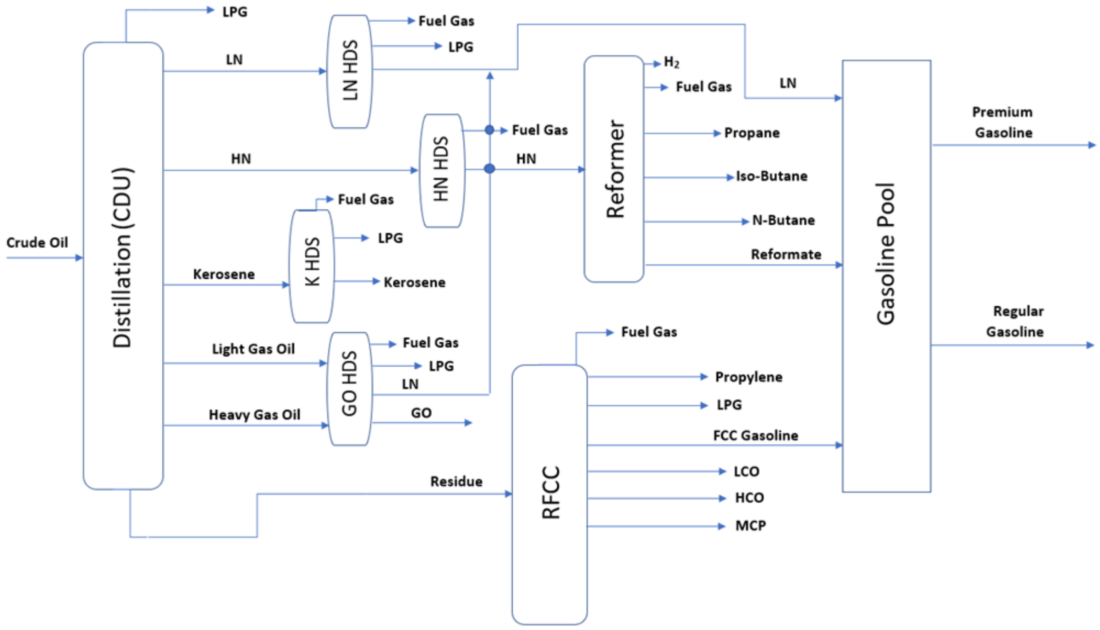

Fig. (1): Schematic Diagram of Units and Streams of Invested Refinery

Table (1) Invested Refinery information and prices of feed and products for May, 2021 according to Platts.

AL-Nasiriya Refinery	
Capacity	100,000 (bbl/day)
Capacity Expenditure (CAPEX)	2,100,000,000 (billion $)
Operation Expenses (OPEX)	5% of capex per year
Construction Time	48 Months
Refinery life after start-up	20 Year
Depreciation per year	105,000,000 (million $)
Taxation Rate	According to Iraqi Law
Inflation	3 % Per Year
Crude Price	65
Discount Rate	Should be given or taken as 10 %
Working days per year	335 Days
Crude oil API	29.9
Losses	(1-2) Vol %

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Product Price($/bbl)	
Fuel Gas	Will be used in the refinery
Propane	39.17
Iso-Butane	25
N-Butane	44.99
LPG	42.08
Kerosene	70.011
Light Naphtha	62.42
Jet Fuel	73.1
Light Gas Oil	71.304
Heavy Gas Oil	71.304
Premium Gasoline	73.769
Regular Gasoline	67.32
Propylene	0.34
Light Cycle Oil	20
Heavy Cycle Oil	15
Slurry Oil	12

Table (2) Gasoline pool specification required for marketing [1].

	Property	Speatication Requirement
Naphtha	RON	74
	RVP (KP)	68
Reformate	RON	100
	RVP (KP)	50
FCC Gasoline	RON	93.5
	RVP (KP)	56

Table (3) Refinery Product specifications

Feature	Regular Gasoline	Premium Gasoline
Octane Number	87≤ Oct ≤91	Oct ≥ 95
Vapor Pressure	≥ 54	≥54

2.1 Crude Distillation Unit Material Balance (CDU)

Feed: Basra Crude Oil 100,000 BPD = X1

API = 29.91

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Table (4) True boiling point of Crude oil distillated fractions

Component	Boiling Range (°C)	Cut Yield Vol (%)	Barrel Per Day (BPD)
Fuel Gas	IBP-15	3.2613	---
Light Naphtha (LN)	15-80	5.2766	X2
Heavy Naphtha (HN)	80-175	15.393	X3
Kerosene (KE)	175-230	8.8259	X4
Light Gas Oil (LG)	230-340	18.022	X5
Heavy Gas Oil (HG)	340-370	4.5042	X6
Residuum	370-FBP	44.717	X7

2.2 Residue Fluid Catalytic Cracking Material Balance (RFCC)

Feed: Residuum (from Distillation Unit) X7 BPD.

Products were assumed close to actual data.

Table (5) Product cuts as volume percentage of RFCC crude oil

Component	Product Yield (vol%)	BPD
Fuel gas	3.80	---
Propylene	4.50	X8
LPG	16.40	X9
FCC Gasoline	50.03	X10
Light Cycle Oil (LCO)	12.07	X11
Heavy Cycle Oil (HCO)	3.0	X12
Slurry Oil (MCB)	4.50	X13
Losses	4.80	---

2.3 Heavy Naphtha Hydrotreater Material Balance (HN HDS)

Feed: Heavy Naphtha (from Distillation Unit) X3 BPD

Products were assumed close to actual data

Table (6) Product cuts as volume percentage of HN HDS

Component	Product	BPD
Fuel Gas	1	----
Heavy Naphtha	98.55	X14
H2S	0.15	----
Losses	0.20	----

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2.4 Catalytic Reformer Material Balance (Reformer)

Feed: Heavy Naphtha (From Hydrotreater Unit) X14 BPD

Products were assumed close to actual data

Table (7) Product cuts as volume percentage of Reformer

Component	Product Yield (Vol %)	BPD
Hydrogen	11.85	----
Fuel Gas	3.70	----
Propane	3.81	X15
Iso-Butane	2.30	X16
N-Butane	3.30	X17
Reformate	87.20	X18

2.5 Light Naphtha Hydrotreater Material Balance (LN HDS)

Feed: Light Naphtha (from Distillation Unit) X2 BPD

Products were assumed close to actual data

Table (8) Product cuts as volume percentage of LN HDS

Component	Product Yield (Vol %)	BPD
Fuel Gas	1.8	----
LPG	2.7	X19
light Naphtha	95.13	X20
H2S	0.07	----
Losses	0.20	----

2.6 kerosene Hydrotreater Material Balance (K HDS)

Feed: Light Naphtha (from Distillation Unit) X4 BPD
Products were assumed close to actual data

Table (9) Product cuts as volume percentage of K HDS

Component	Product Yield (Vol %)	BPD
Fuel Gas	1.5	----
LPG	3	X21
Kerosene	95.15	X22
H2S	0.15	----

2.7 Gas Oil Hydrotreater Material Balance (GO HDS)

Feed: Light and Heavy Gas Oil (from Distillation Unit) X5, X6 BPD
Products were assumed close to actual data.

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Table (10) Product cuts as volume percentage of GO HDS

Component	Product Yield (Vol %)	BPD
Fuel Gas	1.0	----
LPG	0.5	X23
light Naphtha	3.7	X24
Gas Oil	94.45	X25
H2S	0.9	----
Losses	0.20	----

3. Refinery Mathematical Model

The case study of this Refinery is to maximizing profit which are reflected by sale of the products [3 - 4].

Profit = **Sale of Products** – **Crude Oil Price** – **Operation expenses**

As mentioned above, the limitation of Units will be bounded by:-

Maximum = The Maximum production Capacity of the Unit

Minimum = Requirements of Products specifications or minimum economic for the operation Unit (Unit Operation Cost).

Table (11) Boundary limit of production units in Refinery

Minimum	Unit Type	Maximum
Product requirement	≤ (CDU) ≤	Unit Capacity
Product requirement	≤ (RFCC) ≤	Unit Capacity
Product requirement	≤ Reformer ≤	Unit Capacity
Product requirement	≤ Kerosene Hydrotreater ≤	Unit Capacity
Min requirement	≤ Gasoline Fuel ≤	Max requirement
Min requirement	≤ Jet Fuel ≤	Max requirement

3.1 Distillation

Accordingly, X1 represent the feed crude oil to the distillation column and the maximum and minimum processing unit are the inequality equations:

$$\mathbf{X1 \leq 100{,}000} \qquad \text{Eq. (1)}$$

$$\mathbf{X1 \geq 90{,}000} \qquad \text{Eq. (2)}$$

$$\mathbf{-\,0.052766\,X1 + X2 = 0} \qquad \text{Eq. (3)}$$

Note: Fuel gas and Hydrogen are considered used in the Refinery and included in the operation expenses.

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$- 0.15393\ X1 + X3 = 0$ **Eq. (4)**

$- 0.088259\ X1 + X4 = 0$ **Eq. (5)**

$- 0.18022\ X1 + X5 = 0$ **Eq. (6)**

$- 0.045042\ X1 + X6 = 0$ **Eq. (7)**

$- 0.44717\ X1 + X7 = 0$ **Eq. (8)**

$- 0.967387\ X1 + X2 + X3 + X4 + X5 + X6 + X7 = 0$ **Eq. (9)**

X2, X3, X4, X5, X6, X7 represent products of the distillation Unit.

3.2 Residue Fluid Catalytic Cracking

The feed to the RFCC is **X7** according to the Table (4) and the maximum and minimum capacities of Unit are represented in inequality equations are: -

$X7 \leq 45000$ **Eq. (10)**

$X7 \geq 40,245.3$ **Eq. (11)**

$- 0.045\ X7 + X8 = 0$ **Eq. (12)**

$- 0.164\ X7 + X9 = 0$ **Eq. (13)**

$- 0.5003\ X7 + X10 = 0$ **Eq. (14)**

$- 0.1207\ X7 + X11 = 0$ **Eq. (15)**

$- 0.03\ X7 + X12 = 0$ **Eq. (16)**

$- 0.045\ X7 + X13 = 0$ **Eq. (17)**

$- 0.905\ X7 + X8 + X9 + X10 + X11 + X12 + X13 = 0$ **Eq. (18)**

X8 + X9 + X10 + X11 + X12 + X13 represent products of RFCC Unit.

3.3 Heavy Naphtha Hydrotreater

The feed to heavy naphtha hydrotreater is **X3** according to Table (6) and the maximum and minimum capacity Unit are: -

$X3 \leq 15,400$ **Eq. (19)**

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$X3 \geq 14,000$ **Eq. (20)**

$- 0.9855 X3 + X14 = 0$ **Eq. (21)**

3.4 Catalytic Reformer

The feed to Reformer is **X14** according to the Table (7) and the maximum and minimum capacities of Unit are:

$X14 \leq 15,400$ **Eq. (22)**

$X14 \geq 14,000$ **Eq. (23)**

$- 0.0381 X14 + X15 = 0$ **Eq. (24)**

$- 0.023 X14 + X16 = 0$ **Eq. (25)**

$- 0.033 X14 + X17 = 0$ **Eq. (26)**

$- 0.872 X14 + X18 = 0$ **Eq. (27)**

$- 0.966 X14 + X15 + X16 + X17 + X18 = 0$ **Eq. (28)**

X15 + X16 + X17 + X18 represent products of Reforming Unit.

3.5 Light Naphtha Hydrotreater

The feed to the light naphtha hydrotreater is **X2** according to Table (8). The maximum and minimum capacity Unit is:

$X2 \leq 5300$ **Eq. (29)**

$X2 \geq 4000$ **Eq. (30)**

$- 0.027 X2 + X19 = 0$ **Eq. (31)**

$- 0.9513 X2 + X20 = 0$ **Eq. (32)**

$- 0.9783 X2 + X19 + X20 = 0$ **Eq. (33)**

X19, X20 represent products of light naphtha hydrotreater Unit.

3.6 Kerosene Hydrotreater

The feed to the kerosene hydrotreater Unit is **X4** according to Table (9). The maximum and minimum capacity Unit are:

$X4 \leq 8,826$ **Eq. (34)**

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$$X4 \geq 7{,}944 \quad \text{Eq. (35)}$$

$$-0.03\,X4 + X21 = 0 \quad \text{Eq. (36)}$$

$$-0.9515\,X4 + X22 = 0 \quad \text{Eq. (37)}$$

$$-0.9815\,X4 + X21 + X22 = 0 \quad \text{Eq. (38)}$$

X21, X22 represent products of Kerosene hydrotreater Unit.

3.7 Gas Oil Hydrotreater

The feed to the gas oil hydrotreater are **X5, X6** according to Table (10). The maximum and minimum capacity Unit are:

$$X5 + X6 \leq 22{,}527 \quad \text{Eq. (39)}$$

$$X5 + X6 \geq 20{,}275 \quad \text{Eq. (40)}$$

$$-0.005\,(X5 + X6) + X23 = 0 \quad \text{Eq. (41)}$$

$$-0.037\,(X5 + X6) + X24 = 0 \quad \text{Eq. (42)}$$

$$-0.9445\,(X5 + X6) + X25 = 0 \quad \text{Eq. (43)}$$

$$-0.9865\,X5 - 0.9865\,X6 + X23 + X24 + X25 = 0 \quad \text{Eq. (44)}$$

X23, X24, X25 represent products of gas oil hydrotreater Unit.

3.8 Gasoline Pool

Naphtha stream feeding gasoline pool is the summation of light naphtha comes from naphtha hydrotreater and naphtha from kerosene hydrotreater therefore:

$$X26 = X20 + X24 \quad \text{Eq. (45)}$$

$$X26 = X26R + X26P \quad \text{Eq. (46)}$$

X26R represent part of light naphtha to Regular Gasoline.

X26P represent part of light naphtha to Premium Gasoline.

$$X18 = X18R + X18P \quad \text{Eq. (47)}$$

Note: 83% of produced kerosene is marketed as jet fuel in this calculation according to data available

X18R represent part of Reformate to Regular Gasoline

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X18P represent part of Reformate to Premium Gasoline

X10 = X10R + X10P **Eq. (48)**

X10R represent part of FCC gasoline to Regular Gasoline

X10P represent part of FCC gasoline to Premium Gasoline

Let Premium Gasoline product = XP

Let Regular Gasoline product = XR

XP= X26P + X18P + X10P **Eq. (49)**

XR = X26R + X18R + X10R **Eq. (50)**

3.8.1 Octane Number Specification

74 X26P + 100 X18P + 93.5 X10P ≥ 95 XP **Eq. (51)**

74 X26R + 100 X18R + 93.5 X10R ≤ 91 XR **Eq. (52)**

74 X26R + 100 X18R + 93.5 X10R ≥ 87 XR **Eq. (53)**

3.8.2 Vapor Pressure Specification

68 X26P + 50 X18P + 56 X10P ≥ 54 XP **Eq. (54)**

68 X26R + 50 X18R + 56 X10R ≥ 54 XR **Eq. (55)**

X22 = X27+ X28 **Eq. (56)**

X27 = 0.83 X22 Jet Fuel **Eq. (57)**

X28 = 0.17 X22 Kerosene **Eq. (58)**

Up to this point, there are Fifty-Seven (58) constraints and Thirty-Eight (37) variables [5] [6]. Using Lingo Program (LINDO API 13) for maximizing profit with these prices of different products and taking into consideration that the crude oil price is the only one is changeable and the products prices are constant. The programing solution for maximum profit and quantities of 37 variables and 58 constraints [6] , [7] are following:

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Table (12) Shows quantity of each stream according to optimization process

Stream	Quantity (Bbl/Day)	Stream	Quantity (Bbl/Day)
X19	142.4682	X3	15393.00
X21	264.7770	X4	8825.900
X23	112.6310	X5	18022.00
X9	7333.588	X6	4504.200
X15	577.9694	X7	44717.00
X16	348.9054	X10	22371.92
X17	500.6034	X14	15169.80
XP	30161.50	X18	13228.07
XR	11291.580	X20	5019.630
X27	6970.210	X22	8397.844
X28	1427.633	X24	833.4694
X25	21276.00	X26	5853.099
X8	2012.265	X26R	5645.789
X11	5397.342	X26P	207.3104
X12	1341.510	X18R	5645.789
X13	2012.265	X18P	7582.278
X1	100,000	X10R	0.00000
X2	5276.600	X10P	22371.92

These products quantity will be used in the excel sheet for estimation refinery financial analysis [8] ,[9].

4. <u>Refinery Financial Analysis</u>

Build an excel sheet financial model of approach for deterministic the most influenced key variable that can limit the boundaries of profits and financial parameters of the refinery. Different scenarios are performed taking into consideration variation of one variable at time and the multi-variables variation at time. The scenario will take the maximum level of risk (minimum value) of each variable to give indication of how would the model behave rather than the maximum value of each variable [10]. Crude oil price and products price, Inflation, Capex, Opex Inflation as well as time construction will be taken into calculation during this analysis.

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Table (13) Scenario (1) basis crude price at (65$), Discount rate (10%) with (0) Opex inflation rate and (0) inflation rate.

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,666	-1,400	-134.08	1,132	2,398
IRR (%)	-	-	-	6%	12%
PI	-	-	-	1.33	1.93
Payback Period (Year)	-	-	-	11.39	8.47

Table (14) Scenario (2) basis crude price at (65$), Discount rate (10%) with opex inflation rate (10%) and (0) inflation rate.

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,727	-1,461	-195.1	1,071	2,337
IRR (%)	-	-	-	6%	12%
PI	-	-	-	1.30	1.90
Payback Period (Year)	-	-	-	11.61	8.54

Table (15) Scenario (3) basis crude price at (65$), Discount rate (10%) with opex inflation rate (10%) and (3%) inflation rate.

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,317	-1,405	-494.04	417.7	1,329
IRR (%)	-	-	-	3%	9%
PI	-	-	-	-	1.37
Payback Period (Year)	-	-	-	-	9.42

Table (16) Scenario (4) basis crude price at (65$), Discount rate (10%) with opex inflation rate (10%) and (5%) inflation rate.

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,109	-1,364	-619.2	125.9	871.1
IRR (%)	-	-	-	1%	7%
PI	-	-	-	-	1.12
Payback Period (Year)	-	-	-	-	10.25

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Table (17) Scenario (5) basis crude price at (65$), Discount rate (0%) with opex inflation rate (0%).

Products Price ↑ ($/ Bbl)	10%	20%	30%	40%	50%
Crude Oil Price ($/Bbl)	65	65	65	65	65
NPV (mmUSD)	-2,832	-1,731	-631.4	468.9	1,569
IRR (%)	-	-	-	2.9%	8.5%
PI	-	-	-	1.02	1.54
Payback Period (Year)	-	-	-	15.42	10.05

Table (18) Scenario (6) basis crude price at (65$), Discount rate (0%) with opex inflation rate (0%).

Products Price ↑ ($/ Bbl)	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-1,566	800.5	3,167	5,533	7,900
IRR (%)	-	4.7%	15.1%	23%	29.6%
PI	-	1.17	2.30	3.43	4.55
Payback Period (Year)	-	12.89	7.59	6.28	5.63

Table (19) Scenario (7) basis crude price at (65$), Discount rate (10%) with opex inflation rate (10%) and inflation rate (3%).

Products Price ↑ ($/ Bbl)	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-1,525	178.9	1,883	3,587	5,291
IRR (%)	-	1.3%	11.5%	19.2%	25.7%
PI	-	-	1.64	2.45	3.26
Payback Period (Year)	-	-	8.27	6.54	5.77

Table (20) Scenario (8) basis crude price at (65$), Discount rate (10%) with opex inflation rate (10%) and inflation rate (5%).

Products Price ↑ ($/ Bbl)	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-1,461	-69.2	1,323	2,716	4,109
IRR (%)	-	-	9.4%	17%	23.3%
PI	-	-	1.33	2.01	2.66
Payback Period (Year)	-	-	8.7	6.72	6

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Table (21) Scenario (9) basis crude price at (65$), Discount rate (10%) with opex inflation rate (50%) and inflation rate (5%).

Products Price ↑ ($/ Bbl)	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-1,605	-212.9	1,179	2,572	3,965
IRR (%)	-	-	8.5%	16.3%	22.7%
PI	-	-	1.27	1.93	2.59
Payback Period (Year)	-	-	9.16	6.82	6.06

Table (22) Scenario (10) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and products price (+10%).

Crude Oil Price ↑ ($/Bbl)	10%	20%	30%	40%	50%
Crude Oil After Increase ($/Bbl)	71.5	78	84.5	91	97.5
NPV (mmUSD)	-4,098	-4,264	-4,429	-4,595	-4,761
IRR (%)	-	-	-	-	-
PI	-	-	-	-	-
Payback Period (Year)	-	-	-	-	-

Table (23) Scenario (11) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and products price (-10%).

Crude Oil Price ↓ ($/Bbl)	10%	20%	30%	40%	50%
Crude Oil After Increase ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-3,766	-3,601	-3,435	-3,269	-3,103
IRR (%)	-	-	-	-	-
PI	-	-	-	-	-
Payback Period (Year)	-	-	-	-	-

Table (24) Scenario (12) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and Time of construction (4 years) with capex (2,100 mm USD).

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,666	-1,400	-134.08	1,132	2,398
IRR (%)	-	-	-	6%	12%
PI	-	-	-	1.33	1.93
Payback Period (Year)	-	-	-	11.39	8.47

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Table (25) Scenario (13) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and Time of construction (6 years) with capex (2,100 mm USD).

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,352	-1,306	-259.7	786.6	1,833
IRR (%)	-	-	-	4%	9%
PI	-	-	-	1.1	1.59
Payback Period (Year)	-	-	-	14.6	11.12

Table (26) Scenario (14) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and Time of construction (4 years) with capex (2,100 mm USD).

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-2,666	-1,400	-134.08	1,132	2,398
IRR (%)	-	-	-	6%	12%
PI	-	-	-	1.33	1.93
Payback Period (Year)	-	-	-	11.39	8.47

Table (27) Scenario (15) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and Time of construction (4 years) with capex (3,000 mm USD).

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-3,641	-2,375	-1,108	157.2	1,423
IRR (%)	-	-	-	0.7%	5.7%
PI	-	-	-	0.84	1.27
Payback Period (Year)	-	-	-	20.74	11.89

Table (28) Scenario (16) basis crude price at (65$), Discount rate (10%) with opex inflation rate (0%), inflation rate (0%) and Time of construction (6 years) with capex (3,000 mm USD).

Discount	10%	20%	30%	40%	50%
Crude Oil After Discount ($/Bbl)	58.5	52	45.5	39	32.5
NPV (mmUSD)	-3,222	-2,175	-1,129	82.8	963.5
IRR (%)	-	-	-	0%	4%
PI	-	-	-	0.69	1.04
Payback Period (Year)	-	-	-	28.27	15.34

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5. Conclusion

Mathematical model and Optimization process were carried out to construct an invested refinery of capacity 100,000 (Bbl/day) in AL-Nasiriya Governorate. Based on Capex, Opex, Construction time as well as crude oil and products prices, feasibility study (NPV, IRR, PI and Payback Period) was performed to study the profit indicator among different risk scenario. It was noticed that refinery is non-feasible in case of the crude feed price is taken (65$) and the products prices still constant.

Therefore, oil price was discounted by 10% and the products prices stay constant turns the project to be feasible at (50%) discounted oil price which gives positive financial parameters as can be seen in scenario (1), (2) but no longer viable when adding inflation by (3%) and (5%) as shown in scenario (3) and (4). In contrast, the price of crude oil feed was taken constant (65$) and the products prices were gradually increased by (10%) till (50%) with constant other parameters gives negative financial parameters means non feasibility as can be seen in scenario (5). Increasing products prices by 10% and discount crude oil price by 10% together makes the project feasible at (25%) for both as shown in scenario (6). Conversely, when inflation was taken into account for OPEX and cost of capital, the project shifted to be feasible at (40%) for both crude oil and products as seen in scenario (7, 8, 9). In the matter of crude oil feed price and products was increased gradually by (10%) and decreased by the same percent. Both scenarios give negative financial parameters as shown in (10) and (11).

Extending life of project from (4) to (6) years and let other parameters constant including CAPEX to study the impact on the financial parameters. It is noticed that the refinery gives negative income compared to previous period of project in scenarios (12), (13). Additionally, the cost of capital was increased from 2,100 million to 3000 million with no change in the other parameters gives negative income as seen in scenario (14) and (15). On the other hand, cost of capital and life of project were changed together makes the project worse income due to decline in the financial parameters as illustrated in scenario (14) and (16).

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