Algorithm Matches Complexity With Capacity For Refining In Middle East And Africa

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Abstract: *Many consultants, researcher and companies have been studying world-wide developments in the downstream sector from distillation to consumption of refined products. This study has focused directly on Middle East and Africa to preview and determine the trend in growth, and attempt to match refinery complexity with capacities. The parameters for the study include the main drivers for the growth, i.e. refined products consumption and specifications, and the announced refinery projects 2010-2015. Evaluating from available base refining data of 2009, defined relationships, factors and indices were applied to project to 2015 and determine the match between complexity and capacity.*

The outcome of the match showed difference of growth in Middle East complexity (CCI) and distillation capacity of 4% and Africa, 14%. It is worthy to note that Africa's projected distillation capacity growth of 0.474 mbpd for the period is 21% of Middle East with 2.226 mbpd capacity. In general, the prospects for growth in refining complexity and capacities in Middle East and Africa are apparent from this study. The match of complexity with capacity is closer in the case of Middle East than Africa for same period.This concept can be applied with appropriate assumptions to predict refineries complexities and capacities in these regions beyond 2015.

Keywords: *Refining, modelling, algorithm, complexity, capacity*

I. INTRODUCTION

A. Middle East and Africa Situation Reviewed

As part of global happenings, Middle East and Africa are affected by the dynamics of crude supply, demand and price, as well as refining industry developments and performance. This study therefore considered these two regions'/continents' refining capacities, complexities and challenges which obviously are influenced by factors within and without them.

Middle Easthas a population of 199 million as at 2008;as at 2009 the region's oil reserves stood at 745 billion barrels, production 21.64 million bpd, imports 0.3 million bpd and exports 14.85 million bpd.Middle East distillation capacity and consumption of petroleum products as at 2009 stood at 7.28 and 6.81 million bpd respectively. Africahas a population of about 1 billion people with the region sectioned[2]for this study into Northern, Central, Western, Southern and Eastern sub-regions. As at 2009 the region's oil reserves stood at 114.8 billion barrels, production 10.48 million bpd, imports 0.49 million bpd and exports 8.57 million bpd.Africa's distillation capacity and consumption of petroleum products as at 2009 stood at 3.28 and 3.24 million bpd respectively.

B. Objective of the Study

The objective of the study is to evaluate the prospects of matching complexity with capacity in the growth of refining in Middle East and Africa. The main drivers for the growth are the refined products consumption and specifications; while the prospects of growth are in the announced refinery projects.

II. SURVEY AND MODELLING OF REFINING DATA

The approach used for the study involved survey of refining activities in Middle East and Africa, obtain base data to 2009, analyze and project these to 2015 in the context of complexities and capacities.Data considered as a matrix with elements $\mathbf{x_{i,j},\ldots,x_{n,m}}$; **where i (i=1,n)** refers to vertical variation and **j (j=1,m)** horizontal variation.Based on the above, we have developed the data for the refineries capacities, products consumption and complexities using published base data[1,2,3] for 2009, projecting to 2015 and defined:

$$\mathbf{x_{i,j} = x_{i,j-1} * a_i * b_j} \qquad \mathbf{1}$$

Where **i=1,n; j=2,m [i.e. 2010-2015];** and up to 2009,$\mathbf{b_j=(x_{i,j-1} - x_{i,j})/x_{i,j-1}}$**),** and $\mathbf{a_i}$is obtained from reports [4] and [5]. Middle East and Africa countries studied here are contained in Notes (a) and (b).

Applying equation 1 to both regions' base data produced consumption pattern for Middle East. The pattern shows that Saudi Arabia accounts for about 28% of the regions consumption, followed by Iran and then Iraq.While for Africa, the outlook for the consumption pattern on sub-regional[2] basisshows that Northern sub-region accounts for over 50% of this consumption followed by the South and then the West [5].

The distillation capacity represented by $y_{i,j},\ldots,y_{n,m}$, **where i and j**are as defined earlier,,and additional capacities (screened and adopted)defined by $z_{i,j},\ldots..,z_{n,m}$ **(where j refers to 2010-2015);** so that up to 2009**,** $y_{i,j}$applies, and from 2010the matrix becomes

$$y_{i,j} = (y_{i,j-1} + z_{i,j}) \qquad 2$$

Data $y_{i,j}$are published in the literature up to 2009; $z_{i,j}$are determined from the matrix of probability index (PI)-vertical and the year (2010-2015)-horizontal [5].

III. INTEGRATION OF REFINERY PROJECTS AND CAPACITIES

Middle East 2010-2015 planned refineryprojects has been listed and categorized based on Probability Index (PI)[where PI is defined in Note (c)] on a scale 1 to 5, in increasing order of possibility of execution: where PI, 1 signifies the least likelihood of the project proceeding on schedule, while PI, 5 is the highest (Tuner & Mason, 2010). These projects have been summarized and presented[5].Matrix analysis of the PIs and the crude oil types in the context of distillation capacities are defined in the same study for the two continents. From our analysis over 65% of the total additional capacities proposed in these projects belong to PI 1 category, while categories PI 2-5 account for the remaining, about 35%. Based on the analysis on the feasibility of realization before 2015, and results obtained, projects PI 2-5 where admitted as feasible within the period: PI 3-5 retains the projected years of realization while PI 2, may be delayed but will be realized within the period. Projects on PI 1 category are assumed not to be feasible within the period - 2010-2015.These projects have been defined in terms of capacities, PIs and schedule over 2010-2015: Iran has planned 20 projects out of which 12 are new and the others are upgrades.Overall 2.225 mbpd capacity will be added by 2015. For Africa, the key projects and countries in the region, and other smaller projects have been captured in the overall region's calculation. The 'realizable' projects were selected based on the same principle as discussed above. For overall Africa, 0.474 mbpd distillation capacities will be added by 2015.

From the above and applying equation 2 with $z_{i,j}$ (for new projects capacities), Middle East and Africa distillation capacities have been determined. As at 2009, Middle East distillation capacity stood at 7.28 mbpd, with Saudi Arabia having over 26% of this capacity.Saudi Arabia had about 29% of the total region's capacity in 2009, and growing to 30% in 2015;

Africa's gasoline growth is projected at 1.33% annually (average) for 2010-2015. Hart Consulting (2010) Iran follows with 20% share in 2009 reducing to 19.5% in 2015. Beyond 2015, Iran's share of Middle East distillation capacity is expected to increase, considering the projects that are listed in that country's favour, if they are realized as planned.For Africa, the North consistently has over 50% share of the distillation capacity from 2009 to 2015, followed by the West (mainly Nigeria's distillation capacity which is 0.51 mbpd), and then South, (mainly South Africa's distillation capacity of 0.49 mbpd).

For refined products,

$$w_{i,j} = p_i * \psi_{i,j} \qquad 3$$

Where$p_i$is average product **i** yield fraction in crude oil capacity $\psi_{i,j}$ for year **j** (**j** as defined earlier);

And for year **j**,

$$\psi_{i,j} = \Sigma x_{i,j} \qquad 4$$

Where**(i=1,n),n** istotal countries in the region (representing the sum for all the countries in the region);**i** defines **motor gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel, LPG and others.**

Based on equations 3&4, the production evaluation for each region was developed[5]. The result show that motor gasoline yield is more from Africa refineries than Middle East. This is explained by the types of crudes being processed in both regions.Gasoline, the main transportation fuel for Middle East will grow by 5.42% annually. This figure is close to the region's experience of 4.6% prior to 2007 (Hart Consulting, 2010). Saudi Arabia and Iran, large gasoline consumers in the region in 2007 accounted for 29% and 28% of the Middle East demand respectively, nearly 63% of gasoline demand. Both Saudi Arabia and Iran are net importers of gasoline and together account for most of the region's gasoline imports. Iran is one of the world's largest gasoline importers behind the United States. Jet fuel demand in the region was reported to be growing rapidly throughout the past decade reaching 4.5% annual (average) by 2008. After a drop in demand projected for 2009 due to the reduction in air travel and a swift recovery in 2010, jet fuel is projected to grow on average by 2% annually between 2010 and 2030 (Hart Consulting, 2010). Average growth of Jet fuel for 2010-2015 will be 2.34%. Aircraft orders are still strong for the region as growth in air travel is expected to track with continued overall economic expansion. Kerosene demand in 2004 was similar to Jet Fuel and so is the case.

reported growth of 2.6% yearly since 2004 despite negative growth in 2005. It is worthy to note that gasoline has continued to grow in 2009 at 1.8% despite

the economic downturn. Nigeria had the strongest growing market. Jet fuel/kerosene market consists of 67% jet fuel and 33% kerosene (industry, residential and commercial uses). Jet fuel growth was strong (over 7% per year) until 2009 when demand fell by 2.7%. Based on the projects additions in which low capacity qualified, the jet fuel projected average will be 0.47% and kerosene 0.24%.

IV. ALGORITHM FOR MATCHING REFINING COMPLEXITIES WITH CAPACITIES

Refinery complexity evaluation was done using Nelson complexity index (NCI). NCI is a measure of secondary conversion capacity in comparison to the primary distillation capacity of any refinery.The refinery complexity matrix is defined as $f_{i,j}$

$$f_{i,j} = c_j * f_{i,j} \qquad 5$$

Wherec_j **(j=1,m)** represent the NCI for facility **j,** $f_{i,j}$**,** the capacity of facility **j** in country **i.**

Based on equation 5 the results were plotted as shown in Figures 1-4 for Middle East and Africa. Two cases were considered: for PI=1-5, which assumes that all refinery projects in those categories will be realized within the period, while the second case assumes that only PI 2-5 will be realized. The performances of the regions in the context of Capacity Complexity Index (CCI) (average/weighted NCI based on capacity – [5] and the capacitieswere determined as shown in these figures.

Figure 1: Middle East Complexity & Distillation Capacity to 2015: PI=1-5

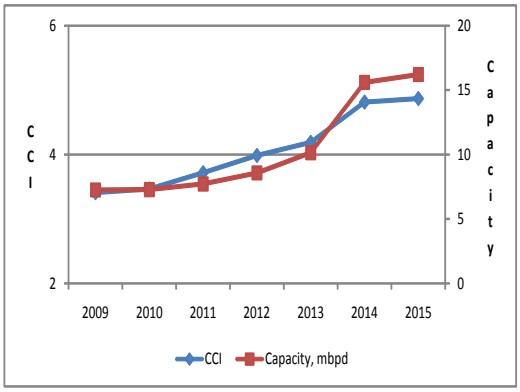


Figure 2: Africa Complexity & Distillation Capacity to 2015: PI=1-5

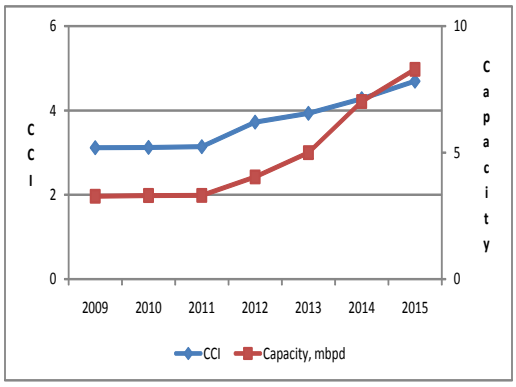


Figure 3: Middle East Complexity & Distillation Capacity to 2015: PI>1

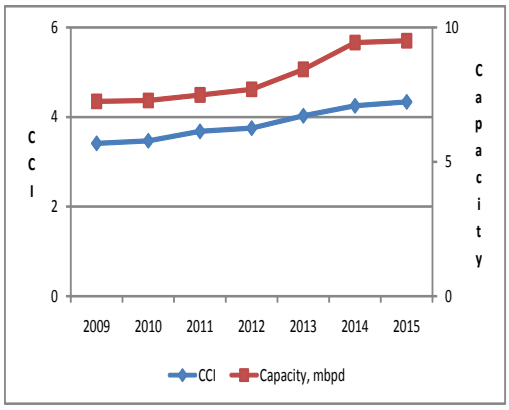
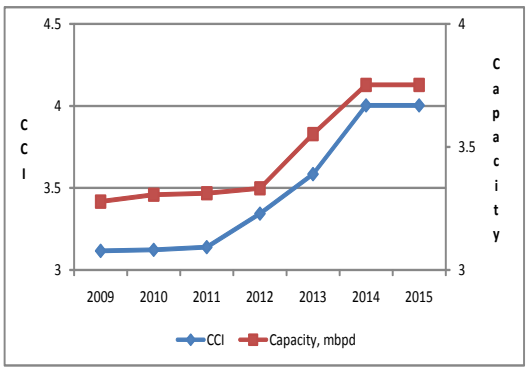


Figure 4: Africa Complexity & Distillation Capacity to 2015: PI>1



This study applies the CCI concept for matching complexity with capacity. Hence from the analysis of CCI outlook in Middle East and Africa in Figures 1-4,we observed a steady improvement in the capacity complexity index (CCI) as new capacities and upgrades are added to the previous year'srefining conditions. The improvement for capacity and CCI are in different proportions. Generally, the new refinery projects appear to be designed both to add capacity and to improve complexity in most cases. Further evaluation of the CCI result shows for Middle East CCI grew by total of 43% while distillation grew by 124% for 2009-2015 for PI 1-5; for Africa CCI grew by 51% and distillation capacity 153% for same period and PI. For PI 2-5, CCI grew by

27% and distillation capacity by 31%, whereas for Africa, CCI grew by 29% and distillation capacity by 15% for same period and PI 2-5. The trend for PI 2-5 shows that consideration for complexity improvementcould have been taken into account in planning the projects especially those placed on these categories and admitted.

V. CONCLUSIONS

Middle East and Africa consumption of refined products has continued to grow; products requirements to meet specifications in targeted countries for supply are continuously becoming a challenge especially to Middle East refiners. Determined to meet targets and achieve growth both regions had planned some projects to grow the refining industry in complexity and capacity. After systematic evaluation, the capacities added to the projection 2010-2015 enabled the refining complexity to be matched with capacities in both regions. The outcome of the match showed a difference between the growth in Middle East complexity (CCI) and distillation capacity of 4% and Africa this difference was determined to be 14%.It is worthy to note that Africa's projected distillation capacity growth of 0.474 mbpd for the period is 21% of Middle East of 2.226 mbpd.

In general, the prospect for growth in refining complexity and capacity in Middle East and Africa is apparent, from this study. The match of complexity with capacity is closer in the case of Middle East than Africa for same period.This concept can be applied with appropriate assumptions to predict refineries complexities and capacities in these regions beyond 2015.

Notes

(a) Middle East comprises of Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Saudi Arabia, Syria, United Arab Emirates (UAE), and Yemen.

(b) Countries in Africa sub-regions: **North** - Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, Western Sahara; **Central** - Angola, Cameroon, Central Africa Republic, Chad, Congo Brazzaville, Congo Kinshasa, Equatorial Guinea, Gabon, Sao Tome & Principe; **West** - Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Saint Helena, Senegal, Sierra Leone, Togo; **South** - Botswana, Lesotho, Namibia, South Africa, Swaziland; **East** - Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, Tanzania, Uganda, Zambia, Zimbabwe.

(c) Probability Index (PI)=m (where m=1,…,5: 1 least, 5, highest, and n(m), (n=number of projects in the category, m=PI)

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