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Energy Shortages and Impact on Overall Equipment Effectiveness in Manufacturing Firms in Nigeria

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Original Research Article

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Abstract: Energy availability is a vital factor for the survival and optimal performance of industries worldwide. Energy deficit poses a serious threat to the optimal performance of industrial processes, industrial growth and economic development of any nation. Nigeria is blessed with abundant natural resources from which energy could be freely harnessed to meet the nation's ever spiralling energy needs. Owing to various reasons some of which are pin-pointed here, however, Nigeria continues to suffer acute shortage of energy to power the manufacturing sector therefore hindering her industrial and economic development. The study seeks to investigate the impact of energy deficit on the overall equipment effectiveness (OEE) of selected manufacturing firms in Nigeria as well as suggest ways of using OEE to maximise energy and improve productivity. Data extracted from the sampled firms were used in the computation of the Availability (A), Performance (P), Product Quality (Q) and the Overall Equipment Effectiveness (OEE) applicable to each firm. The findings show that Nigeria must adopt vigorous steps to explore and exploit its abundant energy resources in other to achieve her dream of becoming an industrial giant in the nearest future.

Keywords: Energy, Energy Shortage, Industries, Manufacturing firms, Overall Equipment Effectiveness.

INTRODUCTION

Nigeria nurtures the dream of becoming a global industrial giant in the nearest future yet her industries face perennial acute energy shortages from the national grid. Nigeria has huge natural deposits of energy resources that include oil, natural gas, coal, biomass, solar, wind and hydro resources among others [1,2].

Despite her abundant natural resources, however, Nigeria is still energy deficient therefore adversely affecting the nation's economy perennially [2]. Several factors are responsible for the perennial energy shortages in Nigeria. Currently, Nigeria's transmission system network has a maximum wheeling capacity of about 4,000 MW due to its technical weakness and high responsiveness to major system disturbances. Some sections of it have become outdated and are yet to be upgraded to meet the present load demand [3]. Many of the nation's networks (transmission and distribution) have become weak, some broken others heavily loaded and prone to voltage instability [4, 5].

Energy is an important driver of industrial productivity growth as well as a key production input in industrial processes. Energy represents between 1% and 10% of total production costs. Energy intensity is the energy consumed per unit of output. For energy intensive industries such as those which specialise in the manufacturing of Steel, Chemical, Paper, Pharmaceutical, Cement, Plastics and Construction materials, the share of energy costs is even higher, between 15% and 40% on average [6]. For example, the electricity price for large industrial consumers in the UK was 35 percent higher in January 09-June 09 compared to the same period the previous year [7]. See Figure 1.

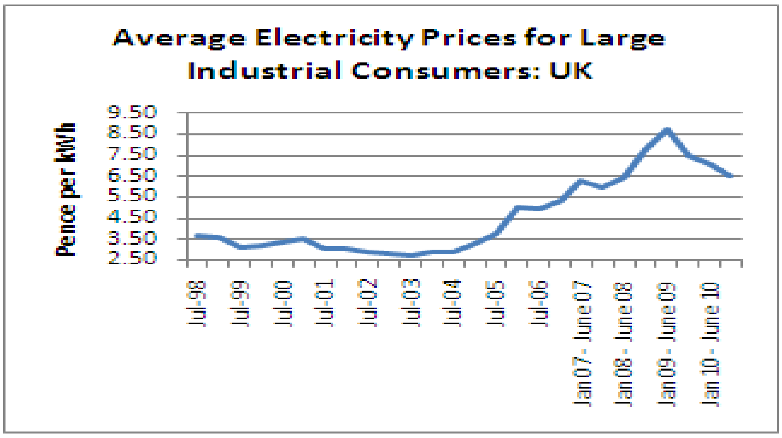

Fig-1: Graph of average electricity prices for large industrial consumers in the UK in 2010[6]

The total installed capacity of Nigeria's generating plants is above 5,000 MW, but the available capacity is about 4,000MW and coupled with the fact that significant number of these power plants are over 20 years old, the average daily power generation is below 2,700MW. The result is that present power demand in Nigeria is far above the available generating capacity [8,9].

The last transmission line in Nigeria was constructed over twenty years ago. Many of the distribution facilities too have become undersized and can no longer carry the available loads since these are above their originally designed capacities [5,10]. The number of available generating plants are also not enough to provide adequate electricity to meet the ever growing demand for its supply [11].

The Nigeria 330 KV transmission grid is characterized by high power losses due to its very long transmission lines. Power losses result in lower 6ower availability to the consumers, leading to brownout or inadequate power to operate appliances; a situation synonymous with power shortage [5]. The aggregate transmission and distribution loss in Nigeria averages 40% of electric energy generated and is also among the world's highest [12,13]. Energy losses make it difficult for electricity distribution companies (Dis Cos) to breakeven and reinvest into their business.

Nigeria is rich with natural gas reserves ranging into several trillions of standard cubic feet, still the country is in dire need of gas to fire its power stations [10]. But poor management of these resources by successive governments remains the bane of nation. For instance, owing to misplacement of priorities coupled with policy somersaults, some of the nation's power plants such as Geregu and Omotosho Plants in South Western Nigeria do not have the needed gas supply infrastructure [5,14]. Added to these is the problem of flagrant gas flaring. Nigeria currently flares about 2 billion standard cubic feet of gas thus making itself responsible for over 75 per cent of the gas flared in Africa [15].

The citizens are ignorant of the need for energy conservation. In spite of the shortage in electrical energy, most consumers leave their electrical appliances e.g. Television sets, room and security lights, etc. switched on for long hours even while away from homes during the daytime. Some leave air conditioners, refrigerators and other energy-consuming fittings on in the offices and shops over the weekends. This leads to wastage of scarce electrical energy and hinder those in dire need of the energy from accessing it [5,8,9].

Utility staff discourage electricity consumers from settling bills officially, preferring rather to adjust energy meter readings in favor of such customers in exchange for some fees usually far less than what the consumer would have otherwise paid officially to the utility as bill. These impacts negatively on the finances of the utility and renders it financially incapacitated to meet its statutory obligation of delivering the needed energy to the consumers [5, 8].

Overall equipment effectiveness (OEE) provides a better understanding of system energy efficiency useful to achieve a more effective control and fostering a continuous improvement of manufacturing performance. As a metric, OEE helps to predict energy demand by the firm through a monitoring and targeting approach involving some regression analysis processes.

Overall Equipment Effectiveness (OEE) is a metric that identifies the percentage of planned production time that is truly productive (See Figure 2). An OEE score of 100% represents perfect production: manufacturing only good parts, as fast as possible, with no down time [16]. OEE is a way to monitor and improve the efficiency of the manufacturing process. Developed in the mid 1990's, OEE has become an accepted management tool to measure and evaluate plant floor productivity. OEE is broken down into three measuring metrics of Availability, Performance, and Quality. These metrics help gauge your plant's efficiency and effectiveness and categorize these key productivity losses that occur within the manufacturing process. OEE empowers manufacturing companies to improve their processes and in turn ensure quality, consistency, and productivity measured at the bottom line. OEE is the product of three measures: Availability, Performance, and Quality [17].

Fig-2: OEE measures the percentage of planned production time that is truly productive [16]

OEE is used to track and trace improvements or decline in equipment effectiveness over a period of time [18].

Ref [19] demonstrated the potential of using OEE and productivity measures in combination as fundamental drivers for improvements on process level within manufacturing industry. At Airbags International Ltd, the implementation of OEE as a primary production measure highlighted a number of losses and enabled new levels of performance measurements [20,21]. In a Beverage industry in Nigeria also, the implementation of OEE increased its value by 50% and facilitated a significant reduction in the losses while improving equipment uptime [20,22].

In a typical world class factory, the minimum requirement is that every equipment operate 90% of the time at 95% capacity with an output of 99% good quality.

The 6 Big Losses as can be seen in Figure 3 are as follows:

Availability (downtime): 1. Equipment failure (breakdowns) 2. Setup and adjustment; Performance (speed): 3. Idling and minor stoppages 4. Reduced speed of operation; Quality (defects): 5. Process defects (scrap, repairs) 6. Reduced yield (from startup to stable production).

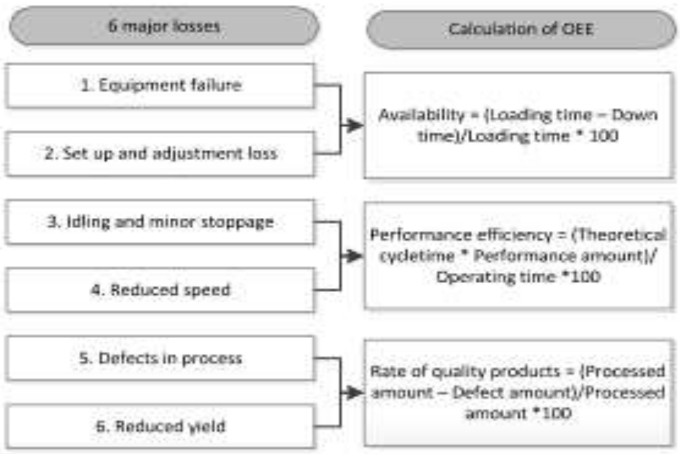

Fig-3: The OEE Formulation [23]

Energy shortage is a major factor militating against the growth of industries in Nigeria. The situation imposes obvious huge costs on the economy and compels private generation of electricity across the strata of energy consumers [24,25]. Due to the scarcity of energy, the industrial consumers especially are forced to patronise the black market where the petroleum products are readily available at much higher prices than the government approved rates. Many manufacturing firms also resort to the use of self-electricity generating plants which further increases operational costs and significantly reduces the profit margins [26]. The study seeks to investigate the impact of energy shortages on the overall equipment effectiveness (OEE) of selected manufacturing firms in Nigeria as well as suggest ways of using OEE to maximise energy availability and improve productivity.

METHODOLOGY

In order to achieve the objective of the study, primary data were collected from sampled One Hundred and Five energy-intensive industries in Nigeria using a structured, open-ended questionnaire. The questionnaire was first tested on ten (10) manufacturing firms to ascertain its content validity and to make necessary amendment/corrections. Final copies of the questionnaire were later administered to the Contact persons of the selected energy-intensive firms. The manufacturing firms investigated comprised Paper, Chemical, Plastics and Pharmaceutical industries. Data collected included information on equipment runtime, equipment downtime, length of time used in equipment maintenance etc. These data were used in the computation of the Availability, Performance, Product Quality and the Overall Equipment Effectiveness applicable to each firm. The data and the responses from the respondents were analysed and the results presented in tabular form for easy comprehension and interpretation. Conclusions were drawn from the results so obtained from the analysis. For the purposes of this research, the following definition of terms is hereby rendered.

Availability is the Percentage of the actual amount of production time the machine is running to the production time the machine is available. The Variance with International Standards of Availability Rate,

VWISA = A minus 0.9 ………… (1)

Performance is the Percentage of total parts produced on the machine to the production rate of machine. The Variance with International Standards of Performance Rate,

VWISP= P minus 0.95 ………… (2)

Quality is the Percentage of good parts out of the total parts produced on the machine.

It is degree to which product characteristics agree with the requirements specified for the product or output. The Variance with International Standards of Quality Rate,

VWISQ= Q minus 0.99 ………… (3)

Overall Equipment Effectiveness, OEE is the product of the measures: Availability, Performance, and Quality. Overall Equipment Effectiveness expressed therefore as a percentage

(%) = (A*P*Q) * 100…………… (4)

Where:
A = Availability Rate
P = Performance Rate
Q = Quality Rate
VWIS = Variance With International Standards
AVG = Average

Table 1 shows the International or world class standards for ease of comparison of the calculated values.

Table-1: World Class Standards

OEE Factor	World Class
Availability	90.0%
Performance	95.0%
Quality	99.9%
OEE	85.0%

RESULTS AND DISCUSSION

As represented in Table 2 in the Appendix, the sampled manufacturing firms had an average ‘availability rate’ of 41%. Compared to the World Class rate of 90% (Shown in Table 1), the availability rate of 41% translated into 49% less than the expected value. Performance rate of the industries averaged 76%. This rate was 19% less than the World Class rate of 95% (Shown in Table 1). Quality rate of the industries averaged 85%. This value translated into 14% less than the World Class standard of 99% (Shown in Table 1).

In terms of the Overall Equipment Effectiveness, OEE, the One Hundred and Five manufacturing firms studied reported an average OEE of 27.2%. This implied that the firms’ equipment overall effectiveness was reduced by an average of 57.8% per production run as a result of power outages when compared to the World Class Standard rate of 85% (Shown in Table 1). It is obvious that the low value of OEE of the studied industries’ equipment was due to the low value of ‘availability rate’. Frequent power outages meant that the equipment were not available for use most of the times thus lower availability rate resulted in lower value of the OEE.

The One Hundred and Five industries which OEE were investigated reported individual OEEs which ranged from 12% to 70.5%. These calculated OEE values for the industries were found to be lower than the internationally accepted value of 85%. Most of the industries had individual availability, performance and quality rates that were significantly lower than the internationally accepted value of 90%, 95% and 99% respectively. Only ten representing about 10% of the one hundred and five industries selected for this study reported a quality rate of 1 showing that these industries did not encounter any sub-standard products in spite of readjustment processes which often resulted from unannounced power outages.

In Figures 4 to 7 are shown the graphs of Overall Equipment Effectiveness (OEE) versus Plant Availability, Performance and Product Quality respectively in the sampled Paper, Chemical, Plastics and Pharmaceutical Manufacturing industries in Nigeria in 2017.

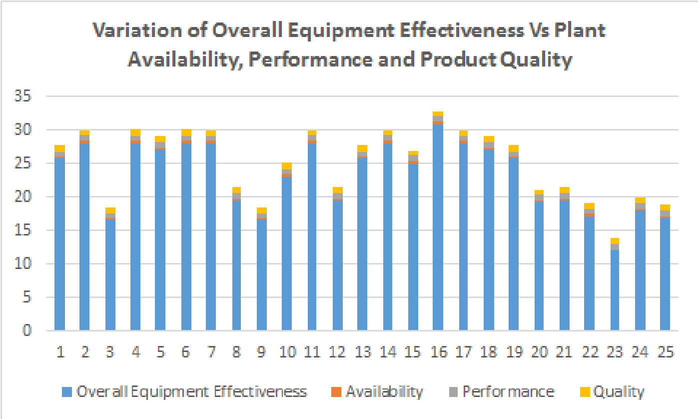

Fig-4: Overall Equipment Effectiveness versus Plant Availability, Performance and Product Quality in the sampled Twenty-five Chemical Manufacturing Industries in Nigeria in 2017

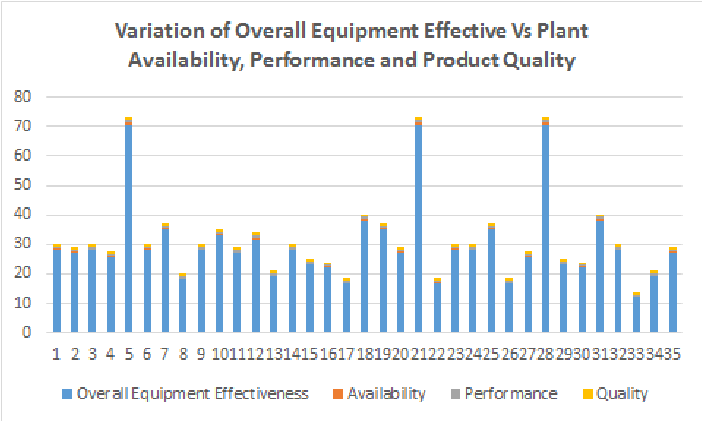

Fig-5: Overall Equipment Effectiveness versus Plant Availability, Performance and Product Quality in the sampled Thirty-five Paper Manufacturing Industries in Nigeria in 2017

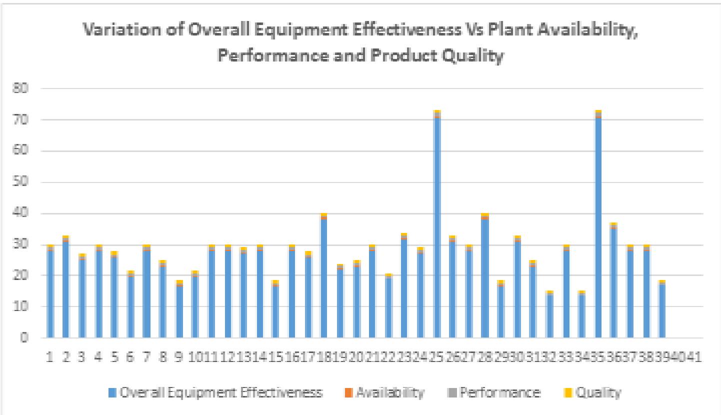

Fig-6: Overall Equipment Effectiveness versus Plant Availability, Performance and Product Quality in the sampled Forty Plastics Manufacturing Industries in Nigeria in 2017

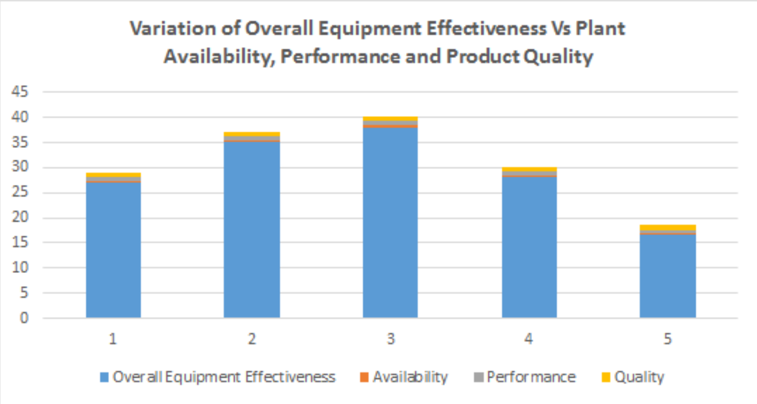

Fig-7: Overall Equipment Effectiveness versus Plant Availability, Performance and Product Quality in the sampled Five Pharmaceutical Industries in Nigeria in 2017

CONCLUSION

The findings of this study show that energy deficit has significant impact on the overall equipment effectiveness of manufacturing firms in Nigeria. When there is no electricity supply, the equipment availability is lost and no production takes place. The result is that set up and adjustments must be made when electricity supply is eventually restored. Consequently, owing to their peculiar design, most equipment takes considerable time to warm up and attain normal speed of operation. The loss of speed leads to reduced rate of operations and consequent reduction in production output. These in the long run constitute defect losses and add significantly to the overall operational costs borne by the manufacturing firm. The study therefore suggests that if the nation's dream of becoming an industrial giant in the nearest future must be achieved, the Federal Government of Nigeria must adopt vigorous steps to explore and exploit its many energy resources so as to increase the availability of electricity to the industrial sector. To successfully optimize productivity and profitability as well as meet energy efficiency goals also, the study recommends that Industrial operators in particular should adopt an integrated system approach to unlock the full potentials of energy savings. This, in addition to partnering with specialists who understand energy management technologies and practices, industrial operators will require leveraging on open, collaborative energy management solutions that link process and energy monitoring systems in order to regularly optimise energy availability and utilization.

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Conflicting Interests

The author declares that no conflicting interests exist.

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APPENDIX

Table-2: Computed Overall Equipment Effectiveness (OEE) of One Hundred and Five Firms

Firm	A	VWISA	P	VWISP	Q	VWISQ	OEE (%) (A*P*Q)	VWISOEE (%)
1.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
2.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
3.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
4.	0.35	-0.55	0.80	-0.15	1	+0.01	28	-57
5.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
6.	0.45	-0.45	0.70	-0.25	0.90	-0.09	28	-57
7.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
8.	0.28	-0.62	0.82	-0.13	0.85	-0.14	19.5	-65.5
9.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
10.	0.30	-0.60	0.85	-0.10	0.90	-0.09	23	-62
11.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
12.	0.28	-0.62	0.82	-0.13	0.85	-0.14	19.5	-65.5
13.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
14.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
15.	0.45	-0.45	0.74	-0.21	0.75	-0.24	25	-60
16.	0.55	-0.35	0.80	-0.15	0.70	-0.29	30.8	-54
17.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
18.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
19.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
20.	0.30	-0.60	0.80	-0.15	0.80	-0.19	19.2	-65.8
21.	0.28	-0.62	0.82	-0.13	0.85	-0.14	19.5	-65.5
22.	0.35	-0.55	0.70	-0.25	0.70	-0.29	17.2	-67.8
23.	0.20	-0.70	0.75	-0.20	0.80	-0.19	12	-73
24.	0.25	-0.60	0.80	-0.15	0.90	-0.09	18	-67
25.	0.25	-0.65	0.75	-0.20	0.90	-0.09	16.9	-68.1
26.	0.45	-0.45	0.70	-0.25	0.90	-0.09	28	-57
27.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
28.	0.35	-0.55	0.80	-0.15	1	+0.01	28	-57
29.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
30.	0.75	-0.15	0.94	-0.01	1	+0.01	70.5	-14.5
31.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
32.	0.55	-0.35	0.75	-0.20	0.85	-0.14	35	-50
33.	0.25	-0.60	0.80	-0.15	0.90	-0.09	18	-67
34.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
35.	0.625	-0.275	0.70	-0.25	0.75	-0.24	33	-52
36.	0.35	-0.55	0.80	-0.15	0.98	-0.01	27	-58
37.	0.40	-0.50	0.88	-0.07	0.90	-0.09	31.7	-53.3
38.	0.28	-0.62	0.85	-0.10	0.80	-0.19	19	-66
39.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57

40.	0.30	-0.60	0.85	-0.10	0.90	-0.09	23	-62
41.	0.625	-0.275	0.70	-0.25	0.50	-0.49	22	-63
42.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
43.	0.60	-0.30	0.80	-0.15	0.80	-0.19	38	-47
44.	0.55	-0.35	0.70	-0.25	0.90	-0.09	35	-50
45.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
46.	0.75	-0.15	0.94	-0.01	1	+0.01	70.5	-14.5
47.	0.30	-0.60	0.70	-0.25	0.80	-0.19	16.8	-68.2
48.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
49.	0.35	-0.55	0.80	-0.15	1	+0.01	28	-57
50.	0.55	-0.35	0.75	-0.20	0.85	-0.14	35	-50
51.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
52.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
53.	0.75	-0.15	0.94	-0.01	1	+0.01	70.5	-14.5
54.	0.30	-0.60	0.85	-0.10	0.90	-0.09	23	-62
55.	0.625	-0.275	0.70	-0.25	0.50	-0.49	22	-63
56.	0.60	-0.30	0.80	-0.15	0.80	-0.19	38	-47
57.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
58.	0.20	-0.70	0.75	-0.20	0.80	-0.19	12	-73
59.	0.28	-0.62	0.85	-0.10	0.80	-0.19	19	-66
60.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
61.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
62.	0.55	-0.35	0.80	-0.15	0.70	-0.29	30.8	-54
63.	0.45	-0.45	0.74	-0.21	0.75	-0.24	25	-60
64.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
65.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
66.	0.28	-0.62	0.82	-0.13	0.85	-0.14	19.5	-65.5
67.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
68.	0.30	-0.60	0.85	-0.10	0.90	-0.09	23	-62
69.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
70.	0.28	-0.62	0.82	-0.13	0.85	-0.14	19.5	-65.5
71.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
72.	0.45	-0.45	0.70	-0.25	0.90	-0.09	28	-57
73.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
74.	0.35	-0.55	0.80	-0.15	1	+0.01	28	-57
75.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
76.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
77.	0.375	-0.52	0.70	-0.25	0.98	-0.01	25.7	-59.3
78.	0.60	-0.30	0.80	-0.15	0.80	-0.19	38	-47
79.	0.625	-0.275	0.70	-0.25	0.50	-0.49	22	-63
80.	0.30	-0.60	0.85	-0.10	0.90	-0.09	23	-62
81.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
82.	0.28	-0.62	0.85	-0.10	0.80	-0.19	19	-66
83.	0.40	-0.50	0.88	-0.07	0.90	-0.09	31.7	-53.3
84.	0.35	-0.55	0.80	-0.15	0.98	-0.01	27	-58
85.	0.75	-0.15	0.94	-0.01	1	+0.01	70.5	-14.5
86.	0.55	-0.35	0.80	-0.15	0.70	-0.29	30.8	-54
87.	0.45	-0.45	0.70	-0.25	0.90	-0.09	28	-57
88.	0.60	-0.30	0.80	-0.15	0.80	-0.19	38	-47
89.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
90.	0.55	-0.35	0.80	-0.15	0.70	-0.29	30.8	-54
91.	0.30	-0.60	0.85	-0.10	0.90	-0.09	23	-62
92.	0.20	-0.70	0.85	-0.10	0.80	-0.19	13.6	-71
93.	0.37	-0.53	0.80	-0.15	0.80	-0.19	28	-57
94.	0.20	-0.70	0.85	-0.10	0.80	-0.19	13.6	-71
95.	0.75	-0.15	0.94	-0.01	1	+0.01	70.5	-14.5
96.	0.55	-0.35	0.75	-0.20	0.85	-0.14	35	-50
97.	0.35	-0.55	0.80	-0.15	1	+0.01	28	-57
98.	0.50	-0.40	0.70	-0.25	0.80	-0.19	28	-57
99.	0.30	-0.60	0.70	-0.25	0.80	-0.19	16.8	-68.2
100.	0.40	-0.50	0.75	-0.20	0.90	-0.09	27	-58
101.	0.55	-0.35	0.70	-0.25	0.90	-0.09	35	-50
102.	0.60	-0.30	0.80	-0.15	0.80	-0.19	38	-47
103.	0.45	-0.45	0.70	-0.25	0.90	-0.09	28	-57
104.	0.25	-0.625	0.70	-0.25	0.95	-0.04	16.6	-68.4
105.	0.55	-0.35	0.80	-0.15	0.70	-0.29	30.8	-54
AVG	**0.41**	**-0.48**	**0.76**	**-0.18**	**0.85**	**-0.13**	**27.2**	**-56.94**

Author (2017)