



## DETERMINATION OF ECONOMIC SUSTAINABILITY OF ALUMINIUM EXTRUSION INDUSTRY IN NIGERIA USING INDEX-BASED METHOD

NWACHUKWU, S.O.<sup>1\*</sup>, ISIOHIA, D.O.<sup>1</sup> AND ANYANWU, K.O.<sup>2</sup>

<sup>1</sup>Department of Mechanical Engineering, Imo State University, Owerri, Nigeria, <sup>2</sup>Department of Materials and Metallurgical Engineering, Federal University of Technology, Owerri, Imo, Nigeria.

### ABSTRACT

This paper covers a study made to determine the economic sustainability of aluminium extrusion industry in Imo State Nigeria in the year 2021. In this work, the economic sustainability of the industry was evaluated per trimester from January through October 2021 using Index Based method. Some economic sustainability metrics were developed at production line/plant level and enterprise level in accordance to the six clusters given by Wanigarathne. The metrics were measured appropriately and the values obtained were normalized in the range 0 to 10 using a proposed model of Best case to Worst case scenario. The normalized values were used to evaluate the economic sustainability of the organization. From the results obtained, the economic sustainability fluctuated between 4.06 and 4.27 within the period of study with average value of 4.14. This result shows low sustainability and suggests that quick remedial measures should be employed to prevent the industry from going moribund.

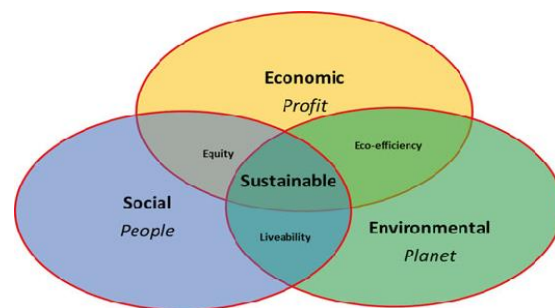
**Keywords:** Aluminium industry, economic, index-based method, sustainability

**\*Correspondence:** stanleync@gmail.com, 08034002149

### INTRODUCTION

So many industries have gone moribund as a result of incapacitation to control the factors that affect sustainability of the industries. Generally, the factors that influence the sustainability of production industries are referred to as metrics. Different metrics have different units and affects the sustainability of the industry at different degrees. One of the most commonly used engineering materials is aluminium. Aluminium is the third most abundant element in nature. The earth crust consists of about 8% aluminium [1]. Due to its importance in engineering critical study on the sustainability of its production is deemed necessary. All the factors that affect the sustainability of aluminium production should be critically examined as a measure to take decisions that favour the continuity of its production. Faulkner and Badurdeen [2] carried out a research on sustainability of Satellite Television Dish Production Line using index-based method. Economic sustainability index of 7.39 was obtained. Huang [3] carried out another research on sustainability and obtained an economic sustainability score of 3.38 at the enterprise level of a consumer electronics industry using index-based method. In this study, the economic sustainability of aluminium extrusion plant was studied using index-based method and the metrics were generated according to Wanigarathne *et al.* [4]. The essence of this study is to investigate economic sustainability of the industry at various levels as to enable stakeholders take decisions that favour economic progress of the organization.

Several definitions have been given for Sustainable Manufacturing (SM). Arguments have been raised that there is no commonly acceptable definition of that [5, 6]. However, the United States Environmental Protection Agency [7] defined sustainable manufacturing as “the creation of manufactured products through economically sound processes that minimize negative environmental impacts while conserving energy and natural resources. Aluminium industry, among others has always engaged strategies that favour sustainable manufacturing. To achieve this, all aspects of globally accepted Triple Bottom Line (TBL) concept of sustainable manufacturing which include economic benefits (profit), environmental soundness (planet), and social well-being (people) has been the focus, given as Figure 1. However, this study focuses on only economic sustainability. This is industrial approach to “life-cycle thinking” and management of products [8].



**Figure 1:** The Triple Bottom Line of Sustainability [8].

There are numerous SM tools and indicators which could be technically applied as basis for sustainability assessment. These indicators are; Life Cycle Assessment (LCA) [9], Dow Jones Sustainability Index (DJSI) [10], Walmart Sustainability Index [11], Global Reporting Initiative (GRI) [12] and more. In this work, the GRI approach was adopted due to its advancement in sustainable reporting and enables businesses, policy makers, investors and civil society to dialogue and make decisions favourable to sustainable development. The GRI guidelines have been voluntarily applied in over 1000 companies around the world [13]. Economic sustainability provides sustainable benefits to stakeholders with positive social impacts. Thus, when evaluating these impacts in sustainable manufacturing of an aluminium production company, the total life-cycle, including the four life-cycle stages (pre-manufacturing, manufacturing, use and post-use) must be emphasized. In addition, the 6R concept (Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture) needs to be implemented looking at its several benefits explained theoretically. The analysis of sustainable manufacturing is often done at different levels given as product level, process level, and systems level.

The systems level spans the *production line, plant and the enterprise*. In order to monitor and assess the progress towards systems level sustainability in the aluminium industry, it is necessary to develop key performance metrics at the production line, plant and enterprise levels. In this study, emphasis is on the system level. To promote sustainable manufacturing in aluminium industries, the sustainability performance of products, processes and systems must be considered simultaneously, with reasonable consideration of the impact of one aspect on the other. Comprehensive evaluations of sustainable manufacturing performance at the product and process levels have been given in previous studies [14, 15] and much work is yet to be done at the system level especially in evaluating manufacturing industries such as aluminium extrusion, textile, paint/building, automobile, agricultural equipment and more. Therefore, this study is an attempt to investigate the economic sustainability of aluminium extrusion in Nigeria using index-based method.

## MATERIALS AND METHODS

### Materials

The materials used in this work were basically the data collected from an Aluminium Extrusion Industry located in Inyishi, Imo State, Nigeria. The company manufactures aluminium profiles of various grades, sizes and shapes.

### Methods

The Index-based method was used for this study. According to Huang [3], the Index-based Sustainability Assessment Method is computed via four steps: metrics measurement, normalization, weighting, and aggregation. However, in this study, metrics identification was done prior to their measurement as shown in Figure 2.

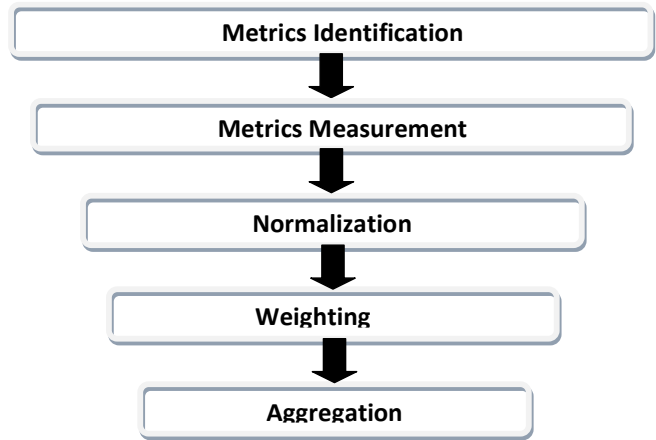


Figure 2: Research method in flow chart

A selection of 14 metrics at production line-plant level (LiSI/PlaSI) and 13 metrics at enterprise level (EnSI) were combined to determine the economic sustainability of the aluminium industry. The metrics were sourced from various units of the plant which include offices, archival documents, on-site observation and staff opinions in the months of January, April, July and October 2021. Data collection was done by 1-on-1 interviews with experienced staff and recording of various parameters such as energy consumption, materials, worker’s health, waste management and others at the production site. Some pictures taken at various units during data collection are shown in Plate I.



**Plate I:** Data collection at various departments A: Environmental; B: Product stack; C: Billet yard; D: Extrusion press

### Metrics measurement

Metrics are the sub-elements or parameters that have influence over the sustainability of production process. According to Wanigarathne *et al.* [4], the sustainability of a production process is influenced by environmental impact, manufacturing cost, personal health, energy consumption, operational safety and waste management as shown in Figure 3. On this basis, all the metrics considered in this study were extracted under the stated headings. The unit of each metric was assigned based on the industry standard. Table 1 shows the metrics at production line / plant level and enterprise level.

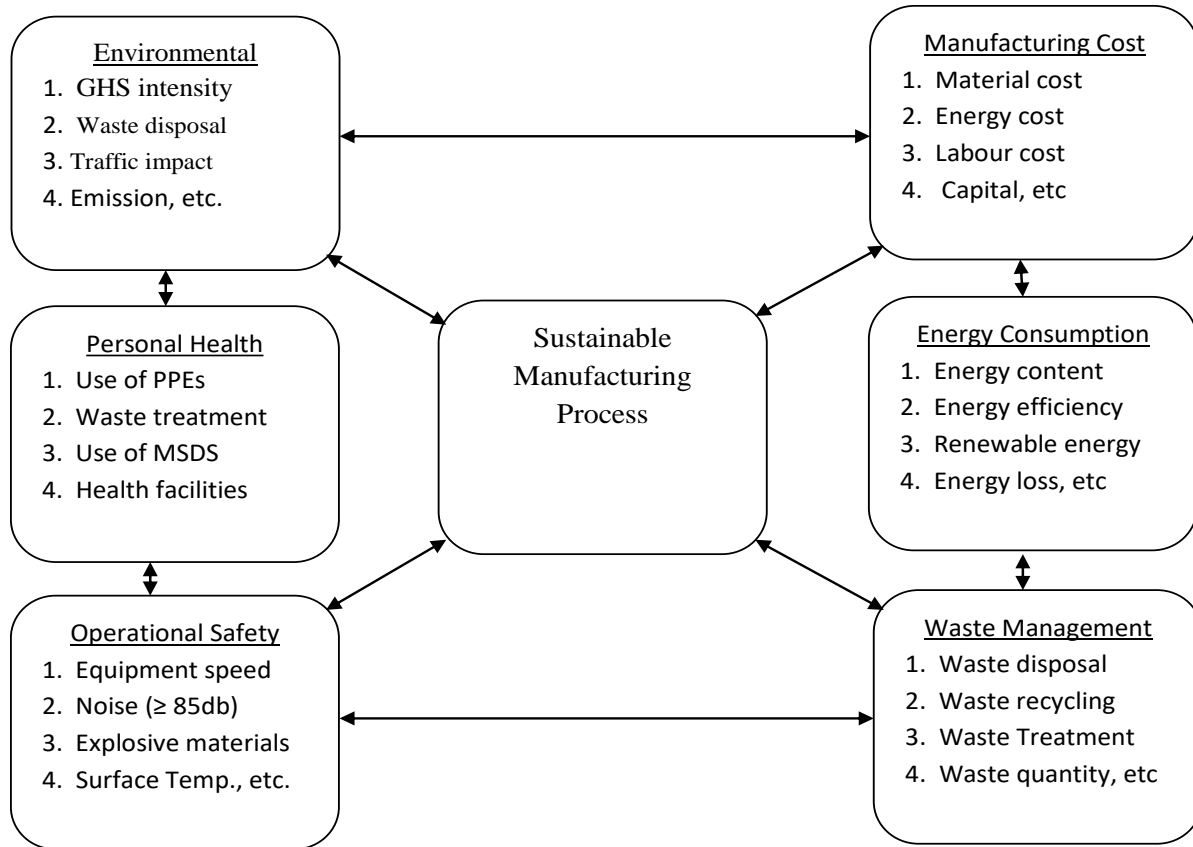
### Normalization

After data collection and metric measurement, the values obtained were normalized using a proposed model. Normalization process enables the measured data to be directly summed up together. The most

commonly used normalization methods are benchmark normalization, minimum-maximum and best case-worst case scenario [16, 17]. The best case-worst case scenario was used for this study. The best-case scenario gives value of normalized data at most favorable condition while the worse-case scenario gives value of normalized data at worst or critical condition. Based on this ideology, a model was proposed, which is deemed to be suitable for the set of metrics involved in this study.

### Model formulation

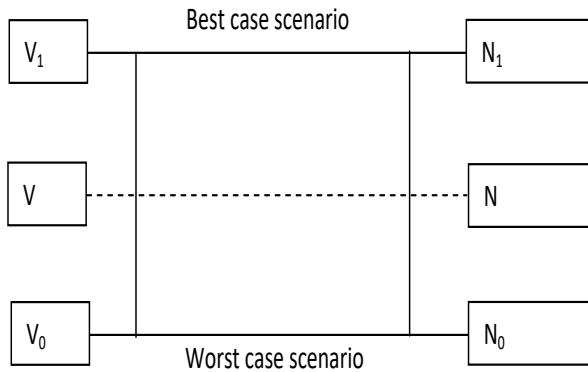
Following the best case-worst case scenario, the raw data obtained in this study were normalized using a proposed model illustrated as Figure 4.



**Figure 3:** Plant Sustainability Metrics and their major areas of influence.

**Table 1:** Metrics of Economic Sustainability at Production line/Plant level and Enterprise level.

<b>Metric</b>	<b>Definition</b>	<b>Units</b>
<b>Production line and Plant level</b>		
EC-L/P-1	Operation energy cost	₦/KWH
EC-L/P-2	Direct labour cost	₦/unit
EC-L/P-3	Product material cost (scrap cost per unit)	₦/Kg
EC-L/P-4	Maintenance cost	₦/unit
EC-L/P-5	Cost of PPE and other related equipment	₦/unit
EC-L/P-6	Non-operational energy cost	₦/unit
EC-L/P-7	Indirect labour cost	₦/unit
EC-L/P-8	Training cost	₦/unit
EC-L/P-9	Cost of waste disposal/treatment	₦/unit
EC-L/P-10	Cost of advert	₦/unit
EC-L/P-11	Production time input	hr/unit
EC-L/P-12	Time to market	hr/unit
EC-L/P-13	Productivity	%
EC-L/P-14	Labour efficiency	₦/KWH
<b>Enterprise Level</b>		
EC-ENT-1	Sales revenue	₦/unit
EC-ENT-2	Research and development	₦/unit
EC-ENT-3	Material cost per unit	₦/unit
EC-ENT-4	Energy	₦/KWH
EC-ENT-5	Labour	₦/unit
EC-ENT-6	Water	₦/unit
EC-ENT-7	Transportation cost	₦/unit
EC-ENT-8	Other expenses	₦/unit
EC-ENT-9	Taxes	₦/unit
EC-ENT-10	Inventory	₦/unit
EC-ENT-11	Facility	₦/unit
EC-ENT-12	Equipment	₦/unit
EC-ENT-12	Cost of capital	₦/unit



**Figure 4:** Schematic Illustration of the proposed model.

From Figure 4,  $V_1$  is a raw value of a metric obtained at best case of the plant system,  $V$  is an arbitrary value taken,  $V_0$  is the value obtained at worst case,  $N_1$  is the normalized value of  $V_1$ ,  $N$  is the normalized value of  $V$  and  $N_0$  is the normalized value of  $V_0$ . Using linear interpolation, the normalized value,  $N$ , obtained for any raw value  $V$  is given as in Equation 1.

$$\frac{V - V_0}{V_1 - V_0} = \frac{N - N_0}{N_1 - N_0} \quad (1)$$

According to Huang and Badurdeen [18], normalized values are taken within the range 0 to 10, which implies that  $N_0 = 0$  and  $N_1 = 10$ ; thus Equation 1 is simplified to obtain Equation 2 which was used to convert raw data to normalized values.

$$N = 10 \left( \frac{V - V_0}{V_1 - V_0} \right) \quad (2)$$

Since the normalized values would be taken within the range of 0 to 10, generally one can say that a score in the range 0-4 is “poor”; 4-6 is “average”; 6-8 “good” and 8-10 “excellent” [3]. In this study, a score of 5.0 represents average performance.

### Weighting

The next step when computing the sustainability assessment focuses on weighting the individual metric (element). Weighting permits assigning different levels of importance to each metric. A number of weighting

methods such as equal weighting, Analytical Hierarchy Process (AHP) and Budget Allocation Process (BAP), have been used [14, 16, 19]. Singh *et al.* [20] and Saaty [21] are related articles. However, no standard or universally applied weighting methods can be found in sustainability assessment studies. The Analytical Hierarchy Process was adopted in this study.

### Analytical hierarchy process (AHP)

The AHP is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Saaty in the 1970s. This method requires experts in a particular field to judge the importance of one element relative to another element by assigning numerical value to each based on its degree of importance. Based on the comparison the overall weighting factors can be generated [20, 21]. In this study, weight was assigned to each metric by three experienced staff of the company. Equation (3) was used to calculate the average weight of each metric.

$$W_F = \frac{1}{3}(W_1 + W_2 + W_3) \quad (3)$$

$$W_1 \leq W_2 \leq W_3 \leq W_F \leq 1$$

Where  $W_1, W_2$  and  $W_3$  are different weights assigned by different experienced persons for a metric and  $W_F$  is the average value.

### Aggregation

Aggregation is the final step in calculating sustainability index. Aggregation involves the classification of data into a cluster. The normalized data are systematically aggregated into the next higher level based on the weighting factors [3]. In this study, Equation (4) was used for aggregation.

$$Ec.EnSI = \frac{1}{2}(Ec.LiSI / PlaSI + Ec.EnSI) \quad (4)$$

Where  $Ec.LiSI / PlaSI$  is the economic sustainability index at production line and plant level while  $Ec.EnSI$  economic sustainability index at enterprise level.

**RESULTS**

**Table 2:** Economic Sustainability Assessment at Production/Plant level in January 2021 (Metrics and values)

<b>Metric</b>	<b>V<sub>0</sub></b>	<b>V<sub>1</sub></b>	<b>V</b>	<b>N</b>	<b>W<sub>1</sub></b>	<b>W<sub>2</sub></b>	<b>W<sub>3</sub></b>	<b>W<sub>F</sub></b>	<b>NW<sub>F</sub></b>
EC-L/P-1	90	50	50	10	0.65	0.8	0.7	0.72	7.17
EC-L/P-2	50	40	48	2	0.7	0.6	0.75	0.68	1.37
EC-L/P-3	70	45	55	6	0.5	1	0.85	0.78	4.7
EC-L/P-4	50	80	60	3.33	0.75	0.65	0.75	0.72	2.39
EC-L/P-5	90	70	82	4	0.75	1	0.7	0.82	3.27
EC-L/P-6	60	70	65	5	0.7	0.6	0.75	0.68	3.42
EC-L/P-7	50	80	70	6.67	0.7	0.6	0.75	0.68	4.56
EC-L/P-8	90	80	80	10	0.7	0.6	0.75	0.68	6.83
EC-L/P-9	70	50	60	5	0.5	1	0.85	0.78	3.92
EC-L/P-10	50	80	62	4	0.5	1	0.85	0.78	3.13
EC-L/P-11	4	3	3.2	8	0.65	0.8	0.7	0.72	5.73
EC-L/P-12	6	4	4.5	7.5	0.7	0.6	0.75	0.68	5.13
EC-L/P-13	60	80	75	7.5	0.5	1	0.85	0.78	5.88
EC-L/P-14	40	80	70	7.5	0.75	1	0.7	0.82	6.13

**Table 3:** Economic Sustainability Assessment at Enterprise level in January 2021 (Metrics and values)

<b>Metric</b>	<b>V<sub>0</sub></b>	<b>V<sub>1</sub></b>	<b>V</b>	<b>N</b>	<b>W<sub>1</sub></b>	<b>W<sub>2</sub></b>	<b>W<sub>3</sub></b>	<b>W<sub>F</sub></b>	<b>NW<sub>F</sub></b>
EC-ENT-1	20	50	30	3.33	0.65	0.8	0.7	0.72	2.39
EC-ENT-2	40	80	75	8.75	0.7	0.6	0.75	0.68	5.98
EC-ENT-3	50	40	45	5	0.5	1	0.85	0.78	3.92
EC-ENT-4	11	50	45	8.72	0.75	1	0.7	0.82	7.12
EC-ENT-5	90	50	50	10	0.65	0.85	1	0.83	8.33
EC-ENT-6	50	80	70	6.67	0.75	0.65	0.75	0.72	4.78
EC-ENT-7	50	70	55	2.5	0.75	1	0.7	0.82	2.07
EC-ENT-8	60	90	70	3.33	0.7	0.6	0.75	0.68	2.28
EC-ENT-9	50	70	57	3.5	0.65	0.8	0.7	0.72	2.51
EC-ENT-10	45	65	50	2.5	0.7	0.6	0.75	0.68	1.71
EC-ENT-11	50	60	60	10	0.5	1	0.85	0.78	7.83
EC-ENT-12	30	70	45	3.75	0.75	1	0.7	0.82	3.06
EC-ENT-13	30	60	40	3.33	0.65	0.85	1	0.83	2.78

**Table 4:** Economic Sustainability Assessment at Production line/Plant level and Enterprise level in April, July and October 2021

Metric	N(Ap)	W <sub>F</sub> (Ap)	NW <sub>F</sub> (Ap)	N(Ju)	W <sub>F</sub> (Ju)	NW <sub>F</sub> (Ju)	N(Oc)	W <sub>F</sub> (Oc)	NW <sub>F</sub> (Oc)
<b>Production line and Plant level</b>									
EC-L/P-1	10	0.72	7.17	10	0.72	7.17	10	0.7	7
EC-L/P-2	5	0.68	3.42	1.25	0.68	0.85	2	0.76	1.53
EC-L/P-3	6.8	0.78	5.33	5.65	0.78	4.43	6	0.78	4.7
EC-L/P-4	2	0.72	1.43	3.94	0.72	2.82	3.33	0.72	2.39
EC-L/P-5	5	0.82	4.08	2	0.82	1.63	4	0.82	3.27
EC-L/P-6	6.25	0.68	4.27	6.67	0.68	4.56	5	0.68	3.42
EC-L/P-7	8	0.68	5.47	6.67	0.68	4.56	6.67	0.68	4.56
EC-L/P-8	8.33	0.68	5.69	10	0.68	6.83	10	0.68	6.83
EC-L/P-9	4.12	0.78	3.23	5	0.78	3.92	5	0.78	3.92
EC-L/P-10	4.38	0.78	3.43	4.8	0.78	3.76	4	0.78	3.13
EC-L/P-11	5	0.72	3.58	8	0.72	5.73	8	0.72	5.73
EC-L/P-12	5	0.68	3.42	5	0.68	3.42	7.5	0.68	5.13
EC-L/P-13	8	0.78	6.27	7.92	0.78	6.2	7.5	0.78	5.85
EC-L/P-14	7.14	0.82	5.83	8.57	0.82	7	7.5	0.82	6.13
<b>Enterprise Level</b>									
EC-ENT-1	3.33	0.72	2.39	3.7	0.72	2.65	3.94	0.72	2.82
EC-ENT-2	8.89	0.68	6.07	9.21	0.68	6.29	8.81	0.68	6.02
EC-ENT-3	0.00	0.78	0.00	4.55	0.78	3.56	5.83	0.78	4.57
EC-ENT-4	8.75	0.82	7.15	9.44	0.82	7.71	8.68	0.82	7.09
EC-ENT-5	10	0.83	8.33	20	0.83	16.67	10	0.83	8.33
EC-ENT-6	7.14	0.72	5.12	8	0.72	5.73	6	0.72	4.3
EC-ENT-7	3.18	0.82	2.6	2.94	0.82	2.4	3.18	0.82	2.6
EC-ENT-8	4.29	0.68	2.93	3.57	0.68	2.44	3.1	0.68	2.12
EC-ENT-9	4.8	0.72	3.44	3.33	0.72	2.39	3.18	0.72	2.28
EC-ENT-10	3.48	0.68	2.38	2.63	0.68	1.8	3.33	0.68	2.28
EC-ENT-11	11.54	0.78	9.04	8	0.78	6.27	7.69	0.78	6.03
EC-ENT-12	2.41	0.82	1.97	4.21	0.82	3.44	3.95	0.82	3.22
EC-ENT-13	4.33	0.83	3.61	4	0.83	3.33	4	0.83	3.33

N(Ap) – Normalized values in the month of April

NW<sub>F</sub>(Ju) – Values of each metric in the month of July

W<sub>F</sub>(Ap) – Weighting factors in the month of April

N(Oc) – Normalized values in the month of October

NW<sub>F</sub>(Ap) – Values of each metric in the month of April

W<sub>F</sub>(Oc) – Weighting factors in the month of October

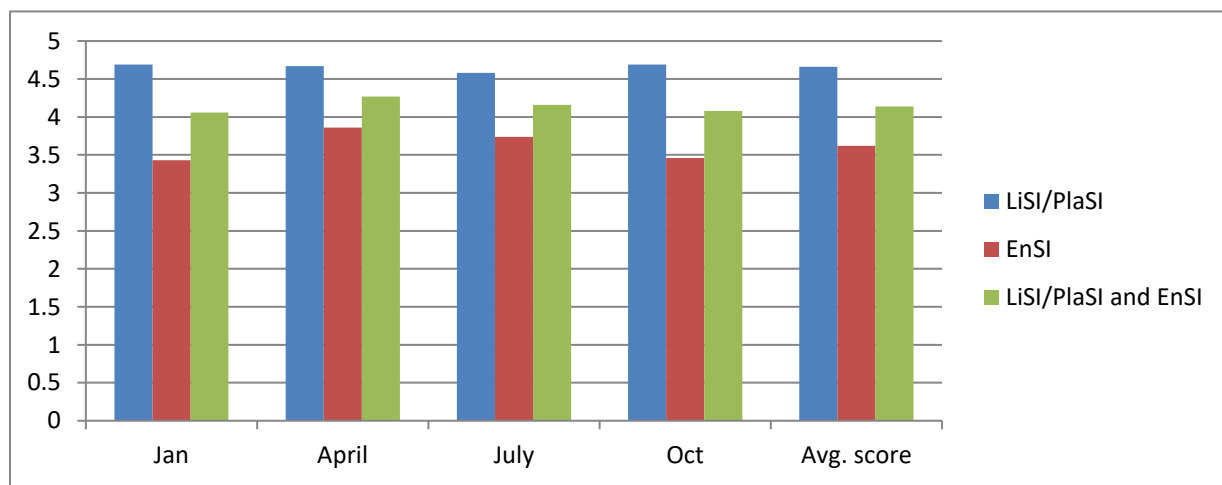
N(Ju) – Normalized values in the month of July

NW<sub>F</sub>(Oc) – Values of each metric in the month of October

W<sub>F</sub>(Ju) – Weighting factors in the month of July

**Table 5:** Summary of Economic sustainability Assessment in 2021.

Aspects	January	April	July	October	Sustainability score
LiSI/PlaSI	4.69	4.67	4.58	4.69	4.66
EnSI	3.43	3.86	3.74	3.46	3.62
LiSI/PlaSI and EnSI	4.06	4.27	4.16	4.08	4.14



**Figure 5:** Economic Sustainability Scores of the Industry in 2021.

## DISCUSSION

From Figure 5, it is seen that economic sustainability of the company at production line/plant level fluctuated between 4.58 and 4.69 within the period of study with average index of 4.66, as against an average index of 7.39 obtained by Faulkner and Badurdeen [2]. It is also seen that the highest score was recorded in the months of January and October. The highest score recorded in January might be as a result of new-year industrial policies, favourable to the economy; always implemented at the beginning of a year but followed with laxity as the year progresses. At enterprise level, the sustainability score is relatively low, and varied between 3.43 and 3.86 within the study period with average score of 3.62. This is similar to an average score of 3.38 obtained by Huang [3]. Improvements are mostly needed in the economic sustainability at the enterprise level of the aluminium extrusion industry. An effective approach to improving sustainability at the enterprise level is to periodically update the current assets of the company. The overall economic sustainability index, which includes production line/plant and enterprise levels varied between 4.06 and 4.27 with average score of 4.14. It is of great importance for industries to keep sustainability data/records to enable monitoring and areas of improvement in sustainability performance.

## CONCLUSION

Following the rating given by Huang [3], one may say that the economic sustainability of this industry is on average rating. Thus, proactive measures should be employed to prevent economic decline.

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