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Minimization of Root Causes of Declining Productivity in a Manufacturing Company: A Case Study of Jocalis Company

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Abstract
This presents a comprehensive methodology employed to identify and address declining productivity issues within the JOCALIS Aluminium Roofing Sheet Manufacturing Company Limited, situated in Onitsha, Nigeria. The study encompasses various manufacturing divisions, with a primary focus on aluminium roofing sheet production of three lines involve in production of red, black, and milk colour coated roofing sheet. The research aims to uncover the root causes of defects in the manufacturing process and develop effective strategies for improvement. Key methods include data collection through interviews, company records, library research, and internet sources, followed by data analysis and root cause identification. From the result obtained, the average availability of critical machine like the roller machine after root cause analysis is increased by 10.62%. Also, the average MTBF (mean time between failure) of the critical machine after root cause analysis is increased by 13.66% and MTTR (mean time to repair) is decreased to 46.42% respectively. The applications and general impact of this study includes enhancing machine availability, reducing downtime, increasing efficiency, optimizing maintenance practices, implementing preventive maintenance schedules, improving equipment diagnostics, and prioritizing root cause analysis to reduce breakdowns.

Keywords: Roofing Sheet, MTBF, MTTR, Productivity Improvement, Root Cause Analysis, Preventive Maintenance, Manufacturing Efficiency

1. Introduction

The manufacturing industry plays a pivotal role in the economic growth and development of nations, contributing significantly to employment, revenue generation, and overall industrialization, Mishra and Rao [1]. In Nigeria, the aluminium roofing sheet manufacturing sector has experienced substantial growth, providing roofing solutions to a burgeoning construction industry and meeting the demands of a rapidly urbanizing population, Oluwole [2]. One of the prominent players in this sector is Jocalis Aluminium Roofing Sheet Manufacturing Company Limited, situated in Anambra.

Over the years, Jocalis Aluminium has demonstrated its commitment to producing high-quality roofing sheets, contributing to the development of the construction industry in Nigeria. However, like many manufacturing enterprises, Jocalis Aluminium faces the ever-present challenge of ensuring sustained productivity and efficiency in its operations. Declining productivity can have adverse effects on the company's competitiveness, profitability, and ability to meet the growing demands of the market, Dinovitzer [3].

While Jocalis Aluminium has been successful in producing aluminium roofing sheets that meet industry standards, it has in recent times experienced a noticeable decline in productivity. This decline has manifested in various aspects of the company's operations, including output per hour, defect rates, downtime, and overall employee feedback. Productivity is a multifaceted concept, and its decline can be attributed to a combination of factors that may be interrelated, Chien *et al* [4].

One of the primary issues faced by Jocalis Aluminium is the increase in defect rates, resulting in rework and higher production costs. The defects not only lead to resource wastage but also impact customer satisfaction negatively and the company's reputation, Sousa *et al* [5]. Furthermore, increased downtime due to machine breakdowns and maintenance issues has led to production interruptions and decreased output per hour, Gosavi [6]. These challenges have financial implications for the company, as labour costs and operational inefficiencies rise, Ali and Ali [7].

The impact of declining productivity is not limited to operational aspects alone; it extends to the workforce. Employee feedback has indicated dissatisfaction with the current state of affairs, citing concerns about working conditions, machinery reliability, and overall morale,Appelbaum *et al* [8]; Hu *et al* [9]. Addressing these issues is crucial for maintaining a motivated and engaged workforce.

This research holds significance on several fronts. Firstly, it is of practical importance to Jocalis Aluminium as it seeks to enhance its productivity and competitiveness. Secondly, the study contributes to the broader manufacturing sector in Nigeria by shedding light on common challenges faced by manufacturers and offering potential solutions, Olajide and Kekong [10]. Lastly, it adds to the body of knowledge on productivity improvement strategies in manufacturing, with implications for industries beyond roofing sheet manufacturing (Li *et al*., 2020).

Jocalis Aluminium Roofing Sheet Manufacturing Company Limited's commitment to addressing the root causes of declining productivity is a critical step towards sustaining its growth, maintaining its reputation, and meeting the dynamic demands of the market. By understanding the underlying factors contributing to these issues, the company can adopt targeted strategies and interventions that will drive positive change and propel it toward a future of increased efficiency and competitiveness.

Productivity is a critical determinant of an organization's competitiveness, profitability, and long-term sustainability, Bhadury *et al* [11]. In the context of the manufacturing industry, where efficiency and quality are paramount, declining productivity can pose significant challenges, Gosavi [12]. This literature review explores the factors affecting productivity in the aluminium roofing sheet manufacturing sector, with a focus on the identification and minimization of root causes. While significant research has addressed productivity improvement in manufacturing, there is a need to contextualize these findings within the specific challenges faced by Aluminium Roofing Sheet Manufacturing Company Limited.

The Jocalis Aluminium Roofing Sheet Manufacturing Company Limited, located in Anambra, Nigeria, has been a significant contributor to the roofing sheet manufacturing sector. Manufacturing companies when run in smooth and effective processes plays a vital role in the construction industry and urbanization, Oluwole [13]. However, most manufacturing companies have recently encountered a pronounced decline in productivity across various operational facets, including output per hour, defect rates, downtime, and employee satisfaction, Chien *et al* [14]. This decline threatens the company's competitiveness, profitability, and capacity to meet market demands.

Increasing defect rates in some producing companies is a rising trend, leading to rework and elevated production costs. Defects not only result in resource wastage but also affect customer satisfaction and the company's reputation, Sousa *et al* [5].

Frequent machine breakdowns and maintenance issues (Downtime and Machine Breakdowns) have caused substantial production interruptions and decreased output per hour, Gosavi [6]. These challenges contribute to operational inefficiencies and financial implications for the company, Ali and Ali [7].

Employee dissatisfaction which implies the Employee feedback, indicates a growing dissatisfaction with working conditions, machinery reliability, and overall morale, Appelbaum *et al* [8]. This discontent poses a risk to workforce motivation and engagement.

Factors Affecting Productivity in Manufacturing

1. **Defects and Quality Control:** Defects in manufacturing processes can lead to increased rework, resource wastage, and customer dissatisfaction, Chien *et al* [14]. A study by Sousa *et al* [5]. emphasizes the importance of robust quality control practices in minimizing defects and improving productivity.
2. **Machine Reliability and Downtime:** Frequent machine breakdowns and maintenance issues contribute to unplanned downtime, leading to decreased output per hour, Ali and Ali [7]. Gosavi [6] highlights the significance of preventive maintenance programs in minimizing disruptions.
3. **Employee Satisfaction and Engagement:** Employee morale and job satisfaction significantly influence productivity in manufacturing, Appelbaum *et al* [8]. Dissatisfied employees may exhibit reduced motivation and contribute to operational inefficiencies. Hu *et al* [16]. Stressed the importance of engaging employees in problem-solving and continuous improvement efforts.

Machine Failure

According to Nadler [15], when a piece of machinery fails it inevitably cost a company resources, time and money.

Main causes of Industrial Machine failure

The main causes of industrial machine failure include inadequate maintenance, corrosion, and misalignment (bearing failure, metal fatigue, accidents).

Steps to Prevent Equipment Failure

1. Establish a Maintenance Schedule
2. Eliminate potential defects
3. Utilize equipment monitoring

Although, a good number of research have been done using root cause analysis on machine reliability and availability, for different industries including aluminium sheet companies, to optimize the productivity of the company and suggested various maintenance strategies, but no research work yet on the application root cause analysis of JOCALIS Aluminium Roofing Sheet Manufacturing Company Limited, situated in Onitsha, southern part of Nigeria, to detect the machine failure in three different production lines (red, black, and milk colour coated roofing sheets) of the company and suggest remedy to increase the machine efficiency.

2. Materials and Methods

In this section, we provide a comprehensive overview of the methodology employed in the pursuit of identifying and mitigating the root causes of declining productivity within JOCALIS Aluminium Roofing Sheet Manufacturing Company Limited, located in Onitsha, Nigeria. A robust and well-structured methodology is fundamental to the success of this research endeavour, as it underpins the systematic investigation and strategic interventions aimed at restoring productivity in the aluminium roofing sheet manufacturing sector. This section serves as a roadmap, guiding readers through the systematic journey of inquiry that characterizes this study. Fig 1 presents the process flow chart of the study.

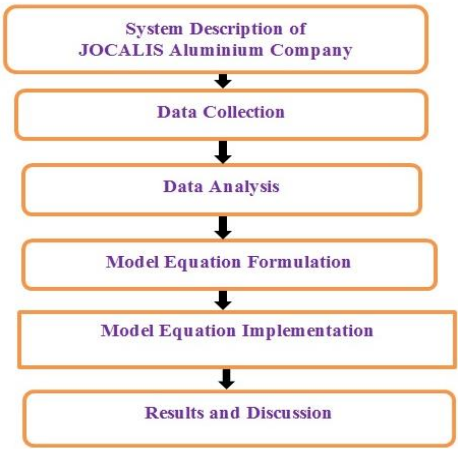

Fig 1: The Process Flow Chart of the Methodology

Methods of Data Collection

The materials used for this research include the following:

1. Oral interview/interaction with some selected staff of JOCALIS Aluminuim Industry.
2. Use of the company's journals/magazines/bulletins and data storage systems.
3. Use of the libraries.
4. Research on internet.
5. Maintenance log sheets.

Data Analysis

From the questionnaires retrieved and oral interrogation, the following data were collected on the production department and tabulated.

Data Analysis on the Labour

As of the time of this research, the company is made up of 130 workers, functioning at the production line department, which are grouped in skilled and unskilled. Table 1 presents the number and classification of the workers.

Table 1: Labour (Production Department)

Job designation	Number
Casual workers	17
Operators	50
Artisans	20
Forklift drivers	6
Machine specialists	14
Team leaders	8
Maintenance planners	2
Maintenance controllers	3
Logistic controller	1
Unit managers	1
Packaging Engineer	1
Packaging manager	1
Others (clerks, administrative officer)	3
Total	130

The percentage of unskilled workforce from the above data is 17.7% which includes all the casual workers, while the remaining 82.3% are taken by skilled staffs.

Data Analysis on the System Maintenance

In as much as all (including the casual workers) participate during a maintenance session, it is the sole responsibility of some key people in the department known as the "asset care" to drive it. A planned maintenance session lasts an average of 8hours weekly although sometimes exceeds that due to some unplanned events that will result in the course of the maintenance session but ideally, the shift in which a maintenance session was carried out is meant to start up and stabilize the line for the incoming shift to start up full production. Triggers for maintenance include original equipment manufacturer (OEM) recommendations, breakdown Parreto chart, and regular 8hourly weekly plan, machine cycle hour (also known as preventive or scheduled maintenance). Table 2 presents the data collected from the maintenance questionaries.

Table 2: The Maintenance Team Composition (Asset care)

Job designation	Number
Casual workers	17
Operators	50
Artisans	20
Forklift drivers	6
Machine specialists	14
Team leaders	8
Maintenance planners	2
Maintenance controllers	3
Logistic controller	1
Unit managers	1
Packaging Engineer	1
Packaging manager	1
Others (clerks, administrative officer)	3
Total	130

In addition, we collected data on maintenance costs over a one-year period within the scope of our research on 'Identification and Minimization of the Root Cause of Declining Productivity in JOCALIS Aluminium Roofing Sheet Manufacturing Company Limited, Onitsha.' Notably, these maintenance costs primarily encompass expenditures on machine parts and aluminium sheet product, with a specific focus on achieving a target cost of N1,350.75 ($1.5) per square meter of product. The comprehensive breakdown of these maintenance costs over the course of a year is presented in the Table 3, while further analysed on a chart in Fig 3.3.

Table 3: Maintenance Cost (From August 2021 to July 2022)

Month	Maintenance Cost in Naira (#)
August	10,863,792.93
September	10,072,550.51
October	13,360,266.22
November	15,388,173.04
December	12,825,811.26
January	19,735,682.48
February	21,975,705.88
March	19,607,159.38
April	12,023,906.46
May	13,485,335.19
June	18,929,708.97
July	14,836,231.43

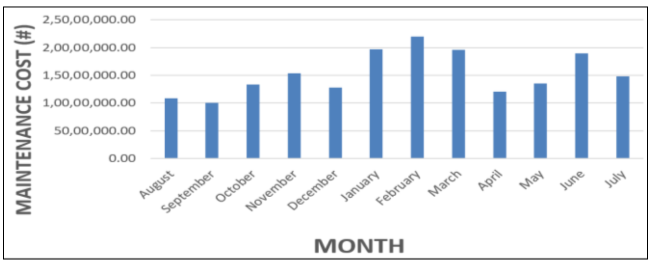

Fig 2: The Maintenance Cost Chart over a Period of 12 Months

Machines used and its Performance

This section presents three lines production used by the company, each line possesses the same production process and machine, the data collected runs from August - July 2022 (12 months). Table 4 - 6 presents the machines used in the product manufacturing, packaging, its break down pattern, and monthly down time frequency information at the three lines.

Table 4: The Production Break Down Pattern and Down Time Record Over a Year Period in Line 1 (Red Coated Line)

Machine/ Downtime incurred (mins)	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Rolling Mills	249	181	262	193	106	128	170	143	127	148	233	167
Shearing Machines	212	190	175	168	159	173	148	157	123	106	154	1183
Coating Machines	40	17	54	16	70	55	69	56	102	33	159	17
Annealing Furnaces	37	34	46	122	18	37	154	109	123	44	69	106
Slitting Machines	255	313	196	249	332	149	271	178	136	114	228	143
Laminators	146	209	241	268	270	183	174	162	198	187	175	162
Cutting Machines	447	359	182	355	277	319	452	313	285	177	184	464
Extrusion Machines	179	183	113	172	209	216	177	185	162	152	138	173
Stamping Presses	258	309	352	388	371	358	260	359	318	264	208	354
Welding Machines	2372	1300	1269	1311	1362	1481	1533	1540	1451	1316	438	1515
Casting Equipment	147	146	150	175	108	131	239	176	138	144	105	152
Quality Control Equipment	102	110	97	148	116	129	133	154	162	184	175	116
Material Handling Equipment	48	20	59	162	83	179	156	108	137	44	66	40
Forklifts	56	140	136	104	16	29	437	153	116	145	179	188
Conveyors	129	136	187	152	329	326	148	176	179	168	174	47
Cranes	871	583	742	651	718	577	950	500	471	586	612	347

Table 5: The Production Break Down Pattern and Down Time Record Over a Year Period in Line 2 (Black Colour Coating)

Machine/ Downtime incurred (mins)	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Rolling Mills	288	362	183	199	332	401	258	179	186	177	181	149
Shearing Machines	178	264	192	338	491	414	258	439	662	173	189	155
Coating Machines	76	88	162	179	183	189	131	168	213	175	136	111
Annealing Furnaces	108	113	169	183	316	200	188	169	254	183	179	158
Slitting Machines	137	399	448	1200	1662	983	179	567	540	622	181	162
Laminators	192	189	266	362	165	249	133	142	185	194	188	199
Cutting Machines	207	319	347	1320	545	300	520	680	159	180	135	375
Extrusion Machines	48	117	250	310	281	158	179	188	291	542	163	540
Stamping Presses	922	1822	2610	1458	933	820	1336	1740	670	515	1860	1774
Welding Machines	3106	4000	2860	3008	1924	2664	1843	1680	1720	1740	3312	2740
Casting Equipment	206	331	147	326	558	729	184	1677	156	170	228	476
Quality Control Equipment	18	142	196	181	37	48	69	77	52	161	183	151
Material Handling Equipment	27	184	166	175	189	105	260	149	182	171	233	168
Forklifts	49	66	39	45	69	54	168	25	90	77	86	50
Conveyors	126	121	201	316	289	143	116	185	178	109	74	132
Cranes	330	1640	1380	1744	2960	183	1055	329	1770	2080	1489	1622

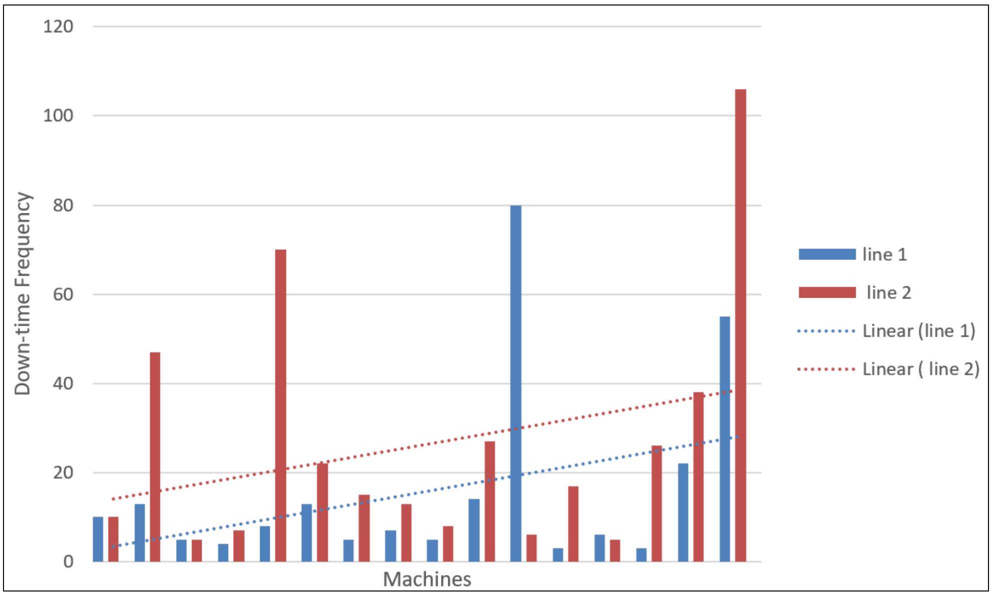

Fig 3: Average Machine Down-Time Frequency in Production Line 1 And 2

Table 6: The Production Break Down Pattern and Down Time Record Over a Year Period in Line 3 (Milk Colour Coating)

Machine/ Downtime incurred (mins)	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Rolling Mills	116	123	146	310	187	139	105	122	138	84	164	114
Shearing Machines	185	148	137	1558	1670	189	1532	800	175	182	176	338
Coating Machines	14	0	152	136	144	37	162	173	15	100	33	9
Annealing Furnaces	170	199	164	138	133	115	244	283	154	166	150	33
Slitting Machines	29	118	262	138	175	132	152	109	154	148	166	130
Laminators	2662	149	344	633	312	209	423	313	123	144	14	178
Cutting Machines	146	520	844	167	132	53	343	518	545	332	155	196
Extrusion Machines	116	240	174	134	544	298	651	371	359	243	257	173
Stamping Presses	181	374	218	196	266	149	200	159	186	247	446	224
Welding Machines	337	527	332	1186	1006	499	176	1526	1340	1265	1255	1118
Casting Equipment	0	9	0	0	11	315	38	152	166	174	122	06
Quality Control Equipment	420	365	172	199	155	318	568	196	186	742	195	187
Material Handling Equipment	250	337	215	378	179	210	111	371	459	236	380	494
Forklifts	314	387	143	379	118	273	429	208	353	409	437	513
Conveyors	800	193	222	148	160	187	415	387	208	177	162	349
Cranes	12	140	169	133	141	283	164	140	139	122	1440	386

This downtime occurs in bits but after the day's job, an average of 5hours is lost daily and this has some consequences, for instance output target not met, therefore the company losses money, machine, and other factory efficiencies are equally not achieved.

Analysis of the Cost Implication of an Hour Down Time Incurred from the System

Using the data provided above for the various line capacities, an analysis was carried out to ascertain the level of lost money wise incurred in an hour down time and the result is as follows:

For Aluminium Roofing Sheet Production line 1:

Line capacity = 28,000 sheets per hour

Numbers of sheets per company complete product package in a bundle = 12

Quantity produced/hour = 28000 ÷12 = 1708 sheets per hour (approximately)

12 sheets make a bundle therefore quantity of bundles produced per hour

A sheet of red colouraluminium roofing sheet is sold at the rate of #1370 by the company which implies that in an hour the company makes or loses 1708 X #1370 = **#2,339,960** on downtime for line1

For Aluminium Roofing Sheet Production line 2:

Line capacity = 40,000 sheets/hour

Numbers of sheets per bundle = 12

Quantity produced per hour (in bundle) = 40,000 ÷ 12 = 3333 bundles per hour (approximately)

Cost per sheet = #1370

Therefore, the cost in an hour downtime = N1370 × 3333 bundles = N4,566,210

This implies that the company loses on black coated metal roofing sheet is **#4,566,210** in an hour's downtime for line 2.

For Aluminium Roofing Sheet Production line 3:

Line capacity = 35,000 sheets/hour

Numbers of sheets per bundle = 24

Quantity produced/hour (bundle) = 35,000 ÷ 24 = 1458 bundles per hour (approximately)

Cost per bundle = #1950

Therefore, the cost in an hour downtime = N1950 × 1458 bundles = #2,843,100

This implies that the company loses on the milk colour coated metal roofing sheet is **#2,843,100** in an hour's downtime for line 3.

In the course of this work, machine has been identified as the common source of loss time in JOCALIS Aluminuim Roofing Sheet LTD Onitsha, which at times runs into hours. In fact, on an average 15-20 minutes production time is lost every hour. This has posed a great concern as the factory is running below its efficiencies.

Model Equation Formulation/Implementation

The expression to define the reliability is given as:

$$R(t) = 1 - F(t) \quad (1)$$

Hence *R(t)* is the reliability also called the survivor function. This is defined as the probability of operation without failure to time. *F(t)* is the cumulative failure distribution function (CDF). In reliability *F(t)* is the probability that randomly chosen part will fail by time *(t).*

A life time distribution model F(t) is the probability density function (PDF) over the time range 0 to ∞ (infinity). The relationship between CDF and PDF is illustrated below:

$$F(t) = \int_0^t F(t^1)dt^1 \quad (2)$$

$$f(t) = \frac{d}{dt} F(t.) \quad (3)$$

Hazard Rate H(t)

This also known as the instantaneous failure rate, is the probability that a failure will occur in the next time interval divided by the reliability R(t). It is mainly for non-repairable material.

The probability of normal operation up to a given time is called reliability;

$$h(t) = \frac{f(t)}{R(t)} = \frac{F(t)}{1-F(t)} \quad (4)$$

It can also be written as

$$h(t) = \frac{-1dRt}{R(t)dt} \quad (5)$$

Which is equivalent to

$$h(t) = \frac{-d}{dt}\ (lnR.t) \qquad (6)$$

The integral of the hazard rate is the cumulative failure rate (cumulative hazard rate).

$$H(t) = \int_0^t h(t^1)dt = \ln Rt$$

$$\rightarrow H(t) = \int_0^t h\,(t^1)dt = -\ln R(t) \qquad (7)$$

Reliability Distribution

The hazard rate *h(t)* or instantaneous failure rate
Since *R(0)* = 1 (perfect reliability)
No failure at time of zero
The reliability rate over a time period t is

$$R(t) = e^{-\int_0^t h(t)^1 dt^1} \qquad (8)$$

This also termed mean time to failure (MTTF) more specifically, the mean time to failure

$$MTTF = 1 = \int_0^\infty tf(t)\,dt \qquad (9)$$

The Bathtub Curve

The distribution of failures over the life time of a product population is initially important to the detection of reliability physics. Using these concepts hazard rate that changes over the life time of the product starting high, reducing and increasing towards the end of the product life is termed the bathtub curve.

The population will have defective items that will fail within the first few weeks to months of the product life time (infant mortality) is termed the bathtub curve because of the shape of the curve itself. An ideal life time distribution failure behaviour is to eliminate the failures due to defects in the infant mortality portion of the curve through born-in and /or defect reduction programs and do not operate the product into the wear out phase. The operational life is within the typical constant hazard rate section of the curve for proper life time distribution modelling, individual failure mechanisms must be modelled independently and there must be only one population. If there are multiple populations (or subpopulation) within the data must be individually extracted and statically analysed as single populations. There is various time to failure distributions to express population life time behaviour statically, three popular statically reliability distributions are to be expended, they are exponential distribution. Weibull distribution and the lognormal distribution.

The Exponential Distribution for Calculation of Failure Rate and Reliability

The exponential distribution is the least complex of all life time distributions models. The failure rate or hazard rate *h(t) = λ*. The failure rate is a constant in this model which is suitable for the stable for failure rate regime.

$$\rightarrow R(t) = e^{-\lambda t} \qquad (10)$$

$$F(t) = 1 - e^{-\lambda t} \qquad (11)$$

$$f(t) = \lambda\, e^{-\lambda t} \qquad (12)$$

The mean time to failure of the exponential function is simply the inverse of the failure rate

$$MTTF = {}^{1}/_{\lambda} \qquad (13)$$

The Weibull Distribution for Calculation of Failure Rate and Reliability

The Weibull distribution is used to fit various shapes of reliability curves. The Weibull function can be expressed in multiple ways. The Weibull expression below is the probability of survival *R (t)* between time zero and time.

$$R(t) = e^{-(\frac{t-y}{\alpha})^{\beta}} \qquad (14)$$

There are three Weibull reliability curve pit parameters in even the basic form of the Weibull function. They are:

1. B = the shape parameter
2. Y = the location parameter also known as the detect initial on time parameter
3. α = the characteristic life scale parameter.

This Weibull can have variants, the two-parameter distribution. The difference between the two variants is whether or not failures start at time zero. If failure does start at a time zero, the defeat initiation time parameter (also known as location parameter) is zero and Weibull exponential expression is reduced to.

$$R(t) = e^{-\left(\frac{t}{\alpha}\right)^{\beta}} \qquad (15)$$

When β = 1 equation 3.15 becomes the exponential model 3.10 with β = ${}^{1}/_{\lambda}$

The two-parameter fit model is commonly used in reliability life predictions. The PDF off the two parameter Weibull model

$$f(t) = \frac{\beta}{t}\left(\frac{t}{\alpha}\right)^{\beta} e^{-\left(\frac{t}{\alpha}\right)^{\beta}} \qquad (16)$$

$$F(t) = 1 - e^{-\left(\frac{t}{\alpha}\right)^{\beta}} \qquad (17)$$

The cumulative failure rate of the two parameters Weibull model (cumulative hazard rate) is expressed as:

$$H(t) = \left(\frac{t}{\alpha}\right)^{\beta} \qquad (18)$$

The lognormal Distribution for Calculating Failure Rate and Reliability

The other popular statistical distribution is the lognormal time to failure distribution is as it is named. The lognormal distribution is also called the Gausian distribution PDF.

$$f(t) = \frac{1}{\delta t\sqrt{2\pi}}\, e^{\{-\ln(t) - \ln(T50)\}^2} \qquad (19)$$

$$F(t) = \int_0^t \frac{1}{\delta t\sqrt{2\pi}} e\{-ln(t) - ln(T50)\}^2 dt \qquad (20)$$

3. Results

The company sets out some key performance indicators (KPI) which they use to measure factors that are crucial to their business success in their effort to achieve and sustain their vision/mission statements, for production department, these KPI' are hardly achieved as a result of the frequent machine failures. The KPI' are chosen based on what is important to the company's success. The KPI's that usually calls for concern in the production unit are: Factory Efficiency, Adjustable Factory Efficiency, Machine Efficiency, Compliancy to Plan, Line Efficiency, Operating Efficiency, and Availability. The outcome of others. The above mentioned are measured in percentage (%). The incessant machine unavailability has made these KPI's seem unrealistic as the company month after month cannot meet up with its target and KPI's.

Table 7: Downtime Sources, Frequency, and its Degree of Occurrence

Downtime source	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Machine	17318	18216	17571	21811	20811	15516	18061	18691	16236	15852	17666	18584
Operational (man)	10	0	0	5	13	0	0	4	0	0	0	27
Materials	175	277	180	21	115	228	217	101	156	108	138	115
Accident	0	0	0	1	0	0	0	0	0	2	0	0
Utilities supply	215	305	117	205	414	59	65	72	137	149	162	138
Program/software error	12	34	15	0	33	68	49	12	0	4	10	41
Others (jam, trip, dirt carryover etc)	50	44	13	51	62	38	66	75	49	22	61	17

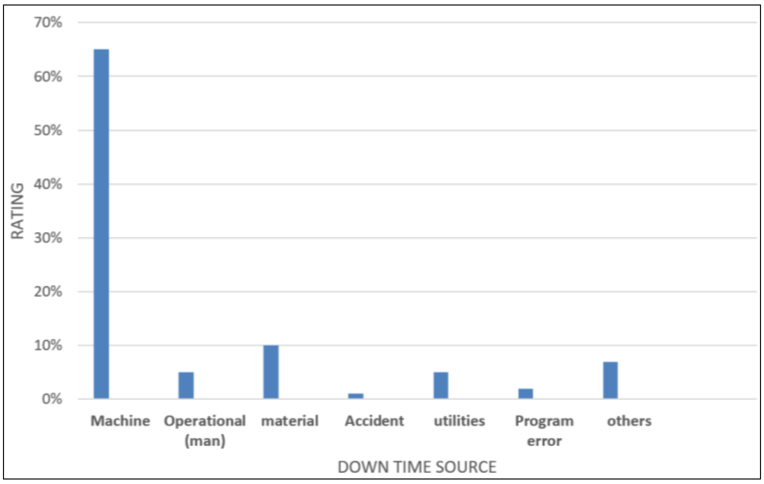

Fig 4: Graphical Representation of Average Downtime Sources

Table 8: KPI'S Over the Last Twelve Months

Type of Efficiency Line 1 (Red Coated)	Target (%)	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MRCH	APR	MAY	JUNE	JULY	AVER
Machine Efficiency	99	83	83	83	83	83	83	83	83	83	83	83	83	84.23
Factory Efficiency	88	67	75	70	68	72	66	70	59	71	73	59	51	66.75
Operating Efficiency	95	74	68	75	72	66	70	61	66	61	62	68	66	67.42
Line Efficiency	92	70	74	71	74	75	71	72	67	69	7369	69	64	70.75
Compliancy to Plan	98	69	71	68	69	70	68	66	59	62	70	67	61	66.67
Line 2 (Black Coated)														
Type of Efficiency	**Target (%)**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MRCH**	**APR**	**MAY**	**JUNE**	**JULY**	**AVER**
Machine Efficiency	99	77	79	82	75	81	77	80	69	76	78	80	82	79.62
Factory Efficiency	88	65	67	71	45	71	69	65	66	73	68	71	69	66.75
Operating Efficiency	95	76	71	69	71	83	77	71	74	61	70	72	68	71.92
Line Efficiency	92	69	70	70	66	79	70	70	68	72	73	70	66	72.15
Compliancy to Plan	98	67	74	77	62	68	64	68	65	71	73	79	72	70.00
Line 3 (Milk Coated)														
Type of Efficiency	**Target (%)**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MRCH**	**APR**	**MAY**	**JUNE**	**JULY**	**AVER**
Machine Efficiency	99	78	77	72	78	76	73	79	70	75	68	75	69	76.08
Factory Efficiency	88	80	81	86	82	79	73	64	72	85	83	77	71	77.75
Operating Efficiency	95	87	81	89	72	83	77	75	72	55	82	79	88	78.33
Line Efficiency	92	77	84	83	89	83	75	71	68	65	80	73	71	76.58
Compliancy to Plan	98	73	83	85	88	85	71	70	71	69	79	75	73	76.83

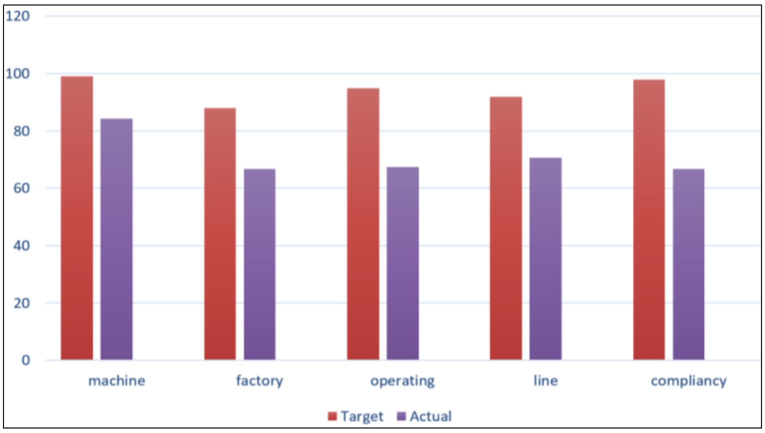

Fig 5: Various KPI Efficiencies for line 1

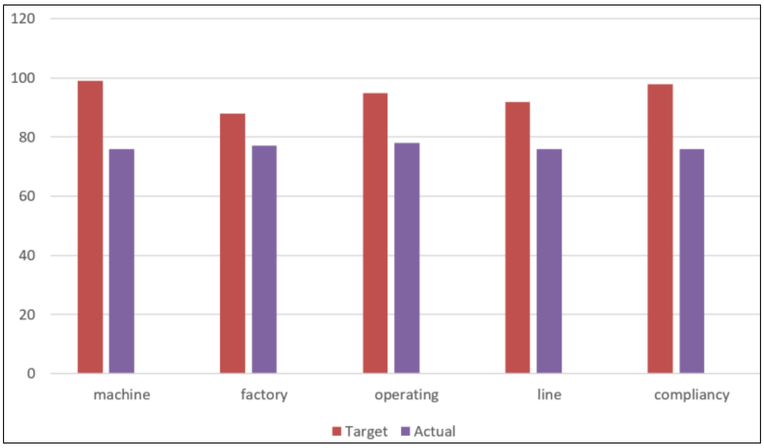

Fig 6: Various KPI Efficiencies for line 2

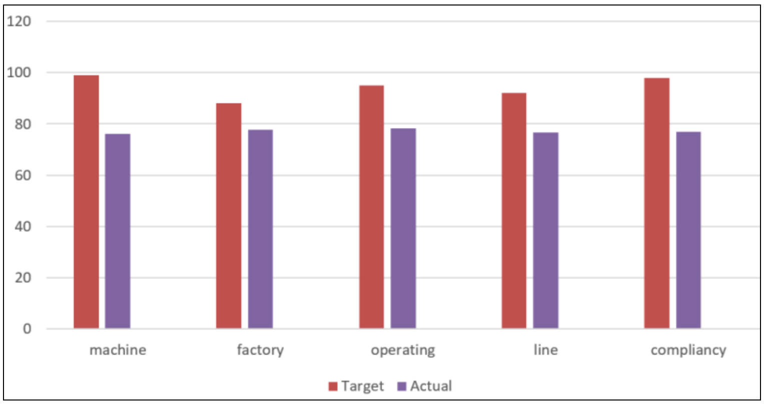

Fig 7: Various KPI Efficiencies for Line 3

Table 9: Quantity of Aluminium Roofing Sheet Produced in a Year (Aug 2021 and July 2021)

Month	Plan	Actual
August	Line 1= 128,000 Line 2 =1,817,000 Line 3 =4,000 **Total =1,949,000**	Line 1= 12,960 Line 2 =1,669,028 Line 3 =3,260 **Total = 1,685,256**
September	Line 1=78,000 Line 2 =1,674,000 Line 3 = 106,000 **Total =1,858,000**	Line 1=167,359 Line 2 =1,580,815 Line 3 = 49,918 **Total = 1,748,174**
October	Line 1=279,000 Line 2 =1,724,062 Line 3 =39,000 **Total = 2,042,062**	Line 1=196,705 Line 2 =1,330,320 Line 3 = 41,985 **Total = 1,610,995**
November	Line 1=232,000 Line 2 =1,676,000 Line 3 =19,000	Line 1= 308,743 Line 2 =1,815,698 Line 3 =18,000

	Total =1,927,000	**Total =1,891,148**
December	Line 1=592,000 Line 2 =1,706,000 Line 3 =17,700 **Total =2,315,700**	Line 1= 759,884 Line 2 =1,815,698 Line 3 =78,857 **Total =2,654,439**
January	Line 1=439,900 Line 2 =1,430,000 Line 3 = 20,000 **Total = 1,889,900**	Line 1=559,283 Line 2 =1,390,217 Line 3 = 21,801 **Total = 1,971,301**
February	Line 1= 655,800 Line 2 =1,321,000 Line 3 = 52,450 **Total = 2,029,250**	Line 1= 648,117 Line 2 =1,193,476 Line 3 = 53,600 **Total = 1,895,193**
March	Line 1= 782,345 Line 2 =1,821,960 Line 3 =85,000 **Total =2,689,305**	Line 1= 719,594 Line 2 =1,586,680 Line 3 = 62,725 **Total =2,368,999**
April	Line 1=651,636 Line 2 =1,751,459 Line 3 =75,000 **Total = 2,478,095**	Line 1= 527,544 Line 2 =1,180,642 Line 3 =72,511 **Total = 1,780,697**
May	Line 1= 808,094 Line 2 =1,791,833 Line 3 = 55,000 **Total = 2,654,927**	Line 1= 726,239 Line 2 =1,584,528 Line 3 = 38,988 **Total = 2,349,755**
June	Line 1= 976,153 Line 2 = 1,869,084 Line 3 = 93,220 **Total =2,938,457**	Line 1= 875,496 Line 2 = 1,626,021 Line 3 = 91,304 **Total =2,592,821**
July	Line 1=790,007 Line 2 =1,164,500 Line 3 =55,450 **Total =2,009,957**	Line 1=612,085 Line 2 =1,036,604 Line 3 = 48,644 **Total = 1,697,333**

Table 10: Summary of the Profit and Loss Incurred on the Companies Output

Month	**Plan**	**Actual**	**Cases Lost or Gained (Plan — Actual)**	**Loss /Profit Incurred [(Plan — Actual) X #1400 — Unit Cost of a Case]**
August	2,209,000	1,979,093	229,907 = **Lost**	321,869,800
September	2,131,000	2,132,645	1,645 = **Gained**	203,000 (profit)
October	2,276,237	1,831,194	445,053 = **Lost**	623,060,200
November	1,975.000	1,928,350	46,650 = **Lost**	65,310,000
December	2,748,700	3,091,630	342,930 = **Gained**	480,102,000 **(profit)**
January	2,334,900	2,269,089	65,811 = **Lost**	92,135,400
February	2,358,250	2,160,961	197,289 = **Lost**	276,204,600
March	3,056,201	2,726,382	329,819 = **Lost**	461,746,600
April	2,849,095	2,000,481	848,614 = **Lost**	1,188,059,600
May	2,992,438	2,570,401	422,037 = **Lost**	590,851,800
June	3,525,174	3,034,833	490,341 = **Lost**	686,477,400
July	2,260,507	1,921,202	339,305 = **Lost**	475,027,000

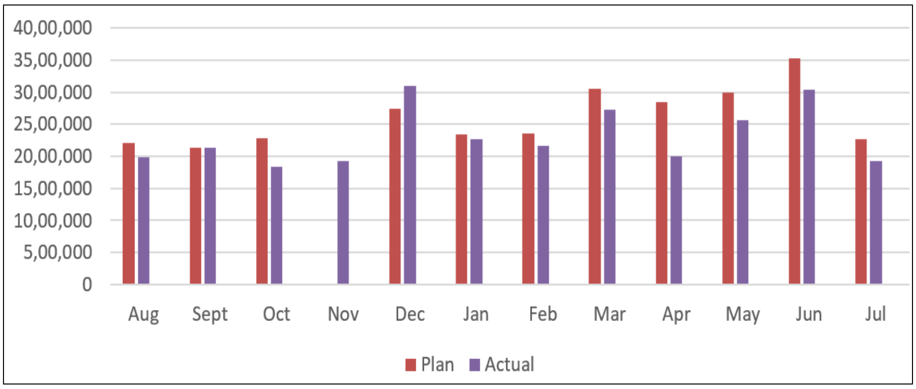

Fig 8: JOCALIS Company Production Plan/ Actual within a Year

4. Conclusion

This project was carried out on the machines in the production line of JOCALIS Aluminium Roofing Sheet Company LTD, Onitsha, Anamabra State, Nigeria. On this study, all repeated breakdowns were analysed along with the critical parts, which has been under breakdown condition is also identified and analysed. Also, the reason for the breakdown has been analysed and some of the tools of root cause analysis like 5-why analysis, fish bone diagram was integrated to identify the actual cause of the breakdown. By this analysis and methods, the root causes of the machine breakdowns were identified. This in turn helped to develop and improve a new preventive maintenance checklist for the machine. This method is used to prevent the failure of equipment before it actually occurs. The average availability of critical machine like the roller machine after root cause analysis is increased by 10.62%. Also, the average MTBF of the critical machine after root cause analysis is increased by 13.66% and MTTR is decreased to 46.42% respectively. After root cause analysis there is an improvement in the maximization of planned productivity, this is because of proper diagnosis of the existing system and by employing proper preventive maintenance schedule. Therefore, whenever a breakdown occurs, the root cause of the breakdown has to be identified. Then some efforts should be made to improve this system using root cause analysis and counter measures, such that similar type of breakdown can be reduced.

Therefore, in summary, this work resulted in reduced machine downtime during production, increased machine availability, increase in machine/factory efficiency by an increased MTBF (Mean Time Between Repair) and decreased MTTR (Mean Time to Repair), increased overall equipment effectiveness (OEE), improved safety and quality conditions, improved factory efficiency, improved adjustable factory efficiency, improved machine efficiency, improved compliancy to plan, improved line efficiency and improved operating efficiency. Furthermore, the general impact of this study impact includes: reduced overtime costs and more economical use of maintenance workers due to working on a scheduled basis instead of a crash basis to repair breakdowns, timely, routine repairs circumvent fewer large-scale repairs, reduced cost of repairs by reducing secondary failures, identification of equipment with excessive maintenance costs, indicating the need for corrective maintenance, operator training, or replacement of obsolete equipment and parts stocking levels can be optimized.

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