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SUMMARY

RESEARCH ARTICLE   **OPEN ACCESS**

STATISTICAL ANALYSIS FOR THE FINANCIAL REPORT FROM ENERGY STREAM/REVENUE IN IRANIAN SMALL AND MEDIUM-SIZED INDUSTRIES

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ARTICLE INFO	ABSTRACT
	The Environmental Impact Assessment (EIA) plan is an indispensable part of all cycles of industrial projects. By the way, it results to compose the initial matrix of data in the preliminary assessment of the screening step. Iranian industrial projects recognized miscellaneous material streams introduced into industrial ambient and in released shapes. One of the important assessments posed in the EIA plan refers to costs/revenue assessment that assigns Data Envelopment Analysis (DEA) to discover the performance of industrial projects along with statistical tests. The objective of the current study prosecuted to discern the cost/revenue analysis in statistical language. Therefore, the empirical equations and SPSS Software of IBM 20 were employed in the analysis of financial reports. The findings were succeeded to present linear relationships for the dependent and independent variables and in full compliance with diagrams developed by SPSS software. The results of the DEA model ended up with the emergence of an efficiency border for 8 industrial groups (334 industries) around a range of 0 to 0.4 by scatter plot. There were no significant differences between dependent and independent variables in different models assessed via T and F and ANOVA tests. It can be concluded that the findings of the DEA model displayed by the scatter plot are a benchmarking level for industrial projects once before complete construction.

I. INTRODUCTION

The scope of statistical science is such that its key role in all sciences is clearly evident today. In this article, only a brief description of the employed parametric tests is mentioned. Parametric tests are used to compare data with normal distributions. These tests should not be used if the data do not follow the normal distribution. For example, the ANOVA statistical test is used to compare the mean of a quantitative variable with the normal distribution in more than two groups to check whether the mean of that variable is the same among the groups. The T-test is used to compare the values of a quantitative variable in more than two groups (which may be two independent groups or one group at two different times). By accessing small quantities of two types of independent and non-independent variables, various functions can be defined. Methods such as regression analysis and least squares can be used to determine the type of function obtained from the values. These methods are mostly used in the preparation and evaluation of analytical grading charts [1, 2]. The dimension of a project depends on a variety of variables such as its capital, number of workers, production stream, and sales rates, etc. In the literature, the scale of small and medium-sized enterprises comprises up to 10, 50, and upper than 50 for micro, small and medium-sized industrial enterprises [3, 4].

Regardless of the dimension and scale of industrial projects all of them must go through the project identification steps in the EIA plan. The screening step of the EIA plan provides an inventory of availability in the initial assessment. Based on the initial assessment the framework of the project underpins financial and economic estimations, examining technologies and practices in the matrix of criteria and alternatives to select the best and optimized technology and moves to decision science theory. The public

involvement in the project also configures the pollutants discovery and many other aspects of projects. The review of alternatives and criteria in reports of EIA is an indispensable step that determines assigning and recruiting relevant technologies in this regard. The expert ideas are taken into consideration in this step. After completing the review process and examining the alternatives, the decision comes into view with the reports of financial & economic stability of the project. After this step project moves towards the implementation step and sustainability of the project is requested in the post-EIA plan [5-8].

DEA is a prominent efficiency assessment instrument that has widely employed in a variety of sciences these days. The configured DEA models comprised from CCR, BCC, IRS, DRS, GRS, AR (Assurance Region), NCN (Non-Controllable), NDSC (Non-Discretionary), BND (Bounded Variable), CAT (Categorical Variable), SYS (Different Systems), SBM-Oriented (Slacks-based Measure), SBM-NonOriented, Weighted SBM, Super-SBM-Oriented, Super-SBM-NonOriented, Super-Radial, Cost-GRS, New-Cost-GRS, Revenue-GRS, New-Revenue-GRS, Profit-GRS, New-Profit-GRS, Ratio (Revenue/Cost), Bilateral, Window, FDH, and Malmquist-Radial. The traditional DEA model was used in the performance analysis of 8 industrial groups of projects by the present study. The Friedman test is a statistical test in the pack of SPSS software and similar to the F test. It was applied as both ranking and weighing systems in Multi-Criteria Decision Making models in a situation of uncertainty [9, 10].

The objectives discussed by the current research encompass (1) developing a linear function based on recent costs of energy and revenue of products streams in the market of Tehran, Iran (2) conducting a regression analysis based on dependent (revenue) and independent (costs of energy stream) variables by SPSS software and empirical equations (3) investigating performance of industrial projects (8 groups of industrial projects individually) once before complete construction via DEA model displayed by scatter plot (4) introducing statistical tests to figure out significant differences between values and further analysis (any possible test). The novelty of the present research refers to the development of a linear function based on recent costs of energy and revenue of products streams (extracted from screening step of industrial projects in EIA plan) in the market of Tehran, Iran.

II. LITERATURE REVIEW

The financial efficiency of 85 Spanish insurance companies assessed by the DEA model and a linear regression plot depicted among the values obtained. Other statistical tests applied to further analyses of values. The variables employed in the DEA model encompassed 5 inputs and 1 output [11]. Shahroudi [12] developed a linear production function of $Y=2.44L0.081K0.97$, $\alpha+\beta\leq 1$; $Y=2.374L0.656K0.974$ via SPSS analysis of kaab Douglas for Iranian small-scale industries. The SPSS and Minitab software's applied to assess data of forty-five enterprises in Iran. The findings resulted in underpinning a model along with weighing indices [13]. The effects of sustainability of new industries have investigated by Madhoushi and Nasiri [14] to figure out the significant relationship between circumstances in the expansion of industries via cox model and SPSS analysis. The weight restrictions of the DEA model in distribution networks have been taken into consideration regarding input, total cost, and various outputs. To analyze the results, the regression model applied to find the aggregation of data around the line [15]. The statistical tests of regression, correlation, etc. assigned to analyze data of financial, and social performances (13 groups of industries). The expert idea distinguished the values

of weights of criteria. The significant differences among various alternatives determined [16]. The 51 Indian domestic banking industries have assessed to find the technical efficiency via both DEA and Tobit analysis during 2006-2007. It reported to average technical efficiency score of about 0.792. A scale efficiency deployed by significant differences caught up using SPSS software. The industries underwent ANOVA test, pair-wise comparison test, and stepwise regression by tabulated information [17]. The 29 datasets examined via conformal regression with uncertainty to guarantee predictions. Further analysis has done using boxplots, error bars, prediction error flow diagrams, etc. The prominent role of conformal regression proved in bioactivity prediction generation via confidence levels [18]. To evaluate the performance of Slovak enterprises in financial statement reports employed a prediction model along with multiple regression analysis from 2015 to 2016. The results provided important points to recede the risk of bankruptcy in the assessed cases. A significant difference, correlation had obtained via t-test and Pearson correlation test and coefficients [19]. Both regression and Tobit analysis models have used to investigate obtained performance ranks via the DEA model for Indian airlines from 2005 to 2012. The links among drivers of technical, operational, and market performances had assessed and suggested to select the technical efficiency as the best evaluator of performance indicator [20]. Conventional and Islamic banking have taken into an investigation in terms of profitability, efficiency, and liquidity factors from 2013 to 2017. The statistical parameters of t-test, ratio analysis, and regression analysis requested to discover the differences between the two systems of banking [21]. The impact of green manufacturing scrutinized in the organizational performance in India. The performance estimated through the regression analysis with one dependent and 5 independent variables. It resulted in developing linear equations and relationships with maximum and minimum fitness levels of 50.4% to 77.9% for lines. The further analysis had done via correlation tests and sensitivity analysis. Finally, many models introduced for financial performance evaluation along with simulation models and validation of them [22]. A study evaluated the operating performance of 14 shipping industries based on financial indicators of assets, stockholder's equity (input variables) operating revenue, and net income (output variables) via the DEA-CCR model. Also, regression analysis assigned for the same purpose, and the findings of both models compared each other. The findings in ranking systems were different in models. Also, the application of regression analysis examined in a linear relationship versus the efficient borderline of the DEA model. The input and output variables were the vertical and horizontal axis of the diagram [23]. The Indian automotive industries examined for performance analysis via Tobin and financial statement analysis based on costs of production, net value-added, fixed capital, number of workers from 1980 to 2007. The statistical analysis tests configured by one dependent and 11 independent variables. The coefficient robust z-value calculated for the independent variables. The negative and positive values of the coefficients tabulated by the way [24]. In the assessment of the performance of 25 Indian automobile companies applied data analysis mean, median, standard deviation as descriptive statistics & correlation, regression, ANOVA, the test of significance, and variety of other flow diagrams displayed in parallel with objectives followed with the present study from 2011 to 2015. A good statistical analysis conducted with valid results [25]. A dataset of 97 various kinds of Indian industries contains four groups considered to be assessed via statistical analysis such as t-test and mean difference, ANOVA test, etc. It resulted in identifying forty

percent of globalized industries [26]. The regression analysis requested for existing variables of Iranian chemical industries registered on the Tehran stock exchange from 2005 to 2010. The relationship between variables and significant differences, F and T-tests investigated. The linear relationships among variables of operating profit, net profit, and cash flows had proved. There were no significant differences between dependent and independent variables in different models assessed [27].

III. METHODOLOGY

The initial data of industrial projects were collected from in-charge organizations of both Iranian industries and Iranian protection agency. The data were evaluated by the evaluator team in the screening step of the EIA plan. The screening step of industrial projects was provided the required information for the initial assessment. Then data were divided into two sections such as costs of energy and revenue of products. The below-mentioned tests were assigned to find the performance of industrial groups of projects according to Figure 1.
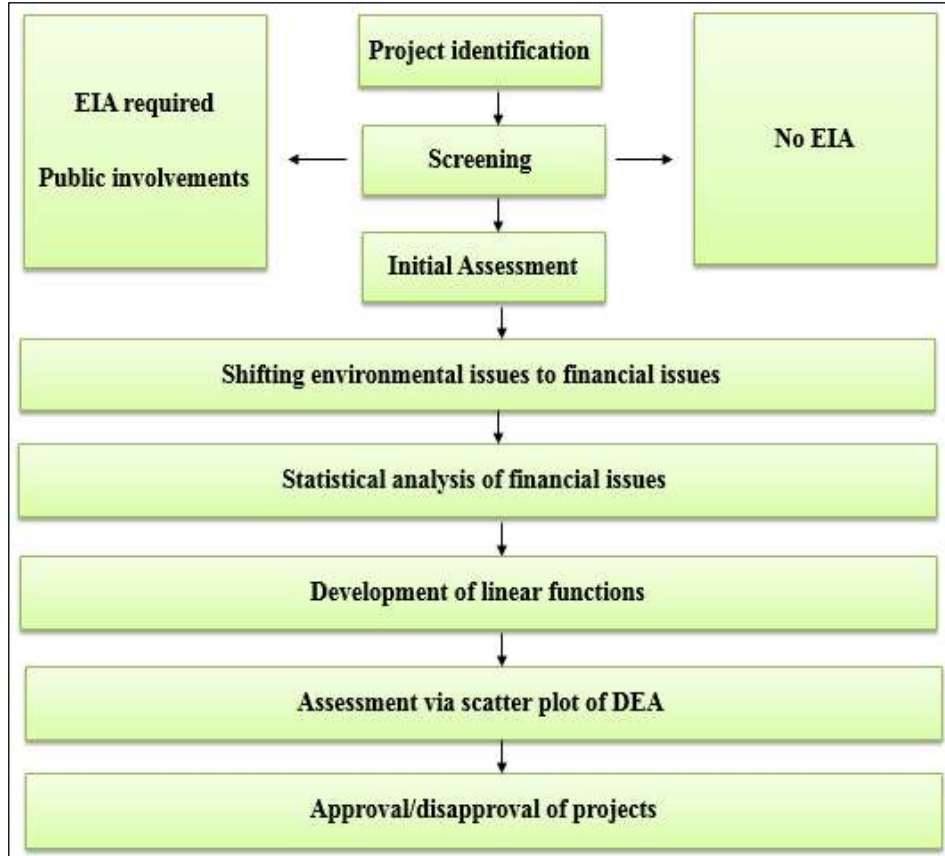
Figure 1. The evaluation steps of EIA and followed work for current research.
Source: Author, (2021).

The costs of the energy stream encompassed the sum of outlays of water, power, fuel consumed, and salary of staff. The revenue of industries engulfs the income from selling industries products individually and annually in each group.

$$y = a + bx \qquad (1)$$

$$b = \sum (x.y) - \sum x. \ \frac{\sum y}{n} / \sum x^2 - \frac{(\sum x)^2}{n} \qquad (2)$$

$$a = \bar{y} - bx^- \qquad (3)$$

$$r = \sum (x - x^-)(y - \bar{y}) / \sqrt{\left(\sum (x - x^-)^2 . \sum (y - \bar{y})^2 \right)} \qquad (4)$$

For the regression equations, n is the number of observations, x is the mean of all x-values, y is the mean of all y-values, and r is the coefficient of the correlation. With regard to this fact that the objective followed by the present research does not specifically include the performance analysis of industrial groups

so the equations of the traditional DEA model united with the weighing system of the Friedman test were ignored to appear in the methodology section.

IV. RESULTS AND DISCUSSION

IV.1 IRANIAN INDUSTRIES

By the present study, the Iranian industries comprised from 8 groups according to appendices such as Iranian Wood and Cellulose Industries (IWCI), Iranian Textile and Leather Industries (ITLI), Iranian Mining and Aggregate Industries (IMAI), Iranian Food Manufacturing and Processing Industries (IFMPI), Iranian Plastic Industries (IPI), Iranian Electronic Products Manufacturing Industries (IEPMI), Iranian Chemical Industries (ICI), and Iranian Household Appliance Industries (IHAI). The existing information the below, figures & Table indicate the data of power, water, and fuel consumed and the number of employees as main industry-specific factors (energy stream) that estimated by the team of evaluators of Iranian organizations. The values have estimated for 8 industrial groups in the EIA plan initially.

Figure 2: The costs (energy stream) of industrial groups.
Source: Author, (2021).

Figure 3: The costs (energy stream) of ICI.
Source: Author, (2021).

Figure 4: The revenue of industrial groups.
Source: Author, (2021).

Table 1: The revenue of industrial groups.

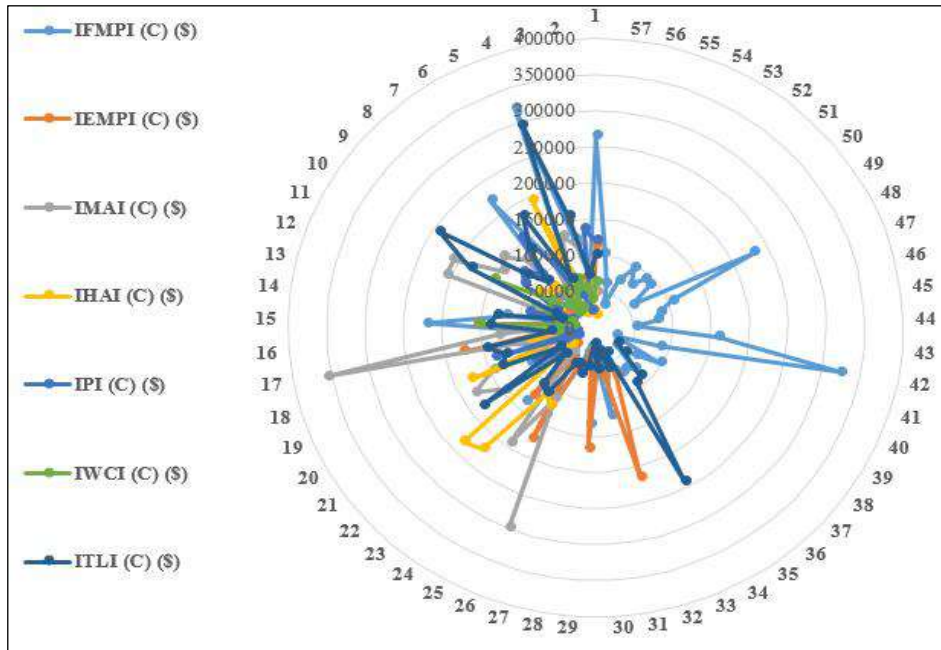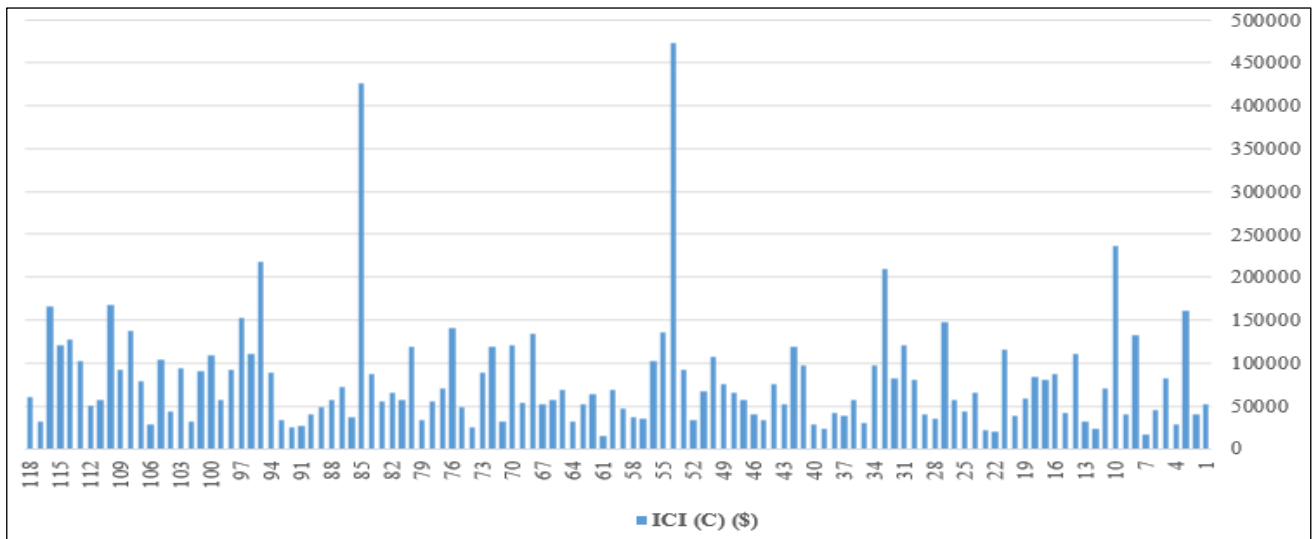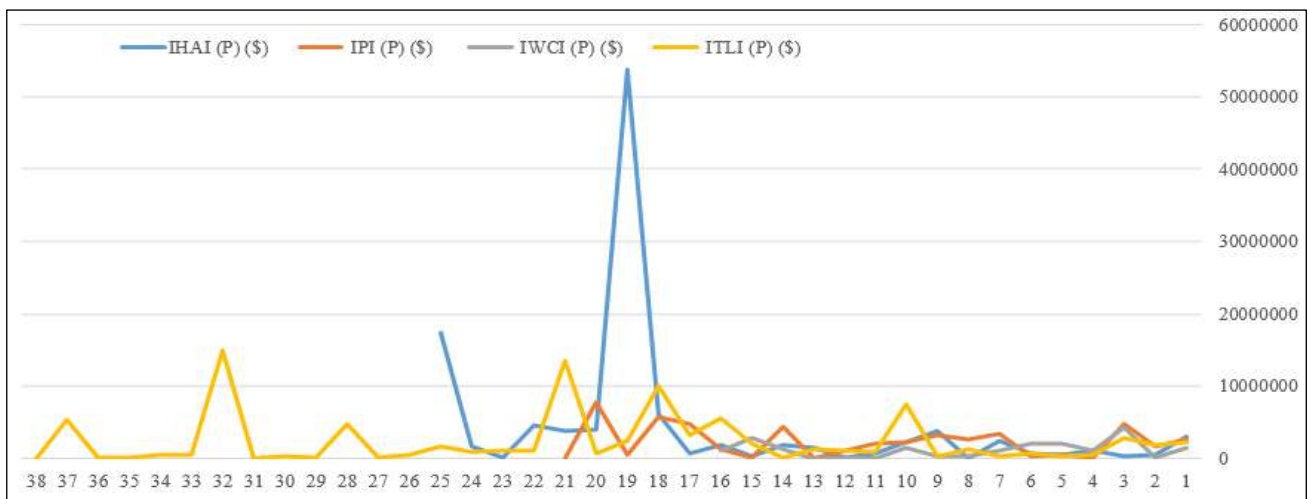| IMAI (P) ($)	IEMPI (P) ($)	IFMPI (P) ($)	ICI (P) ($)	
7269230770	4000000	8076923	1153846.154	50000
1153846154	2000	1300000	1501000	81000
500000	200000	1238076.92	6000000	5697992
1200000	160000	536470	960000	33693600
1200000	54000	3750000	1442308	1500000
150000000	150000	1615384.6	250000	660000
182692.3	300000	19384615.5	150000	1200000
600000	250000	823384.61	2554070	2115384.62
6923076.9	240000	2400000	520000	764307.7
3070000	15000	380000000	110770	186300
5769.23	1200000	57600	1350000	2884615.385
5769230.77	400000	291600	58153.85	360000
5192307.7	30000	1000000	173076.93	36000000
557.5	3500000	7846153.85	38461153.85	200000
390000	350000	7837500	100000	350000000
3000000	1523076.9	2769230.77	130000	5400000
4038461.5	1600	1600000	650000	5244000
342000	200000	27594000	4320000	800000
45000	310000	1923076.95	1090000	2769230.77
356400	615384.61	3160000	585000	230000
30000	3846153.84	3000000	240000	461538.5
240000	630000	1609615.4	15120	1269230.8
2000000	600000	5775000	100000	414000
2300000	553846.16	1615384.6	2000000	42115385.6
200000	2000000	6230769.24	200000	35000000
20000	1000000	5859230.77	153846.2	923077
	307692.3	1121538.5	1700000	1000000
	584615.4	1275000	942307.7	1000000
	500000	7692307.7	2500000	5774859
	900000000	3461538.4	1495384.5	2137500
	540000	3346153.84	960000	19461538
	8160000	1000000	634615.4	400000
	207692.3	13148000	2307692.3	5400
		119000	74870.8	3240000
		3000000	24923076.9	3553846
		6000000	114400	1038461.5
		272750	1000000	2223076.9
		250000	50000	12500000
		243000	1442307.7	5384615.5
		16800	692307.7	38500000
		4147200	911538.5	22730770
		1400000	962350	15000
		18720000	2884615.4	4830572
		15000	1080000	240000
		750000	876923	125000
		12096	2700000	2307692.3
		990769.23	3600000	23100000
		2153846.15	4812692.3	1239300
		380134618	5184000	576923
		770000	10341000	3575000
		372000	17307.7	1538461.5
		16000000	2076923	1500000
		1900666	7427504.8	561538.5
		4000000	617616	2608695
		600000	18269.24	3370000
		3000000000	400000	11434615.4
		1920000	199038.5	2284615.4
			50000	18000000
			81000	12600000
			5697992	500000
				3846153.9

Source: Author, (2021).

In the figures and Table, the symbol of P and C means the revenue of products and costs of energy stream respectively. Tables 2 and 3 show the regression analysis of cost/revenue by SPSS software and empirical equations respectively. Figure 5 displays the linear regression diagrams of cost/revenue analysis of industrial groups.

Table 2: The regression analysis of cost/revenue.

Industries /models	R	R square	F	Sig.	Standard coefficient beta
ITLI	0.132[a]	0.017	0.638	0.430	-
				0.155; 0.430	0.132
IHAI	0.339[a]	0.115	2.995	0.097	-
				0.097; 0.925	0.339
ICI	0.068[a]	0.005	0.534	0.466	-
				0.320; 0.466	0.068
IMAI	0.208[a]	0.043	1.085	0.308	-
				0.144; 0.308	-0.208
IWCI	0.141[a]	0.020	0.284	0.603	-
				0.603; 0.158	0.141
IFMPI	0.095[a]	0.009	0.504	0.481	-
				0.481;0.192	-0.095
IPI	0.235[a]	0.055	1.112	0.305	-
				0.305; 0.185	0.235
IEMPI	0.099[a]	0.010	0.305	0.585	-
				0.585; 0.310	-0.099

(P= revenue) dependent variable
a. predictor (constant). (ITLI (C))
R = Regression

Source: Author, (2021).

Table 3: The results of regression analysis.

Regression /industrial groups	a	b	Linear function (y)	R
ITLI	97923.10781	0.00236	97923.10781 + 0.00236 X	0.132
IHAI	73164.1681	0.001938	73164.1681 + 0.001938 X	0.339
ICI	79844.96	0.000135	79844.96 + 0.000135 X	0.068
IMAI	129842.4025	-1.18E-05	129842.4025 -1.18E-05 X	-0.208
IWCI	57845.1493	0.00438	57845.1493+0.00438 X	0.14088
IFMPI	98253.5	-1.579E-05	98253.5 – 1.579E-05 X	-0.095
IPI	67680.8269	0.00454	67680.8269 + 0.00454 X	0.235
IEPMI	73924.0551	-3.15E-05	73924.0551 – 3.15E-05 X	-0.098

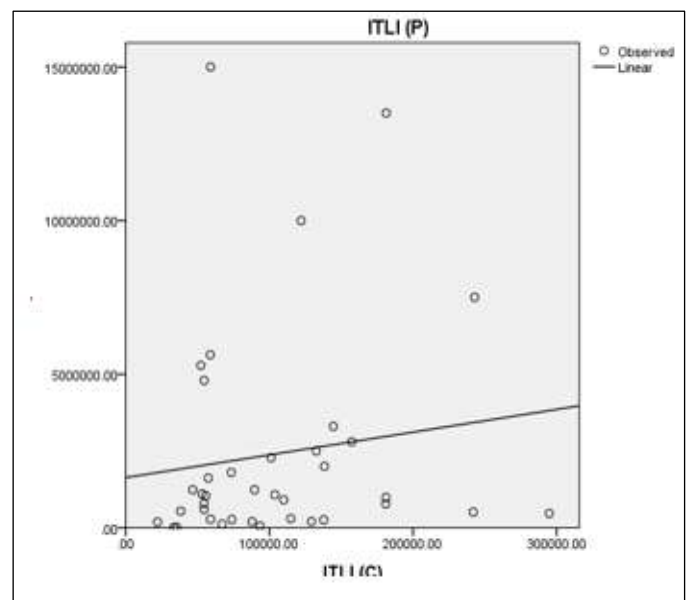X= values of revenue; y = values of costs

Source: Author, (2021).

Figure 5a: The linear regression diagrams of cost/revenue analysis of industrial groups.
Source: Author, (2021).
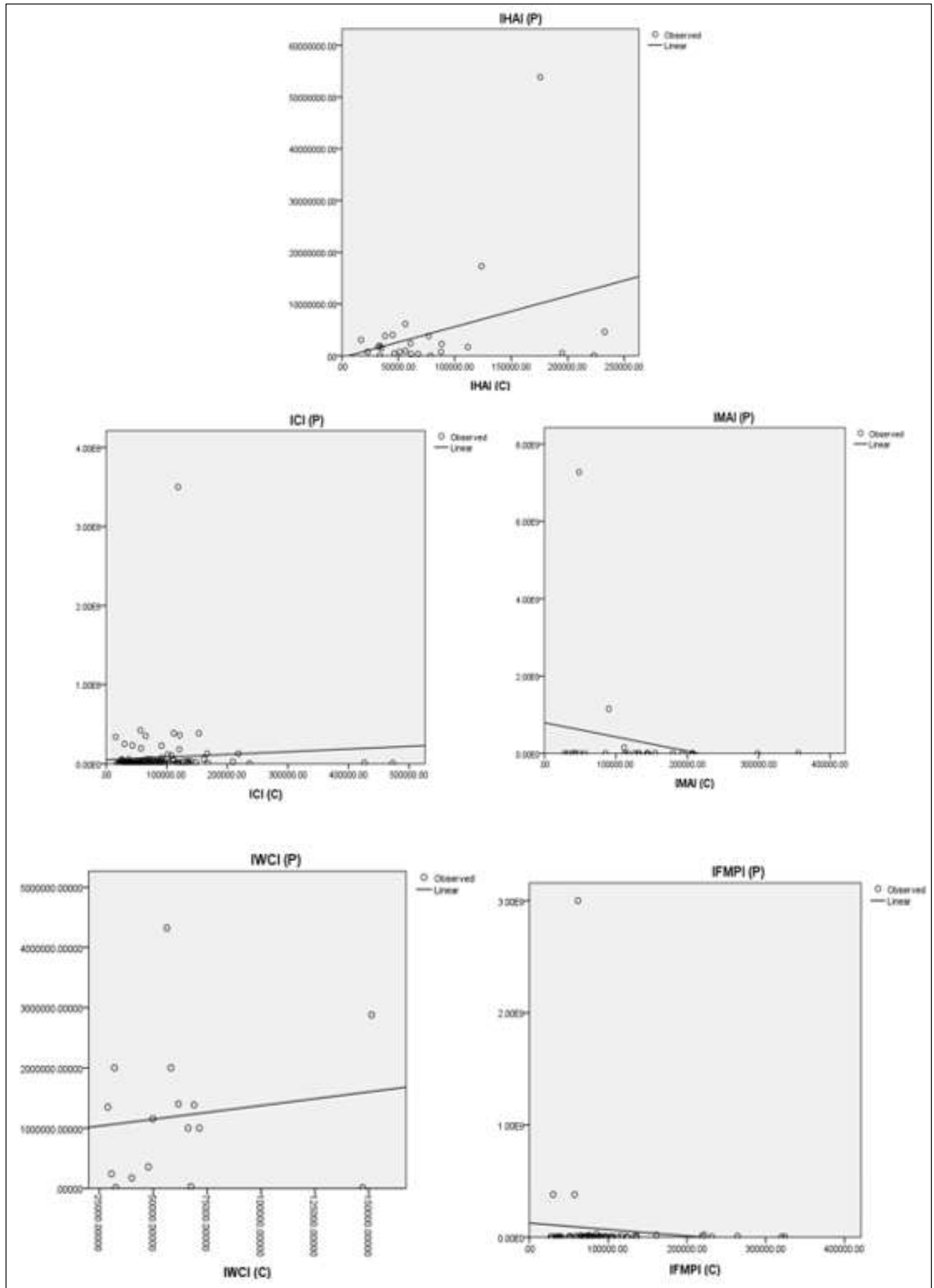
Figure 5b: The linear regression diagrams of cost/revenue analysis of industrial groups.
Source: Author, (2021).
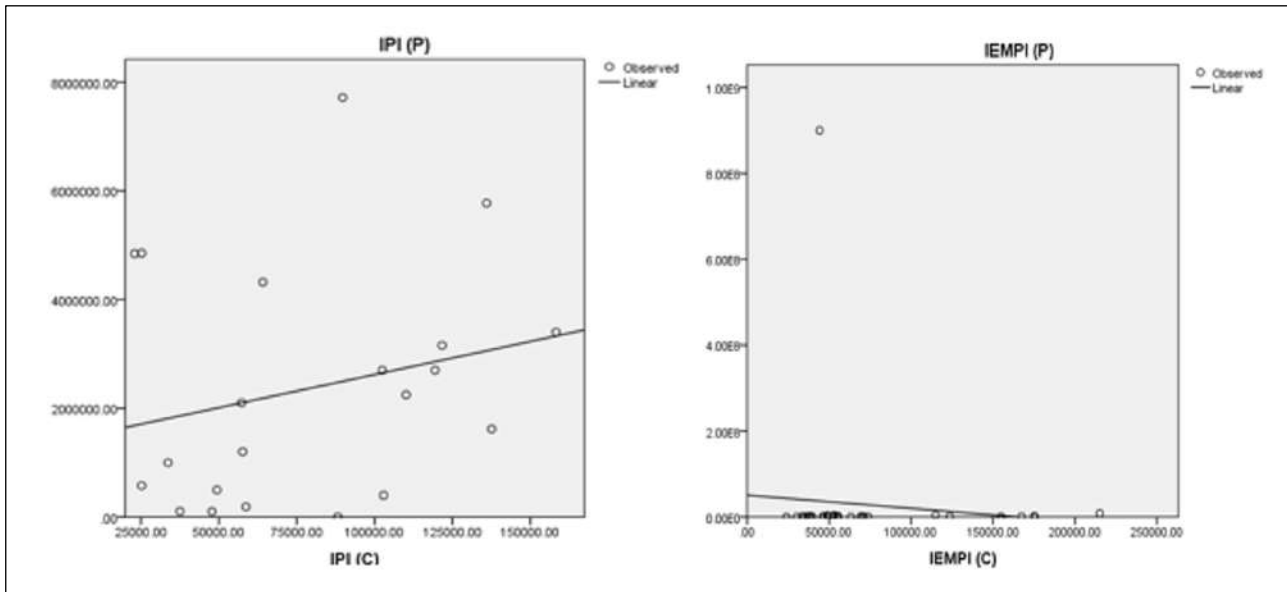
Figure 5c: The linear regression diagrams of cost/revenue analysis of industrial groups.
Source: Author, (2021).

IV.2 STATISTICAL ANALYSIS

The null hypothesis test summary had shown that the distribution of all cost/revenue analysis in all industrial groups is normal via one-sample Kolmogorov Simonov test. So, it has resulted in the rejection of the null hypothesis in six analyses of industrial groups such as ITLI (P), IHAI (P), IMAI (P), IEMPI (P), IFMPI (P), and ICI (P). But keeping the same data in the null hypothesis test summary had proved the rejection of the null hypothesis in both analyses of cost/revenue (in all industrial groups) via related samples Friedman's two-way analysis of variance by ranks. By the way, the distribution of all industrial groups had appeared the same. The t-test analysis has manifested significant differences around (p-value $\leq$ 0.001, 0.047, 0.014) in the analysis of cost/revenue for IWCI (P), IHAI (P), and ICI (P)

among all industrial groups respectively. Using paired sample test analysis also presented the significant differences among IWCI (P, C), IHAI (P, C), and ICI (P, C) around (p-value $\leq$ 0.001, 0.050, 0.016) respectively.

The mean ranks (weights) by Friedman test had released values of 12.81, 10.34, 11.75, 11.78, 12.56, 8.88, 13.50, 11.25, 7.25, 4.25, 5.31, 4, 6.69, 4.19, 6.69, and 4.75 for ITLI (P), IWCI (P), IPI (P), IHAI (P), IMAI (P), IEMPI (P), IFMPI (P), ICI (P), ITLI (C), IWCI (C), IPI (C), IHAI (C), IMAI (C), IEMPI (C), IFMPI (C), ICI (C) respectively. So the highest and lowest ranks were devoted to IFMPI (P) and IHAI (C) respectively. The values of weights estimated by the Friedman test were used to find the efficiency ranks using the DEA model. Then the efficiency scores were displayed by scatter plot according to Figure 6.
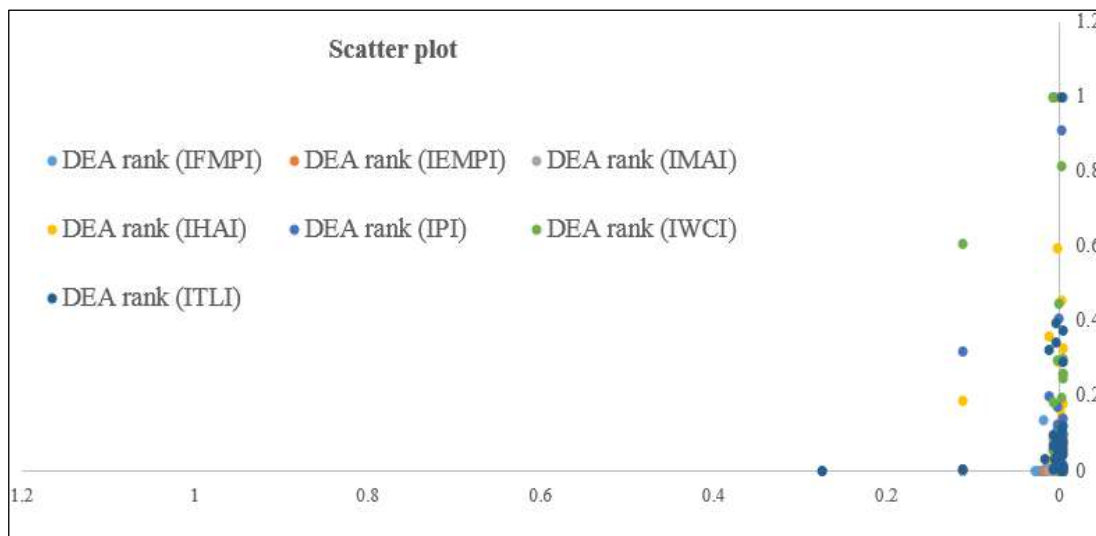
Figure 6: The scatter plot of DEA ranks of industrial groups.
Source: Author, (2021).

To calculate DEA has used the weights obtained from the Friedman test. The division of weighted output variable (products of industries in currency) to weighted input variable (cost of energy stream) was released the efficiency score according to scatter plot in Figure 6. Figure 6 proves that the most efficiency scores were

scattered between a range of 0 to 0.4. The values of DEA ranks for ICI did not appear in the plot due to negligible values in the industrial group. Figure 7 represents the sequence chart for values of ranks of industrial groups in the DEA model.
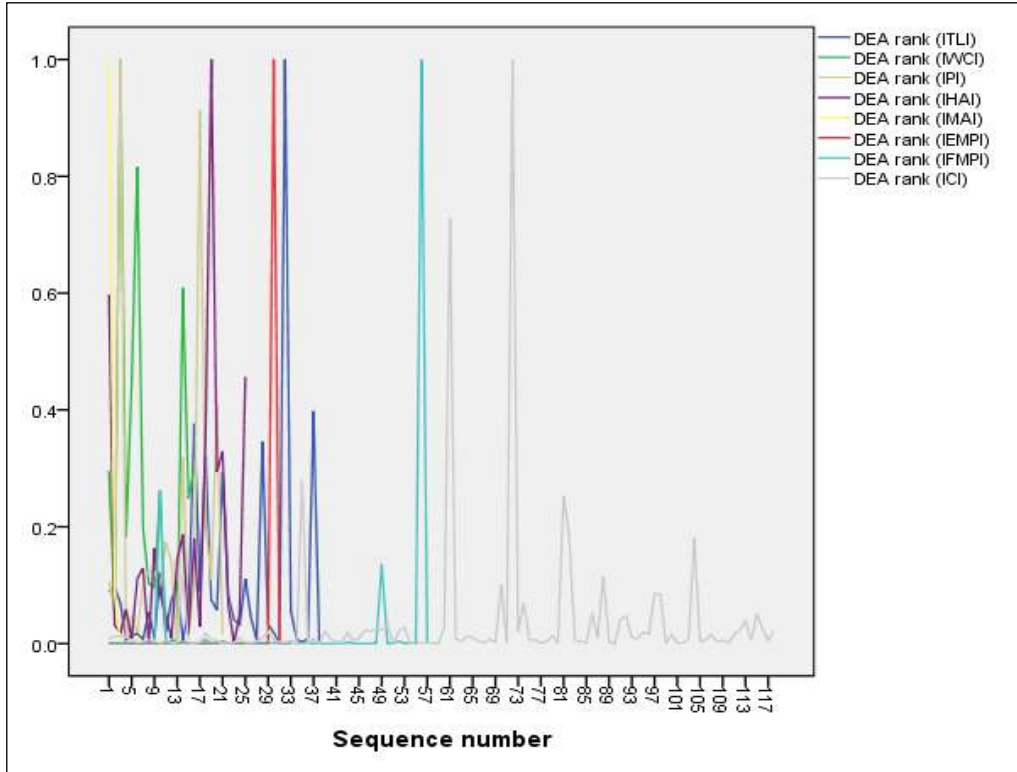
Figure 7: Sequence chart for values of ranks in DEA model.
Source: Author, (2021).

The application of sequence number refers to present interaction among various groups of alternatives in development stages when they are discussed in scenarios. The highest functionality emerges in linear expansion. The highest correlation came into view among values by both DEA rank values of IWCI and IPI with a quantity of around 0.632. The paired samples test had shown a significant difference (p-values ≤ 0.014) among 8 industrial groups. The significance had appeared with (p-value ≤ 0.001, 0.004) for industrial groups of ITLI, IWCI, IHAI, ICI, and IPI via t-test analysis respectively. Figure 8 portrays the scatter plot of cost versus revenue.
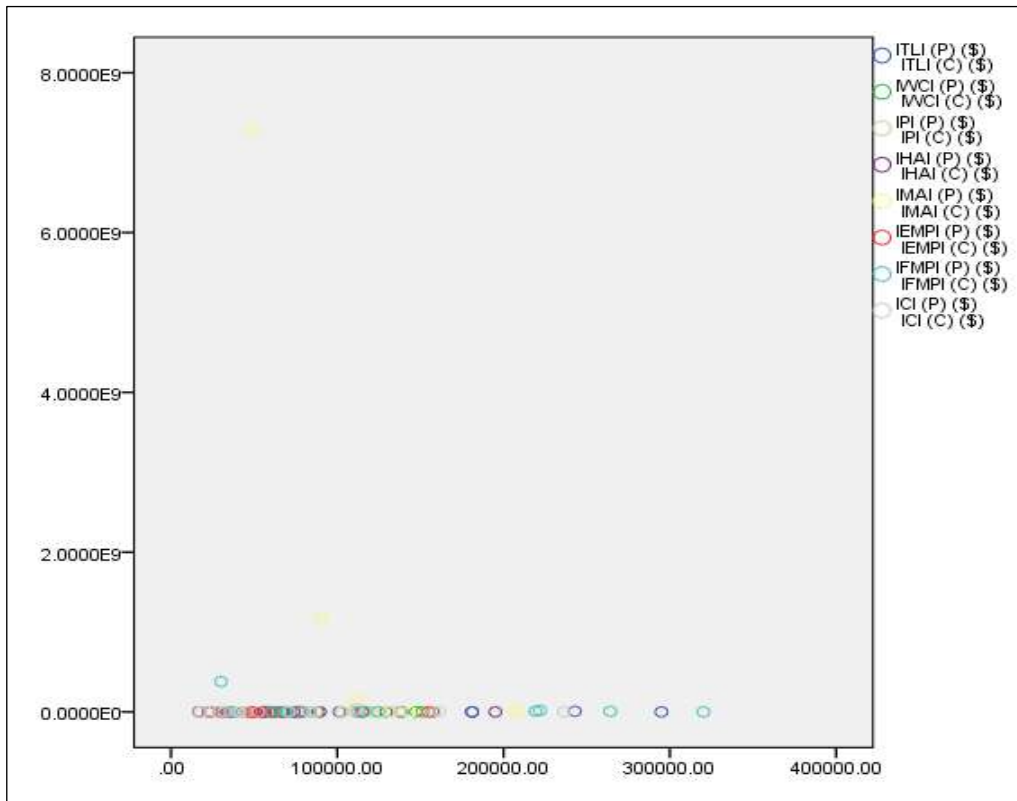
Figure 8: The scatter plot of cost versus revenue.
Source: Author, (2021).

According to Figure 8, the scatter plot drawn among data of cost/revenue analysis of all industrial groups is in a linear distribution. The findings prove the complete linear expansion and development of data in the scatter plot. Figure 9 presents the error bar plot of cost/revenue.
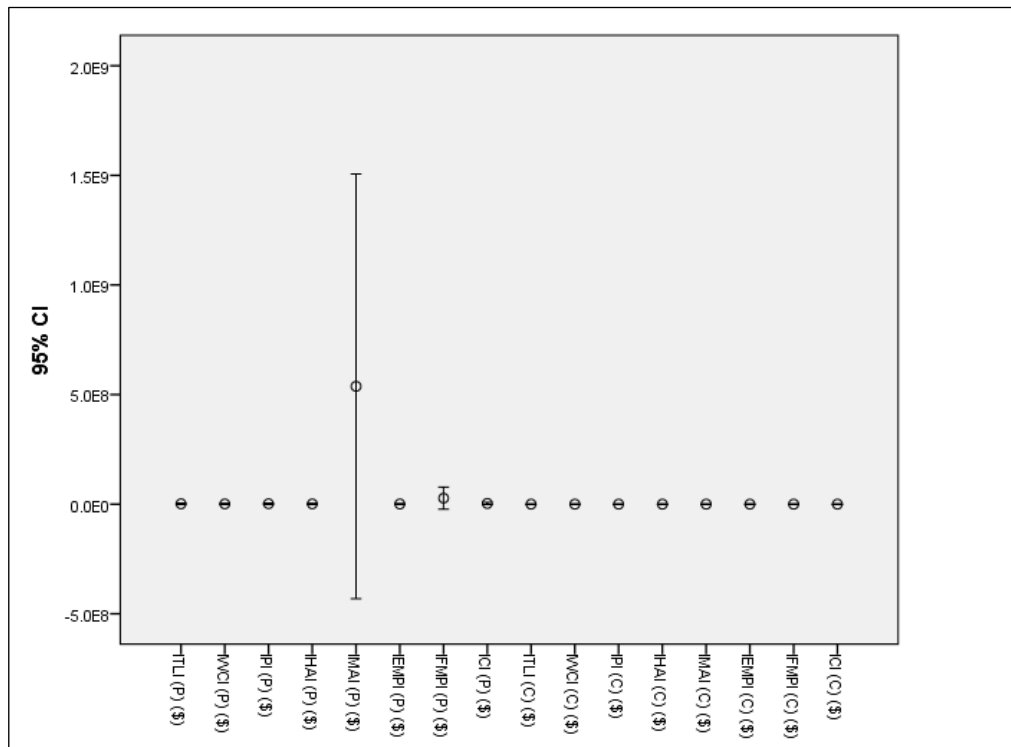
Figure 9: The error bar plot of costs/revenue for industrial groups.
Source: Author, (2021).

The findings in figure 9 represent that there is no scatted data out of mean of data except in the data of IMAI (P) ($). It means a wide distribution among data of IMAI (P) ($) with low and high quantities scattered.

V. CONCLUSION

The present research introduced linear functions for each industrial group that can be expanded via Kaab Douglas modeling. The results of regression analysis via SPSS software occurred in full agreement and compliance with results obtained by empirical equations and linear flow diagrams deployed in the output of SPSS software. It was not observed significant differences among cost/revenue analysis of 8 groups of industrial projects. The good compliance of cost/revenue analysis came into view with linear progress in the scatter plot introduced. The expansion of the sequence number diagram followed a regular development in scenarios but not in a linear trend. The aggregation of DEA ranks of industrial groups had happened around a linear layout. The findings of the DEA model were displayed by scatter plot were a benchmarking level for this kind of assessment as it is for industrial projects once before complete construction. Future research orientation can be directed towards adding some new dependent and independent variables individually or mixed with financial ratio analysis to further processing the data. New types of DEA models united with the various weighing systems are another alternatives in further processing data.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Malek Hassanpour.
Methodology: Malek Hassanpour.

Investigation: Malek Hassanpour.
Discussion of results: Malek Hassanpour.
Writing – Original Draft: Malek Hassanpour.
Writing – Review and Editing: Malek Hassanpour.
Resources: Malek Hassanpour.
Supervision: Malek Hassanpour.
Approval of the final text: Malek Hassanpour.

VII. ACKNOWLEDGMENT

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IX. APPENDIX

Section "IV.1 IRANIAN INDUSTRIES"

IV.1.1 Iranian Textile and Leather Industries (ITLI)

ITLI comprised 38 various kinds of industries such as (1) Bag (NC=120000 No), (2) Carpet thread (NC=600t), (3) Cotton spinning (NC=1400t), (4) Jeans (NC=81000 No), (5) Leather artifacts (NC=90000 No), (6) Leather shoes (NC=135000 pairs), (7) Quilts, mattresses and pillows (NC=85000 No), (8) Raw leather (NC=618300 Ft^2), (9) Sewing and embroidery thread (NC=150t), (10) Spinning (NC=2500t), (11) Tannery (NC= 45500 skin covers+214.988t), (12) Underwear (embroidered series) (NC=350000 No), (13) Wicker oil burner (NC=620000 No), (14) Spinning the woolen yarn (NC= 306t), (15) Knitting cotton, synthetic fibers (NC=1000000 m^2), (16) Band and medical wound texture gas (NC= 1407659 No), (17) Rachel Curtain Fabrics (NC=330000 m), (18) Mink blankets (NC=500000 m^2), (19) Woolen blanket (NC=131500 No), (20) Spinning wool (NC=263.5t), (21) Palash and blanket (NC=2250000 m^2), (22) Winter clothing (NC=137500 No), (23) Clothing (shirt) (NC=135000 No), (24) Knitted Tricot (NC=130t), (25) Fishing net (NC=270t), (26) Stinger mosquito net (NC=300000 m^2), (27) Socks (NC=243000 jeans), (28) Crust leather (NC=2398000 Ft^2), (29) Cotton gloves (NC= 62400 pair), (30) Leather gloves (NC=70000 pair), (31) Wipes (Cleansing) (NC=4000 yard), (32) Ribbon Weaving (NC=3000000 m), (33) Carpet coverage (NC=54000 No), (34) Spinning silk (NC=102.8t), (35) Zipper (NC=3000000 m), (36) Animal skin pickle (NC= 200000 No), (37) Raw silk fabrics (NC= 330000 m), (38) Layer on diapers and sanitary pads (NC=8750 m^2).

IV.1.2 Iranian Household Appliance Industries (IHAI)

Types of IHAI based on NC comprised 25 industries such as Earphone (20000 No) (1), Hairdryer Handheld (100000 No) (2), Household ventilator (100000 No) (3), Household crystal containers (500t) (4), Pyrex glass containers (100000 No) (5), Semi-Automatic Washing Machine (10000 No) (6), Tea flask (100000 No) (7), Teflon containers (211t) (8), Water Cooler (20000 No) (9), Gas oven (12000 No) (10), Steam iron (20000 No) (11), Juicer (48000 No) (12), Electrical miller and mixer (20000 No) (13), Steam cooked double glazed steel (50000 No) (14), Electrical stove (30000 No) (15), Gas stove (20000 No) (16), Semi-automatic electric cooker (20000 No) (17), Ceiling fan (assembly) (50000 No) (18), Desktop fan (100000 No) (19), Household vacuum cleaner (assembly) (30000 No) (20), Meat grinders (assembled) (40000 No) (21), Chinese dishes (800t) (22), Chinese decorative dishes (500t) (23), Samovar (electric and oil) (82500 No) (24), Household refrigerator (15000 No) (25).

IV.1.3 Iranian Chemical Industries (ICI)

Types of ICI based on NC comprised 118 industries such as Animal Feed from Agricultural Waste (NC=10000t) (1), Animal drugs (NC= 500t+50000 No) (2), Ammonium Chloride (NC=1500t+2000t NaSO$_4$) (3), Antifreeze (NC=960 m^3) (4), Baby carriage (NC= 25000 No) (5), Blood Powder (NC=500t) (6), Buds of different seeds (NC=150t) (7), Barium carbonate (NC=3000t+1187t solfide sodium) (8), Braided wax plates (NC= 130t) (9), Calcium carbonate (light and active) (NC= 19200t) (10), Calcium carbide (NC=1350t) (11), Clothes hanger and pin (NC=504000 No) (12), Disinfectants (NC=900000 L) (13), Fiberglass boat (NC=5000 No) (14), Fiberglass pieces (NC=100t) (15), Fragrant aromas (NC=130t) (16), Glass- strip away (NC=650t) (17), Glucose from starch (NC=2160t) (18), Healthy Soap (NC=1090t) (19), Helmet (NC=65000 No) (20), High pressure hoses (NC=240t) (21), Household Lighting Candles (NC=7560 No) (22), Insecticide coil (NC=50000 No) (23), Isolator (NC=2000000 m^2) (24), Kitchen lighter (NC=100000 No) (25), Knife with injectable handle (NC=800000 No) (26), Adhesive plaster (NC=1700t) (27), Lining materials and insulating gas pipes (NC=3500t) (28), Liquid fertilizer (NC=1250t) (29), Matches (NC= 7776000 No) (30), Mechanical disposable lighters (5000000 No) (31), Medicinal glycerin (NC=1500t) (32), Melamine dishes (NC=1000t) (33), Metal flexible hose pipes (NC=309t) (34), Nitrobenzene (NC=1620t) (35), Potassium chloride (NC=400t) (36), Printing ink (NC=500t) (37), Rubber parts (NC= 25t) (38), Shoe wax (NC=3750000 No) (39), Soft polyurethane foam (NC=6000t) (40), Starch from wheat (NC=1580t) (41), Throw-away crockery (NC=962.35t) (42), Tooth brush (NC=5000000 No) (43), Detergents (Shampoo, etc) (NC=1080t) (44), Welding glasses (NC=50000 No) (45), Insecticide spray containing flavoring materials (NC=2700000 No) (46), Acetic acid ester (NC=1200t) (47), Phthalic anodic esters (NC=970t) (48), Calcium stearates (NC=2592t) (49), Boric acid (2700t + 3600t NaSO$_4$) (50), Hydrochloric acid (NC=3000t) (51), Chromic acid (270t) (52), Zinc oxide (500t+887.5t NaSO$_4$) (53), Oxygen; Ar and N$_2$ (NC=3643200 m^3) (54), Alcohol from beet molasses (NC=5000 No) (55), Types of gaskets (200t) (56), Acid and distilled water (NC=1725 m^3) (57), Rubber plugs (NC=25t) (58), Sprinkler (NC=81000 No) (59), Sodium hypochlorite (NC= 837900 gallon) (60), Recycling silver from film and its solution (NC=40.40t) (61), Industrial Paraffin (NC=3000t) (62), Raw silk fabrics (NC=330000 m) (63), Pacifier (NC=300000 No) (64), Unsaturated polyester (NC=1000t) (65), Bleach powder (NC=2700t) (66), Electrostatic coating (NC=81000 m^2) (67), Tri-calcium phosphate (NC=15000t) (68), Hub and rubber ball (NC=360000 No) (69), Synthetic leather of polyurethane (NC=12000000 m^2) (70), Gum stick (NC=200000 No) (71), Wood gum (polyvinyl acetate) (NC=7000t) (72), Shoe adhesive (NC=1800t) (73), Medical and sanitary adhesives (NC=45600000 No) (74), Toothpastes and health cosmetics (NC=800t) (75), Hexagon pen (NC=24000000 NO) (76), Pen (NC=2000000 No) (77), Plugs and screws head (NC=800000 No) (78), Diethyl ether (NC=100t) (79), CO$_2$ (NC=1800t) (80), Epoxy resin (NC=5475t) (81), Alkyd resin (NC=17500t) (82), Bakelite resin (NC=2000t) (83), Resin; urea formaldehyde gum (NC=1000t) (84), Dyeing and printing of fabrics (NC=2000000 m^2) (85), Transformer Oil (NC= 8100 m^3) (86), Used motor oil and grease recycling (NC=3000 m^3 + 750t , grease) (87), Drying oils (500t+1000t wastes) (88), Rubber profiles (200t) (89), Insecticide spray (NC=2700 No) (90), Rubber glass head (NC=3240000 No) (91), Canopy (NC=1540t) (92), Agricultural liquid pesticides, Butachlor (NC=750t) (93), Zinc sulfate (NC=3400t) (94), Sodium sulfate (NC=25000t) (95), Alkyl benzene sulphonation (NC=5000t) (96), Sodium sulfite (NC=5000t) (97), Sodium sulfide (NC=3000t) (98), Sodium silicate (NC=3000t) (99), Drip irrigation system (NC= 1000 No+383.9t) (100), Glasses frames (NC=80000 No) (101), Oil filter recycling (NC=2000t) (102), Thermos and ice box (NC= 150000 No) (103), Industrial and consumable taps (NC=3000000 No) (104), Teflon strips (NC=12393000 No) (105), Hair comb (NC=1000000 No) (106), Glass artifacts (NC=1787.5t) (107), Industrial crystals (NC=1000t) (108), Spectacle glass (NC=500000 pairs) (109), Chinese insulator (NC=730t) (110), Ceramic magnet (NC=869565 m) (111), Tape (for electronic equipment) (NC=3370000 No) (112), Fruit concentrate (NC= 19820t) (113), Shuttered windows (NC=330000 No) (114), Hygiene products made of artificial stone (NC=4500t) (115), Household, industrial and medical gloves (NC=12600000 pair) (116), Metal octet of Ca, Zn, Mn, Co (NC=1000t) (117), Refrigerator above zero for crops (NC=5000t) (118).

IV.1.4 Iranian Mining and Aggregate Industries (IMAI)

IMAI encompassed 26 various types of industries as (1) Bitumen blown 90/15 (NC= 27000t), (2) Building plaster (NC=150000t), (3) Ceramic dishes (NC=250t), (4) Ceramic tiles (NC= 600000 m^2), (5) Floor Tiles (NC=600000 m^2), (6) Glazed tile and ceramic (NC=150000t), (7) Gypsum (NC= 500 packages), (8) Industrial ceramic parts (NC=300t), (9) Ceramic brick (NC=30000000 moulds), (10) Firebrick (NC=10000t), (11) Façade brick (NC=30000 pieces), (12) Semi-automatic brick (NC=30000000 moulds), (13) Hot asphalt (NC=135000t), (14) Building lime (NC=75000t), (15) Orthopedic bandage (NC=1300000 rolls), (16) Rock wool (NC=1500t), (17) Glass wool (NC= 7000t), (18) Stone powder and mosaic (NC= 18000t), (19) Precast pressed beam and concrete pile (NC=15000 pieces), (20) Gypsum prefabricated walls (NC=356400 m^2), (21) Prefabricated wooden wall by wood powder (NC=15000 m^3), (22) Cutting granite stone (NC=30000 m^2), (23) Grindstone (NC= 500t), (24) Broken stone and debris washed (NC=200000t) (25) Mineral powders (NC=200000t), (26) Cement asbestos tube (NC=500t).

IV.1.5 Iranian Wood and Cellulose Industries (IWCI)

IWCI included 16 types of industries based on confirmation information in IIO such as (1) Cooler bangs (NC=1400t), (2) Carton (NC=1500t), (3) Industrial drying wood (NC= 7500t), (4) Hydrophilic cotton (NC=400t), (5) Sheet rolls and packing (NC= 1000t), (6) Wax paper (NC= 1000t), (7) Booklet (NC=2600000 No), (8) Hasp (NC=120000 No), (9) Decal (NC=6250000 piece), (10) Multilayer paper bags (NC= 12000000 No), (11) Row board (NC=12000 Piece), (12) Wooden and paper disposable products (NC=7565000t), (13) Wooden pencil (NC=324000 No), (14) Carbon paper (NC= 450000 package), (15) Parquet (NC=150000 m+150000 m^2), (16) Sandpaper (NC= 2000000 m^2).

IV.1.6 Iranian Food Manufacturing Industries (IFMPI)

IFI comprised many of confirmed industries in the industries organization in Iran such as (1) Barley water (NC=30000000 bottles), (2) Cake and muffins (NC=650 kg), (3) Canned Beans and Caviar Eggplant (NC=3700 No), (4) Canned fish (tuna) (NC=11000 No+1056t), (5) Canned meat (NC=6500000 bottles), (6) Canned mushrooms (NC=2800000 bottles), (7) Compote (NC=8000000 No), (8) Concentrated fructose syrup of corn sugar (NC=2400t), (9) Corn Flakes (NC= 600t), (10) Fantasy Bread (NC=1000000t), (11) Fish food (NC= 12000 kg), (12) Glucose from starch (NC=2160t), (13) Hamburger (NC=1000t), (14) Margarine (NC= 12000t), (15) Milk, yogurt and pasteurized cream (NC=8255t), (16) Date sap (NC=2000t), (17)

Potatoe based foods (NC=800t), (18) Poultry slaughterhouse (NC=3780000 No), (19) Iodinized salt (NC=10000t), (20) Starch from wheat (NC=1580t), (21) Treating fish (NC=1000t), (22) Wafer chocolate (NC=500t), (23) Alcohol from beet molasses (NC= 1500000 No), (24) Mineral water (NC= 12000t), (25) Wheat flour (NC=27000t), (26) Pistachio packaging (NC=1269.5t), (27) Packing grains; peeling off barley (NC= 2430t), (28) Spice Packing (NC=250t), (29) Fruit packaging (NC=10000t), (30) Wafer biscuits (NC=1000t), (31) Corn grits (NC= 5800t), (32) Biscuit (NC=1000t), (33) Soya protein (NC=1900t), (34) Mushroom cultivation (NC=600t), (35) Cheese from fresh milk (NC= 1500t), (36) Cheese Pizza (NC=1500t), (37) Meat and Olive Industrial Powder (NC= 545.5t), (38) Fish powder (NC= 500t), (39) Artificial sausage and sausage coating (NC=243t), (40) Preparation; packaging of honey (NC=24000 No), (41) Purification and packaging of salt (NC=21600t), (42) Cream dyed (NC= 1400t), (43) Dates and liquid sugar (NC=4680t), (44) Smoked fish (NC= 15t), (45) Tomato paste (NC=1500t), (46) Flour string (NC= 24192 No), (47) Olive oil (NC=280t), (48) Oil Seeds from Vegetable Seeds (except soya; olive) (NC=8000t), (49) Drying oils (NC= 1500t), (50) Dried vegetables (NC= 1412000 No), (51) Soya sauce (NC= 60000 barrels+72000 bottles), (52) Ketchup (NC= 16000t), (53) Food sauces (NC= 4451998 (bottles 300 g)+1250000 (bottles 120g)), (54) Raisin Packaging (NC= 1000t), (55) Dates packaging (NC= 400t), (56) Sausage (NC=1000000t), (57) Ice (NC= 12920t).

IV.1.7 Iranian Plastic Industries (IPI)

Types of IPI based on NC comprised 21 industries such as congressional sheets of PP (Polypropylene) and PS (Polystyrene) (2000 T (Ton)), (1), Flat sheets of PP and PS (1200t), (2), Plastic waste recycling (630t), (3), Plastic buttons (100t), (4), PVC (Polyvinylchloride) hose (500t), (5), Plastic rope (1000t), (6), PVC flooring (1700t), (7), PP bags (900t), (8), Plastic bags (1052.67t), (9), PE (Polyethylene) pipes and fittings (1500t), (10), PVC pipes and joints (1400t), (11), Plastic welding artifacts (1000000 No = Number), (12), Plastic bottle (18000 No), (13), PVC shoe bed (2160000 No), (14), Plastic Box (Fruit, Chilli) (246140 No), (15), Plastic flashlight (600000 No), (16), PVC gum (4854109 No), (17), Plastic shaver (75000000 No), (18), Cellular Plastic Sheets (385000 m2), (19), PVC film for agricultural use (21600000 m2), (20), Plastic products (175.26t+13580 rolls), (21).

IV.1.8 Iranian Electronic Products Manufacturing Industries (IEPMI)

Types of IEPMI based on NC comprised 33 industries such as Flux wire (NC=2000t) (1), Thermostat samovar (NC= 200 kg) (2), Automatic starter (NC=100000 NO) (3), Automotive starter (NC=20000 NO) (4), Automatic selector (NC=5400 NO) (5), Adapter (NC=100000 NO) (6), Ampere meter, voltmeter (NC=200000 NO) (7), Alarm (NC=100000 NO) (8), Desktop phone device (NC=20000 NO) (9), Electrical connector (NC=5000 NO) (10), Electro-Motor (NC=120000 NO) (11), Electronic thermostat (assembly) (NC=20000 NO) (12), Electronic laboratory devices (NC=10000 NO) (13), Electronic encoder lock (NC=100000 NO) (14), Electric key and socket (NC=500000 NO) (15), Soldering iron (NC=110000 NO) (16), Sockets and rods (NC=2000 NO) (17), Flashing device (NC=20000 NO) (18), Home electric drill (NC=10000 NO) (19), Household Emergency Light (NC=20000 NO) (20), Gas torch relay (NC=50000 NO) (21), Limit Switch (NC=70000 NO) (22), Moonlight ballast (NC= 200000 NO) (23), Moonlight Starter (NC=2000000 NO) (24), Paper loudspeakers (NC=500000 NO) (25), Projector and spotlight (NC=100000 NO) (26), Plugs and screws head (NC= 800000 NO) (27), Pocket radio (NC=40000 NO) (28), Trans-amplification (NC=100000 NO) (29), Trans moonlight (NC=450000000 NO) (30), Thermal relay (NC=60000 NO) (31), Coaxial cables (NC=408000 crank) (32), Electronic boards and printed circuits (NC=20000 m^2) (33).

RESEARCH ARTICLE   **OPEN ACCESS**

PRO-ATHLETE: A GUIDE SYSTEM FOR VISUALLY IMPAIRED ATHLETES IN OLYMPIC TRACK RACE

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ARTICLE INFO

ABSTRACT

Assistive technologies can improve quality of life of people with special needs, providing autonomy in their daily activities. An opportunity for improvement appears in the athletics race on the track for the visually impaired, where currently the disabled athlete does not have autonomy and runs tied by rope to a guide and may have several problems of disqualification and reduced performance due to the necessary synchronization between athlete and guide. In this context, in this article we developed a hardware and software prototype equipped with wireless communication and a language code that uses vibrating stimuli to generate commands that guide the visually impaired athlete in the Olympic track race. The prototype was tested in simulated athletic races, showing good results, with commands and stimuli being well understood and interpreted by visually impaired athletes.

I. INTRODUCTION

Sports are an important part of human expression and culture. Through sports, athletes can achieve the best performance of body, breaking records of speed, endurance, distance, and precision. It is noticed that human ingenuity has its principle in the use of techniques that are becoming more sophisticated for the well-being of human being [1-3]. In this sense, we reflect how important technologies are in our activities, including sports.

Currently there is a range of technological devices to guide the athlete to his best performance: be it in training, through a balanced diet with supplements, in clothes with fabrics suitable for each type of sport, in the use of technological shoes, various accessories, among others. In para-athletics practiced by people with visual needs, there is a need to overcome some limitations during the para-athletic race accompanied by guides. In this sport, failures happen, the most common being caused by inefficient communication and the need for synchronization between the athlete and the guide. The so-called "assistive technologies" aim to generate better quality of life and well-being for people with disabilities, in this case, visual impairments. In this context, wireless communication technologies, computing and hardware that generate vibration commands can be used to guide the visually impaired in an Olympic track race. Most of the existing research

uses assistive technologies such as, for example, the electronic cane to guide the visually impaired people on the move in everyday life (e.g., streets, schools, closed environments). There are few works that apply assistive technologies in the scenario of visually impaired athletes. Among these works, some need complex infrastructure installations on the track [4]. Others use voice commands transmitted by radio, which ends up creating an extensive linguistic vocabulary, not guaranteeing the correct understanding of commands by the athlete [5]. There are also works that use discrete vocabulary, (ex: left and right command), [6], however limited. This article works in athletics running track scenarios, where each runner carries a hardware and software prototype composed of three wearable devices (02 bracelets and 01 belt) that guide the runner during an Olympic trace race through vibration. Unlike the works found in the literature, the prototype of this article does not use hardware technologies with prior installation on the track. In addition, this work proposes a vocabulary of linguistic codes implemented through vibrating stimuli that guarantee greater autonomy to the athlete. (ex: command informing that competing athletes are in proximity). he general objective of this article is to conceive, implement and validate a software and hardware system that implements a language code applicable to vibrating devices to guide visually

impaired athletes in Olympic track races. To present these subjects, this article is divided into the following subsections. Section II of Theoretical background presents basic theories for understanding the subject of the article; Section III of related works presents recent research on the researched subject; Section IV of the proposed solution presents the architecture and system developed; Section V presents results and performance assessment; and Section VI presents conclusion and future works.

II. THEORETICAL BACKGROUND

Sensory deficiency is the failure to recognize information by recipients of a specific sensory channel, for example, vision [7]. When there is a deprivation of some sensory modality, the person can use methods to provide sensory replacement [8]. Sensory substitution refers to the ability of the human mind to adapt the functionalities of another sensory modality [7]. Visual impairment directly influences communication [9], but there are methods, such as Braille used for sensory replacement to help in the reading process [10]. In the Braille example, touch is stimulated to transmit information. However, stimulation can be through repetitive mechanical stimulation mechanisms, for example vibrating [11]. In particular, the analysis of the vibrating or tactile sensitivity can be performed based on the skin's discriminative response, in which a user can distinguish one stimulus from others, depending on the characteristics of the stimulus (e.g., vibration frequency).

The most used sense as a sensorial substitute to provide visual feedback is touch, even if it presents perceptual limits when compared to the visual modality, since the tactile resolution is three times lower than the visual one [12]. Even so, it is possible through touch to meet the needs of proprioception, defined as the identification of objects and communication [13]. For a user to understand vibrating commands it is necessary to have a language (e.g., Portuguese language) and a code (e.g., Morse code). In this article, we created a language code for communication between vibrating devices and a visually impaired athlete, aiming to guide the athlete in training and running events on the track. In order to create a code, it was necessary to perform tests to measure the amount of energy perceived from the user's sensory system and, among these methods, the following stand out [14]: i) differential threshold method, in which a standard stimulus is used and, in then, the intensity of this stimulus is increased or decreased, in order to identify the intensity, in which there is minimal distinction between one stimulus and another; ii) method of constant stimuli in which two or more stimuli are compared using a standard stimulus and comparison stimuli, based on discrete and successive variations; Both methods were used to generate stimuli and pass information during the race to the athlete, as well as to validate the locations of the body and the perception of different stimuli, defining the positioning, in the user, of the devices for sending the linguistic code to the athlete.

III. RELATED WORKS

The work [6], one of the closest to our, consists of a device to guide blindfolded people, or visually impaired people to leave a maze by means of a remote control and using vibrating stimuli to inform the direction to be taken. The device was tested on 16 people, with commands given by an operator, who observes the path inside the labyrinth.

The work of [15] presents a system developed to assist the visually impaired in closed environments with objects making it difficult to pass. It also uses vibrating stimuli to communicate with the user, but it is only used in an environment previously processed by the image recognition system, serving only to inform obstacles ahead.

The work of [16] developed a system to guide visually impaired athletes on an athletics track, through the sound of the rotors of a drone that is guided by an operator. A deficiency of this system is that, regardless of the number of available drones, the system could only guide a single athlete once the sound stimuli given to an athlete influence the other athletes around him.

The work of [17] developed a system to guide visually impaired athletes in marathons through equipment that creates electromagnetic waves coupled to a car that moves in front of the athlete, guiding him. However, this is a system that would only be used for the marathon modality and even so it has limitations due to the congestion that could be caused if each athlete used a guide vehicle.

This article aims to present a system capable to guide up to 4 visually impaired athletes in track racing, (one in every 2 tracks.). What can be seen in the related works is that they have developed solutions capable of guiding blindfolded people in environments other than Olympic track racing [4][6][15][16]. Another difference is that the related works evaluated their proposals using blindfolds [6][15] or blind people not Olympic Athlete [4][16]. Our proposal was evaluated using 5 track and field athletes. Other differences between the present proposal and those of the highlighted works are shown in Table 1.

Table 1: Related works.

Title	Environment	Stimulus/ actuator	Localization	# People Tested
[4]	Street race	Vibration/engine	Electromagnetic	1 blind people not Olympic athlete
[6]	Indoor (Room with obstacles)	Vibration/ engine	Remote commands	16 (Blindfolded people)
[15]	Indoor (Room with obstacles)	Vibration/ engine	Bluetooth e Kinect	5 (Blindfolded people)
[16]	Street race (Marathon)	Rotor sound/sound	There is not	2 blind people not Olympic athletes
This work	Athletics track	Vibration/ engine	GPS (proposed only in architecture and to be implemented in future work) Remote commands (implemented)	5 blind athletes

Source: Authors, (2021).

IV. PROPOSED SOLUTIONS

The general architecture of the guide system for Olympic races in shown in Figure 1. The system works with a guide of an athlete with visual impairment, operating a smartphone to remotely pass commands to the athlete to guide him during an Olympic racetrack. The commands given by the guide reach the athlete in the form of vibrating stimuli, passed on to the athlete through a vibrating device, that form a set of commands or language code.
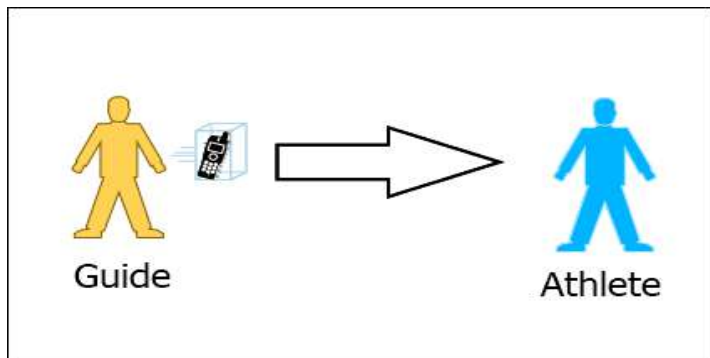

Figure 1: General architecture of the language code system
Source: Authors, (2021).

The development of the prototype followed the procedure specified in Figure 2. In Figure 2, block 1 the prototype started with the development a questionnaire to identify the main commands given by the guides who accompany visually impaired athletes in the Olympic races. The activities started with interviews carried out to identify the needs of the visually impaired athlete and finished with validation of the developed prototype, through tests with athletes. We initially collected information to create the linguistic code. For this, we researched the reality of the visually impaired athletes and professionals trained in physical education (PE) knowledge area through a questionnaire, which we call "Semi-structured questionnaire for guides and athletes". When using this type of tool, there are no precise rules or strict methods to be followed, depending more on the researcher's intuition and experience. According to [5], the questionnaire may have equal questions and in the same order for all people surveyed and the answers can be open, that is, without alternatives or closed, with fixed alternatives.

The interviews can be unsystematic, with spontaneous questions and answers. Attention is drawn to the fact that interviews and questionnaires are helpful and should only be used when the researcher does not obtain answers from other sources, as was the case with this research. It was from this understanding that a semi-structured questionnaire was produced in the research of this article, with closed and open questions and aimed at guides and visually impaired athletes. The questionnaire contained 14 questions as shown in Table 2.

Table 2: Interview questions to athletes.

a)	At what point of the race does the guide transmit the main information to the athlete?			
before		during		after
First, how is the following information passed on to the athlete? Then assign a grade (1-worst to 5-best) regarding the way the command is passed to the athlete				
b)	**Positioning on the track start block**			
Voice			Cord	
1	2	3	4	5
c)	**Incentive during the race**			
Voice			Cord	
1	2	3	4	5
d)	**Race position**			
Voice			Cord	
1	2	3	4	5
e)	**Guidance to accelerate**			
Voice			Cord	
1	2	3	4	5
f)	**Guidance to keep pace**			
Voice			Cord	
1	2	3	4	5
g)	**Identification of athletes in front and behind**			
Voice			Cord	
1	2	3	4	5
h)	**Distance to arrival**			
Voice			Cord	
1	2	3	4	5
i)	**Others? Which and how?**			
j)	**Of the commands listed, which 3 are considered most important to guarantee the result of the race?**			
k)	**What factors usually hinder guide-athlete communication?**			
l)	**What do you think could be done to improve?**			
m)	**Do you think a guidance device could improve athletes' performance during the race?**			
yes		no		I do not know
n)	**What kind of information or command would grow to the device and which today is not informed by the guide?**			

Source: Authors, (2021).

The first questions were used to understand what kind of commands the guides transmitted to athletes before, during and after the race. From these initial questions, it was defined that the linguistic code would only deal with commands transmitted during the race, the main ones identified by the 27 interviewees were: i) Position of the athlete in the race; ii) distance to arrival; iii) command accelerate and danger. Then, the questions were used to understand how the information was passed from the guide to the athlete, via a cord tied to the two or via voice command, and to assess the quality of the information passed by each of the commands. With the answers, it was found that the voice commands passed by the guides and respective quality scores of the information passed on, from 1 to 5, with 5 being the best score, were scored by the athletes as follows: i) orientation to accelerate (5); ii) current position (5); iii) guidance to keep pace (5); iv) approaching opponents (3); v) distance to complete the race (3). The only command transmitted by the cord and its respective note was the positioning of the athlete on the track with a score of (5). The interviewees were also asked if there was any factor that would impair voice communication. In response, 24 of the 27 participants said yes, and the three most answered reasons were: crowd noise, traffic noise and voice commands from other guides to their athletes.
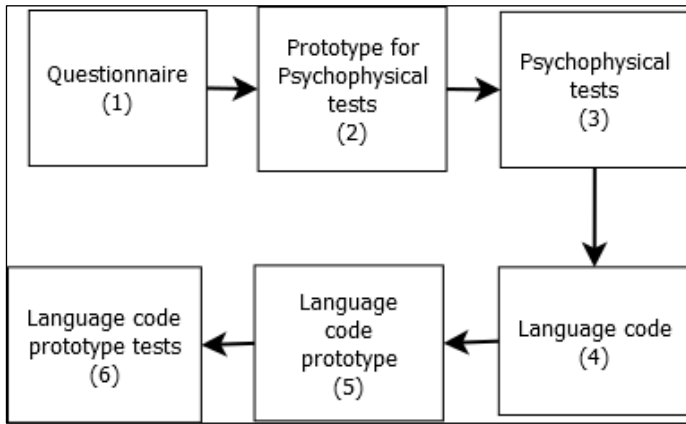
Figure 2: Prototype development procedure.
Source: Authors, (2021).

As shown in Figure 2 block 2, a prototype for psychophysical tests was built, whose function was to identify the form and intensity of vibrating stimuli application so that it was possible to pass commands to athletes during the race. The prototype uses an ESP-32 module [18] to which, using its GPIO (General Purpose Input Output Interface) interfaces, were wired connected to 02 bracelets, with 01 vibrating motor in each, positioned on the athletes' wrists and an elastic strap, positioned at athlete's chest, and containing vibrating motors on the athlete's chest and back. More details about the bracelet and elastic strap will be presented in the next section. In the ESP-32 module, a program was developed to control the vibration intensity of the 02 vibrating bracelets and 02 vibrating motors positioned on athlete's chest and back.

Then, Figure 2 block 3, psychophysical tests were carried out using the vibrating prototype of block 2. The constant stimulus method was applied to verify from which vibration power value it was possible to notice the difference in vibration intensity between the bracelets 1 and 2, with a constant vibration stimulus being applied to bracelet 1 and, a variable vibration being applied to bracelet 2 at the same time. The results of the constant stimulus method evaluation are shown in Table 3 where we can see in the last line that from a vibration frequency difference of 10 Hz, it was possible to perceive the difference in vibration between bracelets 1 and 2.

Then, the differential threshold method was used to identify combinations of vibration frequencies, with differences of 10 Hz, which could be perceived by users. The results of this test are presented in Table 4 where we noticed that the users of the system were able to perceive reduction, increase or if there was no difference between the vibration stimuli of bracelets 1 and 2, with the stimuli having a difference of at least 10 Hz.

Table III. Constant stimulus method.

Vibrating frequency of bracelet 1 (Hz)	Vibrating frequency of bracelet 2 (Hz)	Users' perception of vibration frequencies
135	136	no difference
135	137	no difference
135	138	no difference
135	139	no difference
135	140	no difference
135	141	no difference
135	142	no difference
135	143	no difference
135	144	no difference
135	145	perceived difference

Source: Authors, (2021).

Table IV. Differential threshold method.

Vibrating frequency of bracelet 1 (Hz)	Vibrating frequency of bracelet 2 (Hz)	Users' perception of vibration frequencies
135	140	Higher vibrating power
150	140	Lower vibrating power
135	135	Equal vibrating power
135	160	Higher vibrating power

Source: Authors, (2021).

Based on the analysis of the developed questionnaire (Figure 1, block 1) and the results of psychophysical tests (Figure 1, block 3), we created the language code of Table V (Figure 2, block 4), which was evaluated by performing tests by using the language code prototype (Figure 2, block 5) on each individual athlete and, subsequently, validated in a test environment by accomplishing the language code prototype tests of Figure 2, block 6.

Table V. Language code.

| Command	Meaning
(1) Vibrate left bracelet	Smoothly turn left
(2) Vibrate right bracelet	Smoothly turn right
(3) Do not vibrate	Move forward
(4) Vibrate in the front with increasing power	Approaching the athlete ahead
(5) Vibrate in the back with increasing power	Athlete from behind approaching
(6) Vibrate in the front with decreasing power	Front athlete moving away
(7) Vibrate in the back with decreasing power	Distancing from the back athlete
(8) Vibrate the 4 engines simultaneously (01 engine of each bracelet and 02 engines, 01 in front and one at the back of the belt)	Athlete advanced another 100 meters

Source: Authors, (2021).
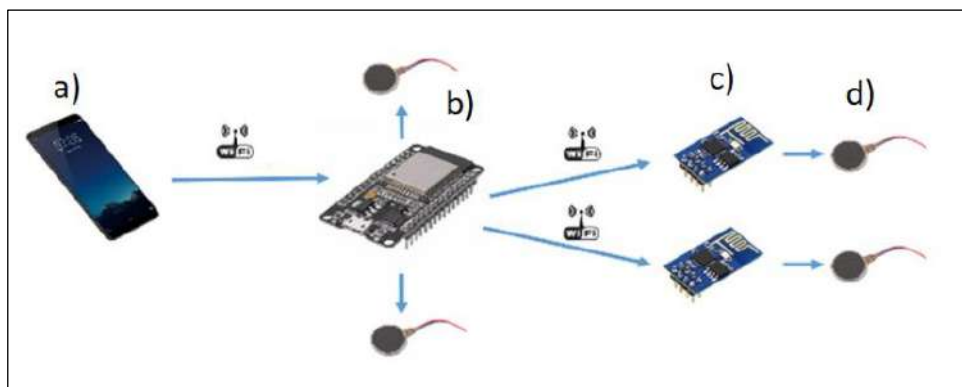
Figure 3: Language code prototype.
Source: Authors, (2021).

After the development of the linguistic code system, tests were applied in a testing environment. In the tests, we evaluated the language code and the developed language code prototype (Figure 3) through commands sent by a smartphone, checking if the athlete's response was consistent with the command. In the testing environment, a visually impaired athlete moved from the start point to the end point of the 400 m racetrack, performing one complete lap on an athletics track.

IV.1 LANGUAGE CODE PROTOTYPE

The developed language code prototype (Figure 3) is composed of: (a) smartphone responsible for sending vibration commands to a set of 4 vibracall motors; (b) an ESP32 microcontroller equipped with Wi-Fi communication, responsible for receiving commands from the smartphone and, forwarding the commands, via wired communication, to the motors located on the front and rear of an elastic strap positioned around the athletes' chest, as well as send, via Wi-Fi communication, commands for the motors of each bracelet, left and right, (c) two ESP01 microcontrollers equipped with Wi-Fi communication, connected each ESP01 to a vibracall engine, which vibrate when receiving commands (ex: turn left or right). The ESP01 microcontroller was chosen because it had the necessary dimension to be placed inside a specially developed bracelet; (d) 4 vibracall type motors.

The vibrating bracelets, Figure 4, positioned one on each athlete's wrist, are composed of an ESP01 microcontroller and a circuit board developed to couple a battery to the vibrating motor, as shown in Figure 5. They also have an enclosure built in a 3D printer to protect each one of circuits / devices. The design of the enclosure was designed to allow it to fit on a watch strap and still fit inside the enclosure an ESP01 microcontroller, a developed circuit board, a vibrating motor, and a battery.
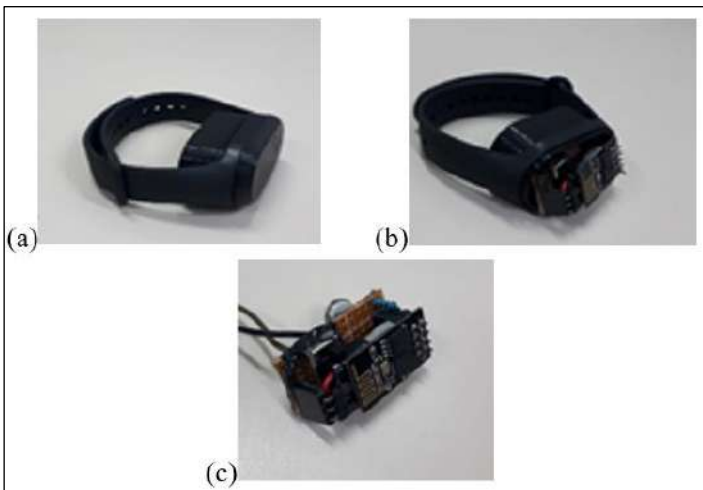

Figure 4: Vibrating bracelets. (a) closed bracelet; (b) bracelet with the apparent internal circuit; (c) circuit board that connects ESP01, battery and motor.
Source: Authors, (2021).

In addition to the bracelets, 2 more points of the body were defined, being the back and chest, to send vibrating commands to athletes during athletics competitions. We also use a smartphone that transmits, via Wi-Fi, commands to the ESP32 microcontroller informing the location (left bracelet, right bracelet, front engine - chest or back engine - back) and vibration pattern, to the

microcontroller to pass on the linguistic code information to the athlete.

When a command sent by the smartphone, required the activation of the vibrating motors on the athlete's back or chest, the ESP32 itself was responsible for driving the correct motor by wire, according to Table 1 of commands. When a command was directed to one of the vibrating bracelets, the ESP32 module forwarded, via Wi-Fi, the command to one of the ESP01 modules located on the corresponding wrist. The vibrating devices implemented the language code with the function of guiding the athlete on the athletics track. As can be seen in Figure 3, the ESP32 module was connected to the vibrating motors using two wired connection outputs.

Figure 5: Circuit board developed to connect ESP32 microcontroller and vibrating motors via wired connection.
Source: Authors, (2021).

In addition, we developed an embedded code in the ESP32 microcontroller, which was used to receive the information transmitted by the cell phone and forward the commands to activate the correct vibrating device, located on one of the arms, back or chest.

V. RESULTS AND PERFORMANCE ASSESSMENT

Android smartphone software was developed to validate the developed linguistic code. This software was used to manually pass information over a wireless network to the athlete during the tests of the prototype and language code, and to verify that the athlete understood the stimuli correctly.

Using the linguistic code and the developed hardware and software prototypes, we perform the following experimental procedures.

V.1 TEST PROCEDURE 1: ASSESS THE MOST SENSITIVE AREAS OF THE ARMS (LOCATION: SPORTS COURT)

The purpose of test 1 was to assess the most sensitive areas of the arms for the application of the vibrating commands to gently turn left and right. For this, tests were carried out with 5 athletes and in 3 different positions on the arms, being the shoulder, above the elbow and on the wrist, to verify which place of vibration of

greater perception for the athlete at the race. As a result, the pulse was chosen, unanimously, by the athletes as the region of greatest perception.

V.2 TEST PROCEDURE 2: ASSESS THE MOST SENSITIVE AREAS IN THE FRONT AND BEHIND (LOCATION: SPORTS COURT)

In test 2 the objective was to test the areas of greatest sensitivity for the commands that involve vibration in the front and behind the athlete's body. These are the athlete approach commands (commands 4 to 7) and a 100m advance command. Tests were performed with 5 athletes and in 2 different positions on the front and back of the athletes' body, with the objective of verifying in which place, the vibration was the most noticeable in running. The two positions to perform belt positioning tests with vibrating devices were the waist region and the chest region of the athlete. The location chosen by all 5 athletes was below the chest as shown in Figure 6. It is said that these tests were applied by sending commands from the developed android application to the ESP32 microcontroller.

Figure 6: Elastic belt with vibrating devices placed in the athlete's chest position.
Source: Authors, (2021).

V.3 TEST PROCEDURE 3: VERIFY INTERPRETATION OF EACH COMMAND (LOCATION: TRACK)

The purpose of test 3 was to verify on an athletics track, the individual interpretation of each of the commands of the linguistic code with each of the 5 evaluated athletes. To perform the tests, each of the commands in Table 1 was sent individually to each athlete at the track, and the athlete was checked to identify the information sent. To carry out the verification, the movement performed was observed and the athlete was asked for verbal confirmation regarding the command identification. As a result, 100% of the tested athletes identified all commands sent after 15 minutes of training. However, for the right and left turn commands, it was difficult for the athletes to determine the degree of the slope, thus having results not so satisfactory with the training time used. It is said that these tests were applied by sending commands, from the application to the ESP32 and by sending the commands to the

ESP01 microcontrollers, placed on the wrists, or vibration motors of the desired position (e.g., chest or back).

V.4 TEST PROCEDURE 4: VERIFY APPROACHING AND DISTANCING COMMANDS (LOCATION: TRACK)

In test 4, we verified whether the commands for approaching and distancing the athlete ahead (commands 4 and 6) and the approach and distance for the athlete from the back had the variation in vibration force (e.g., increase or decrease) necessary for the athlete perceive the approach or distance. The values used for reducing and increasing the vibration power were, the change from 135 to 150 for the increase, and change from 150 to 135 for the decrease. The tests were carried out with the 5 athletes, for whom commands were applied with power variation of the motor located on the athlete's chest and back and asking for confirmation of the interpretation of the commands by the athletes. As a result of the tests, we found that of the total of 35 commands sent to the 5 athletes, 31 were correctly interpreted. In cases where the command was not interpreted correctly, we verified that the prototype slipped due to the athlete's sweat.

V.5 TEST PROCEDURE 5: CHECK ALL THE COMMANDS (LOCATION: TRACK)

The purpose of this test was the athlete to test the system presented in this article when running on the track, without a guide and receiving commands passed through the system. As in test procedure 3, athletes had difficulties in knowing the degree of inclination for the controls to gently turn left and right. To overcome this problem, tests were performed to decrease the engines vibration frequency to perform a lower incline, and even then, the problem continued to occur. From there, a training of approximately 5 hours was carried out so that the athletes were able to use properly the developed system. From the training we obtained a satisfactory result, where all 5 athletes managed to complete the 100-, 200- and 400-meters race using, each athlete, 2 lanes of the athletics track.

VI. CONCLUSIONS

In this article, we present a prototype of hardware and software to guide athletes with visual impairments in athletics competitions. The prototype developed was tested in simulated races on an athletics track, verifying its viability with use by athletes on courses of 100, 200, 300 and 400 m.

We conclude that after the development of a location subsystem using high precision GPS and improvements in the guidance subsystem related to the turn angle on the track, the developed system has the potential to be used in real competitions. The athletes and guides welcomed the prototype and during the tests, the athletes claimed to feel autonomy with the information received by the vibrating devices, as well as praising the fact that they might not be concerned with the synchronization with the guide in the race, focusing on improving the race time.

As a future work, it is also suggested a version of the prototype that makes it possible to choose, via voice commands, a location on a city map so that the developed prototype / device vibrates warning about the directions to be taken on the route selected map.

VII. AUTHOR'S CONTRIBUTION

Conceptualization: André Machado.
Methodology: André Machado and Celso Carvalho.
Investigation: André Machado.
Discussion of results: Celso Carvalho and André Machado
Writing Original Draft: Celso Carvalho and André Machado.
Writing – Review and Editing: Celso Carvalho.
Resources: André Machado.
Supervision: Celso Carvalho.
Approval of the final text: Celso Carvalho and André Machado.

VIII. ACKNOWLEDGMENTS

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ANALYSIS OF POWER QUALITY PARAMETERS AT COMPARING UPS OF DIFFERENT TECHNOLOGIES

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ARTICLE INFO	ABSTRACT
	Commercial and industrial consumers are vulnerable to disturbances in distribution networks. One solution to this is using the Uninterruptible Power Systems (UPS). However, this may have other impacts on the power system. This document describes the main principles of UPS system operation. In addition, the paper presents tests on two UPS to verify the quality of power supplied to the system that the UPS feeds. For this purpose, the power factor, the voltage unbalance factor, the frequency variation and the voltage and current waveform were recorded due to the presence of harmonics. This paper also shows the importance of implementing a UPS labeling program.

I. INTRODUCTION

In some sectors, such as telecommunications, Information Technology (IT), health, transportation, financial, industry and energy, there are some tools which are essential to operating uninterrupted, an aim to prevent them from being harmed by consumers [1].

In order to improve the power quality and consequently reduce the impact caused due to the poor quality in the power supply in their equipment, the industries seek the efficient installation of energy. To protect their belongings some devices are used. The devices are as UPS, dynamic voltage regulator of static compensation of energy distribution and unified power quality conditioner (UPQC) [2]. In this way, it gives to electric power suppliers the certainty of some determinism of the form of consumption and protection of their investments [3].

To protect processes and equipment that are sensitive to network parameters, many consumers have the option of using UPS, ensuring continuity in the source supports.

With the technological evolution and to meet the needs of the load, UPS units were created with three types of technology. These technologies can be classified as: online, offline and interactive. This article will show the main characteristics of each technology, as well as its advantages and drawback.

Because the UPS is a non-linear load, it can cause harmonic distortions of voltage and current in the network. In addition, it can impact other parameters of the power quality. Therefore, it is necessary to analyze the impacts caused by the UPS in the network and how is the quality of power provided by these units the load.

Despite the growth in UPS usage in the Brazilian market, these devices still need improvement. UPS with low-quality components are still found in the Brazilian market. The consequence of this is low-quality UPS that can affect both the distribution network and the load it feeds. In order to reduce the presence of these UPSs in Brazil, a labeling program is suggested with quality levels to be achieved by the manufacturers.

The following sections are divided into Section II, which briefly describes the components of the UPS system, the classification of technologies, and classification of the topology. Also in this section, it presents the definition of power quality and the standards in Brazil. Section III presents the scenario to which the tests performed in this article were executed and then Section IV shows the results obtained and the analysis of such results. Finally, Section V brings the conclusions found in this article.

II. LITERATURE REVIEW

II.1 UNINTERRUPTIBLE POWER SUPPLY

A UPS is, typically, made up of a rectifier, inverter, a batteries bank, automatic transfer switches (ATS), and static transfer switches (STS). It works as an emergency power supply

embedded in a grid to generate continuous and stable electricity, especially for those environments where a power supply is generally erratic or uninterruptible power supply is highly required [4].

Batteries are important for energy back-up in a UPS. The capacity and life of a battery depend on several factors such as charging mode, temperature, maintenance and use time [5]. At present, rechargeable batteries use technologies such as valve-regulated lead-acid (VRLA), nickel–cadmium (Ni-Cd) or lead-acid batteries (LABs) [4].

The use of the inverter in the UPS system requires care because besides adjusting the phase angle and magnitude of the output voltage of the system, it can also be used to help improve some power quality parameters [6].

II.1.1 Classification of UPS

• Online UPS system

In online UPS system, the inverter is always active and there are no transfer delays between the external power source and the battery bank and only uses the battery bank in the absence of power, thus avoiding problems such as very high voltages or very low voltages. By doing double conversion it generates a sine wave with perfect output no matter how the wave is at the input. It is recommended for very sensitive loads that require continuous and uninterrupted power, such as hospital equipment, data centers, and servers.

This type of technology has some advantages. The fact that the load is continuously fed by the inverter, so there is no delay due to the transfer time. The output voltage of the UPS is regulated resulting in a low harmonic voltage distortion rate. In addition, grid disturbances do not reach the load. Another interesting point is the use of a static switch, causing an increase in UPS reliability.

On the other hand, it has a low performance, as the converters are cascaded. In addition, it has a high cost as well as its sized due to the rectifier that is dimensioned to power the inverter plus the battery charge.

• Offline UPS system

In the offline UPS, your inverter remains off while the power supplying the loads is provided by the AC lines. However, when the power distribution network fails, the UPS makes use of the pre-charged batteries to continue supplying power while the batteries are being charged. In these UPS models, there is a transfer delay that is usually a few milliseconds, a time required to power the UPS inverter. It is recommended for homes, businesses, and offices.

The use of UPS of this type of technology presents some benefits like the high efficiency, this because the inverter can operate with no load or off. Another interesting point is its lower cost, compared to online technology UPS, as well as its size, this is a consequence of the battery charger being independent.

Despite the benefits cited, the offline UPS system has a voltage regulation at low load, besides a lack of conditioning of the input current, which can cause an injection of harmonics in the system's electrical network when the loads are non-linear, taking as a consequence a square waveform in the output voltage. Transfer time between the network-to-inverter and the network-inverter modes can be a problem because this can cause zero voltage on the load at these times.

• Interactive UPS System

The interactive UPS system features a static switch, bidirectional converter/inverter, and battery bank in your system.

During normal operation, power is supplied to the load through the distribution network while the bi-directional converter/inverter charges the battery bank. When there is a fault in the AC lines, the static switch disconnects the load from the distribution network and the converter/inverter feeds the load.

Interactive UPS has the advantages of low cost and higher yield. In addition, it presents the possibility of regulating the output voltage or compensating the harmonics of the load current, allowing the input of the converter to be close to a sinusoid.

The main disadvantage of this type of UPS is that the presence of the inductor does not allow the output voltage and the input voltage to be in phase, generating a transient when the switch is used in the by-pass mode.

II.1.2 Topology-Based Classification

In order to meet the requirements of the load, there are a variety of configurations of the UPS system. Thus the UPS system can be classified as the configuration of the topology and its circuit. The UPS system may be transformer-based, transformer-less, or high-frequency transformer based. In the literature, the reference [7] it is possible to have a detail on the topic.

II. 2 POWER QUALITY(PQ)

There are several definitions regarding the concept of PQ. This paper will be based on the concept that "Power quality encompasses the characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters" [8]. PQ issues can be viewed in two perspectives one is on the utility side and the other is customer perspective. In the view of utility perspective it relates to system reliability and in the view of the customer, it is an event that is manifested with current, voltage and frequency [9].

One of the known PQ disturbances is voltage events like voltage dips, rapid voltage changes (RVC), swells and interruptions [10]. Although a large volume of data is not available for comparison, based on available literature, there is considerable evidence to suggest that voltage harmonic levels measured on Australian electricity distribution networks are lower than those observed in Europe. There is also limited evidence to suggest that these Australian harmonic levels may be significantly higher than those observed in other regions such as Asia and South America [11].

In Brazil, ANEEL (National Agency for Electric Energy) elaborated PRODIST (Distribution Procedures). These documents present standards related to the technical activities related to the operation and performance of the electricity distribution systems. The topic of electric PQ is addressed in its module 8. This module considers the following aspects of steady state PQ:

• Voltage at steady state - the voltage contracted at power distribution company at the connection points for accessories complying with a nominal operating voltage of more than 1kV must be between 95% and 105% of the nominal system voltage at the connection point and still coincide with the nominal voltage of one of the branch terminals previously required or recommended for the transformer of the consumer unit. In case the voltage contracted at the connection point by the access or served is equal to or less than 1kV, it must be the rated voltage of the system [12].

• Power Factor (PF) - The PF value must be calculated from the active and reactive power registers (P, Q) or respective energies (active energy - AE, reactive energy - RE), using the following equations:

$$fp = \frac{P}{\sqrt{P^2 + Q^2}} = \frac{AE}{\sqrt{AE^2 + RE^2}} \qquad (1)$$

• Harmonic Distortions - are phenomena related to the deformation in the waveforms of the voltages and currents in relation to the sine wave of the fundamental frequency [12]. The Total Harmonic Distortion (THD) is defined as the total amount of harmonics relative to the fundamental and can be calculated using the equation below up to the 31st harmonic, where the inverter low pass filter typically eliminates other higher order harmonics [13].

$$THD\% = \frac{\sqrt{\sum_{n=3,5,\ldots}^{31} V_n^2}}{V_1} \, x \, 100 \qquad (2)$$

• Voltage unbalance - occurs when a difference between the amplitudes in the three phase voltages of a three-phase system, and/or in the electrical phase-shift of 120º between the phase voltages of the same system is verified. This unbalance is calculated from the following mathematical formulation [12]:

$$VU\% = 100 \sqrt{\frac{1 - \sqrt{3 - 6\beta}}{1 + \sqrt{3 - 6\beta}}} \qquad (3)$$

$$\beta = \frac{V_{ab}^4 + V_{bc}^4 + V_{ca}^4}{\left(V_{ab}^2 + V_{bc}^2 + V_{ca}^2\right)^2} \qquad (4)$$

Where Vab, Vbc, Vca are line voltage of the phases a, b and c

• Voltage fluctuation - is characterized by the random, repetitive or sporadic variation of the peak value of the instantaneous voltage.

• Frequency variation - the distribution system and the generation facilities connected to it must, under normal operating conditions and on a steady state, operate within the frequency range between 59.9Hz and 60.1Hz [12].

III. TESTS

In order to analyze the PQ provided by two distinct UPS, were recorded: voltage and current waveforms and, consequently, the harmonic voltage distortion present in the system; the PF; the voltage unbalance and the frequency variation.

UPS A has a nominal power of 75kVA, with three-phase input and output at 380V and rated frequency of 60Hz. This UPS supply power a research lab, where it exhibits a capacitive load characteristic. The UPS connection features technology that is classified as offline.

The UPS B has a rated power of 40kVA, as well as the UPS A, has input and output three-phase at 380V and rated frequency of 60Hz. A data center is feed by that UPS. Due to the need for the load, UPS uses online technology.

In order to compare the quality of power supplied to the system by UPS of different technologies, two tests were performed on each UPS. In the first moment were verified the parameters of energy that is supplied to UPS, that is, originating from the power distribution company. The second measurement was made from

the output of the UPS, that is, the power that is supplied to the system. Figure 1 shows how the measurement was made at the input of UPS A. Above the UPS is located the PQ analyzer. This equipment measures and records current, voltage, power and THD of voltage and current. The coils used are Rogowski coils. They are meant to measure currents. The wires connected to the circuit breaker and the neutral and ground rods are used to measure the voltages.

Figure 1: Measurement on UPS A.
Source: Authors, (2021).

IV. RESULTS ANALYSIS

Figures 2 to 9 show the results of the measurements made during the test period. The graphics were taken from the PQ analyzer software. Figures 2 to 5 belong to UPS A while Figures 6 to 9 refer to UPS B.

Figure 2 shows the waveform of the input voltage at UPS A from top to bottom in phases A, B and C respectively. It is possible to observe that there is no significant harmonic distortion. A THD of 3.03% was recorded in phase A, 2.63% in phase B and 3.10% in phase C. Figure 3 represents the wave, and its harmonic distortion, of the input current of the UPS. During the measurement period, the waveform presented a THD of 25.64% in phase A, 22.87% in phase B and 23.43% in phase C, where the harmonics of 3rd were mainly highlighted, but there was a large register of 5th and 7th order harmonics. Regarding the PF, the value of 0.95 capacitive was recorded. As for the voltage unbalance factor, the value was 1.52%. The frequency varied around 59.94Hz.

Figure 2: Voltage input to UPS A.
Source: Authors, (2021).
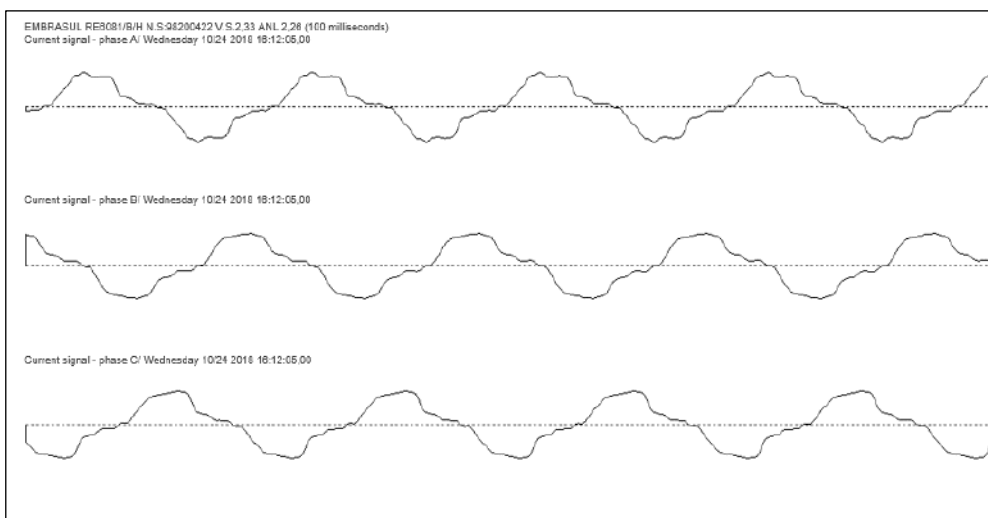
Figure 3: Current input to UPS A.
Source: Authors, (2021).

Figure 4 shows the output voltage waveform of UPS A in phases A, B, and C. As shown in Figure 2, there is no significant harmonic distortion. The THD values do not differ much in relation to the input voltage of the UPS, being 2.92% in phase A, 2.59% in phase B, 3.01% in phase C. Table 1 presents a comparison between the individual orders of the input and output voltage harmonics A. The values are given are% of the fundamental.
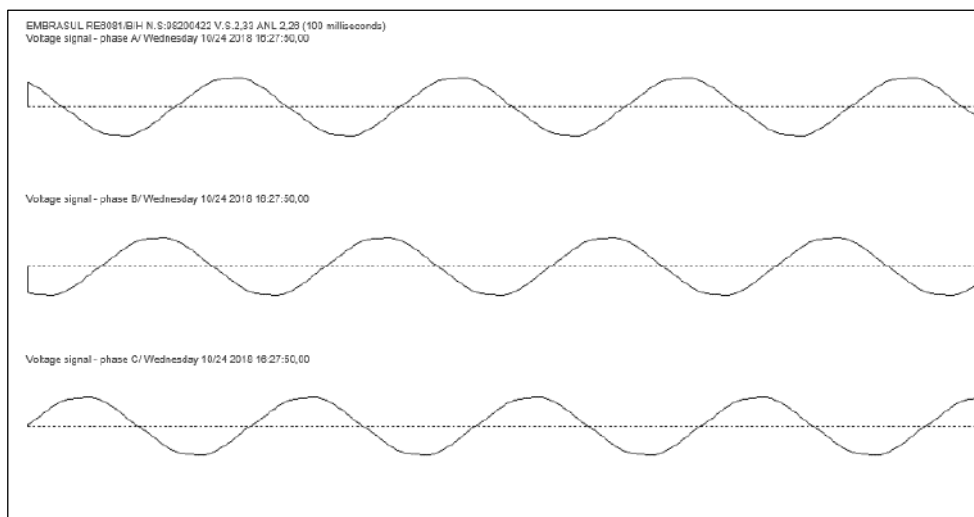
Figure 4: Voltage output from UPS A.
Source: Authors, (2021).

Table1: Comparison of the voltage of UPS A.

Harmonic Order	Voltage Input UPS A			Voltage Output UPS A		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
3	1.93	1.56	2,12	1.47	1.09	1.56
5	1.93	1.97	2,04	2.08	2.13	2.27
7	1.06	0.74	0,97	1.06	0.66	0.97
9	0.74			0.94	0.71	0.66

Source: Authors, (2021).

The waveform of the UPS output current is shown in Figure 5. The recorded THD values are 24.62% in phase A, 25.13% in phase B and 21.77% in phase C. Although not there is a very significant difference in the total values of harmonic distortion, there is a variation in the harmonics order. Table 2 shows a comparison of the harmonic currents of the input and output of the UPS, with values referring to% of the fundamental order.

Figure 5: Current output from UPS A.
Source: Authors, (2021).

The reduction of 3rd order harmonics occurred due to the presence of low-pass filters inside the UPS since the increase of harmonic distortion of 5th, 7th and 9th order originated due to the presence of some electronic components contained in the UPS that resonate with the load, resulting in an increase of these harmonic components.

Table 2: Comparison of the current of UPS A.

Harmonic Order	Current Input UPS A			Current Output UPS A		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
3	22.89	20.16	20.56	13.44	18.74	16.30
5	7.41	8.35	7.85	15.09	12.85	10.26
7	6.06	5.10	6.00	10.93	7.89	7.61
9	4.27	0.87	2.02	6.91	4.83	3.61
11	2.81	3.61	3.16	2.76	3.27	2.94
13	2.70	2.28	3.18	3.8	3.73	4.41
15	0.78				1.26	1.02
17	2.46	0.91	1.62	2.34	1.52	1.51
19				0.80		
21		0.79	0.70			
23	1.20		0.87	1.38	0.91	

Source: Authors, (2021).

Considering the other PQ parameters, the measured PF was 0.95 capacitive. Regarding the voltage unbalance factor, it registered 3.91%. The frequency variation was around 59.94Hz.

The waveform in the voltage input of the UPS B is represented in Figure 6. In this, it is possible to observe that the harmonic distortion of the wave is insignificant. The THD recording was 3.11% in phase A, 3.36% in phase B and 3.50% in phase C. Figure 7 shows the waveform of the input current in UPS B. Through these curves it is possible to observe a large harmonic distortion in the current wave received from the utility. The measurement shows a THD of 33.89% in phase A, 46.92% in phase B and 23.31% in phase C. In these registers there was a predominance of 3rd and 5th order harmonics. With regard to the PF, the value of 0.99 was recorded. The voltage unbalance factor was 0.11%. Regarding the frequency variation was around 60.06Hz.
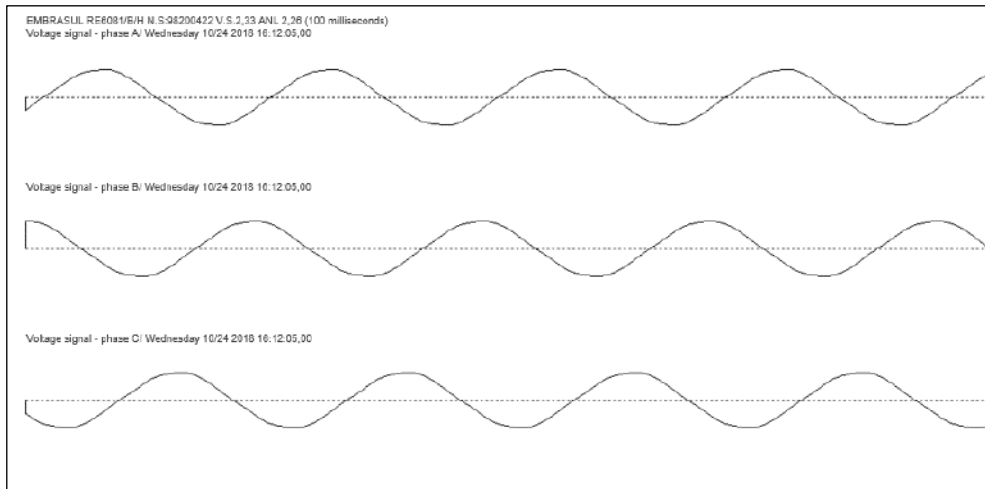

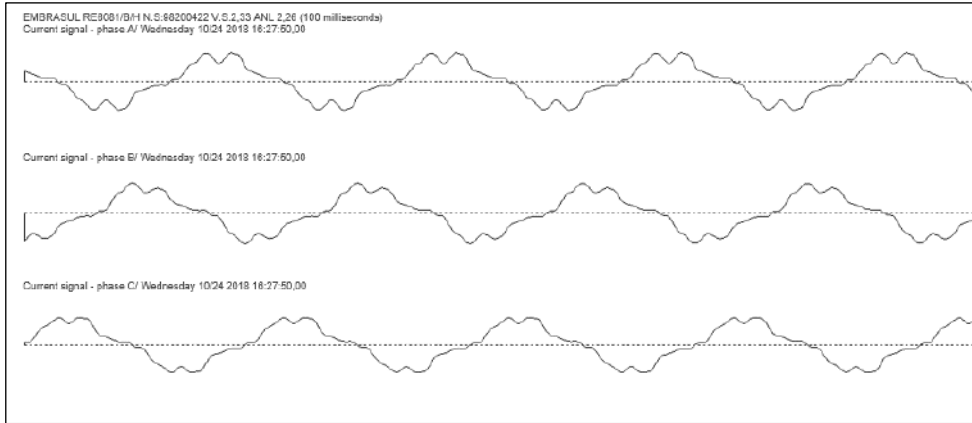Figure 6: Voltage input to UPS B.
Source: Authors, (2021).
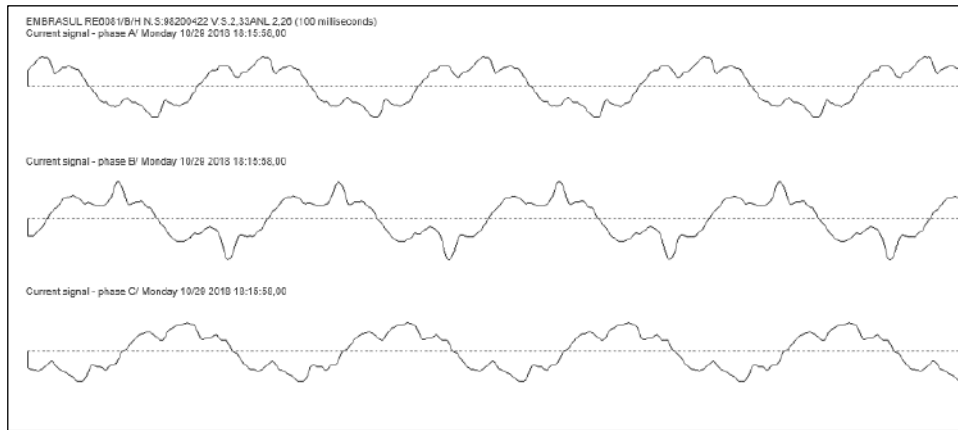
Figure 7: Current input to UPS B.
Source: Authors, (2021).

According to Figure 8 and according to the registered in the PQ analyzer, the waveform of the voltage at the output of UPS B, there was practically no harmonic occurrence in the voltage supplied by the UPS to the system. The THD of phases A and C was zero, whereas in phase B there was a THD of 0.87%. Table 3 presents the comparison of the harmonic orders of the UPS input and output, having their values as % of the fundamental.
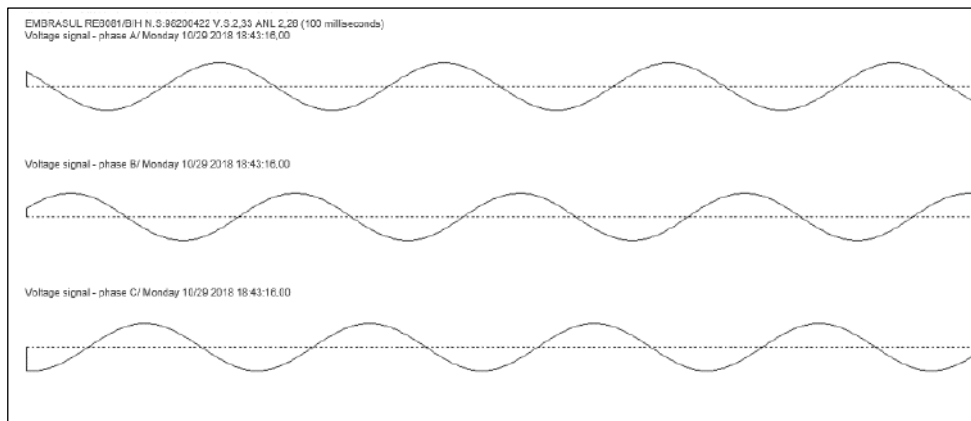
Figure 8: Voltage output from UPS B.
Source: Authors, (2021).

Figure 9 shows the waveform of the current at the output of the UPS B. Through this figure it is possible to observe a significant improvement in the waveform. The THD of 5.93% in phase A, 7.20% in phase B and 5.79% in phase C, actually prove this improvement. The filters in the UPS are responsible for improving the PQ in this measurement. Table 4 shows the contrast between the harmonic orders of the UPS input and output. The values presented are% relative to the fundamental.

Table 3: Comparison of the voltage of UPS B.

Harmonic Order	Voltage Input UPS B			Voltage Output UPS B		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
3	2.54	2.85	3.08		0.87	
5	1.49	1.45	1.38			
7	0.97	0.72	0.89			
9		0.68				

Source: Authors, (2021).
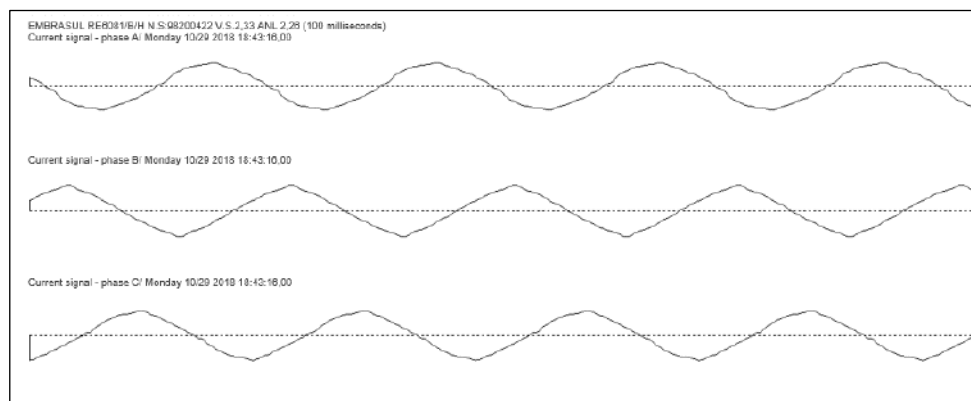
Figure 9: Current output from UPS B.
Source: Authors, (2021).

Table 4: Comparison of the current of UPS B.

Harmonic Order	Current Input UPS B			Current Output UPS B		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
3	21.22	35.15	12.73	4.09	5.62	4.24
5	21.31	20.47	22.05	2.61	2.63	2.51
7	11.50	15.59	4.91	2.23	1.60	2.12
9	4.42	13.38	6.49		2.75	0.47
11	6.13	6.66	5.28	1.13	1.41	1.41
13	2.94	4.52	1.94	1.02		0.58
15	3.27	3.63	2.91	1.70	1.03	0.66
17	1.42	1.46		1.13		
19	2.32		2.21			0.82
21	1.14	0.76	2.00			0.66
23	2.37	0.95	2.39			0.51
25	0.97	1.51				0.55
31	1.23	1.00				
39	0.66					
41	0.76					

Source: Authors, (2021).

Regarding the other PQ parameters analyzed at the output of UPS B, the power factor value of 0.97 was recorded. As for the voltage unbalance factor, the value was 0.09%. Regarding the frequency variation, the value was registered around 60.00Hz.

Tables 5 to 9 present a comparison between UPS A and B and compare them with the minimum indicators described in the PRODIST. Although a minimum indication was not specified in the PRODIST, a comparison was made between the current THD of the two UPS. It is possible to observe that the records made in the measurements are according to the PRODIST, except for the voltage unbalance factor of the UPS A.

Table 5: Comparison of PF.

PRODIST	Output UPS A	Output UPS B
0.92 <*PF*< 1.00	0.95	0.97

Source: Authors, (2021).

Table 6: Comparison of Voltage THD.

PRODIST	Voltage Output UPS A in %			Voltage Output UPS B in %		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
THD<10%	2.92	2.59	3.01	0	0.87	0

Source: Authors, (2021).

Table 7: Comparison of current THD.

Current Output UPS A in %			Current Output UPS B in %		
Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
24.62	25.13	21.77	5.93	7.20	5.79

Source: Authors, (2021).

Table 8: Comparison of unbalance voltage.

PRODIST	Output UPS A	Output UPS B
UV < 3.0%	3.91%	0.09%

Source: Authors, (2021).

Table 9: Comparison of frequency variation.

PRODIST	Output UPS A	Output UPS B
59.9 < *f* < 60.1	59.94	60.00

Source: Authors, (2021).

When comparing the two UPS, although both are in accordance with the PRODIST indicators, except for the voltage unbalance factor of UPS A, we can observe that in UPS B there is an effective improvement in the quality of power supplied to the system through the UPS. Already with the use of UPS A, we cannot see any improvement, especially regarding the harmonic content

provided to the system. This difference in PQ provided by the UPS to the system is due to the classification of the technology present on the UPS is installed.

In order to have greater transparency vis-à-vis the consumer, as far as UPS is concerned with improving the system and reducing the number of low-quality products on the market, Brazilian public policy may adopt a UPS labeling program. This would stimulate the increase in the quality of the products in terms of energy efficiency and the quality of energy supplied. As suggested in the reference [14].

V. CONCLUSION

The growing need for quality energy supplies means that there is a continuous growth in the use of UPS for this purpose. This article shows the relevance of UPS in the quality of power supply. In addition, it shows the importance of the topology classification that the UPS is installed to meet the customer's goal. So if you want to use the UPS to increase the PQ of the system you should install the UPS online. If you install the UPS offline, you will not be able to see an improvement in the quality of the power, and may even make it worse. Another important point that the article shows is that the UPS tested are in accordance with some PQ parameters specified by ANEEL.

In Brazil, UPS consumes about 1.7% of energy production. This percentage represents 8,529,286MWh, which presents losses of about 1,006,790MWh, i.e., 11.8% of the total energy consumed by UPS is losses [14]. Therefore, an efficient labeling program with adequate supervision can increase the quality of the equipment on the market and consequently reduce UPS consumption losses.

Through this article, it is possible to observe the importance of the adopted UPS technology aiming at the sensitivity of the load that this UPS will feed. In addition, this article shows the importance of a UPS labeling program to improve the quality of the equipment supplied on the market.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Rafael Provenzano Jou Alves, André Abel Augusto and Márcio Zamboti Fortes.
Methodology: Rafael Provenzano Jou Alves, André Abel Augusto and Márcio Zamboti Fortes.
Investigation: Rafael Provenzano Jou Alves.
Discussion of results: Rafael Provenzano Jou Alves, André Abel Augusto and Márcio Zamboti Fortes.
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Writing – Review and Editing: Rafael Provenzano Jou Alves, André Abel Augusto and Márcio Zamboti Fortes.
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Supervision: André Abel Augusto and Márcio Zamboti Fortes.
Approval of the final text: Rafael Provenzano Jou Alves, André Abel Augusto and Márcio Zamboti Fortes.

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RESEARCH ARTICLE   **OPEN ACCESS**

IDENTIFYING THE CHALLENGES TO SUSTAINABLE HIGHER EDUCATIONAL INSTITUTIONS COMMUTE

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ARTICLE INFO

ABSTRACT

The first objective was to understand commuters' regular travel mode. The second objective was to understand the reasons for the regular mode and the preferred alternative when this regular mode was not available. The third was to determine the willingness to change to public transport mode and what concerns commuters had about the mode. A questionnaire survey of workers who commuted daily to Higher Educational Institution (HEI) workplaces located at the city of Ado Ekiti was conducted. This survey collected data on respondents' regular commute mode, alternative commute mode, willingness to use public transport mode and the desired improvement in public transport mode. Commuters' most popular commute mode was private automobile with 67% using this mode regularly. This was followed by a variant of carpooling called joining others (19.4%) and then public transport (13%). The most preferred alternative for all commuters was joining others which 49.6% opted for. The willingness to use public transport was found to be 66.5% with improved public transport vehicles and better driver training identified as necessary for improved uptake of public transport. This paper concludes that the choice of respondents generally underscored the need to improve public transport system as well as encourage its acceptability and use.

I. INTRODUCTION

Higher educational institutions (HEIs) throughout the world are striving to create sustainable campuses with transportation regarded as one area that can play a significant role [1, 2]. This is more so as commuting is said to be the largest single impact such places have on their environment [3]. The HEI environment is usually composed of medium to high income earners who can afford automobiles and use the same to commute. Automobile dependence however contributes to environmental pollution, traffic congestion, traffic crashes and other social problems. It is also largely responsible for physical inactivity. Automobile dependence is thus described as being detrimental to both physical health and the environment [4] and requires appropriate management measures, usually transportation demand management (TDM), to mitigate its impacts. Such TDMs include campus transit services, parking policies and other strategies such staggering work/class times, telecommuting to work/class, provision of more housing units within or near campus [5,6].

In many instances, nevertheless, particularly in developing countries, many benefits of appropriate management of the transport demand in HEIs are overlooked. This is particularly with respect to improving the adoption of active commuting. Support for active commuting (non-motorised and public transport) can benefit the local environment as they lead to reduction in congestion and air pollution, while at the same time improving public health. This is more so in HEI settings where campus and off-campus housing are separated by only short distances and amenities and stores are concentrated within a short distance from campus. Similarly, the adoption of active commute modes increases physical activity, leading to increased academic performance and reduction in cases of depression [1]. Furthermore, as pointed out by [7], an HEI is a miniature of the larger society where values and behaviours are formed and therefore have the capacity to influence the larger society.

There have therefore been a lot of work on HEI commuting mode choice decision [1,8,9]. [1] showed that travel time was mostly responsible for the choice of commute mode. They also noted that improving bus service as well as the provision of more

housing units close to HEIs can support modal shifts. [9], in their study, found that auto ownership had the greatest influence on mode choice. [8] found, amidst others, that the availability of sidewalk was significantly associated with how attractive non-motorised transportation was. Understanding the modal choice of members of the HEI community and the influencing factors for the choices can therefore be useful in creating a sustainable campus.

This study seeks to identify the nature of commute mode choice of two HEIs in Ado Ekiti, Nigeria, a developing country setting. Ado Ekiti is the administrative head of Ekiti State, one of the 36 states in Nigeria, a status it acquired in 1996. This status propelled a rapid growth in both social and economic activities with increase in income levels, job availability, vehicle ownership as well as the number of commute trips. While the status offered increased availability of fund for development, including highway development, this is not able to meet up with the rapid growth in vehicle ownership. As pointed out by [10] this situation did not only hinder free flow of traffic, but also led to parking problems, noise and air pollution and increased traffic accidents. Specifically, a study reported that as much as 20minutes was spent to traverse a distance of 500meters during peak period [11]. The contributions of the HEIs to this situation may be much. In addition, many HEI related commute trips experience these problems regularly. A good understanding of the modal choice decision process of HEI commuters may not only improve the traffic but can also reduce the exposure of these commuters to the problems. This is as such understanding can be helpful in developing strategies that can improve the uptake of active mode for commuting. The objectives of the study are therefore to determine: (i) the regular commute mode of workers in the two HEIs; (ii) the reason for their commute choices; (iii) the preferred alternative where the current choice is not available; (iv) the reason for the choice of the alternative; and (v) their willingness to use public transport mode. The rest of the paper describes the methodology in section 2 and the results and discussion in section 3. Section 4 provides a brief conclusion.

II. METHOD

To evaluate the choices of commuters and the basis for their preferences, data was collected from workers of two HEIs in Ado Ekiti, Nigeria via survey questionnaires. These HEIs are located at the city outskirt. To meet the objectives of the study, it was essential for the survey to collect data relating to respondents' regular commute mode, alternative commute mode, willingness to change to public transport, and respondents' socio-economic details.

Once the survey had been designed, the registry departments of the two workplaces were contacted to obtain the population of workers in the workplaces. This information was used to estimate the number of survey instruments that would be produced. Four hundred and fifty copies of the survey instrument were eventually produced to cover 10% of the workforce. .Individual departments were then contacted and the questionnaires were distributed directly to willing members of staff in the two workplaces in line with extant research ethics. The questionnaire contained information about the background and purpose of the survey. All procedures were performed in compliance with relevant laws: informed consent was also obtained from each of the respondents. The circulation and collection of the questionnaires took place between April 10 and April 20, 2019. At the end of the survey, a total of 379 responses were recovered.

III. SURVEY RESULTS AND DISCUSSION

III.1 PERSONAL CHARACTERISTICS

Table 1 shows personal characteristics of respondents. A plot of the age of respondents would reveal normal distribution. The lowest age bracket is poorly represented in the survey. The highest proportion of participants is between 40 and 49 years of age (44%).

In addition, the gender of the participants is split reasonably evenly, with 53% female and 47% male. Lastly, the income, based on age, shows the highest age group of 50 and above earning the most. This shows an increase in income with age. This is usual as workers increase in age and earn more as they stay longer on the job.

Table 1: Respondents' characteristics.

	Frequency	Valid Percent
Age		
20-29	7	1.9
30-39	108	28.8
40-49	165	44.0
50 and above	95	25.3
Total	375	100.0
Non Response	4	
Total	379	100.0
Gender		
Male	178	47.0
Female	201	53.0
Total	379	100.0
Income by age group		
20-29	5	45800.00
30-39	56	50480.36
40-49	109	76354.43
50 and above	82	112347.79
Non Response	123	
Total	379	100.0

Source: Author, (2021).

III.2 MODE OF TRANSPORT USED

Table 2 shows the modes of transport used by respondents for trips to work on a regular basis. The major travel modes used by commuters were driving, public transport and joining others. About 67.1% drove to work while 13% used public transport. Public transport vehicles in use were public buses (mini-buses), and hired and public taxis. Hired and public taxis were passenger cars used within the city for shared taxi services: because of their low capacity, they would not normally operate on routes which were far from city centre. With the workplaces considered being at the city outskirt, the two were less frequently used than the public buses. Finally, about 19.4% joined other vehicle owners to work. Joining others is a form of carpooling where car owners pick up colleagues on their way to/from work.

Table 2: Regular means of transportation of respondentes.

	Frequency	Percent	Valid Percent
Driving self	253	66.8	67.1
Public Transport (Public Bus, Hired Taxi and Public Taxi)	49	12.9	13
Joining other staff	73	19.3	19.4
Others	2	.5	.5
Total	377	99.5	100.0
Non Response	2	.5	
Total	**379**	**100.0**	

Source: Author, (2021).

III.3 REASONS FOR THE REGULAR MODE

Table 3 shows the outcome of responses on respondents' reasons for their choice of regular commute mode. When respondents were asked why they used their regular mode of commute, 35% pointed out that it was because they owned a car. This reason does not indicate that these group had a necessity for driving to work, though they might have. Since they had cars, they used it as they desired and also for commute trips. This might be an indication that there were no policy measures in place to encourage car owners to adopt sustainable travel modes. Measures that discourage car owners from commuting by car may be able to reduce the group of people in this category. On the other hand, 30.9% indicated that it was more convenient for them. These group were obviously car owners who considered car use as convenient probably due to limited access to public transport or the demands of child care, or any other reasons. Nevertheless 2.6% of respondents indicated that the cost of fuel was the basis for their choice of commute mode. These group most likely had a car but were not using car for commute trips due to the cost of fuel. Another reason given by respondents for their choice of current commute mode was access to free transport. These group must be respondents who joined others. Access to free transport for commute trips may be able to reduce the number of commuters by car. Free public transport had been used in some places to reduce car trips and improve traffic. Others were "I don't own a car" (14.5%), "I can't drive a long distance" (2.1%), and (high) car maintenance cost (7.1%). Those who used their current commute mode because they did not own a car were potential commuters by car as they considered their current choice as due to lack of a car. It would be expected that this group might eventually add to those who commuted by driving when their economy improved. Except

there are measures to discourage car use, it may be possible that the percentage of commuters by car would increase as people's economy improved. For those who regarded car maintenance cost as a challenge to commuting by car, it is possible that they were mostly low income staff. Providing safe and convenient alternative for this group might keep them perpetually away from contemplating to commute by car. This also applies to those who indicated that they could not drive a long distance. A good public transport system would make them enjoy their commute mode without attempting to switch to car use.

It should be noted that no respondent gave any reason in favour of public transport. Generally, public transport in developing countries are poorly regulated and mostly poorly operated. Thus, it would not readily attract patrons in most instances.

Table 3: Reason for choice of regular travel mode of transportation of respondentes.

	Frequency	Percent
Access to free transport	28	7.4
I own a car	133	35.1
Fuel	10	2.6
Convenience	117	30.9
I don't own a car	55	14.5
I can't drive long distance	8	2.1
Car maintenance	27	7.1
Others	1	.3
Total	**379**	**100.0**

Source: Author, (2021).

III.4 PREFERRED ALTERNATIVE WHEN THIS REGULAR MODE WAS NOT AVAILABLE

Furthermore, respondents were asked to indicate their alternative commute mode if they had to change their current commute mode. The outcome is shown in table 4. About 14% indicated that driving would be their alternative commute mode. This proportion shows a huge difference between those who drove currently and those who would have to drive as their preferred alternative mode. This is also a pointer to the possibility that a larger proportion of respondents driving to work did not need to and might change their commute mode if appropriate policy measures were introduced that made considering alternative commute mode necessary. Similarly, As much as 25.3% indicated that public transport would be their alternative mode. Again, this is a pointer to the potential for improved adoption of public transport from 13% (table 2/section 4.2) to 35.6% (the sum of public transport, hired taxi and public taxi) if appropriate measures were put in place. The highest percentage of respondents at 49.5% opted for joining others as their alternative commute mode. This high proportion indicates that joining others, a form of carpooling, had potentials for a huge success with high adoption rate if properly implemented. Nevertheless, under the current condition, this proportion is much higher than the proportion of those who would adopt public transport and more than three time the share of respondents who would drive to work as their alternative commute mode. Joining others implies that there would be someone driving who would be willing to share the car. With the percentage of respondents driving being less than a third of respondents who would be willing to join others, it might be difficult to satisfy this group by those driving. This would likely result in some of respondents in this group switching over to other modes, especially, driving. These findings show that preference for private

car use may remain high if nothing is done to support or promote other modes, especially the more sustainable ones.

Table 4: Alternative to get to work.

	Frequency	Percent	Valid Percent
Driving self	52	13.7	14.0
Public bus	94	24.8	25.3
Hired taxi	21	5.5	5.7
Public taxi	17	4.5	4.6
Joining other staff	184	48.5	49.6
Others	3	.8	.8
Total	371	97.9	100.0
Non Response	8	2.1	
Total	**379**	**100.0**	

Source: Author, (2021).

III.5 PREFERRED ALTERNATIVE WHEN THIS REGULAR MODE WAS NOT AVAILABLE

Having considered respondents' alternative commute modes, it was necessary to find out the reasons for the choice of the alternatives they made. The result in table 5 shows that *convenience* was the most valued reason for the choices respondents made, being the reason 60% of respondents gave. This is followed by *accessibility* at 14.2% and *cost* at 9.9%. Other reasons had lower considerations being *time saving*, 5.2%, *residence location*, 4.9%, and *no alternative*, 3.4%. This points to the value placed on convenience by commuters. Whatever commute plans that may be contemplated for implementation by policy makers would therefore need to understand the characteristics of patrons and what convenience is to them if such plans would be successful.

Table 5: Reason for Alternative chosen.

	Frequency	Percent	Valid Percent
Accessible	46	12.1	14.2
Cheap	32	8.4	9.9
Convenience	195	51.5	60.2
Faulty car	3	.8	.9
Neighbourhood	16	4.2	4.9
No Alternative	11	2.9	3.4
Safety	4	1.1	1.2
Time saving	17	4.5	5.2
Total	324	85.5	100.0
Non Response	55	14.5	
Total	**379**	**100.0**	

Source: Author, (2021).

III.6 WILLINGNESS TO CHANGE TO PUBLIC TRANSPORT MODE

In addition, respondents were asked to indicate whether they would be willing to use public transport mode for their commute trips and what changes/improvement to public transport mode would enhance this decision. As shown in table 6, 66.5% of respondents indicated that they would be willing to use to public transport while only 33.5% were not willing. It had been shown earlier that 60% of respondents valued their comfort/convenience and this was their reason for choosing the modes they adopted. This implies that a certain percentage of respondents which would be more than 25% (being the difference between respondents (60%) who valued convenience and those who would not use public transport (33.5%) if it was assumed that their reason was largely due to convenience) believed that the convenience they desired for

their commute trips could be provided by public transport mode when improved. The potential for a more sustainable travel is therefore high especially with the use of public transport and other more efficient modes if these are properly implemented.

Table 6: Willingness to go to work using public transport.

	Frequency	Percent	Valid Percent
Yes	250	66.0	66.5
No	126	33.2	33.5
Total	376	99.2	100.0
Non Response	3	.8	
Total	**379**	**100.0**	

Source: Author, (2021).

III.7 WHAT CONCERNS COMMUTERS HAD ABOUT PUBLIC TRANSPORT

Furthermore, respondents indicated the nature of improvement they desired in public transport to become more appealing to them. Three major issues were most important to the respondents. These were: improved quality of the roadway, being 44.8%, improved quality of public transport vehicles, being 30.2%, and improved driver training for public transport drivers, being 15.6%. These were ahead of other themes such as reduction in the cost of public transport, being 6.2%, provision of good terminals/bus stops, 2.3% and reduction in stop dwell time, being 1%. It must be noted that the same roadways were used by both public transport and other travel modes. The attachment of improved quality of roadway to the adoption of public transport mode might just be a concern about the poor condition of the roads at the time of the survey. Nevertheless, travelling in private automobile on bad roads might be more comfortable for vehicle occupants than travelling along the same road in poorly maintained public transport vehicles. This is more so as improved public transport vehicles was the second most important improvement desired in public transport operation.

In addition, drivers' training also had high importance attached to it. Public transport drivers were generally rough, impolite, and often engaged in high risk behaviours which usually discouraged patrons who had alternatives. It is therefore important that drivers' training for public transport operation is given attention to improve commuters' experience when using this public transport mode.

Table 7: Improvement needed to make public transport acceptable.

	Frequency	Percent	Valid Percent
Creation of bus terminals	7	1.8	2.3
Good bus/car	93	24.5	30.2
Motorable Road	138	36.4	44.8
Reduced cost	19	5.0	6.2
Reduced loading time	3	.8	1.0
Training for drivers	48	12.7	15.6
Total	308	81.3	100.0
Non Response	71	18.7	
Total	**379**	**100.0**	

Source: Author, (2021).

IV. CONCLUSIONS

In this paper, it has been shown that substantial percentage of commuters in the two HEIs considered commute by self driving. Commuting is most responsible for peak hour trips and therefore contributes significantly to congestion and air pollution, amidst other issues [6] The fact that about 67.3% drive self to work as found in this study suggests that the problem of congestion and air pollution can be substantially reduced with fewer people self-driving, considering the population of workers involved. The challenge of moving commuters from their current mode to a more sustainable mode nevertheless needs to note the basis for the choice of their current mode. It is important to note that auto ownership is the most important reason for the current mode. Re-orientation and the creation of awareness on the benefits of sustainable modes are needed to reduce the number in this category. But this is not possible without considering the convenience of available sustainable options. This is more so as convenience is second to ownership as the reason for the choice of the current mode. Generally, public transport system is poorly operated in many developing country settings and would be difficult to move commuters from automobile to it. Aoun et al (2013) however noted that innovating new services that cater for the need (especially convenience) of campus members may be better than merely promoting available conventional public transport service. Where this is done, a public transport system may do better than it does currently. This is more so as about 66.5% admitted that they would change to public transport if the system is improved.

Finally, when workers were asked what alternative mode would be considered if their current mode was not available, about half (48.5%) selected "joining others". "Joining others" is a form of carpooling which is well promoted in many developed country settings. The promises offered by carpooling may be exploited when the HEI transport unit in conjunction with local authority provide appropriate policy support for the mode. Similarly, Aoun et al., (2013) suggested a variant they described as a dynamic taxi-sharing service. This service which is an improvement upon taxis combines the higher vehicle occupancy of a shared taxi with the reliability and comfort of a private taxi. They pointed out that this can come at the reduced cost of a public transport fare and still meets the high-income users' preference for cars over buses. The market for this variant is, however, a subject of another research.

This study did not compare characteristics across different commute modes. This is due to the limitation in the amount of data available for analysis. Future work will require collecting more data and comparing characteristics across various modes.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Oluwasegun Oluyemi Aluko.
Methodology: Oluwasegun Oluyemi Aluko.
Investigation: Oluwasegun Oluyemi Aluko.
Discussion of results: Oluwasegun Oluyemi Aluko.
Writing – Original Draft: Oluwasegun Oluyemi Aluko.
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Resources: Oluwasegun Oluyemi Aluko.
Supervision: Oluwasegun Oluyemi Aluko.
Approval of the final text: Oluwasegun Oluyemi Aluko.

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RESEARCH ARTICLE   **OPEN ACCESS**

MODELING A CLOSED CONTROL MESH FOR CALENDER USING MATLAB: CASE STUDY AT STINFER ART IN STEEL

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ARTICLE INFO

ABSTRACT

The purpose of this article is to conceive automation and control in the process of calendering metal sheets in a calender that currently do not have these resources. The study will propose a viable solution so that the metallurgical company Stinfer Arte em Aço, which currently uses this equipment with manual operation processes, can have a control and automation solution in the calendering process. Taking into account the need to adapt other equipment that provide automation and control for the pre-existing calender and with a view to delivering a lean solution to the calender, which aggregates sensors, and actuators that control and optimize the efficiency of the process, this equipment was evaluated for the CFW-500 frequency inverter model, as it not only has the internal controller for closed loop PID - Proportional Integral Derivative, it also has special functions and inputs of a PLC - Programmable Logic Controller. In this process, in addition to the configuration to be inserted in the control interface of the frequency inverter by the user, it will require the placement and removal of the material to be formed, as the present study focuses only on automation and process control and automation of the calender.

I. INTRODUCTION

Due to the advancement of modern production systems, increasingly sophisticated and detailed, it is necessary to understand the mapping of the development of intelligent autonomous machines. To this end, the present work will demonstrate the modeling of a pre-existing sheet roll forming machine in the company Stinfer Arte em Aço [1]. Figure 1 shows the calender for modeling the closed loop in Matlab.

Figure 1: Sheet Metal Forming Calender.
Source: Author, (2021).

Aiming at the closed loop operation from the use of the PID controller, present in the CFW-500 frequency inverter model, they propose to use sensors for the feedback of the system, with information on 5 measurement points of the plate forming process for improvement equipment performance (calender) and reduced equipment setup time, depending on the material to conform.

Operating profiles must be generated for each raw material (sheet metal) of varying dimensions. By measuring strategic points with different controls at each modeled point of the PID controller (proportional, integral, derivative). Once the intention to generate calendering profiles is defined, it is necessary to add items due to the impossibility of feeding information to the system, which, until then, operates in open loop, with no means of eliminating possible errors in relation to the desired value. Figure 2 shows the intelligent control model for the sheet metal forming calender.

II. THEORETICAL REFERENCE

According to the CFW-500 Inverter model user manual [2], there are special functions included in the inverter software that, when activated, cease to assume a pre-configured constant frequency and start to apply the derivative integral proportional control factor, for compensate for any frequency readjustments in the calender motor, so this function assumes the PID regulator that is used to control the closed loop process.

This special function allows to establish a process variable as a setpoint, that is, a variable that in the applied study controls the angle of curvature of the metal sheet through a digital angle meter, goniometer, which when reaching the angle established on the HMI interface or via P525 (digital setpoint) disables the compression of the control to the system through the measurement signal generated by the sensor (goniometer), responsible for the feedback of information, which in turn makes the comparison of the measured value with the reference value, a value that is fixed In this phase of the process, the difference between values (measured and reference) determines the error, then we use the error to generate the correction signal in order to

eliminate the deviation by bringing the variable to desired values, then acting on the analog input of the drive motor. hydraulic pump that exerts pressure on the roller whose function is to press the metal sheet, thus reaching the expected angle of curvature (reference value cia).

In Figure 2 the process is shown through a diagram of the PID regulating function that uses these special functions of the frequency inverter.

Basically, the procedure for putting the PID regulator into operation on the CFW-500 frequency inverter is shown in Figure 2.

1) Process - Define the type of PID action that the process requires: Whether forward or reverse. The control action must be direct (P527 = 0) when it is necessary for the motor speed to be increased to cause the process variable to be increased. Otherwise, reverse must be selected (P527 = 1).

Examples: a) Direct: Pump driven by an inverter filling a reservoir with the PID regulating its level. In order for the level (process variable) to increase, it is necessary that the flow rate and consequently the motor speed increase. b) Reverse: Fan driven by an inverter cooling a cooling tower, with the PID controlling its temperature. When you want to increase the temperature (process variable) it is necessary to reduce the ventilation by reducing the motor speed.

2) Feedback - Measurement of the process variable: It is always via analog input AI1 and the transducer (sensor) must be used for feedback of the control variable. It is recommended to use a sensor with a full scale of at least 1.1 times the highest value of the process variable to be controlled.

Example: If it is desired to control the pressure at 20 bar, choose a sensor with a full scale of at least 22 bar. The type of signal is adjusted via P235 according to the signal from the transducer (4-20 mA, 0-20 mA or 0-10 V). The digital setpoint P234 must be adjusted according to the variation range of the feedback signal used (more details can be obtained in the description of parameters P234 to P240 of the CFW-500 frequency inverter).
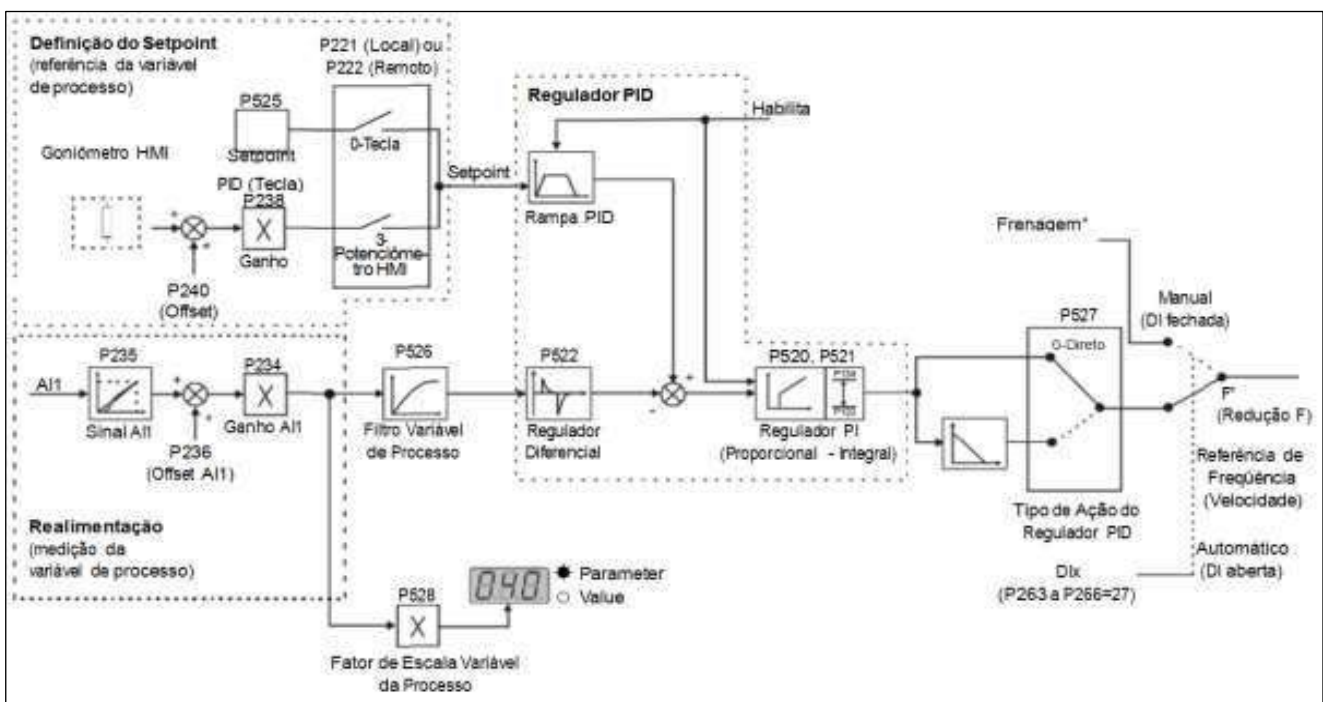

Figure 2: Inverter PID regulator CFW-500.
Source: WEG, (2021).

III. MATERIALS AND METHODS

For the elaboration of this modeling, bibliographical and documentary researches were carried out on calenders, frequency inverters, electric motors, pneumatic compression pumps [3], pressure gauges, sensors. In this way, relating the need for acquisition for the caclender plant the following items:

01 CFW-500 frequency inverter;
02 electric motors;
01 hydraulic pump;
01 compression meter with analog output;
04 digital sensors.

Work routines on industrial automation machines were investigated, as well as the communication of these machines with the programmable logic controllers; it was verified with this, the possibility of making viable through the SoftPLC software for the development of the control via computer [4].

The methods and techniques that were used in making the work are:

Deductive method: comes from the study of the general to the particular;

Qualitative research: bibliographic or documentary.

IV. RESULTS AND DISCUSSIONS

The present study aims to model a closed loop in a calendering process that currently works in open loop. For the success of this objective, a model is fundamental, a model that must cover the largest number of stages where the performance of the variables has the greatest influence on the behavior of the process. For this purpose, the existence of the following operation model was observed, as shown in Figure 3.

Mapping the main points of the calendering process, there was a need for equipment that provides measurements at each of the following points:

• Compression adjustment (to fix the part to the calender before starting the process);

• Angulation adjustment (determines the spacing between the rollers that will determine the angle of the part to be processed by the calender);

• End of stroke control (sensor that determines the end of the plate),

• Torsion adjustment (determines the force applied to the compression process, so that the material does not exceed the limit of elastic deformation, so that its retraction stops at the expected plastic deformation point, avoiding that the slip point does not remain away from the margin);

• Speed Adjustment (determines speed variation through a frequency controller, so that, according to the force applied to the process, there is a change in speed).

For each of the measurement points raised there is a need to determine reference variables (which can be fixed or variable) in the calendering process, in order to use a reduced model in the study, to determine the calendering profile of the equipment adapted to each plate or material.

With the aim of improving performance, increasing process efficiency through closed-loop control, we arrived at the particular closed-loop model for control shown in Figure 4.

For the control of the curvature or calendering process of a plate, we determine the reference value by analyzing multiple factors. The main mechanical force applied to a body that undergoes deformation, which is studied by the variable "K" of Hooke's law. This law considers, in addition to the deformation force, also the retraction force of the material, that is, the elastic force of recovery to the previous state, thus the equation that applies Hooke's law foresees an additional force to compensate for the retraction of the material, the formula is obtained by:

$$F = k \cdot x \qquad (1)$$

Where:
F is the intensity of the applied force (Newton),
k is the elastic constant (N / m),
x is the material deformation variable.

It is important to note that although the equation is usually studied by the extension of a spring, it can also be applied to compression, flexion, torsion and others.

For the calendering process, the force F is directly proportional to the angle that will be applied to the final piece, and, to reach the determined angle, the process usually goes through several cycles with this force being applied gradually throughout the entire process.
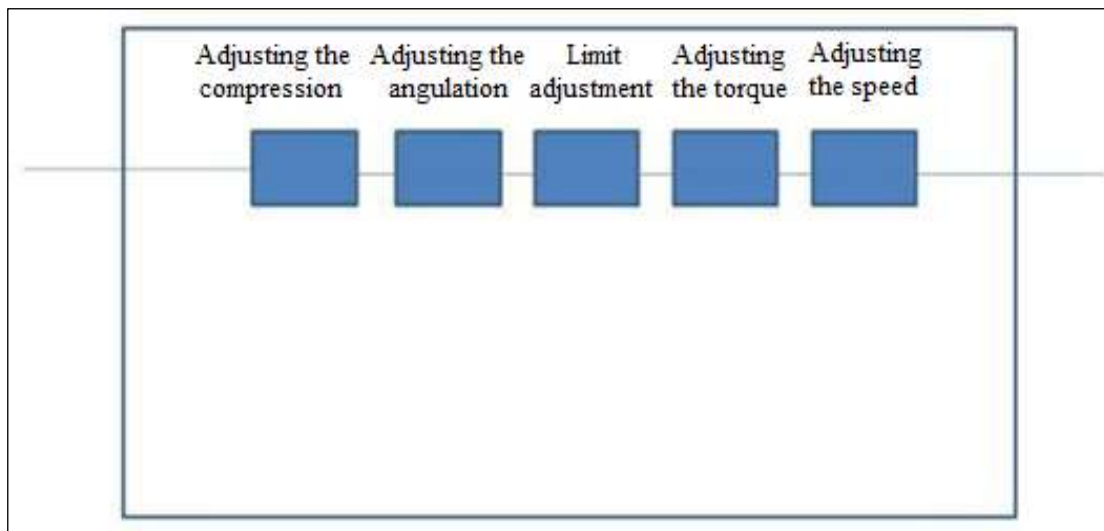

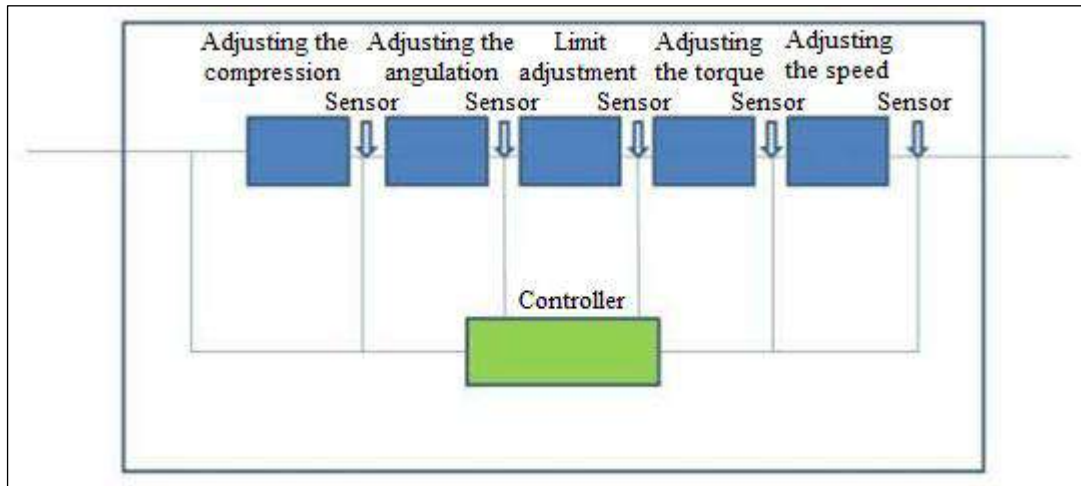Figure 3: Current process.
Source: Author, (2021).

Figure 4: Future process.
Source: Author, (2021).

These are factors that influence the applied force to reach the reference angle, thickness and material; quantities that are variable due to the difference in parts to be manufactured and their variation directly influence the number of cycles to complete the process.

Speed is also among the indispensable variants that need to be monitored for feedback and subsequent performance in the closed-loop calendering process, since the electric motor is responsible for the operation of the machine, transforming electrical energy into mechanical force. Also, limitations regarding the applied torque must be raised, an excessively high torque may be necessary to form the desired angle in the part, however, it can be above the capacity of the electric motor, and it is essential to control this variable.

The use of closed loop to the process occurs by inserting a control to match the reference values of the measured values, for this purpose the PID controller, derivative integral proportional controller, or simply PID was used; it is a process control technique that unites the derivative, integral and proportional actions, thus causing the error signal to be minimized by the proportional action, zeroed by the integral action and obtained with a speed anticipated by the derivative action. Defined mathematically by the following formula:

$$u(t) = K_p \ e(t) + K_i \int_0^t e \ (r) \ dr + K_d \ \frac{de(t)}{dt} \qquad (2)$$

Where:

K_p is the Proportional Gain,
K_i is the Integral Gain,
K_d is the Derivative Gain,
e it's the Error,
t is Time,
r is the Integration Time.

IV.1 PROPORTIONAL ACTION

Proportional control acts by applying a signal called proportional gain to the actuator that will cause the actuator to act in the inverse proportion to the error.

The error is nothing more than the difference between the reference value and the measured value, therefore, the greater the error the greater the gain to compensate for this error, however

the error will never reach a null value using only the proportional control.

Applying the reference value to the process will be the angle of the plate at the end of the process, this angle is obtained by the force applied to the plate as mentioned in Hooke's law, for the creation of work profiles it is necessary that the first cycle of the process has a applied experimental force, after the first cycle with a force x applied, the digital goniometer will measure the angle obtained z, feeding this information to the PID controller, where the difference between the angle obtained z and the reference that we will call y will be made, then :

$$Error = z - y \qquad (3)$$

As the error value has been determined, the controller will apply a signal contrary to the error, called a proportional gain, to bring this variable closer to the reference value, highlighting that by proportional error control it will not reach a null value (= 0). For example, for the reference angle Az of 400 a force of 100N is applied, and in the first cycle it is measured by the goniometer, the angle obtained was 250.

Through the Proportional control formula:

$$P_{exit} = K_p \ e(t) \qquad (4)$$

It has if:
Az = 40; Error = 15; P_{exit} = 15 K_p
Az = 35; Error = 10; P_{exit} = 10 K_p
Az = 30; Error = 5; P_{exit} = 5 K_p
Az = 30; Error = 5; P_{exit} = 5 K_p

Since K_p is a proportionality constant, at a certain point it will no longer influence the error, an error that will be compensated for by full control.

IV.1I INTEGRAL ACTION

Proportional The integral action makes the sum of the errors over time, the error is represented numerically by an area that exists between the reference value and the area of the last measurement, the value of the error is compensated for by the constant integrality or integral gain K_i, K_i current in the compensation at regular intervals, therefore, even if the error has a very low value, the integral response increases, the effect is to drive the error to a null value.

For this process uses the formula:

$$I_{exit} = K_i \int_0^t e(r)\, dr \qquad (5)$$

Analyzing the formula we realize that the error is integrated in relation to the time and the K_i, which in turn will make the compensation in each instant of time, no matter how small the error, there will always be a K_i gain compensation, unless the error is null (Error = 0), for error values very close to zero (0), the system displays a damped response, then the derivative control acts.

Applying the reference value to the process being the angle, and this value being changed by increasing the applied force, we will arrive at the angle value, applying the integral to the smallest error reached by the proportional gain, in the range of 0 at, taking the error to the zero which is the same thing as the process reaching the reference value. In the case of the example, the angle value of 250. As already mentioned, in the phase of an error very close to zero, the integral gain will cause the system response to be over-damped, so the process may take a long time until it reaches zero error (0).

IV.1II DERIVATIVE ACTION

The Derivative Control is the simplest, it is responsible for reducing the accommodation time making the control system obtain the value more quickly, in addition, it reduces the overshoot time having a direct effect on the climb and also on the error of permanent regime.

IV.1V PID ACTION

According to the writer Katsuhiko Ogata, [5] renowned author of the book Modern Control Engineering, we have the function of transfer between the displacement z, y described by the following equation:

$$\frac{Z(s)}{Y(s)} = \frac{1}{Ms^2 + bs + K} \qquad (6)$$

Where we have:
M = 98.67 kg
b = 10 N.s/m
K = 100 N/m
F(s) = 1

The transfer function to the closed loop of the system with PID control is as follows:

$$\frac{Z(s)}{Y(s)} = \frac{K_{ds}{}^2 + K_{ps} + K_i}{s^2 + (10 + K_d)s^2 + (100 + K_p)s + K_i} \qquad (7)$$

After several trial and error executions, the gains $K_p = 950$, $K_i = 1500$ and $K_d = 95$, resulted in a response closer to the desired one, the following commands were executed in MATLAB:

```
Kp=950; Ki=1500; Kd=95
num=[Kd Kp Ki];
den=[1 10+Kd 100+Kp Ki];
t=0:0.01:2;
step(num,den,t)
```

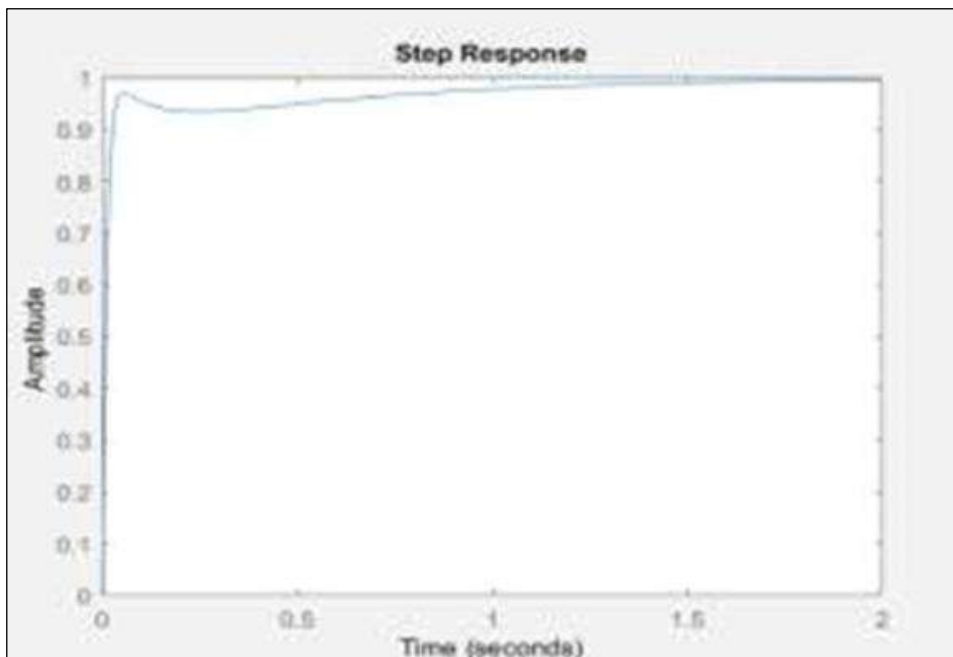That after the simulation in MATLAB [6] the following graphs were obtained:

Figure 5: Amplitude of the Transfer Function
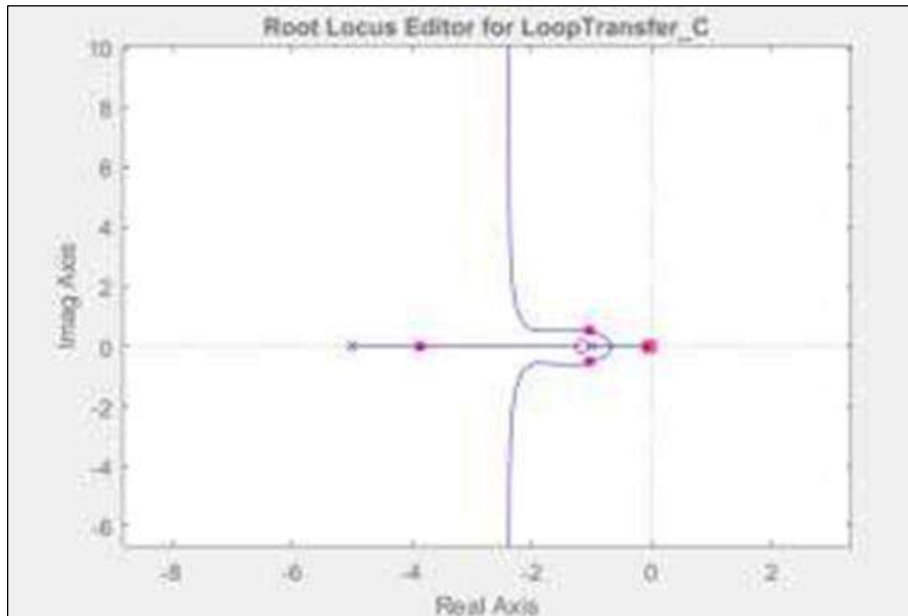Source: Author, (2021).

Figure 6: Pole Orientation for Gain in Transfer Function
Source: Author, (2021).

V. CONCLUSIONS

The work developed based on a practical model allows to identify control and automation design points effectively, since, when evaluating an open loop, it is possible to identify points to be implemented in closed loop modeling.

It was observed a wide possibility of applications of frequency inverters, in view of the multiple models found in the market, with their functionalities differentiated according to the application. Currently, the company WEG takes the market leadership in this segment of the Brazilian market.

The company Stinfer, evaluated in the implementation of the control, will certainly obtain efficiency in its production processes, once the standardization in the conformation of the metal sheets will be reached and it will be detached from manual controls until then used.

Thus, in this study, it is concluded that the application of the addition of the PID controller (Proportional, Integral and Derivative) allows to improve the rise time and at the same time makes it possible to be cautious about the system presenting an overshoot or very high signal, and through of adjustments in the control variables it is possible to minimize the losses and maximize the gains.

VI. AUTHOR'S CONTRIBUTION

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STRATEGIES TO REDUCE COSTS IN THE PLANNING OF HOUSE BUILDING PROJECTS WITH GOVERNMENT FINANCING FOR LOW-INCOME POPULATIONS

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ARTICLE INFO

ABSTRACT

The execution of housing construction projects for low-income populations in developing countries requires projects with low diversification, using quality materials and meeting project deadlines, qualified workforce are essential actions for the success of these projects. Thus, this work aims to simulate aggregate planning strategies in housing construction projects for low-income populations financed by the government. The methodology consisted of the simulation of four aggregate planning strategies (demand monitoring, constant workforce allowing for delays, constant workforce without delays and mixed) using the entire linear programming technique. The methodology used was a two-year case study in twelve civil construction projects for a civil construction company whose market segment is low-income housing with public funding. The chosen strategy with the lowest cost was the mixed strategy, which presented the lowest cost, with hiring employees and no layoffs. The aggregate planning simulation also did not show delays in the 12 projects, proving to be an efficient alternative for the planning management of companies that operate several projects at the same time.

I. INTRODUCTION

Acting in the civil construction market presents challenges due to projects being increasingly more focused on efficiency related to cost, quality, variety, and time [1-3]. These factors require the skillful planning of the construction project to better execute it. However, for constructions financed by government organs, the cost is the determining factor for obtaining the right to build houses paid by government funds [4][5].

The challenge lies in planning several house-building projects, financed by the government for low-income populations, simultaneously. The projects need to feature similar characteristics: quality materials; execution of construction processes; faster deliveries; and lower costs; according to the government's specifications. Inefficient project planning may cause higher costs and delays in construction process [6-10]. In specific, some works

recognized that around 70% of all construction projects end up in time overruns and cost overruns take regularly up to 14% of project contract sum [6][11][12]. Thus, poor planning renders the company less competitive than its competitors in a government bidding.

For [6] the management tools most used in civil construction are Critical Path Method (CPM), Earned Value Analysis (EVA), Last Planner System (LPS), Program Evaluation and Review Technique (PERT), Line of Balance (LOB), Flowline and Location Based Management System (LBMS). However, these tools focus on project management and do not act on executing and controlling practical project variables.

For [13], the planning of the variables employed in the execution of construction projects mostly comprises the quantity of materials employed and the numbers of hires and layoffs in the workforce. The construction stages outsourced (electrical wiring,

structure, painting and textures, among others), square footage built before the deadline, and square footage not built at the deadline (inability to deliver the finished house within the time specified by the project). To plan these variables with several projects happening at the same time in different stages of execution, a practical and detailed tool is needed to identify an optimization of the time and each cost of the projects. An alternative to perform the management of several projects is linear programming in order to minimize time and cost.

In addition to planning and programming the variables of the construction project for a house, it requires the identification of the strategy employed by the construction company throughout the execution of the project. This strategy needs to be different from product planning for consumer goods such as food, for example, since the production systems of civil construction are based on projects and not on assembly or stock.

However, the planning of several projects for the construction of standardized houses can be conducted equally to the planning of conventional products (which already present finished production models and are replicated without great variations). Bringing benefits to the company that operates in this market segment to realize planning these projects in sets and mainly managing to manage the cost variables at the same time in all projects, for example, to minimize the cost of labor in several projects at the same time.

Aggregating project management planning for these buildings with similar characteristics can be a key factor for the success of their execution. However, aggregate planning requires strategies to minimize the costs of these projects, through optimizing the workforce, purchasing materials, finishing house construction earlier during periods of low demand or working with prefabricated products and anticipating the need for subcontracting during periods of high demand to avoid delays. So, focus on these strategies to be carried out in aggregate for various projects.

Thus, the objective of this article is to simulate aggregate planning strategies to reduce costs of several house-building projects financed by the Brazilian government through linear programming executed at the same time. This study is structured in five sections: description of the problem examined of minimizing costs of house projects in an aggregate way; proposal of the model and its mathematical formulation through linear programming, case study illustrating the characteristics of project works performed at different stages of execution, restrictions and resolution of the analyzed case to minimize the costs of aggregate projects, results and conclusions of the simulation of the management of these projects and suggestions for future work.

II. THEORETICAL REFERENCE

II.1 AGGREGATE PLANNING IN HOUSE BUILDING PROJECTS

Thirty-three million Brazilians have nowhere to live presenting an exorbitant housing deficit for the government of this same country [14]. Brazil is a developing country with an unequal income distribution among its own, thus, it increasingly needs public policy projects that help the well-being of its population.

In Brazil, popular housing is financed by the government through projects in which the government buys houses from construction companies and establishes long-term payment plans for low-income people at lower interest rates than other non-governmental financial entities. a program called "My home my life" (my home my life). The program standardizes the dimensions and style of the houses according to the income range of the

possible buyers [15], they are generally small houses with values up to approximately up to Thirty-six thousand dollars.

The ability to build houses at lower costs and in shorter terms is necessary to win the bidding process that chooses the company that will build the set of houses in the program. The company that presents the best project, usually with the lowest cost, wins the government tender. The company can operate in several government financing projects at the same time, as long as its houses have the features of cost, length and quality required by the Brazilian government.

In 2018, when the study was carried out, the My home my life program still provided for the financing of one million homes for the coming years. Thus, in addition to a social context of helping the Brazilian population to have their own homes, good management of various housing construction projects for the My home my life program contributes to the profit of the companies that execute these projects, they increase the amount of employment in the sector and contribute to the growth of material suppliers for the construction of these houses. Developing the local economies where these projects are being carried out.

The problem in project management for these buildings lies in the need for planning that meets the low cost production requirements (material, labor, documentation, among others) while building the required square footage on time [16][17] for several projects to be carried out at the same time. Thus, the solution to this problem would be to aggregate projects with similar characteristics as the projects of the Brazilian government program. Aggregate planning comprises a product or product family, project or family of similar projects with small differences that can have their production planning aggregated to minimize costs. This consists of programming the general production capacity or the capacity of several projects in different medium-term phases, which generally varies from three to twenty-four months [18].

Planners in the aggregate planning process to make decisions aimed at general levels of production for each product category to meet fluctuating or uncertain demands in the near future and also consider policies and decisions on hiring, layoff, overtime, back orders, subcontracting and inventory [19].

Companies that carry out home construction projects can employ aggregate planning for projects with the following characteristics: a set of determined production resources, usually the fixed or similar cost as those of government financing; restrictions and square footage, ie similar footage, if they have the same structural features and design. Since the popular housing units follow the same pattern of material, footage and design to reduce costs, aggregate planning can be an efficient and effective alternative in planning these projects.

In aggregate planning, data and demands, mainly, can be classified as deterministic (single objective or diverse objectives) or as uncertain demand found, through fuzzy or stochastic logical models and all with single or multiple objectives. The most used tools to calculate these are Stochastic Programming, Fuzzy, Linear Programming, Goal Programming, Metaheuristics (including Neural Network, Simulated Annealing Algorithm, Tabu Search Algorithm, Genetic Algorithm) and Software Solver [20]. The simulation of discrete hybrid events (DES) and the systems dynamics (SD) methodology are applied to model and simulate the problem of aggregate production planning (APP) [19]. However, [21] use the theory of restrictions to solve the problem of aggregate planning with diffuse demand.

The most used mathematical tool to carry out the simulation and execution of an aggregated planning is the linear programming, since the demand is deterministic, as is the case of the housing

projects financed by the Brazilian government. Linear programming is one of the optimization techniques used to minimize resources, through mathematical programming using variables and parameters [1][16][22]. [23][24] use linear programming to solve the problem of aggregate planning, while [25-27], also use linear programming, but for uncertain demands. Thus, of course, linear programming can be used to minimize the costs of resources if they behave as a linear function of the quantity of the resource, restricted by meeting demand and respecting production capacity.

Research on aggregate planning, in addition to the characteristics of the demands of the products or projects, addresses in its structure problems about finance, supplies, use of machines, market for multiple products and characteristics of these products, aggregate planning for multiple plants, configuration, workforce characteristics and multiple products [20].

However, according to [22], there are five strategies for aggregate planning that point to the possible ways of using variables and parameters to optimize aggregate planning, as shown in Table 1.

Table 1: Aggregate planning strategies.

Strategies	Positive aspects	Negative aspects
Demand Monitoring (AD)	Avoids high carrying costs and no stock	Affects the workers' morale, low capability to monitor the demand in the short term, risk of shortages, difficulty in maintaining quality standards and service level
Constant workforce allowing delays (FTC)	Able to anticipate the production of units in low-demand periods. Holds knowledge in the company by not firing the workforce according to demand	Allows delays in the delivery of the units
Constant workforce not allowing delays (FTN)	Does not allow delays in the delivery of the units	High cost to finish the units before the deadline and maintain a constant workforce
Mixed (MIS)	Lower costs	Large variation in hires and layoffs of the workforce depending on the period, units may be delivered late, among others.

Source: [28].

Besides the aggregate planning strategies displayed in Table 1, there are also strategies directed at subcontracting all of the house building processes and utilizing only overtime hours to meet the demand. However, the goal is to minimize costs through aggregate planning strategies without compromising the quality of the product or construction. This situation requires training the workforce, which takes time after the hiring. Layoffs in planning also present problems related to creating a culture of lack of stability and commitment of the collaborators to the company.

III. MODEL PROPOSAL

Linear programming is a traditional method to minimize aggregate planning costs with parameters and variables [26]. With the purpose of simulating aggregate planning strategies for house building financed by the government through integer linear programming, the mathematical model employs the following parameters:

T = Number of quadrimesters (four-month periods) to be planned;
t = Quadrimester in planning ($t = 1, ..., T$);

D_t = Demand, in number of square meters built, in the quadrimester t;
Y_t = Ratio of square meters built to acting workforce in the quadrimester;
C_r = Unitary cost of layoff per workforce of one square meter of construction;
C_c = Unitary cost of hiring per workforce of one square meter of construction;
C_f = Workforce cost to build one square meter;
C_h = Cost per square meter built with overtime;
C_e = Cost, in the quadrimester, of one square meter built to be delivered early;
C_s = Cost of subcontracting the construction of one square meter;
C_p = Cost of raw materials to build one square meter;
C_u = Cost of one square meter built to be delivered late in relation to the planned deadline;
W_t = Available workdays in the quadrimester t;
The variables of the proposed model are:
E_t = Square meters built early at the end of the quadrimester t;
U_t = Square meters not built at the end of the quadrimester t;
R_t = Amount of workforce, per square meter of construction, laid off in the quadrimester t;
C_t = Amount of workforce, per square meter of construction, hired in the quadrimester t;
F_t = Amount of workforce, per square meter, available in the quadrimester t;
H_t = Number of square meters built with overtime in the quadrimester t;
L_t = Limit of square meters that can be built with overtime in the quadrimester t;
S_t = Number of square meters subcontracted in the quadrimester t;
P_t = Number of square meters built in the quadrimester t;

Thus, the goal-function is formulated as:

Objective function:

$$\sum_{t1}^{T} (C_f.F_t + C_h.H_t + C_c.C_t + C_d.D_t + C_e.E_t + C_u.U_t + C_p.P_t + C_s.S_t) \quad (1)$$

Subject to:

$$F_0 = 0 \quad (2)$$

$$F_t = F_{t-1} + C_t - D_t \qquad t = 1, ..., T \quad (3)$$

$$P_t \le W_t.F_t + C_t - D_t \qquad t = 1, ..., T \quad (4)$$

$$H_t = \frac{H_t.F_t}{5} \qquad t = 1, ..., T \quad (5)$$

$$E_0 = 0 \quad (6)$$

$$U_0 = 0 \quad (7)$$

$$E_{t-1} + P_t + S_t = D_t + U_{t-1} + E_t - U_t \quad t = 1, ..., T \quad (8)$$

$$F_t \ge 0 \qquad t = 1, ..., T \quad (9)$$

$$D_t \ge 0 \qquad t = 1, ..., T \quad (10)$$

$$C_t \ge 0 \qquad t = 1, ..., T \quad (11)$$

$$H_t \geq 0 \qquad t = 1, \ldots, T \qquad (12)$$

$$E_t \geq 0 \qquad t = 1, \ldots, T \qquad (13)$$

$$U_t \geq 0 \qquad t = 1, \ldots, T \qquad (14)$$

$$S_t \geq 0 \qquad t = 1, \ldots, T \qquad (15)$$

$$P_t \geq 0 \qquad t = 1, \ldots, T \qquad (16)$$

$$F_t \in \mathbb{Z} \qquad t = 1, \ldots, T \qquad (17)$$

$$D_t \in \mathbb{Z} \qquad t = 1, \ldots, T \qquad (18)$$

$$C_t \in \mathbb{Z} \qquad t = 1, \ldots, T \qquad (19)$$

The objective-function (1) presents the multiplication of the costs of the variables: workforce, overtime, hires, and layoffs, square meters finished before the deadline, square meters delivered after the deadline, production materials and subcontracting by the multiplication of the number of square meters built in the quadrimester. The first restriction (2) determines that the initial workforce is null. The second restriction is for the variable workforce (3), concerning the relationship between hires and layoffs of the workforce in the constructions in the quadrimester. It is worth stressing that the workforce may be allocated by every construction in planning depending exclusively on its stage and the expertise of the people composing the workforce. The restriction productive capacity (4), in which the workforce is multiplied by the days worked in the quadrimester plus the hires and layoffs, must be lower or equal to the number of square meters built [29]. The restriction overtime (5) presents the total number of overtime hours that may be used by the workforce in the planned period. Finally, the restriction construction balance (6) presents the balance between the demand, houses delivered late, houses delivered early, and subcontracting in the planned period and in the previous period [16; 25].

Conducting the four aggregate planning strategies presented by Table 2 (AD, FTC, FTN, MIS) requires transforming some variables into parameters in mathematical modeling. The AD strategy varies the number of hires (C_t), layoffs (R_t), production (P_t), and workforce (F_t) employing the demand (D_t) as a parameter and taking the other variables to zero (S_t, E_t, H_t, L_t, U_t) through Equation 20.

$$F_t : \frac{D_t}{Y_t} \qquad (20)$$

The FTC strategy, which allows delays or failures to deliver the houses setting the layoff variable to zero, has the differential of calculating the workforce through the sum of the demands of all the periods to be planned aggregately by the ratio of square meters built per workforce in the quadrimester. This is illustrated in Equation 21.

$$F_t : \frac{\sum D_t}{\sum Y_t} \qquad (21)$$

In addition to varying F_t, R_t and C_t, the FTC strategy also alters the variable U_t, which represents the houses that can be delivered late as long as that minimizes the total cost, keeping the variables hires and layoffs null after the second quadrimester. On the other hand, the FTN strategy is constant but does not allow delays in the delivery of houses. Equation 22 illustrates the calculation of the variable F_t in the FTN strategy.

$$F_t : \frac{\max(D_t)}{Y_t} \qquad (22)$$

The FTN strategy transforms the same variables as the FTC strategy. However, it nullifies the variable U_t while tending to increase the values for the variable E_t. It employs the same restrictions as the FTC, but it works with maximum workforce, that is, the number of workers necessary to meet the highest demand in the quadrimesters. The MIS strategy is programmed with all the parameters, model decision variables, and all the restrictions to minimize planning costs, as displayed by Table 2.

Table 2: Parameters, variables, and restrictions according to the strategies.

Strategy	Parameters	Variables	Restrictions
AD	D_t, C_f, C_r, C_p and C_c	P_t, F_t, R_t and C_t	3 and 20
FTC	D_t, C_f, C_p, C_c, C_e and C_u	P_t, F_t, C_t, E_t and U_t	3, 8 and 21
FTN	D_t, C_f, C_p, C_c, C_e and C_u	P_t, F_t, C_t and E_t	3, 8 and 22
MIS	$D_t, C_f, C_r, C_p, C_c, C_e, C_u,$ C_s, C_h	$P_t, F_t, R_t, C_t, E_t, U_t,$ S_t and H_t	3, 4, 5 and 8

Source: adapted from [28].

The summary of the strategies, variables and restrictions was presented in Table 2 in order to identify the best strategy according to the needs of the aggregate planning being programmed. Thus, Figure 1 summarizes the model employed and illustrates the steps required to conduct the aggregate planning according to the strategies identified.

The model was divided into the inputs of the defined parameters, and the variables demand and costs as not defined The second stage involved conducting the integer linear programming for each aggregate planning strategy through the minimization of the planning costs for each simulated strategy. The integer linear programming also pointed to the values of each variable so that they minimize planning costs. Finally, the selected strategy will be between the lowest cost and the positive and negative points presented in Table 1.
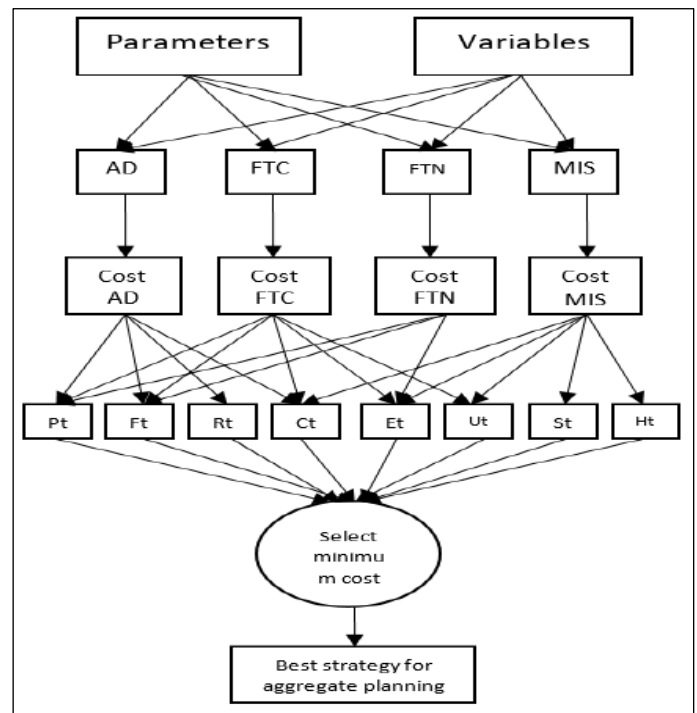

Figure 1: Summary of the proposed model.
Source: Authors, (2021).

IV. PROBLEM DESCRIPTION

The research company operates in Brazil in the market with the construction of government-funded housing for low-income people. The research was carried out for a 2-year planning with the demand for 12 works carried out in parallel according to the phase of execution of % of the work to be completed or total footage of all the works to be completed and 172763 m² built. The construction of the houses to be planned has their lengths, approximately, between 38.5 m² to 64.64 m² and reach an age group of buyers who have a minimum monthly income of UU $ 823. These houses are standardized in living room, kitchen, two bathrooms, three or two bedrooms and a garage. The entire project built in this period has, in addition to the houses: a party room; multisport court; tennis court; playground; bike rack and outdoor gym. The demands for the periods to be planned, as well as the unit quantity of houses are Illustrated in Table 3.

Table 3: Demand of the surveyed construction company.

Project	Demand (m²)	Amount (unid)
1	7462	138
2	12730	254
3	5934	116
4	15587	272
5	13953	244
6	16243	298
7	53890	1102
8	16255	286
9	20320	418
10	6400	104
11	8371	146
12	15587	272

Source: Authors, (2021).

The demand for the square meters to be built was planned according to the delivery date of the projects over a period of two years every four months, with a higher peak demand in the fourth quarter with 53890 square meters built to be delivered only for the construction project of housing 07. However, in month 3 the demand is 5934, thus the differentiation between the maximum and minimum demand 47956 square meters built, even though it is a deterministic demand. This situation presents a difficulty for planning demand with large varieties and forcing the planning to work with options for anticipating the delivery of square meters built in periods of low demand, or with hiring of workforce in these periods, usually temporary workers or subcontractors. of the processes to be carried out for the construction of the houses.

Table 4 distributes the demand for Table 3 into six quarters and indicates the number of square meters that need to be made at each stage of construction of the popular housing to be planned.

Table 4: Demand by period and phases to be planned.

Quaters	Demand (m²)	Phases
1	26683	Painting and texture, crockery and metals, outdoor areas and landscaping
2	23705	Finishes and coatings
3	22777	Hydro sanitary and electrical installations
4	53890	Walls, fences, roofs and ceilings
5	37764	Foundation and structure of the house
6	30358	Project, planning, documentation and budget

Source: Authors, (2021).

Even adding the projects and their deliveries every four months, the project for the construction of public housing has the need for a greater workforce in the housing construction project 07, which was in the construction phase of walls, roof fences and lining

at the time of collection data from this research. The meters are only counted as finished when the works finish the Painting and texture phase, crockery and metals, external areas and landscaping according to the footage that needs to be completed in the four-month period. As the 12 housing construction projects are in different phases, the planning will only be completed when all the works in in quarterly time organization six have completed the painting and texture phase, crockery and metals, outdoor areas and landscaping and available on the market for sale through government funding.

The costs of the variables per square meter for the construction of the twelve housing projects used in aggregate planning are shown in Table 5.

Table 5: Costs of variables for planning.

Variável (m²)	Cost (US$)
Cost per dismissed worker (Rt)	138.46
Cost per hired worker (Ct)	81.42
workforce (Ft)	108.1496
Overtime work (Ht)	162.2243
Stock (Et)	0.29
Lack of stock (Ut)	67.3077
Subcontracting (St)	408.2973
(Pt)	245.1542

Source: Authors, (2021).

However, the variables F_t, E_t and U_t start the first four-month period with a value of 0, as there are no works in arrears or advances in the construction company and the majority of the workforce is being reformulated and contracted in the location where the work originated. In the case of this 12 projects contracted in the regions of the state of Paraná located in the southern region of Brazil.

V. RESULTS

The mathematical modeling to solve the aggregate planning modeled the four strategies according to the preset demand parameters already presented in Table 4 and the variables costs already illustrated in Table 5. The data related to the aggregate planning costs of the 12 projects for the homes for each strategy are shown in Table 6.

Table 6: Aggregate planning cost per strategy.

Strategy	Cost
AD	U$ 51,223,529.15
FTC	U$ 51,236,908.28
FTN	U$ 53,567,403.08
MIS	U$ 47,758,990.00

Source: Authors, (2021).

Among the planning strategies aggregating the simulated projects, the FTN presented the highest cost, as it involved the hiring of 113 temporary workers, necessary for production during the four quarters with the highest delivery of houses (53890 m²). It also had a high number of square meters built before the delivery quarter, generating higher planning and inventory costs for project maintenance.

The FTF strategy has the second highest cost, 68 hires, no layoffs and the second highest number of square meters built before the delivery deadline. However, its biggest disadvantage was the delay in the delivery of houses in the 4th and 5th quarters. Thus, this strategy accepts up to 8 months of delay, which can create a negative reputation among customers, even if fines for delays in purchase contracts are duly paid.

The AD strategy also featured hiring and layoffs in three of the aggregate planned quarters, illustrating the disadvantage of the workforce not having sufficient training to build the necessary homes immediately after hiring. The insecurity of employees regarding instability at work in low-demand quarters (1, 2 and 3) is another negative factor in this strategy. However, it still had the second lowest cost in aggregate planning.

Finally, the lowest cost strategy was MIS, with hires in quarters 1 and 3, a workforce of 56 workers during the first three quarters and 23 workers in the 3 quadrimester. In addition to being the optimal solution for presenting the lowest cost, this strategy also did not present layoffs or delays in the delivery of houses. However, the houses were completed in advance during quarters 2 and 3 to meet the high demand in quarters 4 and 5.

Table 7 presents the results of the decision variables for the six four-month periods and the twelve construction works of popular housing in different stages of construction, according to the four simulated strategies.

Table 7: Number of square meters built per decision variable.

Strategy	Variable	1	2	3	4	5	6
AD	C_t	56	0	3	66	0	0
FTC		68	0	0	0	0	0
FTN		113	0	0	0	0	0
MIS		56	0	23	0	0	0
AD	R_t	7	0	0	0	34	15
FTC		0	0	0	0	0	0
FTN		0	0	0	0	0	0
MIS		0	0	0	0	0	0
AD	F_t	56	49	42	112	79	63
FTC		68	68	68	68	68	68
FTN		113	113	113	113	113	113
MIS		56	56	79	79	79	79
AD	H_t	0	0	0	0	0	0
FTC		0	0	0	0	0	0
FTN		0	0	0	0	0	0
MIS		0	0	0	0	0	0
AD	E_t	0	0	0	0	0	0
FTC		5957	8935	10463	0	0	2282
FTN		27557	30535	32063	350	16476	23882
MIS		0	227	15970	0	0	0
AD	U_t	0	0	0	0	0	0
FTC		0	0	0	21250	5124	0
FTN		0	0	0	0	0	0
MIS		0	0	0	0	0	0
AD	S_t	0	0	0	0	0	0
FTC		0	0	0	0	0	0
FTN		0	0	0	0	0	0
MIS		0	0	0	0	0	0
AD	P_t	26683	23705	22177	53890	37764	30358
FTC		32640	32640	32640	32640	32640	32640
FTN		54240	54240	54240	54240	54240	54240
MIS		26683	23932	37920	37920	37764	30258

Source: Authors, (2021).

The decision variables H_t and S_t showed null results in all simulated aggregate planning strategies, since they would increase their cost greatly. And the S_t variable can compromise the quality of the project execution if the supplier of this service does not have the necessary training. The variable H_t, on the other hand, may be tired in its workforce and decrease its productivity and efficiency. The variable P_t points the results according to all the other decision variables employed, mainly the demand for constraint 8, which leads to the balance of production through the variables stock, demand and scarcity. The AD strategy is the only one in which the variable P_t has the same value as the parameter D_t. However, following the criterion of lower planning costs and not using the layoff variable, the best aggregate planning strategy for construction companies in construction projects financed for low-income customers was the MIS strategy.

VI. CONCLUSIONS

Aggregate planning can be a strategy in home construction projects without many variations that seek lower costs and a strategic view of decisions in an aggregate manner such as hiring and firing operators. However, it is essential to guarantee the quality of these constructions and the training of the workforce is essential for this. Thus, strategies for planning aggregate projects that tend to have fewer layoffs to maintain the knowledge of their employees throughout each stage of the project are desirable.

Another significant factor in choosing the best aggregate planning strategy in the case analyzed is the refusal to accept delays in the delivery of houses. Thus, the strategies that accepted layoffs were received as an option in the planning of the Brazilian construction company in this case study, in order to maintain its reputation for punctuality and its competitiveness in the market in which it operates.

The use of whole linear programming to determine the best aggregate planning strategy for the examined company revealed the mixed strategy (MIS) as the main option. It presented the lowest cost (U $ 47,758,990.00), a fundamental factor for competition in the public works bidding process, seeking lower costs, and without waivers. The strategy had a 10.84% lower cost than the FTN strategy, the one with the highest cost. Sometimes, aggregate planning requires employees to act in different stages of each project and in different housing construction projects. Therefore, hiring employees with differentiated knowledge is another strategy to seek the best planning and execution of the construction works

of popular houses. However, the greatest contribution of this work is in the production systems by project, capable of scheduling the aggregated planning for different projects together. Even though they need to be similar in size and design. This can be an effective differential to carry out the construction works of the house with higher quality, lower cost and within the stipulated period and assist in the decisions of the company's management strategies.

VI. AUTHOR'S CONTRIBUTION

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THE ANALYSIS OF THE RECENT PERIODS OF OAT MARKET IN TURKEY

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ARTICLE INFO

ABSTRACT

Recently, the demand for sufficient and safe food has been increasing, and alternative food sources have gained importance. Oat, which is in the cereals group, is used in animal breeding besides being a human food. Turkey, while in the twentieth in the world in terms of production, is ranked thirty-second in terms of efficiency. The purpose of this study, the production quantity of oat market in recent years in Turkey, cultivation area, yield, average selling price, exports, imports, and foreign trade balance to evaluate. In the research, the statistical data of the Turkey Statistical Institute and the United Nations Food and Agriculture Organization, the relevant sector reports, and other studies were used. Trend analysis was conducted in the research, and projections were carried out until 2025, using data from 2000 and 2019. According to the obtained results, in the next period, oat cultivation areas in Turkey, production volume, yield, and prices will tend to rise at different rates. The regression coefficients of these increases were determined as 52.67%, 11.72%, 75.8%, and 98.25%, respectively. On the other hand, it is expected that exports will increase, imports will decrease and foreign trade balance will turn positive, and their regression coefficients are determined as 20.23%, 49.79%, and 50.4%, respectively. It has been determined that the production amount and yield are based on climatic conditions and low productivity is a problem. The problem of low yield can be solved by measures such as developments in agricultural technologies, certified seed, variety improvement, and inclusion in the crop pattern in irrigated farming. In addition, increasing the amount of public agricultural support, and extension activities can increase cultivation, production and productivity. This research also provides useful results in terms of covering up-to-date data on oats.

I. INTRODUCTION

Globally, more frequent climate changes and droughts [1-4] have started to raise concerns in terms of sustainable agricultural production [5], consequently food security [6], consumption of safe, healthy and nutritious food [7],[8]. The increasing world population brings along the problem of sufficient, quality, and balanced nutrition [9],[10]. These concerns direct people to alternative food sources. Due to the carbohydrates and proteins, it contains, oats have become one of the foods recommended for human health and included in consumption [8].

Oat (Avena sativa) is from the Grammineae family and is one of the annual cool climate cereals [11]. Oat, which is a newer cultivated plant compared to wheat and barley, was cultivated in the 1st-century a.d. and spread to Europe in the 5th century and from there to the whole world. Especially in the Seljuk and Ottoman Periods, oats were also used as bread cereals during the scarcity years [12]. Oats, which can be used as both animal and human food, have become more important in terms of health in human nutrition today [13], [14]. In addition to being used in baby food, oats are consumed as breakfast with oatmeal and rolled oats, and it is also common to use oat grains in biscuits, soups, sausages, gravy, and bread-making [11],[13],[15]. Being rich in protein, fat,

vitamins, phosphorus, iron and calcium increases its consumption [11], [13], [16]. Oat is an important grain for human health in terms of reducing cholesterol and fat in the blood, preventing anemia, and reducing the risk of coronary heart disease in diabetic diets [8], [11]. On the other hand, oats have an important place in hay and silage feed mixes in livestock [17], [18]. There is also the use of oats as a green fertilizer. The substance of "avenin" in oat grain provides important benefits in strengthening and developing animal muscles and increasing milk yield [15].

Oat is the cool climate cereals in terms of cultivation area on this group ranks 4th in Turkey [19]. In addition to being a cereal plant with less soil selectivity, oats can be grown for low yield and animal husbandry purposes even in barren soils with low soil moisture. On the other hand, oats are one of the plants that can be planted in turning swampy areas into agricultural land [15], [16], [20].

In Turkey, in oat production within the scope of agricultural support payments in 2020, 19 TL/da diesel, 8 TL/da the fertilizer subsidy, 6 TL/da domestic certified seed usage support, and 0.08 TL/da international certified seed usage support are given support production overseas certified seed are given. In addition, 40 (TL/Sample) for Soil Analysis Support, 10 TL for solid organic-organ mineral fertilizer support, 35 TL/da for agricultural extension and consultancy, 60 TL/da for one-year forage crop support, and 40 TL/da for forage plants planted in dry conditions are given [21].

According to FAO data, it was determined that oat production is widespread in the world, and oat farming was carried out in 73 countries in 2019. The top 20 countries in the world in 2019 oat cultivation areas are given in Figure 1.
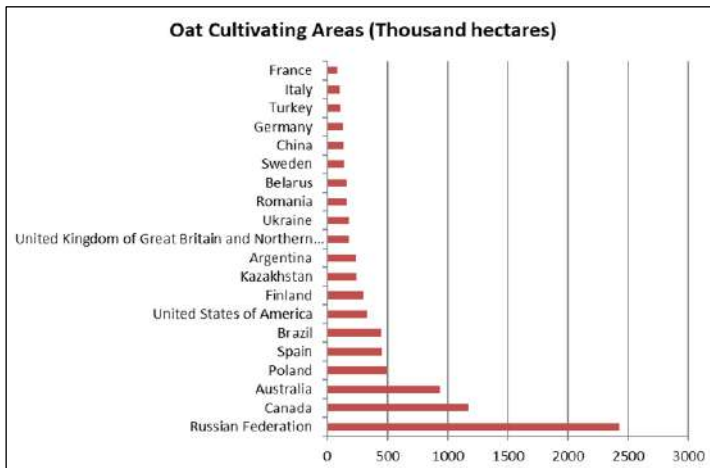

Figure 1: Oat cultivation area in the world (2019).
Source: [22].

Russia is the largest producer of oats in the world and uses the majority of its production in its domestic consumption. Location of oat production in Turkey as well as in the world and the amount varies according to the nature conditions. Therefore, even if the cultivation areas do not change, the amount of production varies from year to year depending on the climate. Turkey, in terms of oats acreage, ranks 18th in the world in 2019 (FAO, 2021). According to FAO's data for 2019, the top 20 countries in terms of oat production amount in the world are given in Figure 2.

In the world, as in the cultivation areas, Russia takes first place in oat production, and the total production amount in 2019 is 4.43 million tons. According to FAO data, oat farming is carried out in 73 countries around the world in 2019, and the average oat production amount of these countries is 316.5 thousand tons. The amount of oat production in Turkey in 2019 is 265 thousand tons, 16.3% less than the world average. Turkey ranks 20th in the world of oat production by the amount of this production [22].
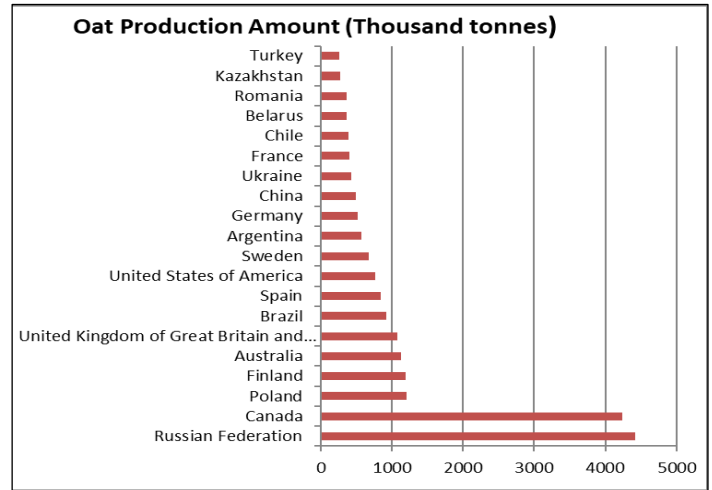

Figure 2: Oat production in the world (2019).
Source: [22].

Due to the increasing world population globally, consumers tend to seek healthier and safer food and alternative products. Oat is one of the cereals whose consumption areas have diversified and become widespread recently. According to FAO data, the top 20 countries in the world in terms of oat yield are given in Figure 3.
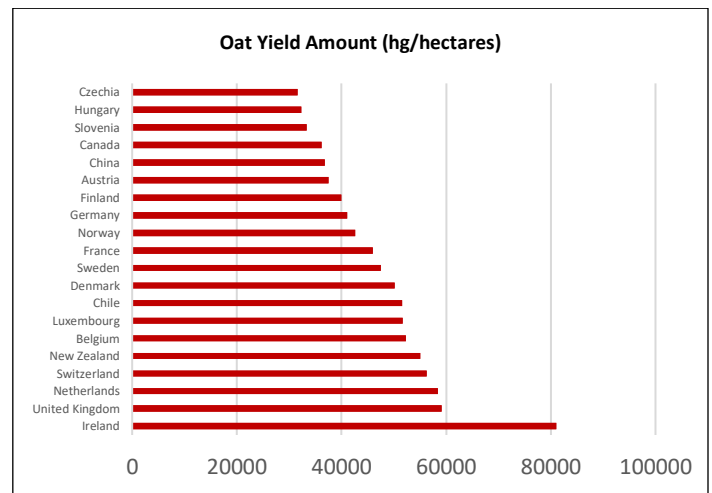

Figure 3: Oat yield in the world (2019).
Source: [22].

In 2019, the average oat yield in the world is 2889 kg/hectare. The average yield in Turkey 2419 kg/hectare was realized as is below 15,9% of the world average. Turkey ranks 32 in the world with this efficiency value [22]. The main purpose of this study, based on selected indicators, making an overall analysis of the oat market in Turkey in recent years and the presentation of proposals according to the results obtained.

II. MATERIALS AND METHODS

In the research, the statistical data of the Turkey Statistical Institute (TURKSTAT) and the United Nations Food and Agriculture Organization (FAO), and secondary data obtained from the relevant sector reports and other studies were used. For this purpose, oat production area, production amount, yield, sales

price, import and export data between 2000 and 2019 were used. Trend analysis was conducted in the research, and projections were carried out until 2025, using data from 2000 and 2019. Trend analysis was carried out Microsoft Office program with these data. Using the data from 2000 to 2019 in the analyzes, projections were made until 2025 and the regression coefficients were determined. In addition, other studies and researches on the subject have been used in the interpretation of the results.

III. RESULTS AND DISCUSSIONS

To determine the trend of the oat acreage in Turkey over the years and to estimate future projections, by using the TURKSTAT data between 2000-2019 years trend analysis was carried out until 2025. The analysis result is shown in Figure 4.
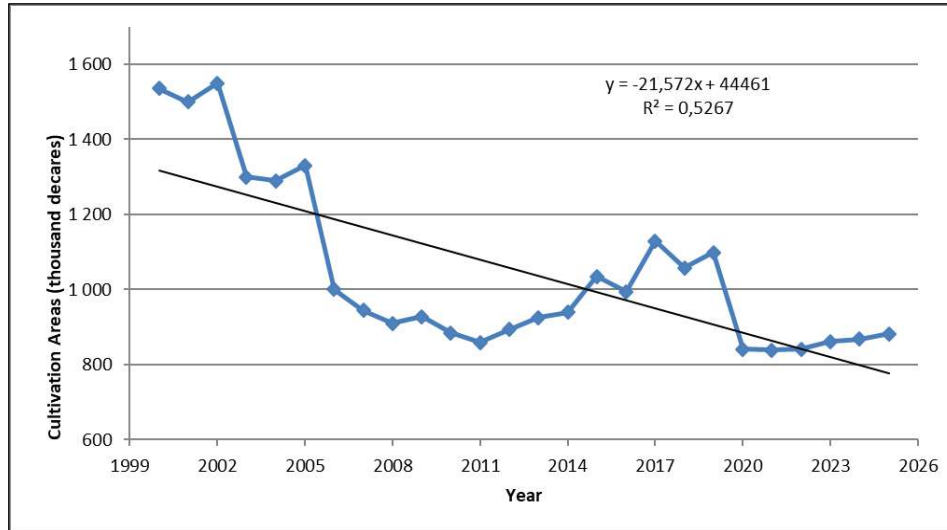

Figure 4: Oat cultivation area in Turkey (2000-2025).
Source: [23].

Accordingly, cultivation areas, which were 153.6 thousand hectares in 2000, decreased to 109.82 thousand hectares in 2019. In oat acreage in Turkey, between the beginning and end of the study period, between the years 2000-2019 decline occurred of 28.5% [23]. In the projection analyses which is conducted until 2025, the oat cultivation area in Turkey as of 2020 is expected to be in the increased tendency, the regression coefficient was determined to be 52.67%. The amount of oat production realized depending on the years and future projections are shown in Figure 5.
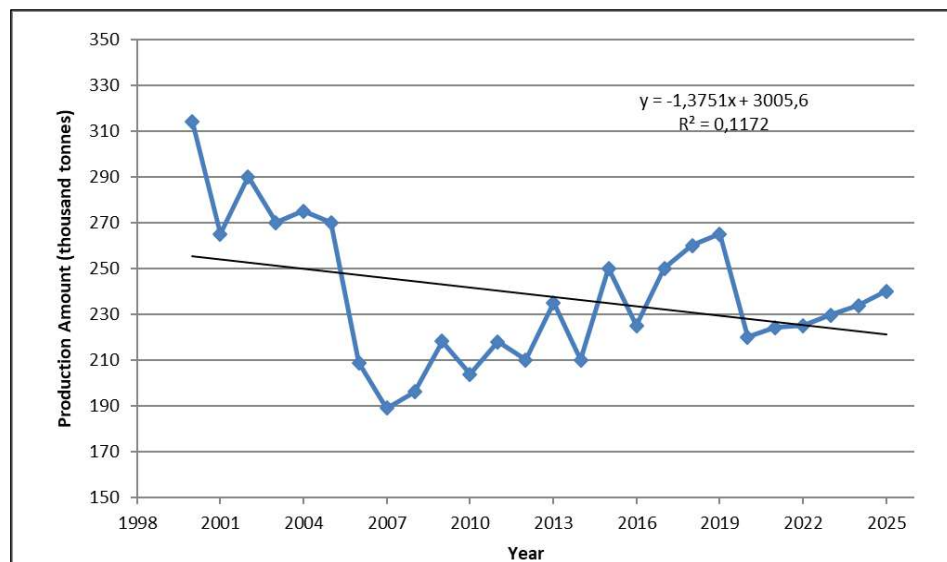

Figure 5: Oats production amount in Turkey (2000-2025).
Source: [24].

Accordingly, the production amount, which was 314 thousand tons in 2000, decreased to 265 theousand tons in 2019. The amount of oat production in Turkey between the beginning and the end of the period have decreased by 15.6% between the years 2000 to 2019 [24]. In the projection analyses which is conducted until 2025, oat production amount in Turkey as of 2020 is expected to be in the increased tendency, the regression coefficient was determined to be 11.72%. To determine the trend of the oat yield in Turkey over the years and to estimate future projections, by using the TSI data between 2000-2019 years trend analysis was carried out until 2025. The oat yield change graph until 2025 is shown in Figure 6. The yield, which was 2040 kg/hectare in 2000,

reached 2410 kg/hectare in 2019 after an increase-decrease at a fluctuating rate. Accordingly, between 2000 and 2019, oat yield increased by 18.1%, and the average yield in the 20 years considered is 2200 kg/hectare. It is predicted that the increase in efficiency will tend to increase in the future periods, too, and the regression coefficient is 75.8%. The fluctuating change in yield is explained by climatic conditions and precipitation. Because oat is a plant included in the cool climate cereals [21]. Oat yield in 2001 and 2007 in Turkey is at the lowest level. The low yield in these years was due to the precipitation in a decrease of approximately 9% compared to normal [25]. The largest increase in oat yield was 1.25 times in 2011 and 2013, and the annual average total precipitation in this period was 654.7 mm, which was above the average of rainfall for many years [26]. Therefore, precipitation and climatic conditions are effective in yield increases and decreases. It is expected that there will be an increasing trend in the projections made for the future periods, and it should not be forgotten that the most determining factor here will be the climate.
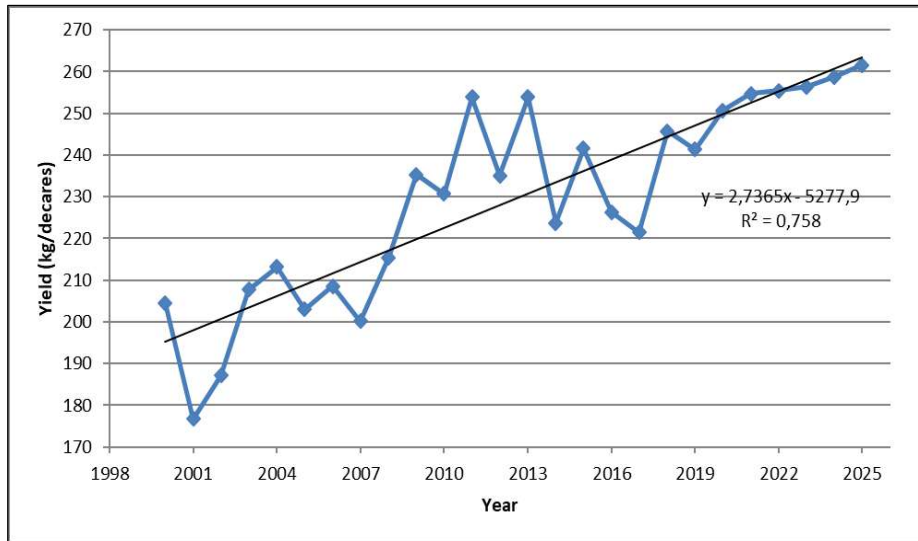

Figure 6: Oats yield in Turkey (2000-2025).
Source: [24].

To determine the trend of the oat average sales price in Turkey over the years and to estimate future projections, by using data between 2000-2019 years trend analysis was carried out until 2025. The analysis is shown in Figure 7. Sales prices increased by 14.52 times between the beginning of the period and the end of the period (between the years 2000-2019). According to the trend analysis, it is estimated that oat prices will show an increasing trend with a regression coefficient of 98.25% until 2025.
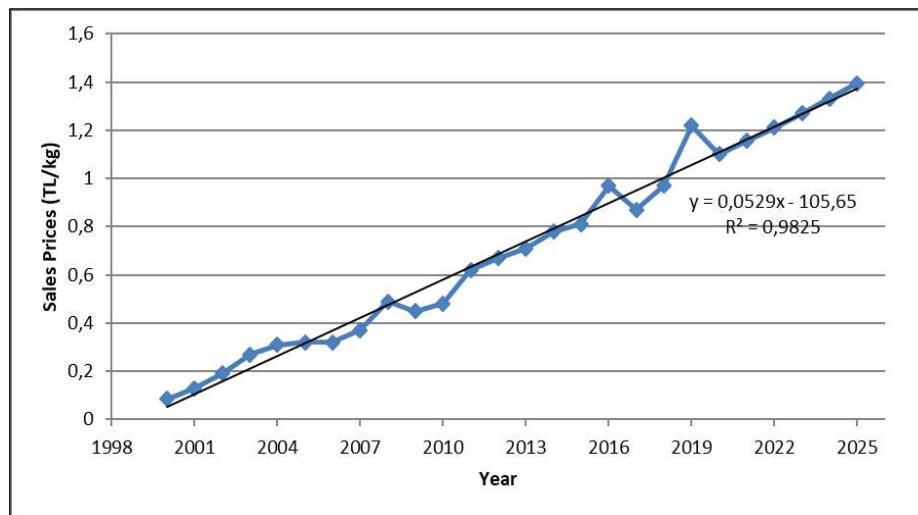

Figure 7. Oats sales price in Turkey (2000-2025).
Source: [22],[24].

Oats sales prices in Turkey between the years 2000-2019 showed a rising trend overall. Prices depend on supply and demand under general economic conditions. It is expected that prices will increase until the amount of supply meets the amount of demand. The latest data on exports and imports of oats in TURKSTAT data belong to 2018. Accordingly, trend analyzes were carried out for the period until 2025, using data between 2000 and 2018.

Between the years 2000-2018, which is the research period, the average annual export amount was 96.42 tons. Export values fluctuated at an excessively increasing and decreasing rate depending on the years. It is interpreted that this situation arises due to the domestic consumption demand.

The graph of the trends in exports is given in figure 8. Accordingly, exports show an increasing trend with a fluctuating course, and the regression coefficient was determined as 20.23%.
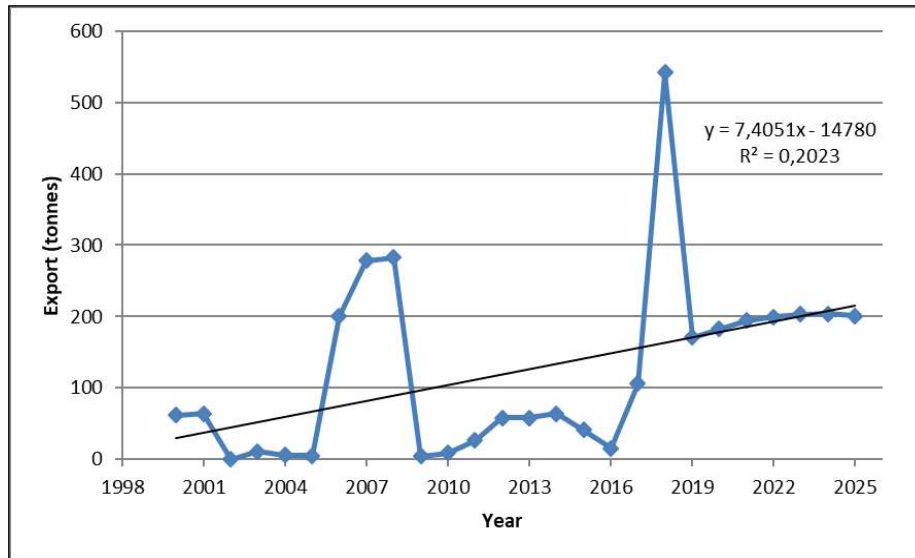
Figure 8. Turkey's oat exports (2000-2025).
Source: [24].

To determine the trend of the oat import amount in Turkey over the years and to estimate future projections, by using data between 2000-2018 years trend analysis was carried out until 2025. The analysis result is shown in figure 9.
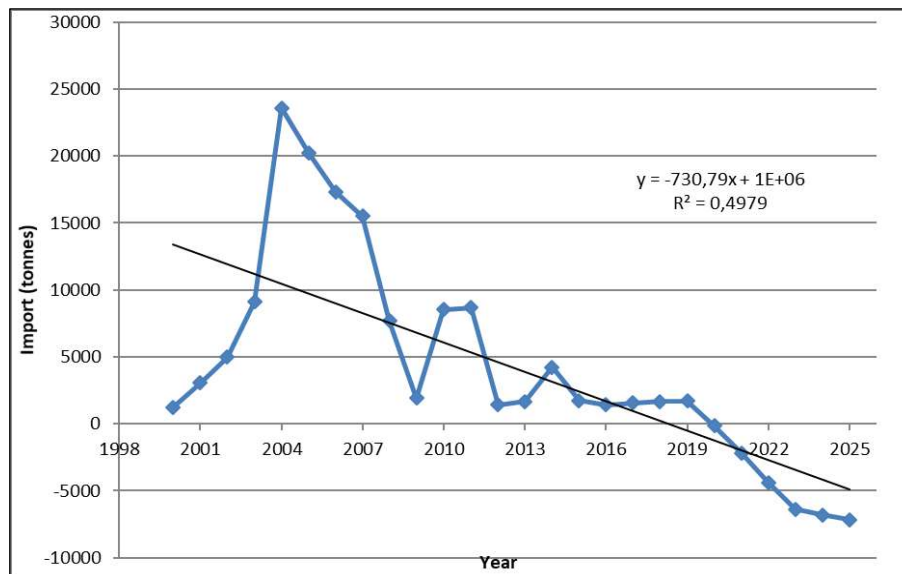

Figure 9. Turkey's oats import (2000-2025).
Source: [24].

Turkey, despite having a variable appearance of oats foreign trade, is mostly importers. Oats import; depending on the production areas and amount, use as a domestic nutrient, and the production amount of feed plants that can be substituted as raw materials to meet the developing needs of the feed industry, it varies over the years. But considering the data during the research period; increases and decreases in the amount of imports are mostly explained by cultivation areas, yield, and climate-based precipitation. The increase in the amount of imports between 2000-2004 is directly proportional to the increasing population and the number of animals. Import values have decreased continuously between 2004 and 2018, and it is estimated that future projections will also tend to decrease [24]. The regression coefficient of this decrease is predicted to be 49.79%.

In consequence of oat processing facilities operating below the current capacity and the dry season in some production periods, oat production is at a level that cannot meet domestic consumption.

Due to the occurrence of these situations, it becomes mandatory to import oats. According to the trend analysis, oat imports are expected to decrease by 2023. In contrast to the decrease in imports of oats in Turkey, an increase in acreage it has occurred. Oats, which are used as a nutrient in human nutrition and especially used as feed-in livestock breeding, have been produced in sufficient quantities by increasing the oat planting areas. Determination of the change in the foreign trade balance over the years in Turkey and in order to make projections for the future, export and import data were used. In terms of foreign trade, between 2000 and 2018, oat imports and exports fluctuated at increasing and decreasing rates depending on the years. As the investigated period, Turkey is a net importer until 2020, the ratio of imports shows a declining slope. As of 2020, the transition to the export trend has been detected, and it is predicted that this will continue in the coming periods. The graph of the foreign trade balance is shown in Figure 10 and the regression coefficient has been determined as 50.4%.
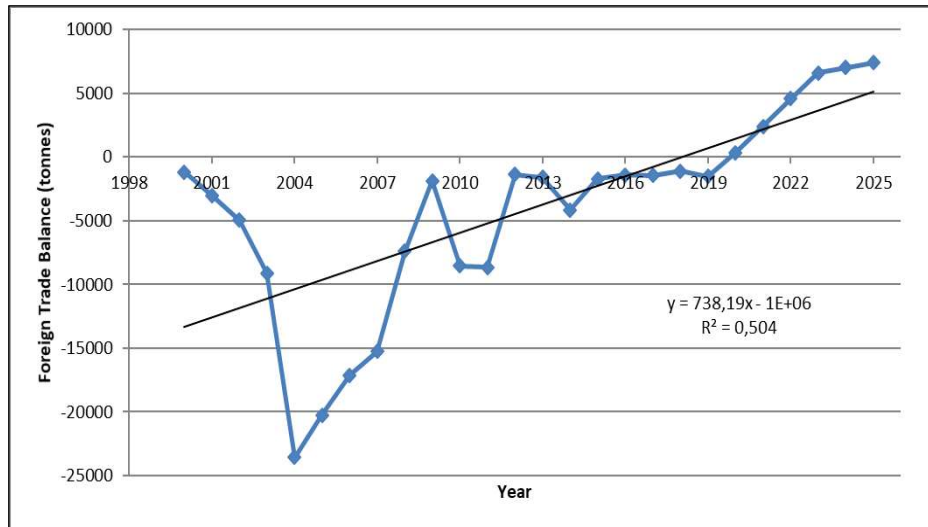
Figure 10. Turkey's foreign trade balance of oats (2000-2025).
Source: [24].

IV. CONCLUSIONS

While Turkey among the first 18 countries in the world oat acreage, the amount of oat production is lower than it. One of the most important issue in oat cultivation is the low yield, the yield is below the world average in Turkey. In order to increase the yield, it is necessary to expand the use of technological developments, to include oats in the product pattern in irrigated agriculture, and to ensure the use of fertilizers, suitable varieties, and good seeds. Growing population in Turkey, the increase in livestock breeding, and with the development of the food industry, oat consumption has increased. Accordingly, it is necessary to increase the production level to meet domestic consumption. It is necessary to follow incentive policies and support the producers in order to expand the cultivation areas of oat, which is an alternative to many forage crops. Due to the constraints and disadvantages of rural areas, structural changes and developments in agricultural production and product pattern can be made mostly through agricultural extension activities. So much so that farmers can even show a willingness to pay for agricultural extension activities where they can earn more income [27]. Therefore, oats should be given more place in agricultural extension activities. Due to the pricing policy implemented in Turkey and the decrease in production, oats cannot compete with other products, improvement efforts are also not given adequate attention. In order for oats to be a competitive product, it needs to be supported by more public policies. This situation will also impact positively on Turkey's foreign trade. This research is important in terms of covering up-to-date data on oats and future predictions. This research provides useful data for decision-makers and agricultural policymakers.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Zeliha Şahin, Mustafa Hakkı Aydoğdu and Gönül Sevinç.
Methodology: Zeliha Şahin, Mustafa Hakkı Aydoğdu, Gönül Sevinç and Nihat Küçük.
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Supervision: Zeliha Şahin.
Approval of the final text: Zeliha Şahin, Mustafa Hakkı Aydoğdu, Gönül Sevinç and Nihat Küçük.

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RESEARCH ARTICLE   **OPEN ACCESS**

GSM BASED SMART FIRE AND HIGH-TEMPERATURE DETECTION SYSTEM

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ARTICLE INFO	ABSTRACT
	This research refers to an Arduino and Global System for Mobile (GSM) based system for efficient detection of fire hazards. This project's purpose is industrial and domestic safety, and the primary concern is to avoid the fire hazards that occur to the employees and the properties inside the buildings. As a solution, a smart fire and high-temperature detection system is design using GSM technology, smoke/temperature sensors, and Arduino technology. A smoke sensor is used to detect the smoke from the fire and a temperature sensor is used to detect temperature increase inside the building. In event of a fire, an alert message will be sent to the user via short message service (SMS) via the GSM module. Furthermore, when a fire is detected, a signal will be sent to the main power supply circuit breaker via a microcontroller and then the power supply of the particular building will shut down. Results from the test are documented and discussed in this paper. This system helps users to respond immediately to the situation and so improve their safety by protecting their lives and the properties from a disaster.

I. INTRODUCTION

An increase in temperature or fire occurred in remote locations, where human interaction is limited, is a major cause for deaths and disasters in industrial areas and factories. Due to poor fire extinguishing arrangements, lack of adequate fire alarm, and emergency exit, the extent of the disaster could worsen. Nowadays people can take the advantage of the technology to provide early warnings and alerts to avoid danger and to react quickly. When temperature increase or fire occurred in remote locations, technology is the best thing we can use.

This project will be used in a "Solar inverter room" for high temperature and fire detection. For this purpose, the project has used highly sensitive smoke (MQ5) and temperature (DHT11) detectors, by which the microcontroller will get a high pulse at the input pin which is preprogrammed for desired output signals.

This project also uses an alert warning system based on Global System for Mobile (GSM) network. When a temperature increase or fire occurs, the sensors used in a circuit will detect it and GSM modem (SIM 900) will send out an SMS alert to the person-in-charge of the "Solar inverter room", to the head of the particular department, and the security guard room. This will allow those persons to respond quickly. This system can also be installed in other places like food storage rooms, cool rooms, powerhouses, hotels, buildings, and any other places where fire and temperature are highly controlled.

II. LITERATURE REVIEW

In 2011 L Chun-yuan has designed an intelligent fire alarm system based on GSM. The purpose of the project is to solve the problem of complex cabling, missed declaration, and missing alarm of traditional fire alarm system [1]. By adapting smoke detectors and using a variable threshold alert algorithm with temperature compensation the accuracy of the fire alarm is improved.

In 2014 M Faris, M Fuzi, A F Ibrahim, M. H. Ismail, N. Syakira, and A. Halim, has developed a low-cost home dedicated fire alert detection system using ZigBee wireless network. Along with ZigBee an Arduino Uno microcontroller, Arduino digital

temperature sensor, Buzzer alarm, and X-CTU software were used in the project. It is called "Heat sensor for home use" [2].

In 2016 S Suresh has developed a home-based fire monitoring and warning system using Arduino Uno R3. During the existence of smoke or flame at a particular level, this system will send an alert to the property owner effectively and quickly via GSM [3].

In 2012 H Elbehiery has designed and developed an intelligent fire alarm system for home fire alarms with an Arduino-based system utilizing GSM Module. This system has an ATmega328 and a temperature sensor along with an Arduino board. The project's purpose is for house safety where the main purpose is to avoid the fire accidents that occurred to the residents and the properties inside the house as well [4].

In 2015 K Sen, J Sarkar, S Saha, A Roy, D Dey, and S Baitalik, has developed an automated fire detection and controlling system based on smoke and heat detection. It is comprised of a combination of electrical/electronic devices/equipment working together to detect the presence of fire and alert people through an audio or visual medium after detection. The system will send Short Message Service (SMS) to the registered mobile numbers and switch on a water sprayer or a solenoid pump to spray water or fire ceasing foam [5].

In 2013 P Y Mulge, has designed remote temperature minoring using a wireless sensor network prototype for remote room temperature monitoring. This network will be used for the management of fire rescue operations. LM35 sensor senses the remote room temperature and temperature status is transmitted to the smartphone via GPRS. This work aims at the monitoring of remote room temperature. This provides an opportunity to quickly respond to fire emergencies [6].

III. MATERIALS AND METHODS

The design and development of this project are divided into two main parts which are hardware architecture and software details. In the hardware architecture, the design of the circuit was constructed and the prototype of the project was built. In the software development, the whole complete prototype was operated via programming codes.

III.1 HARDWARE ARCHITECTURE

Arduino is the mainboard, which is an open-source microcontroller-based kit. The Arduino system offers a set of analog and digital pins that can be interfaced with many other boards and circuits which have different functions in a design. Figure 1 shows the Arduino Uno board that is used throughout the project.

Figure 1: The Arduino Mega board uses a microcontroller ATmega328 onboard.
Source: Authors, (2020).

The GSM module, GSM SIM900A type is selected to carry out the task of communication between Arduino board and mobile phone. Figure 2 shows the GSM SIM900A device before connecting to the Arduino board.

Figure 2: The GSM SIM900A module to communicate with Arduino board.
Source: Authors, (2020).

Temperature/heat sensor (DHT11) is chosen for measuring the temperature, which is a commonly used temperature and humidity sensor. The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%. Figure 3 shows the DHT11 sensor before connecting to the Arduino board.
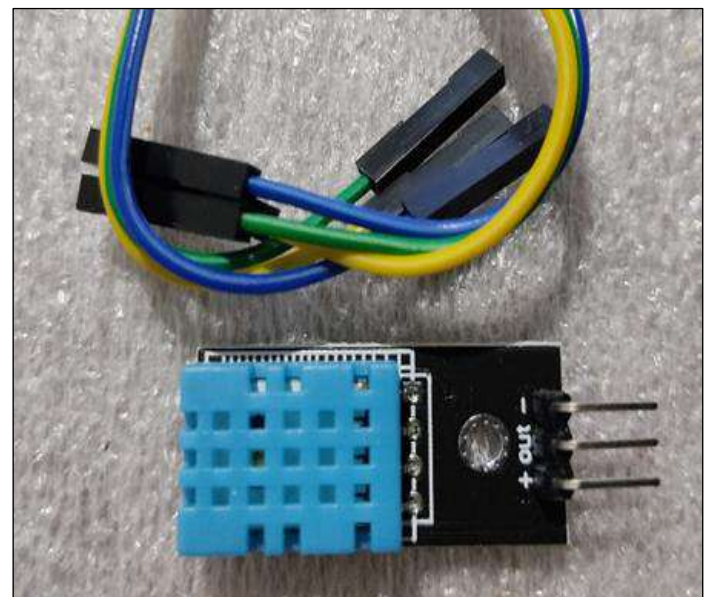

Figure 3: The DHT11 sensor.
Source: Authors, (2020).

To detect the smoke during a fire, a Gas sensor has been used. The project used the MQ5 Gas sensor module. The digital output of the sensor has only two possible outputs – High and Low. Figure 4 shows the MQ5 Gas sensor before connecting to the Arduino board.

Figure: The MQ5 Gas sensor.
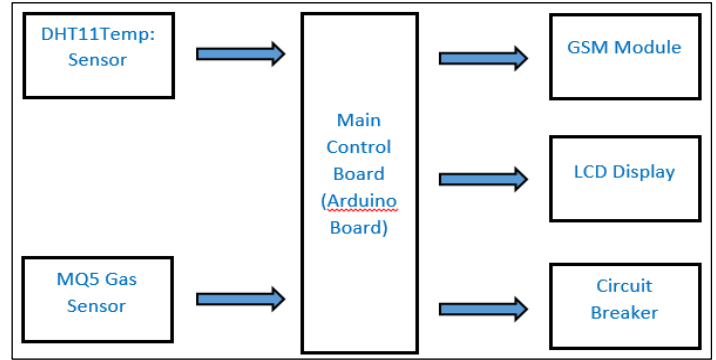Source: Authors, (2020).

Figure 5: Block diagram of the home fire alert system.
Source: Authors, (2020).

Figure 5 presents the block diagram for the fire and high-temperature detection system. The hardware design entails three main components which are the connections between Arduino board and the GSM SIM900A and Arduino with the temperature sensor (DHT11) and Gas sensor (MQ5).

When a fire has broken out, MQ5 will trigger the smoke. Upon sensing the smoke, it will directly send a signal to the Arduino informing the fire. The smoke will make the Arduino alert the user about the situation through the GSM module. An SMS will be sent promptly to the user to let the user know the existence of the fire. At the same time, a signal will be sent to the main power supply circuit breaker via a microcontroller and then the power supply of the particular building will be shutting down and the existence of the fire will be notified as well on the LCD.

When the temperature is increased in the solar inverter room, DHT11 will trigger the temperature. Upon reaching the temperature of 30 C, it will directly send the signal to the Arduino informing the high temperature. The increased temperature will make the Arduino alert the user about the situation through the GSM module. An SMS will be sent promptly to the user to let the user know the temperature increased in the solar inverter room. At the same time, increasing temperature will be notified as well on the LCD.

III.2 SOFTWARE DEVELOPMENT

The software of the project is based on the flow chart in figure 6. When the system begins, DHT11 will always sense the surrounding temperature and MQ5 will sense smoke. Whenever a fire is broken out, even a small little fire, smoke, and temperature rise will have occurred. In that situation, DHT11 can detect the temperature value instantly and MQ5 detect smoke. The DHT11 will detect the temperature changes inside the solar inverter room not only in case of fire but when an air conditioner malfunction occurred. At the time when the temperature reaches 30 ºC or above and the presence of smoke, the microcontroller on the Arduino Mega board will notify the GSM module to send an alert message to the user. And simultaneously send a signal to the main power circuit breaker of the room, so the power supply to the room will be shut off. The value of the temperature limit that can be triggered by DHT11 can be changed in the code upon request by the user. Figure 6 illustrates the flow chart of the fire alert system.
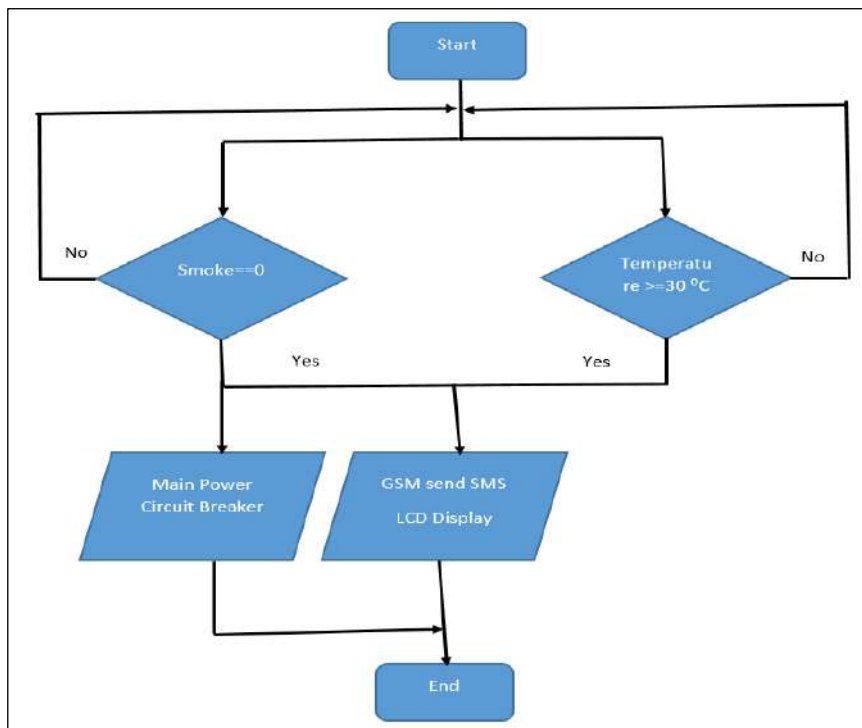
Figure 6: Flowchart of the smoke and temperature alert.
Source: Authors, (2020).

III.3 SCHEMATIC DIAGRAM

The overall project schematic diagram is shown in figure 7. While figure 8 illustrates the connection schematic diagram between the Arduino board with DHT11, MQ5, and GSM module. Since the Proteus© software does not have the GSM module component, it is replaced with the input connector available which the connector pins will be attached directly to the Arduino board. For the particular part of detecting Smoke from MQ5 and Temperature from DHT11, the code is written and portrayed in figure 9. In the code, measured temperature from the surrounding is identified in voltage. It is because DHT11 is an analog sensor which values voltage unit. The voltage unit received will then be converted into a comprehensible standard SI unit; degree Celcius in the subroutine called 'CheckTemp()'
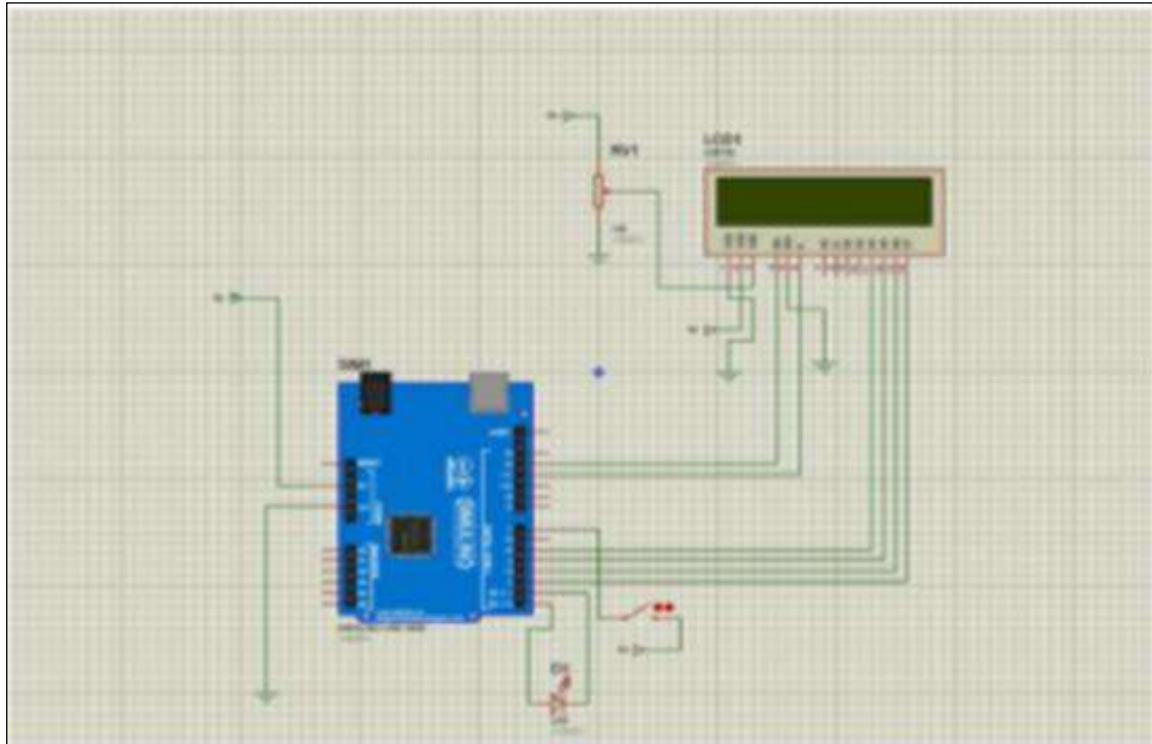
Figure 7: Project schematic diagram.
Source: Authors, (2020).
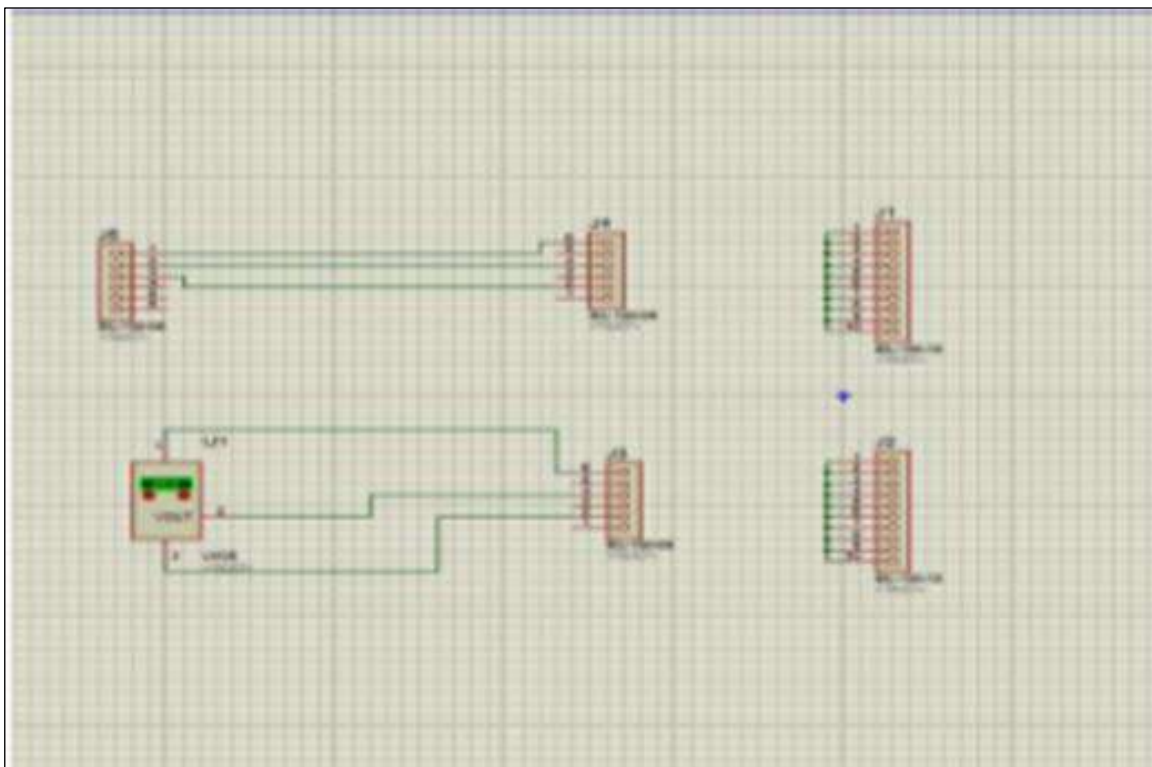
Figure 8: The schematic diagram for connection.
Source: Authors, (2020).

```
Void Check fire()                              Float check temp{
{        lcd.setCurser(0,0)                        tempread=analogread (DHT11)
         Lcd.print("fire SCAN_ON")                 temp read = temp read*5
Smoke Alert val=check smoke()                      temp read = temp read/10
         If(Smoke Alert val>0)                     return temp read
         Fire set=1                             }
         {
         lcd.setCurser(0,1)
         lcd.print("fire alert SMS sent")
         while(SMS count>3)
                 {
                 Sent fire alert Message().
         }
}
}

Void Check temp()
{        lcd.setCurser(1,0)
         Lcd.print("temp SCAN_ON")
         temp Alert val=check temp()
         If(temp Alert val>30)
         Temp high=1
         {
                 lcd.setCurser(1,1)
         lcd.print("pemp high alert SMS sent")
         while(SMS count>3)
                 {
                 Sent temp alert text Message()
         }
}
}
```

Figure 9: The program code for detect smoke and measuring temperature.
Source: Authors, (2020).

IV. RESULTS AND DISCUSSIONS

Few tests were done to observe the system's performance. The tests were completed by applying smoke near to the MQ5. Figure 10 shows the condition in which the MQ5 is in ready mode (ready to detect smoke) and DHT11 in ready mode (ready to detect temperature). Figure 11 displays alert messages on the LCD when MQ5 detected fire and DHT11 detected temperature increase. While figure 12 reveals the SMS received by the user when a fire or temperature increase alert is notified by the system.
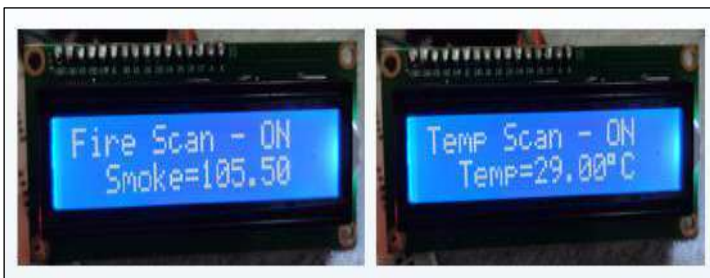

Figure 10: MQ5 is in ready mode and DHT11 in ready mode.
Source: Authors, (2020).

Figure 11: Alert messages on the LCD when MQ5 detected fire and DHT11 detect temperature increase.
Source: Authors, (2020).

Figure 12: SMS received by the user.
Source: Authors, (2020).

As per the results, this system works when a certain level of smoke detected during fire breakout or the temperature increased more than a certain value, was detected. LCD revealed the smoke and temperature alerts and simultaneously a signal was sent to the GSM module. Then GSM module sent an alert SMS to the user's mobile phone. The important part of this system was the power shutting down technique, which was activated during a fire breakout. This is helpful to minimize the damage that could occur due to fire breakout. Therefore this GSM based fire and high-temperature detection system can be easily and effectively applied to premises even where human interaction is limited.

V. CONCLUSIONS

This project has been made to help the responsible person of "Solar Inverter Room", to overcome the problem that occurred when fire spreading or temperature increasing happened whenever the responsible person is not in nearby. Based on the results obtained, the fire alert system is doable and functional to the residents, factories to protect their assets. The system built, is cheap in value compared to other existing fire alarm systems in

the market and easy to apply to the residents also. Users can simply apply the device in their interested area to protect the area from the existence of fire and heat. Whenever the temperature reaches the limit (30 ºC) or the smoke level reaches its limit, the device will instantly alert the users by sending a message via GSM. This System can be applied in varied areas due to its flexibility and simplicity in handling; for instance in houses, hostels, hotel industries, factories, material storage areas, warehouses, and many more areas that are related to the gathering of people or valuable assets.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Manjula Welihinda and Hasitha Nuwan.
Methodology: Ravindra Koggalage, Manjula Welihinda and Hasitha Nuwan.
Investigation: Ravindra Koggalage, Manjula Welihinda and Hasitha Nuwan.
Discussion of results: Ravindra Koggalage and Hasitha Nuwan.
Writing – Original Draft: Ravindra Koggalage and Hasitha Nuwan.
Writing – Review and Editing: Ravindra Koggalage, and Hasitha Nuwan.
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Supervision: Ravindra Koggalage, Manjula Welihinda.
Approval of the final text: Ravindra Koggalage.

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RESEARCH ARTICLE   **OPEN ACCESS**

REFORESTATION AND RECOVERY OF DEGRADED AREAS OF THE TARUMÃ-AÇU WATERSHED AND ITS CONTRIBUTION TO REDUCING GREENHOUSE

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ARTICLE INFO	ABSTRACT
	Here we present the results of the reforestation project in degraded areas of the Tarumá-Açu Watershed and the estimation of the CO fixation for the reduction of greenhouse gas emissions during the 20-year period. For each species analyzed after planting, during the period 2015-2019, the method used was participatory observation, where those involved analyzed the data in loco, recording, through photos, the development of seedlings in terms of growth, mortality and survival in order to replace the dead with others that could carry out the functions of environmental protection and minimize the degradation process of the area. It can be said that the management of the process was necessary due to the climatic changes that occur during the year, since the monitoring of the species occurred in March, the rainy season and August, the summer season, or different periods: complete and dry. The observation was part of the whole process, from the moment of requesting the seedlings to replace the dead ones, analyzing those that have a higher survival rate and those that need a closer monitoring, due to the mortality rate. The growth, mortality and survival rates of the species are highly variable. Each species has different characteristics, therefore, the data found present different percentages for species planted in the same area, either lowlands or igapó. In 5 years of topography of the species and data, it can be said that the plants gradually adapt to the adversities of the soil and climate. Planting seedlings in the field should preferably be carried out after 30 days of preparation of the pits. The planting procedure is the same as described above, needing to remove the package containing the seedling and only then insert it into the well. The pit is then closed with the soil pressing it, so that there is more contact between the seedling substrate and the soil. As a result of the first step of the experimental methodology, with the participation of the community, students and volunteers, a brochure on how to care for the environment was distributed free of charge, illustrated by the Amazonian fauna, existing in the area, in schools and the community, at the end of each conference on environmental education.

I. INTRODUCTION

The Tarumã-Açu-BHT Hydrographic Basin is located on the west side of the municipality of Manaus. Since the 1950s, it has been occupied by farmers and later by extractivists, with a great urban expansion, generating real estate speculation in the area. The high demand for occupancy by the middle and upper classes led to the creation of marinas, condominiums and second homes, for use on weekends. Over time, the occupation by commercial establishments, the so-called floating ones, occupied the entire hydrographic basin. These occupations and the disorderly removal of boulders and sand from the site, have caused soil degradation and deforestation in the area, which has led us to develop environmental education and reforestation practices in the basin, in order to minimize the impacts. generated.

In order for us to achieve the proposed objectives, it was necessary to sensitize the surrounding community through Environmental Education, initially in schools with children, considering the rest of the community members so that everyone could know the importance of the Basin and the need to conserve it for the future generations.

Environmental education is a continuous process in the development of research and species monitoring. There are talks, group activities, correct disposal of waste and finally, everyone plants a tree seedling.

As a result of the dissemination of environmental education in the community, it is possible to create a children's magazine, with images of the local fauna and flora, in a simple and objective language, oriented towards the protection of the forest and rivers.

The recovery and reforestation area is part of the Tarumã Açu - Tarumã Mirim Settlements, part of the Tarumã-açu Hydrographic Basin, located on the left bank of the Negro River, it has 56,793ha, it is located between parallels 2º 41 '44 "and 3º 03'37" South Latitude and meridians 60º 03'41" and 60º 18'27 "West Longitude, in the municipality of Manaus - State of Amazonas.

The Tarumã-Açu River Basin (BHT), located in the north and west of the Manaus municipality, is considered one of the main waterways of the Tarumã-Açu River. It is a tributary of the Río Negro on the left bank, it is located very close to the urban perimeter of the city of Manaus. Access to the Tarumã basin can be through secondary roads, branches and rivers.

In the research development area, it has rainfed, shallow, campinarana and campina vegetation, as well as epiphytes such as bromeliads and orchids - Bryophytes, Orchids and Bromeliads.

Through research in books and articles on the subject, we found several works developed in the basin, however mostly focused on the sustainability of water resources, without finding any specific on reforestation and recovery of the degraded area. However, we propose to develop the research, taking into account the need to recover and reforest an extensive degraded area, which effectively causes an environmental impact on the site.

For this, we rely on the traditional indigenous and local population in the planning and development of the recovery plan for the degraded area. - PRAD, in addition to professional volunteers. Thus, we hope to contribute to the development of other research works, in order to preserve and conserve the Tarumã Basin.

II. THEORETICAL FOUNDATION

II.1 ENVIRONMENTAL MANAGEMENT

For [1], the more general definition of environmental management suggests that it is a set of actions that involve public policies, the productive sector and society in order to encourage the rational and sustainable use of environmental resources. It is, therefore, a process that links conservation and development issues at all levels.

An efficient environmental management system, according to [2], needs to articulate different areas of the organization, with emphasis on the marketing, production, human resources, legal and financial, research and development sectors.

For [3], both the command and control mechanisms by the State and those of environmental competition between companies play a decisive role in advancing environmental management strategies in operations, especially in economies such as Brazil, in the that is required to advance. In terms of universalization of socio-environmental rights.

II.2 DEGRADED AREA

According to Federal Decree 97.632/89, the concept of degraded area or degraded landscapes can be understood as places where there are (or have been) processes that cause damage to the environment, by which some of its properties are lost or diminished, such as quality productive of natural resources.

For [4], considers that the structural problems associated with harmful forms of urbanization have had a strong influence on environmental deterioration, in its broadest sense, ranging from the degradation of natural resources to deeper social problems, such as own homelessness. and its location in areas far from the urban fabric, in contrast to the existence of empty plots in urbanized regions, having as one of its causes the little effectiveness of social policies for access to land and housing.

For [5], environmental degradation is a consequence of activities that directly or indirectly damage the health, safety and well-being of the population; create adverse conditions for social and economic activities; adversely affect biotic factors; Affect the aesthetic or sanitary conditions of the Environment and release materials or energy that do not comply with the established environmental standards.

II.3 REFORESTATION AND RECOVERY OF THE DEGRADED AREA

Degradation of an area occurs when native vegetation and fauna are destroyed, removed, or driven out; the fertile soil layer is lost, removed or buried; and the quality and flow regime of the water system are modified. If there is a loss of adaptation to physical, chemical and biological characteristics and socioeconomic development, it is not feasible [6].

Many heterogeneous reforestation projects with native species have failed due to scarce technical knowledge, mainly about the biology of the species used, or their behavior in artificial reforestation. The lack of scientific criteria to understand the behavior of the dynamics of natural forests (the process by which species regenerate and develop after the natural fall of trees, with clearing formations that are then occupied by new individuals of different species), or technologies to collect seeds, process and produce seedlings, are other factors that influenced the process of forest restoration [7].

Says that the reforestation of degraded areas with native species is an important alternative for environmental recovery. In reforesting degraded environments, it is important to select species that are better able to settle and grow in poor soil conditions [8].

Clarifies that native legumes occupy a prominent place in each and every one of the ecologically prepared reforestation processes, since they are plants that fix atmospheric nitrogen in the soil, enriching it and making it suitable for agricultural cultivation [9].

II.4 WESTERN ANACARDIUM

The cashew is considered a native plant of Brazil. When the colonizers arrived here, they found it very widespread on the northeast coast, composing the vegetation of beaches, dunes and sandy areas [10].

The cashew is a perennial plant, with a low branch (branches close to the ground), which presents a varied size [11]. According to the size of the plants, the cashew is classified into two types, the common (giant) and the early dwarf [12].

Due to its dispersion, carried out by the colonizers since the 16th century (between 1563 and 1578), the cashew is currently found in various parts of the world, vegetating and producing even

in ecological conditions considered unsatisfactory, which characterizes it as a plant with great adaptive capacity [13].

The aerial part (crown) of the common cashew can reach up to 20 m in height, which is why it is also called a giant. However, it is more common for cashew nuts between 8 and 15 m tall, with a diameter (wingspan) proportional to or greater than the height [14].

According to [15], there is consensus that the inflorescence, the type of flowers (perfect, staminate and anomalous), the number of flowers, the flowering pattern and the sex ratio of the flowers are correlated, to a greater or lesser extent. less measure. to a lesser degree, with the productivity of the cashew. In general, the percentage of fruits formed in relation to the number of perfect flowers produced is considered very low.

From a nutritional point of view, cashews are considered a source of vitamin C, B vitamins and iron, and can be considered a relevant source of antioxidant compounds, which are necessary for human health. Thus, peduncles, when eaten fresh, confer direct benefits to human health [16].

Affirms that the flowering of the cashew occurs preferably during the dry season, in which little cloudiness and high insolation predominate. The author also states that, as the producing regions move away from Ecuador, the flowering gradually becomes later, a fact linked to insolation [17].

The cashew is part of these trees; if the environment is poor, they will grow slowly and bear little fruit, but they will survive. If you plant them with other species that will fertilize the soil and moisten the environment, after a while they will take advantage of new resources (nutrients and moisture in the soil) and will begin to produce a lot of fruit [18].

II.5 INGÁ EDULIS

Ingá is a pioneer species, belonging to the Mimosácea family, widely used in the afforestation of streets and squares and very suitable for the recovery of riverside forests in rivers, lakes and reservoirs [19].

It blooms during the months of October to January and the fruits ripen from May onwards. Its wood is moderately heavy, soft, hardly durable, and moderately mechanically resistant. The wood is used for drawer work, charcoal and firewood. Its fruits are consumed and commercialized by the populations of the Amazon region [20].

According to [21], its wood is recommended for the manufacture of fine furniture, making artifacts for civil construction, poles, posts, sleepers and others. Tannin is obtained from the bark, which is widely used in leather tanning. It is also a honey plant 16 and with potential for use in urban forestry and landscaping, mainly squares and public parks.

According to [22], species of the genus Ingá should not be lacking in riparian forest restoration programs, since they are typical species of the soils of the lowlands of the Atlantic Forest and support places with floods.

Characterizes the mechanical fixation of the vegetation under the Amazonian soil in which he emphasizes that it is only in the soil where growth occurs and does not come from the soil, nourishing itself through a closed circulation, in contrast to land soils. Lowlands are extremely fertile, especially for crops such as corn and beans, due to the extensions of the pre-Andean region, constituted and maintained by the intermittent transport of eroded soils, which is why they are classified as infertile soils [23].

II.6 FLEXUOSA MAURITIA

Buriti is a species of palm of Amazonian origin, also known by the names of buriti-do-brejo, carandá-guaáu, carandaí-guaáu, coco-buriti, itá, palm-dos-brejos, buritizeiro, meriti, miriti, muriti, muritim, muruti. [24].

This species of palm is found in various plant formations, being common in flooded, sandy soils, such as igapó, ribera and igarapés, tolerating remaining with part of the trunk submerged in water for long periods [25].

II.7 EUTERPE OLERACEA

According to [26], the plantation of açaí in rainfed areas represents an excellent alternative for the recovery of deforested areas, as well as to reduce the pressure on the alluvial plain ecosystem, much more fragile, avoiding its transformation into homogeneous forests of this palm tree.

The açaizeiro grows well in these ecosystems, however, the different patterns of structural adaptability allow for full reproductive development in highland areas [27].

In floodplain areas, native-managed açaizais are concentrated in the estuary of the Tocantins, Pará and Amazon rivers. In the municipality of Igarapé-Miri, Pará, this practice began in the early second half of the 1990s, in areas subject to tidal flooding [28].

The flood consists of a gradual increase in the water level, which takes a period of 6 hours and 12 minutes to reach its maximum level, called "high tide". At this point, it stays for about 7 minutes until reflux begins. The ebb is, therefore, the lowering of the water level, also for an approximate time of 6 hours and 12 minutes, until it reaches its minimum level, the "low tide". At this time, in the same way, the level stabilizes for another 7 minutes until the flow begins again [29].

The availability of water in the soil influences the growth, distribution and survival of plants. Under natural conditions, plants that live in humid places, such as açaí, are naturally subject to a moderate water deficit on certain occasions. The ability to tolerate moderate stress is very important for the propagation of the species in environments other than its natural habitat [30].

Palm trees are adapted to different environments such as lowlands, igapó and firm ground, due to their ability to allocate resources to leaves and roots. The efficiency of the leaves to capture light energy, the ability to convert that energy into carbohydrates, as well as its transport and metabolism in the different parts of the plants are factors that influence the growth and survival of palm trees when they grow in adverse places [31].

The objective of recovering degraded areas is the restoration of an ecosystem, by planting native species adapted to the conditions of the natural environment [32].

A fundamental aspect in this process is the choice of the species, where the adaptability of the species to local environmental conditions, the attraction of fauna, the rapid growth and the large deposition of garbage must be considered [33].

The buriti is a perennial plant that is found in swampy or permanently humid areas, it serves as a source of food, shelter and breeding ground for various elements of the fauna [34]. These characteristics indicate great potential for wetland recovery.

Studied the survival and initial growth of seedlings of Euterpe edulis Mart. transplanted to clearings and understory in a seasonal semi-deciduous forest found higher survival in clearings (53%) and lower in shaded understory (20%) [35].

States that shallow areas are usually relatively flat surfaces within which the igarapé is located. The soil is sandy because, over

a long period of time, the water in the local watershed slowly removes the clay it contains. The water table is near the surface and blooms in the stream, however the soil is not completely soaked all the time, especially in the areas closest to the slope [36].

II.8 GREENHOUSE GASES

According to [37], greenhouse gases form a kind of layer that surrounds the Earth with gaseous constituents, through which solar radiation enters and part of the heat generated is eliminated into space in the form of infrared radiation. But today much of this infrared radiation is not capable of passing through the GHG layer, which raises great concern, since some of these gases remain in the atmosphere for years, retaining the radiation that should be emitted into space, becoming responsible for climate change [38].

The industrial revolution was a great benefit for the population, but pollution grew along with the emission of polluting gases that contribute to global warming, the main ones being carbon dioxide and monoxide [39]. The increase in carbon dioxide, consequently the cause of global warming, is mainly produced by anthropogenic activities, such as deforestation of forests and burning of fossil fuels, power generation, among others [40].

Deforestation emits carbon dioxide (CO_2) and other greenhouse gases. Some of the CO rea is then reabsorbed through the regrowth of secondary forests in deforested areas, but the other greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), are not. The amount of carbon absorbed as CO_2 by regrowth of secondary forests is small compared to the initial emission, because the biomass per hectare of secondary forest is much lower than that of primary forest [41].

II.9 GREENHOUSE EFFECT

The greenhouse effect is mainly caused by the emission of CO_2, CH_4, N_2O, chlorofluorocarbons (CFCs) and water vapor. Among them, CO_2 is the gas that contributes the most to the greenhouse effect, due to the large amount that is emitted, around 55% of the total. In turn, the amount of CH_4 emitted into the atmosphere is much lower, but its warming potential is 23 times greater than that of CO_2. Although the concentrations of N_2O and CFC in the atmosphere are even lower, the global warming power of these gases is much greater, being, respectively, about 298 and 6,200 to 7,100 times that of CO_2 [42].

The fires that accompany deforestation determine the amounts of gases emitted not only from the part of the biomass that is burned, but also from the part that is not burned. When there is a fire, in addition to the release of carbon dioxide (CO_2), trace gases such as methane (CH_4), carbon monoxide (CO) and nitrous oxygen (N_2O) are also released. The part of the biomass that is not burned in the initial combustion, which is hot, with flames, will also be oxidized [43].

The concentration of CO_2 and other greenhouse gases has increased dramatically since the industrial revolution. Since 1750, approximately 35% of anthropogenic CO_2 emissions are directly related to changes in land use [44].

According to the [45], forests are the largest reservoirs in the carbon cycle that contain around 80% of this atom. The vegetables, using their photosynthetic capacity, fix the atmospheric CO_2, biosynthesizing in the form of carbohydrates, and finally, depositing themselves on the cell wall, thus carrying out the "sequestration" of carbon.

The greenhouse effect can directly cause the death of the Amazon rainforest, in addition to its probable effect through El Niño. Higher temperature averages require each tree to use more water to perform the same amount of photosynthesis. The greenhouse effect does not occur uniformly on the planet and the Amazon is expected to be one of the places with the highest temperature increases [46].

Estimates indicate that the deforestation rate in the Brazilian Amazon is 1.1 to 2.9 Mha yr-1 [47]. Despite this high rate of deforestation, the Amazon, in Brazil, still has approximately 40% of the remaining area of tropical forest in the world [48].

II.10 CARBON ABSORPTION

States that a tree fixes an average of 249.6 kg of CO_2 in 20 years and that in the worst case it can fix up to 140 kg. Transformed into exact numbers, it can be said that a tree can fix between 7 kg and 12.48 kg of CO_2 per year, according to the author's data [49].

The incentive to reduce CO_2 in the atmosphere generates expectations for the dissemination of the Brazilian forestry potential, even so, there is a lack of publications that can demonstrate the potential that SAFs have for agricultural production and the recovery of degraded areas [50].

Carbon sequestration has become a viable alternative in CO_2 capture to control the emission of greenhouse gases and reduce the effects of global warming [51].

For [52], a tree in the Atlantic Forest absorbs, on average, 163.14 kg of CO_2 in the first 20 years or 8.15 kg per year, which shows that after twenty years the same tree can fix more or less carbon.

States that a tree can capture about 15.6 kg of CO_2 per year, during the first 20 years and 4.4 kg after that period. Data that can be studied later, to have information on carbon fixation after 20 years of life of the tree [53].

For [54] studied the survival and initial growth of seedlings of Euterpe edulis Mart. transplanted to clearings and understory in a semi-deciduous seasonal forest, they found greater survival in clearings (53%) and lower in shaded understory (20%). On the other hand, the evaluation of other families of plants in the recovery of degraded areas is more frequent.

When analyzing a 10-year sowing with species from the Myrtaceae, Fabaceae and Clusiaceae families, in Restinga areas degraded by the intense process of removal of vegetation and soil layers for the extraction of sand until 1997, obtained an annual average growth in height of 14.2 cm, considered low by the authors, attributed to soils poor in nutrients, high incidence of light and strong wind action [55].

III. METHODOLOGY

The experimental methodology was implemented following 4 steps:

First step: dissemination of environmental education in schools and traditional and indigenous communities around the basin, through conferences, discussion and group work, joint efforts, debate, reflection, imitation and exploration of the local environment. The actions also included theater activities, videos, posters made by children, puppets, sweepers of joy, ending with the creation of an environmental brochure, prepared with the active participation of the community.

The dissemination of environmental education with community members and permit holders in the watershed allows them to be committed to the environment. The talks and activities carried out demonstrated the real importance of planting and reforesting degraded areas, as well as contributing to a more pleasant environment, helping to minimize the contamination of the ozone layer.

Second step The search for a bibliographic review, consultations of dissertations, theses, scientific articles and books began, with the aim of identifying the level of depth of the information generated on the study area. The acquisition and collection of pre-existing data available in analog and digital media was carried out, such as: satellite images, topographic maps, pre-existing maps, among others.

Third step The collection of data and images was carried out in the period from 2015 to 2019, always in the rainy and dry seasons of the region, more precisely in the months of March to August. It was established as parameters for the mortality rate 20%, a percentage considered satisfactory for the continuity of the project, considering the adversities of the region and the planting site.

Finally, to evaluate the percentage of mortality of the species, 500 seedlings of Euterpe Oleracea, 500 of Anacardium Ocidentale, 500 of Ingá Edulis and 500 of Mauritia Flexuosa, approximately 50 to 60 cm tall and at six months of age, were selected.

For the data on the probability of carbon fixation of species in 20 years, previous studies with information on the amount of carbon absorbed by a tree per year and its projection to 20 years were taken into account, obtaining variable indices in the literature that vary from 7.1 kg to 15.6 kg per year.

The data used took into account the results of the analyzes from the period 2015 to 2019, establishing a grand total for the calculations of the percentage of mortality, survival, highlighting the statistical probability of the contribution in the fixation of CO_2, in 20 years.

The worksheets used to calculate the data were from Excel with the action stat tool, establishing parameters and projections with the data obtained in the consulted references, where the lowest fixation index considered was 7.1 kg of CO_2 per year and 15.6 kg as the fixation index being the highest.

For the records, the following were used: Kodak HD Stills camera, Digital IS and then MOTOROLA ONE cell phone, dual camera; a GPS, to mark the location of the area; computer and printer, for storage and printing of research.

The work was carried out with data collected in the field between 2015 and 2019, in the months of March and August, periods of rain and drought respectively in the region. 2000 seedlings of 4 species of fruit trees were selected for planting in the degraded area. As previously described, the selected species are Anacardium Ocidentale (cashew), Ingá Edulis, Ingá açu o zapatilla (ingá), Mauritia Flexuosa (Miriti or Buriti) and Euterpe Oleracea (Açaí), with 500 seedlings of each species.

Table 1 shows the mortality data of the species during the monitoring and study of the data in the period 2015-2019.

Table 1: Seasonal results of species mortality in the flood.

Species	2015 (uno)	2016 (uno)	2017 (uno)	2018 (uno)	2019 (uno)
Cashew	0	0	0	0	0
Ingá	5	6	6	5	5
Buriti	8	6	5	7	6
Açai	8	6	5	5	5

Source: Author, (2020).

Table 1 shows that the Buriti ind AAI are those with a mortality rate higher in relation to the ingá and cashews. The survey took place in March of each year, a period of still heavy rain in the region.

Table 2: Results of mortality in the dry season.

Species	2015 (uno)	2016 (uno)	2017 (uno)	2018 (uno)	2019 (uno)
Cashew	0	0	0	0	0
Ingá	10	9	7	7	5
Buriti	10	10	10	7	7
Açai	8	8	9	5	5

Source: Author, (2020).

Table 2 shows the mortality data of the species in the dry season of the region. The survey took place in August of each year, the month considered the warmest in the region. It is observed that the mortality rate is higher in relation to the rainy season.

Table 3 shows the overall number of dead seedlings of each species from 2015 to 2019, as well as the amount of survival, where from this demonstration, all carbon fixation calculations were made in kg of CO.

Table 3: Survival and overall mortality results from 2015 to 2019.

Species	Quantity Muds(un)	Surviving (un)	Dead Muds(un)
Cashew	500	500	0
Ingá	500	435	65
Buriti	500	424	76
Açai	500	436	64

Source: Author (2020).

Table 3 shows the data on the real number of mortality and survival of the species, where the cashew nut presented zero mortality, remaining with the 500 planted seedlings. Ingá had 435 live seedlings and 65 dead ones. The buriti had 424 live seedlings and 76 dead and the açaí had 436 live seedlings and 64 dead ones.

Table 4 shows the calculation of the mortality and survival percentages of the species, Excel software was used to obtain the percentages, taking into account 500 planted seedlings.

Table 4: Calculation of the percentage of mortality and survival.

Species	Initial Quantity(un)	Mortality %	Survival %	Amount. Finaly (uno)
Cashew	500	0,00%	100%	500
Ingá	500	13,00%	87,00%	435
Buriti	500	15,20%	84,80%	424
Açai	500	12,80%	87,20%	436

Source: Author, (2020).

The result presented took into account the data obtained in May and August of each year, with a final sum of the number of seedlings that died and those that survived. It was observed that the highest mortality rate occurred in the hottest periods and few rains, where there is a reduction in rainfall.

Survival and mortality rates are different when analyzed in the rainy periods (high rainfall) and in the dry season (low rainfall), where plants are the ones that suffer the most due to little rainfall.

The mortality rate in the rainy season is not higher than 5% of the planted seedlings, so the replacements of the dead occur in this period of high rainfall, which facilitates the survival and development of the species.

Even in the dry season, cashew scans can survive with high rates, its power to adapt to adversity makes it the most widely used species in reforestation in the area. In addition to contributing to the fixation of carbon, it also contributes to the feeding of its fruit for fauna and man.

IV. RESULTS

Figure 1 shows the percentages of mortality and survival of the species.
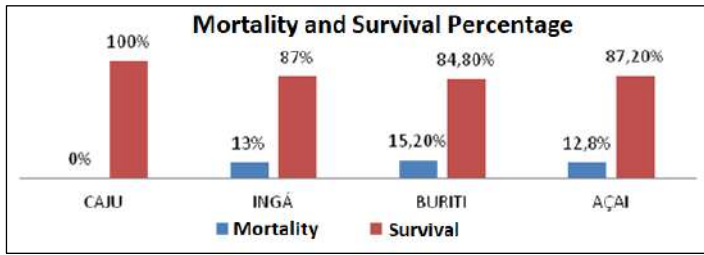

Figure 1: percentage of mortality and survival.
Source: Author, (2020).

IV.1 PROBABILITY OF CARBON FIXATION OF THE SPECIES IN 20 YEARS

The calculations were made in the Excel spreadsheet, through the Stock Statistics tool, in a simple and objective way. The calculation of the CO fixation at 7.1 kg is considered the lowest fixation index per year and later at 15.6 kg, considered the highest fixation index found in the theoretical framework.

With the use of the data obtained in the literature, a probability of carbon fixation of the species was made, which varies according to the quantity and the adopted index. Therefore, the amount of carbon fixation is presented by species, by year and in 20 years.

The tables and graphic figures were prepared taking into account the carbon fixation values found in the literature. Calculations can be performed using formulas and results of laboratory research that identify how much each one changes and fixes the carbon species, however, one of the objectives of the research is to analyze and quantify the mortality and survival rate of four species planted in the Tarum-AU Watershed -BHT and carbon fixation in 20 years, for which we chose to use the bibliographic data, considering 7.1 kg as the lowest index and 15.6 kg as the highest.

A variation in the carbon fixation index by the age of the plants was not found in the literature, which is found are authors who report the experiences of the plants after 20 years, where the data found showed lower absorption results to those reached in the first 20 years. Table 5 presents data related to the estimation of carbon fixation of the analyzed species, taking into account the lowest fixation index per year, using 7.1 kg of CO.

Table 5: Estimated carbon fixation for 20 years with an index of 7.1 kg of CO_2.

Species	Planted (un)	Survivors (un)	CO_2 / kg (years)	CO_2 /kg (20 years)
Cashew	500	500	3550,0	71000
Ingá	500	435	3088,5	61770
Buriti	500	424	3010,4	60208
Acai	500	436	3095,6	61912

Source: Author, (2020).

Table 5 shows the amount of CO that the number of surviving trees in the period 2015-2019 can absorb per year and in 20 years of life.

To calculate carbon fixation, the number of surviving plants of the species was multiplied by the index of 7.1 kg of CO_2, the annual estimate of each one is obtained, then multiplied by 20 years, taking into account that the variation is constant in period.

Equation 1 was used to calculate cashew carbon fixation per year.

$$FIX = S \times B \qquad (1)$$

$$500 \; x \; 7{,}1$$

$$FIX \, /ano = 3.550 kg \; de \; CO_2$$

The 500 cashew plants fix a total of 3,550 kg of CO per year, if we take into account the constant variation in mortality during the absorption period. The 500 cashew plants were considered because there was no mortality of the species during the period of the research work.

To calculate the fixation of the species in 20 years still with the lowest absorption rate of 7.1 kg per year, equation 2 is used.

$$FIX/20 - FIX \; x \; Time \qquad (2)$$

Calculation of the CO_2 fixation estimate for cashew nut species, using equation 2.

$$FIX/20 - FIX \, /year \; x \; 20 \; years$$

$$FIX/20 \; x \; 3.550 \; x \; 20$$

$$FIX/20 - 71.000 \; kg \; de \; CO_2$$

The cashew can absorb 71,000 kg of CO in 20 years. It can be concluded that the 500 cashew seedlings establish between 3,550 kg of CO per year and 71,000 kg of CO in 20 years. It should be noted that despite the fact that a considerable number of kg of C0 is absorbed, it is necessary that more seedlings are planted, that people are aware that the standing tree is important for the conservation of the climate.

To calculate the carbon fixation of the other species, the two equations 1 and 2, respectively, were used, obtaining the following result for Ingá in the year:

$$FIX = 435 \; x \; 7{,}1$$

$$FIX = 3.089 \; kg \; de \; CO_2 \; p/year.$$

For 20 years you get:

$$FIX/20 = 3.089 \; x \; 20$$

$$FIX/20 = 61.770 \; kg \; de \; CO_2 \; em \; 20 \; years$$

The 435 surviving plants of Ingá were considered in the period from 2015 to 2019, resulting in 3,089 kg of CO per year and 61,770 kg in 20 years, so it can be said that the variation in carbon fixation of Ingá ranges between 3,089 kg and 61,770 kg of CO_2.

Buriti's calculation per year obtains:

$$FIX = 424 \; x \; 7{,}1$$

$$3.010 \; kg \; CO_2 \; p \, /year$$

For 20 years of Buriti

$$FIX/20 = 3.010 \; x \; 20$$

$$60.208 \; kg \; CO_2 \; em \; 20 \; years$$

For Buriti's calculations, the 424 surviving plants were considered, which can absorb 3,010 kg of CO_2 per year and are estimated to absorb 60,208 kg of CO in 20 years.

For the calculation of CO fixation of acai berries, the 436 surviving plants were considered from 2015 to 2019.

By replacing the data in equations 1 and 2, you get for one year:

$$FIX = 436 \; x \; 7,1$$

$$3.095 \; kg \; p/year$$

Calculation of 20 years, you get

$$FIX/20 = 3.095 \; kg \; x \; 20$$

$$61.912 \; kg \; em \; 20 \; years$$

Taking into account the 436 açaí plants, it can be said that they can absorb 3,095 kg of CO per year and can absorb 61,912 kg of CO in 20 years.

Taking into account that the research worked with 500 seedlings of each species, 2000 plants were analyzed in general, however, only 1795 survived in the period from 2015 to 2019. The calculations were made for the number of survivors in equations 3.is, with the lowest fixation index by plant (7.1 kg) of CO_2, per year and in 20 years, the results obtained:

Carbon fixation of the 1795 plants with an index of 7.1 kg of CO_2 per year.

$$FIX = 1795 \; x \; 7,1$$

$$12.744 \; kg \; CO_2 \; years$$

Calculation of fixation in 20 years

$$FIX/20 = 12.744 \; X \; 20$$

$$254.890 \; kg \; em \; 20 \; years$$

The results showed that the 1,795 surviving trees can absorb 12,744 kg of CO per year with a probability of fixing up to 254,890 kg in 20 years, taking into account the lowest fixing index.

Figure 2 shows the result of fixation per year for each species, taking into account the 7.1 kg CO index and the probability of fixation in 20 years. Through the graph it is possible to analyze the results and conclude that the species contributes to the minimization of environmental impacts through the absorption of CO.
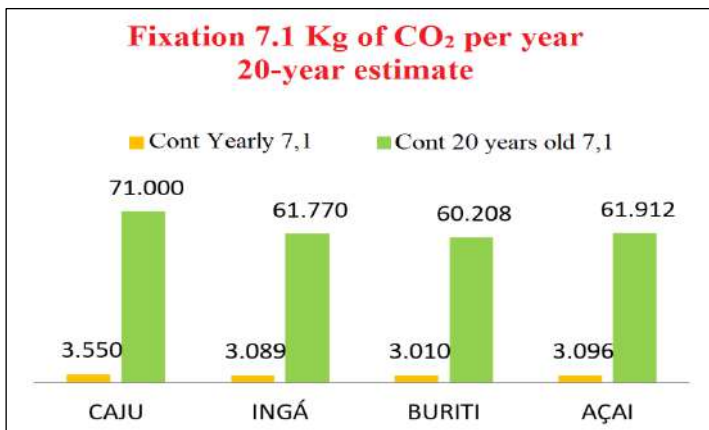

Figure 2: Carbon fixation with 7.1 kg.
Source: Author, (2020).

Table 6 presents the data on the CO fixation of the species, estimated for 20 years, using the highest index found in the consulted bibliographies. In this case, each tree absorbs 15.6 kg of CO per year.

Table 6: Carbon fixation with an index of 15.6 per year.

Species	Planted	Survivors	CO2/years	CO2/(20 years)
Cashew	500	500	7800	156000
Ingá	500	435	6786	135720
Buriti	500	424	6614,4	132288
Açai	500	436	6801,6	136032

Source: Author, (2020).

To obtain the results, we consider the number of surviving plants from 2015 to 2019, replacing in equations 1 and 2, changing the literature index to 15.6 kg of CO per year.

To obtain the cashew results, equations 1 and 2 were used.

$$FIX = 500 \; x \; 15,6$$

$$FIX = 7.800 \; kg \; year$$

Substitution in equation 2

$$FIX/20 = 7.800 \; x \; 20$$

FIX/20o 156.000 kg

To calculate ingá fixation, the following were used and obtained as results:

$$FIX = 435 \; x \; 15,6$$

$$6.786 \; kg \; CO^2 \; por \; year$$

For the calculation of 20 years

$$FIX/20 = 6.786 \; x \; 20$$

$$135.720 \; kg \; CO_2 \; in \; 20 \; years$$

For the Buriti calculation, you get:

$$FIX = 424 \; x \; 15,6$$

$$6.614 \; kg \; de \; CO_2 \; / \; years$$

Probability for 20 years

$$FIX/20 = 6.614 \; kg \; x \; 20$$

$$32.288 \; kg \; de \; CO_2 \; em \; 20 \; years$$

Finally, calculation of carbon fixation of the acai berry, where the results are obtained:

$$FIX = 436 \; x \; 15,6$$

$$6.801 \; kg \; de \; CO_2 \; p/year$$

Probability of carbon fixation in 20 years

$$FIX/20 = 6.801 \; kg \; x \; 20$$

$$136.032 \; kg \; de \; CO_2 \; em \; 20 \; years$$

Carbon fixation of surviving plants from 1795 using the literature index of 15.6 kg CO_2 per year.

FIX 1795 X 15,6

28.002 kg CO year

Fixing calculation at 20 years

FIX20 X 28.002 X 20

560.040 kg de CO 20 years

The result presented in the calculation of carbon fixation in 20 years, taking into account the highest index in the Literature of 15.6, showed that surviving trees from 1795 can absorb 28,002 kg of CO per year with a probability of absorbing 560,040 kg of CO in 20 years. A significant number in the fight against environmental degradation

Figure 3 shows the result of the projection of carbon fixation of the species, taking into account the CO_2 index of 15.6 kg that each one absorbs per year, using in the calculations the number of survivors in the period 2015-2019.
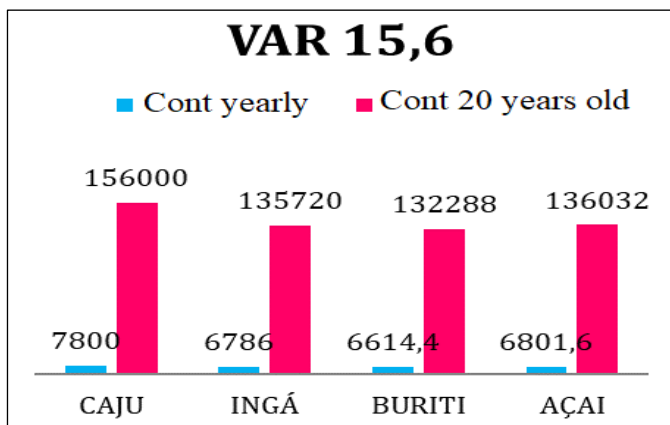

Figure 3: Carbon fixation with 15.6 kg CO per year.
Source: Author, (2020).

To analyze the estimate, we consider the study of mortality and survival of the species, obtained between 2015 and 2019. Survey carried out in March and August of each year, considering the initial planting of 500 seedlings of each species.

The carbon fixation of each one was considered with 7.1 kg and 15.6 kg per year and the probability of fixation in 20 years, both individually and collectively. You can tell how much a fixed plant can repair a fixed plant and how many 100, 200 or even the total number of survivors can fix carbon, removing greenhouse gases from the atmosphere.

In addition to the species used for reforestation and recovery of the degraded area, they still contribute to the cleaner environment. They conserve the igarapés that are part of the BHT, providing a quality environment for people and for existing fauna.

The planted species have the capacity for natural dissemination, due to seeds that proliferate more rapidly in the rainy season, not failing to proliferate also in a dry season, even if this proliferation is slower.

Figure 4 shows the carbon fixation data of the species in one and 20 years, considering the lowest and highest index in the literature of 7.1 and 15.6 kg of CO_2.
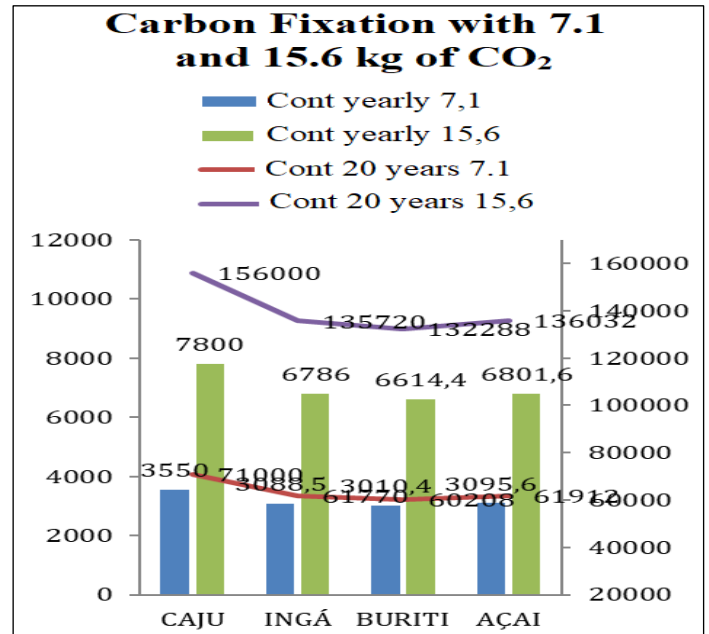

Figure 4: fixation comparison, CO_2 7.1 kg and 15.6 kg.
Source: Author, (2020).

V. CONCLUSIONS

To conclude the investigated data and with the objectives proposed in the research work, a synthesis of the results obtained in the comparison of the carbon fixation index with 7.1 kg of CO and 15.6 kg per species is carried out. In the research, we used data from 4 species selected for the recovery and reforestation of the degraded area in the BHT, and 500 trees from each were analyzed for mortality and survival.

It is perceived that in the course of research work and with data obtained in situ and through the literature, these species can successfully absorb and fix carbon, reducing and minimizing greenhouse gases. Regarding the general objective, it can be concluded that the investigation of the mortality and survival rate of the species was answered clearly and objectively, taking into account the data obtained in 2019, in addition to presenting the estimates of carbon fixation in 20 years.

Regarding the specific objectives, the survival and mortality analysis showed the cashew with the highest survival rate and the contribution to carbon fixation in 20 years. He mapped the data and disseminated environmental education in communities and schools adjacent to the deforested area.

Although the bibliographic research knew the an assistants of the research work, the lack of methods and studies on carbon fixation by species was identified. It was also verified that among the studies and bibliographies investigated, less than 5% bring on the subject, specifically, and more studies are needed focused on the topic, and therefore we can have more content smoother for what the research. It can be concluded that the reforestation and recovery of the degraded area of the BHT, using fruit species, objects of research, contribute to improving the quality of life of people and minimize the impacts of greenhouse gases.

Due to the broad scope of the topic addressed in this study, here are some suggestions for the continuation of this research work.

i) New research on species fixation after 20 years;
ii) → the survival rate from the first year;
iii) → Carbon Neutralization;
iv) → Diffusion of seeds through fauna;
v) → Carbon Credit;

vi) → The Fauna and Flora of BHT and their contribution to the preservation process of degraded areas.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Eliana da Conceição Rodrigues Veras.
Methodology: Eliana da Conceição Rodrigues Veras.
Investigation: Eliana da Conceição Rodrigues Veras.
Discussion of results: Eliana da Conceição Rodrigues Veras.
Writing – Original Draft: Eliana da Conceição Rodrigues Veras.
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Resources: Eliana da Conceição Rodrigues Veras.
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RESEARCH ARTICLE   **OPEN ACCESS**

LONG-TERM SUSTAINABLE ENERGY PLAN TO REDUCE AIR POLLUTION IN THE REPUBLIC OF MOLDOVA

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ARTICLE INFO

ABSTRACT

This paper is an energy system analysis of current energy systems in the Republic of Moldova. By recognizing the adverse health effects of pollution-based energy sources, a new energy plan for the Republic of Moldova is introduced. This sustainable energy plan is based on three main renewable energy sources: wind power, solar energy, and pumped hydropower. In addition, the amount of energy produced for electricity and heat, transportation and other residential, commercial, and industrial purposes is assessed and calculated. Then, based on the accessibility of these three main sustainable energy sources in Moldova, a feasible redistribution of the amount of energy accordingly is suggested. This long-term energy plan would serve as a geo-political strategy that also provides Moldova with the opportunity to reduce air pollution and increase their quality of life.

I. INTRODUCTION

Moldova is a small landlocked country in Eastern Europe located in between Romania and Ukraine. Although it is an independent country since 1991, it has always been under the political, economic, and sometimes military influence of countries like Russia and Ukraine [1][2]. The country's aspirations for the future are towards the west, joining the European Union and rising its economic level to a European standard. But they cannot do so, with the continuous influence of foreign regional superpowers, especially regarding the country's energy use.

Most of the country's energy production comes from natural gas and petroleum, both of which are sources imported by other countries in the region, mainly Russia and Ukraine [1][2]. Finding a way to make the Republic of Moldova produce its energy from its own resources, would be crucial and would make a huge impact in its geo-political position in the region. Fortunately, there are a lot of renewable sources of energy available in Moldova where the three most important ones include wind power, solar energy, and pumped hydropower [3]. Based on these sources of energy is possible to create a sustainable energy plan that would cover all the energy needs of the country. Through using the

available renewable energy sources such as wind, solar energy and filling the gaps with hydropower and biomass energy, Moldova would be able to cut the import of natural gas and petroleum by more than half. This would result in a more stable and self-dependent economy, which would create more possibilities for Moldova to reduce air pollution and increase their quality of life.

II. MATERIALS AND METHODS

This paper is an energy system analysis of current energy systems in the Republic of Moldova. The main discourse of the paper revolves around the Energy Flow Charts created by the Lawrence Livermore National Laboratory in Canada for the Department of Energy's National Nuclear Security Administration. To calculate the amount of energy produced for residential, commercial, and industrial purposes, the energy Flow Chart of the Republic of Moldova was assessed. Then, a renewable energy plan for the year 2050 is introduced based on three main sustainable energy sources available in the region: wind power, solar energy and pumped hydropower.

To find out what energy sources were feasible for implementation, official governmental websites of the Republic of Moldova were reviewed. Energy data was collected from the Flow

Charts of the Lawrence Livermore National Library and then calculated while taking into consideration wind power and solar energy sources. All the measurements and calculations were done in petajoule and in kilowatt-hour. In the end, while using the build a diagram tool: Sankey MATIC (BETA), a new flow chart for the Republic of Moldova was created portraying the renewable energy plan for the year of 2050.

III. RESULTS AND DISCUSSIONS

III.1 THE REGION

According to Lawrence Livermore National Library, Moldova produced 138 PJ in 2011 which is around 3.83 x 1010 kWh. From this amount, there was 64 PJ used for Electricity and Heating which is about 1.78 x 1010 kWh [4]. Most of the energy consumed in Moldova is used to produce electricity and heat for residential, commercial, industrial as well as a very small amount for transportation. In general, transportation in Moldova uses about 16 PJ which is about 4.44 x 109 kWh. This includes public transportation as well as individual cars. All this information is illustrated in figure 1 below. Relatively speaking, this energy is not a lot but almost most of this energy comes from petroleum, which is a source that Moldova doesn't have and needs to import it from other countries.

So far, most of Moldova's energy comes from the use of natural gas from that produces 94 PJ which is about 2.61 x 1010 kWh. Almost all of this energy is used to produce electricity and heating, as mentioned above, about 64 PJ. The rest is distributed in a way that 16 PJ is used for industrial purposes in factories and production facilities, 4.6 PJ for commercial purposes in stores and supermarkets, and 13 PJ used for residential purposes which could be mostly for cooking.
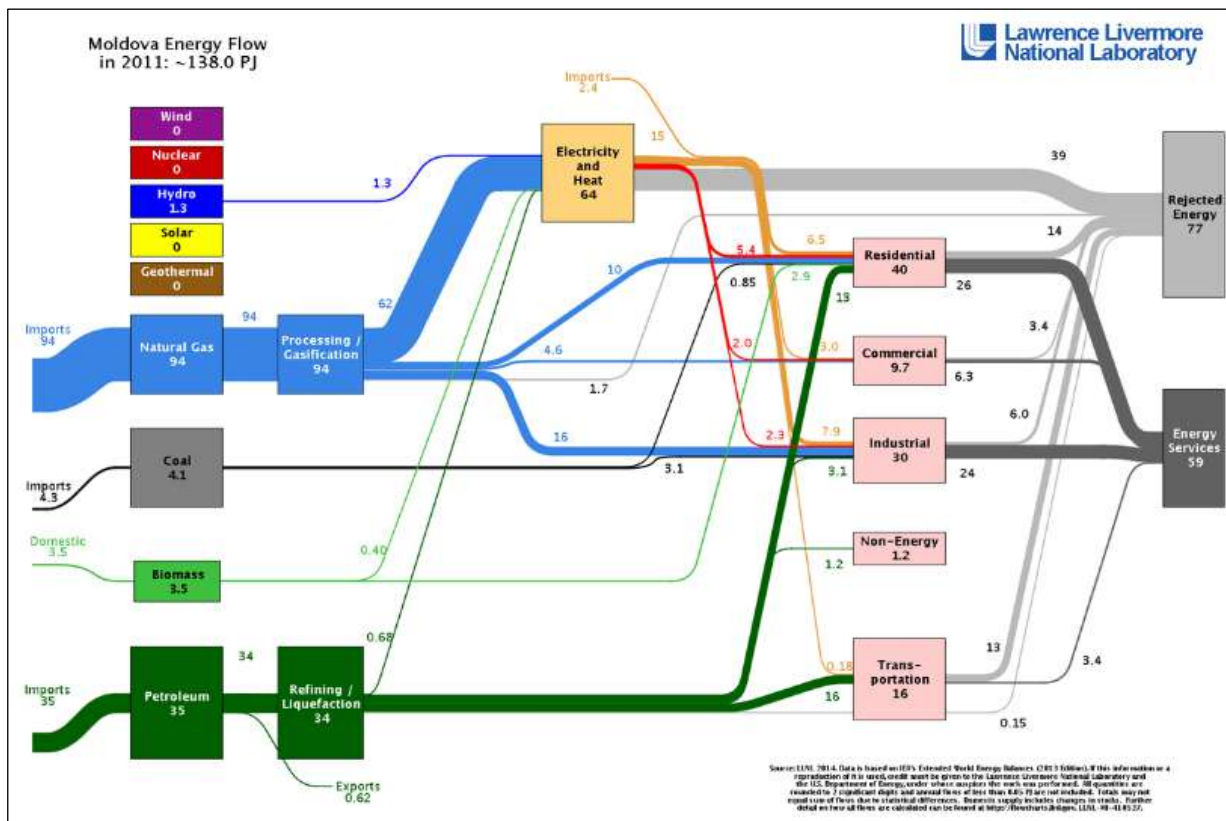

Figure 1: Moldova Energy Flow Diagram in 2011: ~ 138.0 PJ.
Source: [4].

Since a considerable amount of the natural gas is used for residential purposes, it makes it a great way to save the environment because using natural gas for cooking has a lower carbon footprint that burning wood, which is a more traditional way used by households for heating and cooking, especially during winter days. However, the fact that most of the energy that comes from natural gas is used for producing heat and electricity its not very efficient, mainly because there are better and more efficient and available options for the Republic of Moldova. In addition, Moldova imports the whole amount of Natural Gas that is uses, so 94 PJ [5].

Right after natural gas, the second most used source of energy is petroleum that produces about 35 PJ, which is 9.72 x 109 kWh. According to the existing literature the petroleum used by the Republic of Moldova is also imported by other countries. From 35 PJ of petroleum, 1 PJ is used to refine and liquefy it. The 34 PJ left, is distributed among residential use, industrial use, and most important transportation. It is seen that transportation in Moldova uses only 3 PJ more than what is being used for residential purposes. A very small amount of it also goes for heat and Electricity production.

Other sources of energy already being used in Moldova include coal (4.1 PJ) which is also imported, hydro (1.3 PJ) and Biomass (3.5 PJ). The latter two, are the only domestic sources of energy that Moldova uses. There are only 3 co-generation power plants in the whole country that produce both electricity and heat and only one hydro plant [3].

Implementing solar energy in Moldova, where there are about 240 sunny days in a year would supply all the country energy needs because it could produce about 4.3 x 1013 kWh which is much more than what the Republic of Moldova used in year 2011 [6]. Also. the wind power in many areas of Moldova reaches 5 to 6

m/s, which means that in general we would be able to generate about 2 W/m² [6].

III.2 THE PLAN

By 2050 the republic of Moldova will be able to produce 140 PJ which is 2 PJ more than what it produced in 2011. If we would incorporate solar energy and wind power in the energy system by 2050, Moldova will be able to cut its natural gas imports by almost 62 PJ. This amount corresponds to the amount being used to produce electricity and heat. In this case the energy plan illustrated in this paper suggests that the republic of Moldova will be able to produce all its electricity and heat from domestic renewable resources. Compered to its current use of petroleum, the plan doesn't change anything because petroleum, indeed is one of the most needed source of energy for vehicles and automobiles. For a developing country like Moldova will be very hard to replace all the cars, buses and airplanes that run on petroleum, with hybrid or electric automobiles. From the amount of petroleum imported in 2011 (35 PJ), 16 PJ was used for transportation and 13 PJ was used for residential purposes. By implementing this plan, the Republic of Moldova will be able to reduce the amount of petroleum produced by 18 PJ. Petroleum consumed in residential settings is mainly used for heating, and cooking [7]. By implementing this plan, the 18 PJ that comes from petroleum will be able to come in the form of electricity and heat from renewable resources.

From 140 PJ energy that will be produced by 2050, the republic of Moldova will be able to stop using and importing coal. In 2011, 4.3 PJ was imported from countries such as Russia and Ukraine and 4.1 PJ was produced within the Republic of Moldova [1][2]. Almost 90% of the amount produced from coal was used in industrial settings and about 10% was used in residential settings. Although it might be difficult to substitute coal with other types of energy in industrial settings, it would be beneficial for business to eventually move away from these sources of energy and start using natural gas which is more environmentally friendly and relatively cheaper, as well as electricity, that after the implementation of this sustainable energy plan will come 100% from renewable resources.

There are three technologies that this energy plan includes, solar energy, wind power and the pumped hydropower energy. Moldova has a lot of potential to use solar energy for electricity production and that is why, among a lot of different technologies in the solar section, this plan encompasses the use photovoltaics solar panels. Moldova gets about 240 sunny days throughout a year period, which is pretty good for a North-Eastern European country. According to literature, Moldova sometimes is also called "the sunny land", and yet so far there is 0 PJ energy coming from this clean and renewable source of energy. From the global horizontal irradiation map created by GeoModel Solar and illustrated in Figure 2, its pretty clear to see parts of Moldova that get about 1400 kWh/m2 annually [6]. This means that photovoltaics could produce about 3.83 kwh/day/m2 [8][9]. Although it is a small area that could produce this amount of energy, the rest of the south produces a similar amount that differs by 0.1 kwh/day/m2 which is not that much of a difference. Installing photovoltaics in the South of Moldova energy would be able to be produced at about 32 PJ annually. Installing photovoltaics to produce this amount of energy would require an area of 6417 km2. (The 32 PJ set to be produced by photovoltaics was divided with 3.83 kwh/day which is the amount that some regions of Moldova can produce in 1 m2.) Photovoltaics could be installed either in the roofs of the houses and buildings in the south (although there are not many major cities), but most likely they could be installed in large fields.

There would be economic and technological challenges in storing this huge amount of energy that will be produced by implementing solar panels, so the most possible and feasible solution would be to use this energy throughout the day when the demand is high [10]. There might be issues with the solar energy considering weather patterns, and that is the reason why this plan suggests the implementation of wind power and pumped hydroelectric technologies that will fill in the gaps and will make sure that the supply meets the demand.
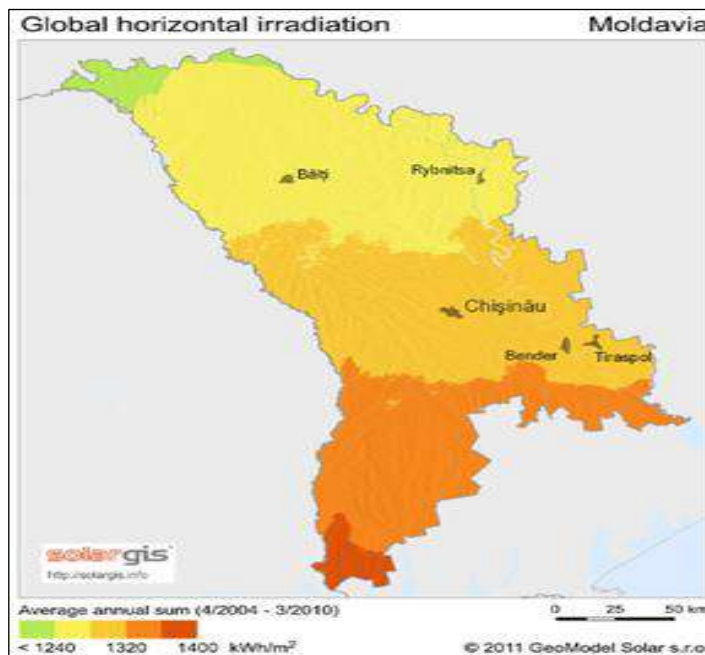

Figure 2: Horizontal Irradiation Map of Moldova.
Source: [6].

The republic of Moldova has a lot of potential to implement wind energy in its future sustainable energy plan. That is why the energy plan 2050 in this paper gives a lot of considerations to this technology. As you can see from this Wind Map by 3Tier in figure

3, there are many areas in the Republic of Moldova where the wind speed reaches about 5-6 m/s [6]. Most of these areas are in the south, but there are a lot of other areas across the country where we can actually generate electricity from the wind speed. To generate electricity, we need at least 5 m/s of wind speed, which Moldova has in addition to many areas where the wind speed goes even higher. According to this plan, the Republic of Moldova will be able to generate 20 PJ of energy annually by the year 2050. All this energy will go towards producing electricity and heat for residential, commercial, industrial as well as transportation purposes.
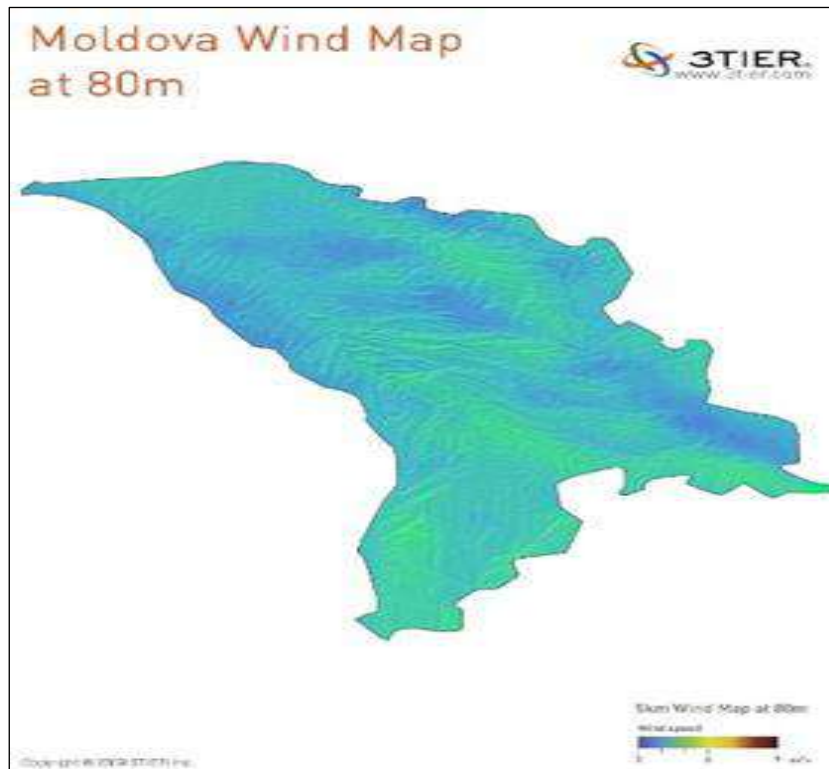
Figure 3: Wind Map of Moldova.
Source: [6].

To generate this amount of energy we would need to build about 18802 windmills with 25 m diameter of blades, which might sound like a lot but the return on investment will be very high in the long run [8][11]. To find out how many windmills were needed the energy that could be produced by a windmill with 25 m blades could produce, which was 816 kwh/day [8][11]. Then 20 PJ was converted into kwh/day and dived by the amount that 1 windmill can produce. According to these calculations we would need an area of 11.8 km2, area which could easily be incorporated with the solar panels in the south and with the pumped hydropower facilities in the north. This number was found by firstly calculating how much area its needed for just one of them, which was 625 m2, and then through the necessary conversions this number was multiplied with the amount of windmills. The biggest challenge of this technology would be the amount of wind turbines that are needed, but if economies of scale are followed you could build bigger wind turbines that will reduce the number of them that need to be installed and in the same time will keep the energy the same.

The third technology that could be implemented is Pumped Hydropower. Calculations show that Moldova would be able to produce about 36 PJ of energy and all of it could be used to produce electricity and heat. In order to produce this amount of energy, we would need about 380 3MW pumped hydropower facilities where each one of them would be about 2 km2. In order to find this number, 36 PJ was divided with the amount of kwh/day that one 3MW pumped hydropower can produce [12].

As a result, implementing the pumped hydropower energy will require 760 km2 of area, and facilities would need to be built mostly in the north and the north east. This area was estimated by multiplying the amount of pumped hydropower facilities with the area that 1 of them. The drawback of using this technology is that more energy is needed to pump the water from the lower reservoir to the higher one, but that process could be done during the night when the demand for energy is low [12]. Also, these reservoirs could be used for raising fish for local consumption.

III.3 ANALYSIS

The implementation of this plan by 2050 comes with a considerable amount of cost, because firstly the Government of Moldova has to manage the construction of all these new technologies. Also, it has to do all the necessary construction to connect them to the existing grid. If the Republic of Moldova sees it as a necessity to upgrade or change the whole grid, then the cost will rise up. However, this plan does not suggest the creation of a new grid, but just simply connecting these three new technologies with one another, in a way so they can be used together in cases when the demand for energy is too high or too low. On the other side the pumped hydropower is a perfect storage technology that would help in cases when there is not enough supply of energy coming from both wind power and solar energy.

The U.S. Energy Information Administration has estimated some simple average of regional values for new generation of resources for plants entering service in 2022. In the absence of finding accurate information about the country of Moldova and the region of Eastern Europe, the US LCOEs were

used as an approximate, even though the prices of incorporating these technologies would be lower in Moldova because there is cheaper labor available as well as less taxes and regulations. Constructing and installing 6417 km2 of solar photovoltaics which will produce 36 PJ, will cost around $756,500,000 USD [13]. To find that, this amount of energy was converted in MWh and then it was multiplied with the LCOE estimated by the U.S. Energy Information Administration. The same approach as to find how much it costs to construct and install the wind turbines and the pumped hydropower facilities was used. Calculations show that, constructing 18802 wind turbines with 25 m blade diameter will cost about $356,720,000 USD. On the other side, constructing the 380 pumped hydropower facilities will cost about $662,000,000 USD. So, to implement this energy plan in total would cost $1,775,220,000 USD.
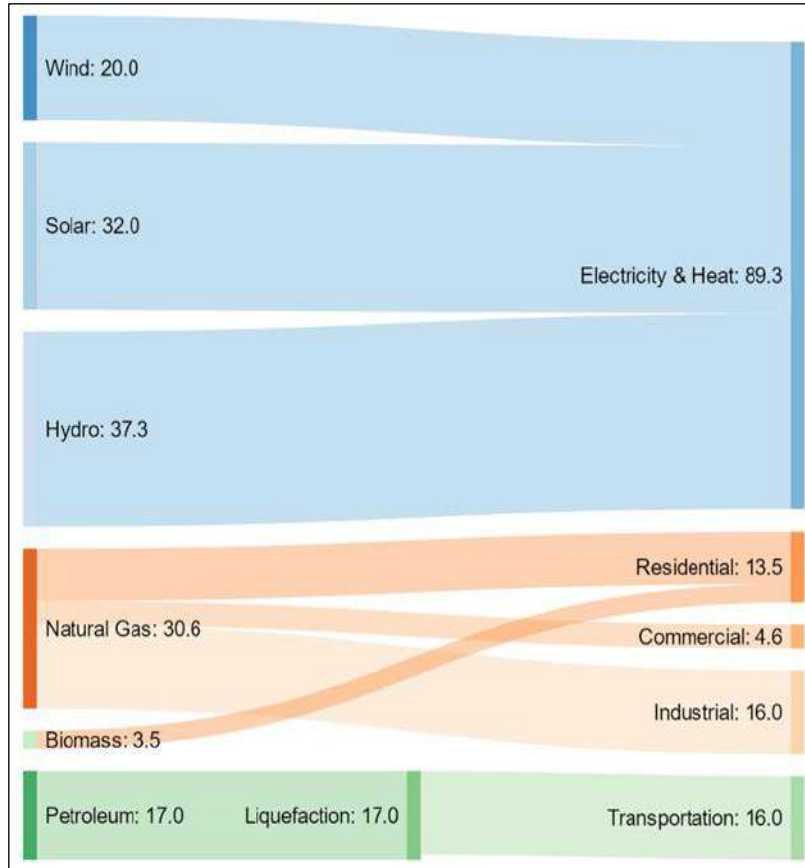

Figure 4: Moldova Energy Flow in 2050: ~ 140.4 PJ.
Source: [14].

According to the Central Intelligence Agency (CIA), Moldova's GDP in 2016 was about $18.54 billion USD [15] As calculated, this energy plan would cost about $1.8 billion USD, amount which the Republic of Moldova has the full capacity to build and implement these new energy facilities. A lot of construction and maintenance jobs will be created, the buying power will rise and therefore the country will set the foundations of a stronger economy in the near future.

IV. CONCLUSIONS

Based on the calculations done in this paper, it makes a lot of sense economically to implement this type of energy plan in the Republic of Moldova. The government has to spend only a small portion of its annual GDP to implement all three technologies that this energy plan is suggesting by also providing so many jobs for the Moldovans as well as other people in that region. According to the Central Intelligence Agency, the unemployment rate in 2016 was 6.3% [15]. Thanks to the creation of these new jobs the unemployment rate will drop considerably. Also, there will be less imports of natural gas and petroleum which will considerably affect the economy of the country as well as its geopolitical position in the region.

In addition, the implementation of a new sustainable energy plan makes sense environmentally because through constructing these new energy facilities and installing these new technologies the country of Moldova will be able to produce 100% of its electricity and heat from renewable resources. There will be a lot of CO_2 emitted in the atmosphere during the time of construction of these facilities but considering the fact that these technologies emit 0 lbs. of CO_2 in the atmosphere, it will pay off in the long run.

The implementation of this energy plan will make a lot of sense socially, because it will provide people the opportunity to get jobs. Most of the population is employed in agriculture and services, but with construction and installation of these new technologies there will be so many other jobs available, from which people will be able to earn more money, afford buying more things and therefore raise their standard of living.

V. ACKNOWLEDGMENTS

guidance to conduct the necessary calculations throughout the paper.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Erblin Shehu.
Methodology: Erblin Shehu.
Investigation: Erblin Shehu.
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Journal of Engineering and Technology for Industrial Applications

RESEARCH ARTICLE   OPEN ACCESS

ANNUAL EFFECTIVE DOSE FROM RADON-222 CONCENTRATION LEVELS IN UNDERGROUND WATER IN BUNGOMA SOUTH SUB-COUNTY, KENYA

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ARTICLE INFO

ABSTRACT

This research measured the concentration levels of radon in groundwater and determined the ingestion and inhalation dose. The study used RAD7 detector with RAD7-H2O accessory from Durridge Company to determine the radon levels. Thirty water samples in granitic dominated regions were collected from various areas of Bungoma County: ten from boreholes (BH), ten from hand dug wells (WL) and ten from springs (SP). The water samples were collected in 250 ml bottles which were tightly covered with lid to avoid radon leakage. The highest value was 303 ± 4.00 KBq/m^3 recorded in Kanduyi well and the lowest was 126 ± 11.4kBq/m^3 from where most of the samples recorded a high radon concentration with a mean of 269 ± 5.25 KBq/m^3 in wells, 213 ± 7.96 KBq/m^3 in boreholes and 290 ± 7.70 KBq/m^3 in springs. The average ingestion dose was found to be 1.5 ± 0.07mSv/yr, 1.9 ± 0.09 mSv/yr and 2.1 ± 0.1 mSv/yr. The average annual effective dose rate for the samples collected were 2 ± 0.1 mSv/yr for boreholes, 2.6 ± 0.13 mSv/yr for wells and 2.7 ± 0.14 mSv/yr for springs. The samples reported an average.

I. INTRODUCTION

Radon-222 is a gaseous highly radioactive element discovered in 1899 by Ernest Rutherford. It is a chemically unreactive colourless inert gas with a half –life of 3.82 days. It has three isotopes ^{222}Rn (radon gas),^{220}Th(thoron) and ^{219}Rn (actinone) [1]. Radon-222 decays by emitting 5.49 MeV alpha particles, two of the ^{222}Rn daughters ^{214}Po and ^{218}Po are alpha emitters and contribute over 90% to the total radiation dose received due to radon exposure [2]. Radon mainly comes from the breakdown of uranium in the soil, rock and in water. It is denser than air and exist as a single atom gas thus can easily penetrate materials, paper, leather, low density plastic, most paint, sand, building materials like gypsum (sheet rock) concrete bock, mortar, wood panelling and most insulations [3]. Radon from natural sources mainly come from uranium rich minerals and soils, it can also accumulate in houses made of mud in areas such as basements. It can also be dissolved in groundwater such as hand-dug wells, boreholes, spring water and hot springs [4].

The presence of radon in the environment and ground water is associated with presence of amounts of uranium in rocks and granitic soils. The uranium levels change from place to place since types and rocks and soils like granite, uranium-enriched phosphates' rocks and shales contain more uranium than others [5]. The quantity of radon dissolved in ground water also depends on some factors such as characteristics of the aquifer, water-rock interaction, mineral content of radium [5]. The concentration of radon level in groundwater from bedrock is high compared to surface water due to the presence of granite, sand and gravels [4]. Radon contributes approximately 55% of the total internal radiation to human beings [6]. The radioactive process that at the end radon is released and other decay products, which include polonium, lead and bismuth is also accompanied with energy. These decay products are small minute solids which have a short

half-life and thus decay through ionizing radiation immediately they are formed. Therefore, if inhaled, they tend to decay before the lungs can clean themselves [7]. These daughters are also electrically charged particles and thus attach to natural aerosol and dust when inhaled, they tend to be deposited to the lungs thus exposing the cells to alpha radiation which can damage sensitive tissues [8]. Among non-smokers radon has been identified to be the number one cause of lung cancer. EPA has estimated that radon causes more than 20000 deaths from lung cancer each year [9].

Exposure to radiation can be harmful to human. Radiation from natural sources has risen over time. Human beings are exposed to radiation mainly from either inside or outside their body. Cosmic rays and gamma ray emitters in soils and walls of buildings contribute most to radiation from outside the body. Inhaling air, ingesting food and water also expose humans to radiation by in cooperating radionuclides in the body. These radionuclides emit alpha and beta particles of low penetrating power [10]. This radiation over time are harmful to the cells and can damage the cells Studies have shown that the major contribution to internal irradiation is as a result of taking water containing high concentration levels of radon-222 and its decay products [11]. In most countries including Kenya, most of the population depend on the ground water sources such as boreholes, hand-dug wells and springs which have been noted to contain higher concentrations of radon-222 as compared to surface water sources like lakes [12].

The importance of ground water in Kenya cannot be overemphasized and the need for monitoring. This study is thus aimed at assessing the annual effective dose from the concentration level of radon in groundwater sources and their potential health hazards to human beings.

II. MATERIALS AND METHODS

II.1 STUDY AREA

Bungoma County is one of the 47 counties in Kenya that borders Uganda to the western part of the country. Its headquarters is in Bungoma town which is located 00 34'N 34 34'E. The County has a population of 1375063 people and 2206.90km^2 in size [13]. Bungoma County is divided into South, North, Central, West, Kimilili, Cheptais, Mt.Elgon, Bumula, Webuye East and Webuye West Sub-Counties. The areas of concern for the study were as shown in Figure 1.
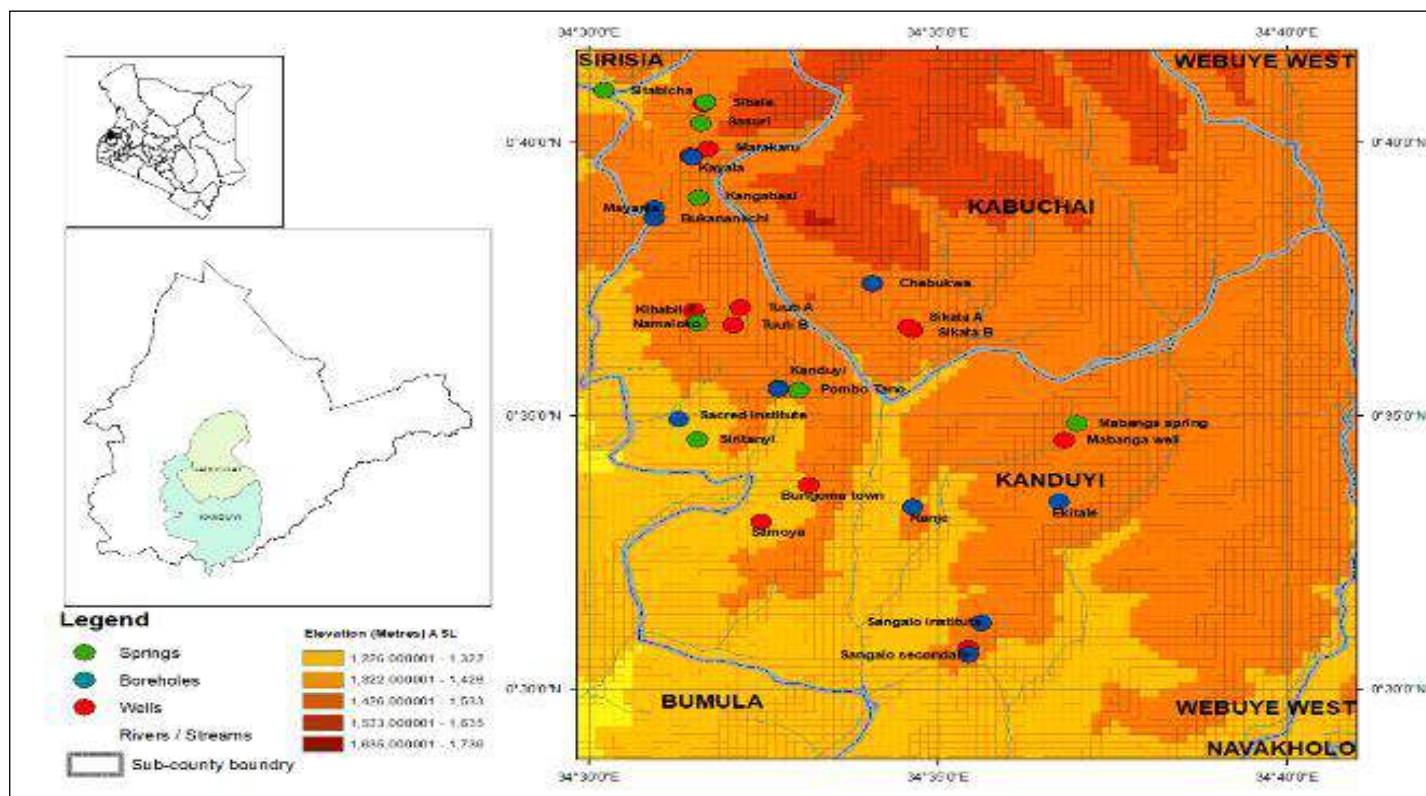

Figure 1: Map of Bungoma County.
Source: [13].

Lack of adequate water for use by people is a growing concern for the people living in this county. This has been brought about by climate change that is being experienced all over the world. People in this region rely on groundwater as their main source of water.

II.2 SAMPLE COLLECTION AND PREPARATION

A total of 30 water samples were collected in this study. Samples were collected from these areas Sang'alo, Musikoma, Marakaru, Tuuti, Namaloko, Sasuri, Siaka, Siritanyi, Bwema, and Bungoma town. The water was collected in a pail with minimal air contact and the vial placed at the bottom of the pail and allowed to fill. The 250ml vial was capped while still under the water and was ensured that there were no bubbles in the vial. The cap was tightened, removed from the bail, dried and labelled ready for measurements [14].

II.3 EXPERIMENTAL METHOD

RAD-7 detector was used for the measurement of radon concentration in underground water. RAD-7 uses silicon as semiconductor material which converts the alpha radiation into electrical energy [15]. The detector inside the RAD-7 distinguishes

the alpha particles from 218Po and 214Po with an energy range of 6.0 MeV and 7.9 MeV, respectively, into their respective windows (Figure 2). Radon concentration in the underground water in this study was determined by using RAD H2O was used [16]. A watt-250 protocol along with Grab mode was chosen on the RAD-7 for

250 ml samples. The internal pump was used to obtain radon from the water sample and it circulates the gas to the counter for measurement.

Figure 2: Rad7 detector and a printer.
Source: [14].

II.4 ANNUAL EFFECTIVE DOSE ESTIMATION

Radon assessment of drinking water is extremely important because of the recognized health risks associated with radon [15]. Committed annual effective dose from in gestion and inhalation was calculated using the Equation 1 [16].

$$AED_{ing=}C_W \times D_W \times DCF \times T \qquad (1)$$

Where C_W is the mean radon activity concentration in water, D_W the weighted estimate of water consumption (2L/day), DCF is the ingestion dose conversion factor of radon and its progeny (10^8 Sv/Bq) T-365 days/y.

The annual inhalation dose from the water was calculated using the Equation 2 [17]:

$$E_{Wih}(mSv/y) = C_{RnW} \times R_{aW} \times F \times O \times DCF \qquad (2)$$

Where, R_a is the ratio of radon in air to radon in drinking water 10^{-4}.

C_{RnW} is concentration of radon in water , F the equilibrium factor between radon and its decay Products (0.4), O the average indoor occupancy time per person (7000h/y) and DCF is the dose conversion factor for radon exposure 9nSv/h (Bq/m^3) [16].

III. RESULTS AND DISCUSSION

Table 1 shows the average radon concentration, ingestion dose, inhalation dose and the annual effective dose rate in underground water of areas within Bungoma County. The underground water radon concentration varied from 126±11.40

KBq/m^3 to 303±4.00 KBq/m^3 with a average mean of 213±7.96 KBq/m^3 for boreholes, 269±5.25 KBq/m^3 for wells and 290.75±7.70 KBq/m^3 for springs. The radon concentration in the underground water was above the recommended concentration level of 11 Bq/L proposed by the US Environmental Protection Agency, USEPA.

The measured values for radon concentration were also compared with the European Commission Recommendations on the protection of the public against exposure to radon in drinking water supplies (2001/928/Euratom), which recommends action levels of 100 Bq/L for public water supplies and exceptional level of 100011 Bq/L, it can be therefore be deduced that the levels were below the criterion limit [18].

Table 1: Average radon concentration values of underground water in Bungoma County.

Region	Borehole	Well	Spring
Sang'alo	259±8.29	245±5.25	294±9.67
Mayanja	223.33±6.32	272.67±4.60	280.5±10.64
Township	245±5.87	303±4.00	293±5.62
Tuuti/Bwema	126±11.40	257.33±7.16	296±4.88
Average	213±7.96	269±5.25	290.75±7.70

Source: Authors, (2020).

ATo determine the health implications of the measured radon concentration, the concentration values were converted into annual effective dose rate by using equation 2.1 and 2.2 (Table 2).

Table 2: Average annual effective dose rate values.

Region	Borehole	Well	Spring
Sang'alo	2.5±0.12	2.4±0.12	2.8±0.14
Mayanja	2.1±0.1	2.7±0.13	2.7±0.13
Township	2.4±0.12	2.9±0.14	2.8±0.14
Tuuti/Bwema	1.2±0.06	2.5±0.12	2.9±0.14
Average	2±0.1	2.6±0.13	2.8±0.14

Source: Authors, (2020).

From Table 2, the average annual effective dose rate was 2±0.1mSv/y, 2.6±0.13 mSv/y and 2.8±0.14 mSv/y. These values were less than the recommended limit range of 3 to 10 mSv/y for action [19]. Figure 3.1 shows the average values of AED of underground water.
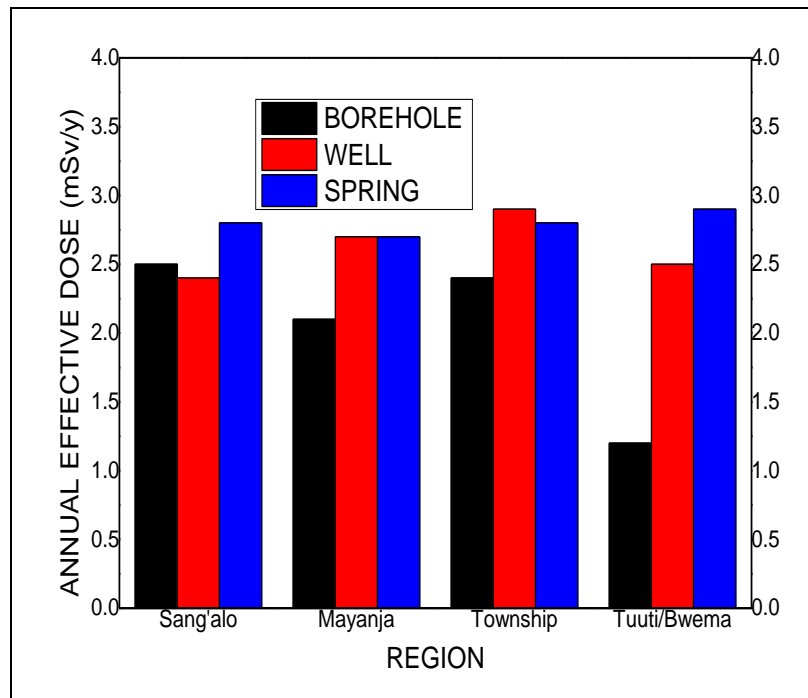

Figure 3: A Graph of Average Annual Effective Dose Rate.
Source: Authors, (2020).

This value was found to be higher than the world permissible limit of 1.15 mSvy[1] [20] above which the populace can be exposed to high levels of radiation but below the action range limit of 3 to 10 mSv/y and thus posing minimal health-related risks. The average effective dose was higher in samples from springs with an average of 2.853 mSv/y. Township region had higher averages as deduced from the graph with hand dug wells having high annual effective dose. This can be attributed to the shallowness of the well and granitic rocks which were seen from the walls and base of the well that are associated with high levels of radon concentration [21].

IV. CONCLUSION

The high concentrations are as a result of the granitic soil formations in the region. Radon-222 diffuses from the bedrock into the underground water which contributed to the high radon concentrations. The geology of this area mainly consists of igneous and metamorphic rocks. This comprises of the gneiss, schist, quartz and granite rocks. The natural weathering of rocks such as granite dissolves the natural radon which goes into groundwater by leaching and precipitation called illumination process. The use of phosphate fertilizers and other human activities such as combustion from coal or other fuels contribute to the concentration of radon in ground water which led to high radon concentration levels. However, the obtained AED values were below the action range criterion hence underground water in the study area poses minimal health threats to the general population.

V. AUTHOR'S CONTRIBUTION

Conceptualization: George Wangila Butiki, John Wanjala Makokha, Fred Wekesa Masinde and Conrad Khisa Wanyama.
Methodology: George Wangila Butiki, John Wanjala Makokha and Fred Wekesa Masinde.
Investigation: George Wangila Butiki, John Wanjala Makokha and Conrad Khisa Wanyama.
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Approval of the final text: George Wangila Butiki, John Wanjala Makokha, Fred Wekesa Masinde and Conrad Khisa Wanyama.

VI. ACKNOWLEDGEMENT

VII. CONFLICT OF INTEREST

The author declares no conflict of interest regarding publication of this paper.

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