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Regression and ANN Models of Pulse Rate for Tricycle Rickshaw

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Abstract*: *Designing for the oppressed part of the generalized public is one of the fundamental prerequisites for comprehensive design in a developing nation like India. With a spurt being developing inside a nation, the financial distance between those who are well off and the wealthy not are expanding and this divergence is making social agitation in the nation. Tricycles rickshaw is a small-scale ordinary means principally utilized for transportation. Numerous deficiencies were reported in the existing type of tricycle. For optimization of those deficiencies, three different models of cycle rickshaw were utilized, and the input parameter that regulates the consumption of human energy and performance was identified. Regression Analysis (RA) and Artificial Neural Networks (ANN) were utilized for analysis of the experimental data. Both RA and ANN modeling were assessed statistically with the aid of a software tool. RA of the experimental data reveals that input variable load is a most prominent parameter to be focused on tor achieving the objective of expending minimum human energy by a rickshaw puller whereas ANN studies acknowledged the assistance of multiple factors in individual energy. However, load is a most prominent parameter for minimization of individual energy as Outcome. Optimization of input variables using Min-Max principle for various regression models yielded the optimal solution at crank length 167 mm and wheel diameter 675mm for human energy for all linear regression models.

Keywords* : *ANN, Chain, pedaling mechanism, Regression Analysis, Sprocket, Tricycle.

I. INTRODUCTION

The quick exhaustion of non-renewable energy sources because of global warming and exponential increment into demand because of emanation of CO_2 prepared designers and researchers to search an eco-friendly, moderate and accessible energy source. India spends huge measure to import raw petroleum [1]. With the utilization of human powered vehicles, reliance on import of raw petroleum can be decreased and sensible measure of outside trade can be spared [2]. India is one of the countries having the biggest technologically specialized human power source on the planet [3,4].

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Indian designing and innovation is perceived all inclusive as truly outstanding. The mechanical exchange to India from out of the country has prompted technological sharing as well, bringing about low indigenous improvement in design capacities. Most of individuals from India are financially poor. Sustainable socio-technological improvement of rustic individuals is needed for rustic poverty improvement.

A tricycle rickshaw is a human-operated three-wheeler [5]. These vehicles are broadly utilized all over India, where rickshaw driving gives source of employment to rural areas, for the most part ruined men. A range of local designs of tricycles are utilized crosswise over world. In an eco-sensitive zone where engine vehicles are restricted, manual cycles are as yet one of the significant types of transport there. It has two-four seats to carry the travelers and some space for baggage in the middle of the puller and travelers [6].

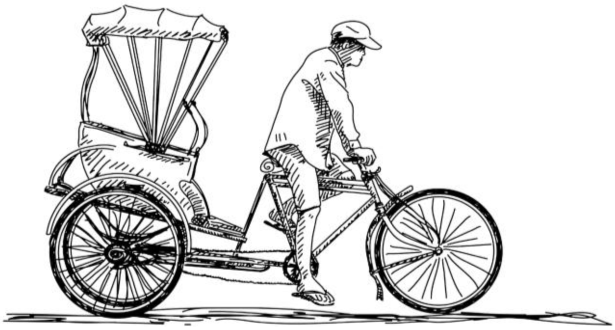

Fig. 1.A typical sketch of tricycle rickshaw.

Tricycle-rickshaw basically comprises chassis, passenger seat, chain drive, cranking mechanism, front/rear wheels [7]. The rickshaw has a solitary arrangement of chain sprocket for driving purpose. Exertion applied by rider on paddle drives the rickshaw. About eight millions rickshaws run everywhere throughout the India in city and rustic zones as a result rickshaws give work of eight millions families of India which pulls the rickshaw [8].

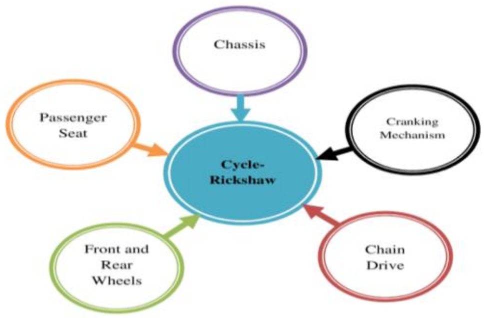

Fig. 2.Generalised components of tricycle rickshaw.

There are numerous makers all over the world, yet for the most part every one of designs are similar and/or outdated, and are ergonomically ineffective to the extent puller of rickshaw is accounted. These outdated designs aren't outfitted with compelling and reasonable mechanisms of gear, suspension and bearing frameworks. Additionally Rickshaws are comparatively heavy. In the event that design of rickshaw should be gets settled for both of the travelers and puller, this can turn into an entirely feasible choice to supplant Diesel/CNG Auto Rickshaw, for voyaging little distance, inside restricted streets and advancing the travel industry. In this way can include a colossal commitment towards efficient green energy [9-10].

A lot of studies have been undertaken in the past related to human performance in cycling. In conventional cycling, numerous factors affect the cycling performance. Researcher of human operated vehicle often focuses on minimization of resistive forces and maximization of propulsive forces. Maximization of propulsive forces is quite unpredictable due to a complex inter action in internal biomechanical factors such as muscle forces, torque, production of power and mechanical external factor such as chain wheel size, crank length, wheel diameter, gear ratio, saddle length etc [11]. Understanding the biomechanics of bicycle pedaling is important in elimination of overuse injuries in the knee incurred from the pedaling activity. However no one reported the significance role of wheel diameter, crank length and load on the optimization of energy consumption. So it's felt necessary to optimize wheel diameter, crank length and load of cycle-rickshaw.

It is observed that most of the researchers consider Oxygen consumption is one of the indications of the energy requirement of the human body at work [12] . As the oxygen requirements are increased with the increases in the level of physical activity, the cardiovascular system speeds up its function thus increasing heart/ respiratory / pulse rate and blood pressure[12]. Thus as a measure of the energy cost of work, pulse rate is use. Therefore performances of the subject are tested by the measuring pulse rate while driving the rickshaw for various conditions. A model of rickshaw is said to be efficient if the pulse rate to drive to any particular model is lesser, under similar condition of test. Less pulse rate means less energy, therefore less stress level in the human body for performing the physical activity and fatigue well is less. So the energy expenditure of operators is commonly measure by operators pulse with the help of highly sophisticated instruments such as Pulse Oximeter.

The use of non-circular or elliptical chain rings (also called chain wheels/ sprockets) has received good attraction amongst specialized cycling society. However, awareness of the systematic study that have examine the performance advantages of non-circular or elliptical chain rings in performance on cycle rickshaw operator need to be focused.

II. PARAMETERS FOR EXPERIMENTATION AND EXPERIMENTAL DESIGN

A scientific approach to planning the experiments and analysis of observed data is a must for drawing valid and objective conclusions and to optimize the system. The objective of the study is to comparison between the wheel diameter, load and crank length of circular and noncircular sprocket. The variables into consideration are anthropometric information of puller, personal factors of puller, cycle rickshaw specification, road conditions, atmospheric situation and mechanical design of cycle rickshaw. The response/dependent variable into the situation is human energy in terms of pulse recorded at various locations. The prime variables believed to influence the man machine system of cycle rickshaw are wheel diameter, load and crank length. These are of prime importance and are independent of each other as necessitated for experimental study proposed in this work. The other factors which researchers have studied but not considered highly significant are speed ratio, optimal chain ring shape, pedaling rate, pedal speed, muscle power etc.

There are four basic psychological parameters in human body concerning the physical activities such as body temperature, pulse/ respiratory rate and blood pressure [13]. Oxygen consumption is one of the indications of the energy requirement of the body at work. As the oxygen requirement are increased with the increase in the level of physical activity, the cardiovascular system speeds up its function thus increasing heart / respiratory / pulse rate and blood pressure. Amongst these, as stated earlier, pulse rate is a more dependable measure of performance. Thus, the performance of the test puller is effectively, measured by continuously monitoring and recording the pulse rate while he drives the rickshaw under different conditions. Detailed literature survey and findings reported in various research studies reveal that (i) Wheel diameter (D), (ii)Load (P), (iii) crank Length (L) are the most important variable [14]. The aim of the experimentation is to consider main interaction between these factors so that the best possible optimal solution should be derived.

Table-I: Three level of independent variables for 3^3 factorial design of experiments

S. N.	Diameter of Wheel (mm)	Load (Kg)	Crank Length (mm)
1	650	150	157
2	675	200	167
3	700	250	177

For 3^3 factorial design of experiments [15], the 3 variables selected are: Diameter of Wheel (D), Load (P) and Crank Length (L).

The standard design matrix shown in Table-II indicates 27 experimental conditions in standard order and the corresponding levels at which each of the three parameters are to be maintained constant during experimentation.

Table- II: Design matrix for 3^3 factorial design of experiments

S.N	Run	Treatment	Condition	Design Matrix		
				D	*P*	*L*
1.	1	$a^0b^0c^0$	650X150X177	0	0	0
2.	a	$a^0b^0c^1$	650X150X167	0	0	1
3.	a^2	$a^0b^0c^2$	650X150X157	0	0	2
4.	b	$a^0b^1c^0$	650X200X177	0	1	0
5.	ab	$a^0b^1c^1$	650X200X167	0	1	1
6.	a^2b	$a^0b^1c^2$	650X200X157	0	1	2
7.	b^2	$a^0b^2c^0$	650X250X177	0	2	0
8.	ab^2	$a^0b^2c^1$	650X250X167	0	2	1
9.	a^2b^2	$a^0b^2c^2$	650X250X157	0	2	2
10.	c	$a^1b^0c^0$	675X150X177	1	0	0
11.	ac	$a^1b^0c^1$	675X150X167	1	0	1
12.	a^2c	$a^1b^0c^2$	675X150X157	1	0	2
13.	bc	$a^1b^1c^0$	675X200X177	1	1	0
14.	abc	$a^1b^1c^1$	675X200X167	1	1	1
15.	a^2bc	$a^1b^1c^2$	675X200X157	1	1	2
16.	b^2c	$a^1b^2c^0$	675X250X177	1	2	0
17.	ab^2c	$a^1b^2c^1$	675X250X167	1	2	1
18.	a^2b^2c	$a^1b^2c^2$	675X250X157	1	2	2
19.	c^2	$a^2b^0c^0$	700X150X177	2	0	0
20.	ac^2	$a^2b^0c^1$	700X150X167	2	0	1
21.	a^2c^2	$a^2b^0c^2$	700X150X157	2	0	2
22.	bc^2	$a^2b^1c^0$	700X200X177	2	1	0
23.	abc^2	$a^2b^1c^1$	700X200X167	2	1	1
24.	a^2bc	$a^2b^1c^2$	700X200X157	2	1	2
25.	b^2c^2	$a^2b^2c^0$	700X250X177	2	2	0
26.	ab^2c^2	$a^2b^2c^1$	700X250X167	2	2	1
27.	$a^2b^2c^2$	$a^2b^2c^2$	700X250X157	2	2	2

Table-III: Summery sheet of crucial point for 3^3 Experiments

Puller1			Puller2			Puller3		
R1	*R2*	*R3*	*R1*	*R2*	*R3*	*R1*	*R2*	*R3*
90	92	97	109	114	112	117	120	128
97	96	100	113	115	120	122	127	136
99	100	104	122	124	128	132	132	140
110	110	114	114	118	122	126	128	128
113	112	121	120	120	128	132	132	138
119	121	129	127	131	132	135	138	145
123	124	127	124	124	129	135	136	136
125	128	131	132	132	132	136	141	148
132	133	139	134	134	138	144	146	152
86	84	87	94	97	103	105	106	112
85	87	95	101	104	111	113	114	116
89	90	94	107	107	109	115	115	122
110	110	114	114	118	122	126	128	128

113	112	121	120	120	128	132	132	138
119	121	129	127	131	132	135	138	145
112	113	117	112	114	118	120	122	123
116	118	120	113	115	132	122	124	135
120	123	126	120	122	128	109	132	134
74	76	81	83	85	89.6	92	94	98
82	81	82	90	92	96	96	98	104
82	80	85	94	95	94	98	103	109
93	96	99	101	100	104	103	106	110
97	102	106	100	107	116	115	114	124
104	105	109	113	115	113	122	123	125
101	103	111	99	103	108	99	105	114
106	108	110	103	107	113	107	103	107
110	111	113	107	111	116	112	116	118

III. EXPERIMENTATION – FIELD TRIAL

The main intention behind undertaking this experimentation is to find a way in which power output can be used optimally without causing much of the exertion to the cycle rickshaw puller [16]. Weather the rickshaw puller can pedal 8 km or not depends on the physical fitness and state of mind since getting exhausted is attributed to one's inner feeling and in such matters a researcher has to rely on the judgment of puller himself. However, to verify the cycle rickshaw puller judgement, it is planned to collect data related to pulse rate as per the methodology of design of experiments. The purpose of the experimentation is to test the effects of wheel diameter and speed ratio on performance of the puller.

The values of pulse rate are recorded with the help of UT-100 pulse oximeter throughout test run of rickshaw along the road track for three models specially designed and develop for this experimentation. Total 81 runs were recorded for gathering full set of data needed for 3^3factorial design.

The values of pulse at these points are given in Table-III. Thus, these points become the crucial and required critical analysis for reducing the energy expenditure of the puller for the same amount of work

IV. FORMATION OF MODEL RA AND ANN

Statistical and analytical modelling methods like regression analysis (RA) and artificial neural network (ANN) were used by the new design of cycle rickshaw and their performances were studies by varying wheel diameter, load and length of crank. Their effects on performance of rickshaw puller were observed. The formulated experimental model were used to fix optimum value using Min-Max principle for RA and univarient analysis of ANN. For each puller, a total three model has been formulated on Regression Analysis and ANN [17-19].

A. Formulation of Multivariate Linear Regression Model

It is important to obtain results of an experiment quantitatively for regression model to faceplate understanding, interpretation and implementation [20-21]. Regression analysis is highly useful in design experiments where somewhat has gone incorrect.

Regression analysis is the relationship between a variable and variables. The relationship was expressed as an equation that predicts answer variable (also called dependent variable) from a function of regression variable (also called independent variable). The relationship between these between these variable is characterized is mathematical model called a regression models. The equation for the i^{th} equation will be in the following form:

$$y_i = \beta_0 + \beta_1 X_1 + \varepsilon_i \qquad (1)$$

Thus y_i is the dependent variable, X_i is a independent variable, β_0 and β_1 are shown estimated parameters and $\varepsilon_i$is an error term and subscript i indexes a popular observation.

1. Regression analysis (RA) model for circular sprocket

Regression coefficient using IBM statistical SPSS 25.0 software based on pulse data yielding the following in which D= Diameter of wheel, P= Load, L= Crank length and R= Pulse:

RAC1-R= βo+ β1*D+β2*P+ β3*L

R=360.8572-0.3628*D+ 0.29411*P-0.4092*L (2)

R=359.2637- 0.3371*D + 0.1146*P-0.3791*L (3)

R=548.7081-0.5365*D+ 0.1121*P-0.5197*L (4)

Where equation (2), (3), (4) represents the RA model for Puller 1, Puller 2 and Puller 3 respectively

2. Regression analysis (RA) model for Non - circular sprocket

Regression coefficient using IBM statistical SPSS 25.0 software based on pulse data yielding the following in which

D= Diameter of wheel,

P= Load,

L= Crank length and

R= Pulse:

RANC1-R = βo+ β1*D+β2*P+ β3*L

R=234.6206-0.2086*D+ 0.1889*P-0.2693*L (5)

R=359.2637- 0.3371*D + 0.1146*P-0.3791*L (6)

R=438.9665-0.08968*D+ 0.1121*P-0.4158*L (7)

Where equation (5), (6), (7) represents the RA model for Puller 1, Puller 2 and Puller 3 respectively.

Multiple regression estimate the coefficient of linear equation when there are more than one independent variable that best predict the dependant variable. Thus pulse is dependant variable which can be evaluated using regression equation containing more than one independent variable viz. diameter of wheel, speed and load.

The coefficient of correlation [R] between pulse observed and that predicted by the regression models are shown in Table-IV.

Table-IV: Model Summery R and adjusted R square RA models

Model	R	R^2	Adj. R^2	Standard Error of Estimate	Change Statistic				
					R R^2	*F Change*	df_1	df_2	*Sig. Change*
RAC1	0.955	0.9112	0.9003	4.9366	0.9112	76.2896	3	22	0.000
RAC2	0.933	0.8705	0.8536	3.7100	0.8705	51.5503	3	23	0.000
RAC3	0.9142	0.8358	0.8135	4.9461	0.8358	37.3514	3	22	0
RANC1	0.912	0.8317	0.8098	4.4244	0.8317	37.8962	3	23	0.000
RANC 2	0.933	0.8705	0.8536	3.7100	0.8705	51.5503	3	23	2.28e-10
RANC3	0.914	0.8358	0.8135	4.9461	0.8358	37.3514	3	22	0.000

B. ANN Topology and ANN Model Formulation.

In general two dimensional layouts of layers and cells are in use. The network numerically comprises input and output layers. Some hidden are also used to achieve the complex transformation expected to be present in original process. Topology with one, two or three hidden layers is common phenomenon. One hidden topology provides better answers when contribution of linear relationships is more [22-24].

IBM statistical SPSS 20.0 is utilized for ANN model formulation. It gives connected diagram of network, prediction plots, and residual to variable significance analysis.

Table-V: ANN Topology used for the models

Model	Symbol	Topology	Number of hidden layer
ANN model for Puller 1 circular sprocket	ANNC1	3-4-1	1
ANN model for Puller 2 circular sprocket	ANNC2	3-4-1	1
ANN model for Puller 3 circular sprocket	ANNC3	3-4-1	1
ANN model for Puller 1 non-circular sprocket	ANNNC1	3-4-1	1
ANN model for Puller 2 non-circular sprocket	ANNNC2	3-4-1	1

In the current research, several architectures are attempted and examined to know the best for the different models. The following are yielded the best result and is given in Table-V.

ANN result analysis with multilayer feed forward network as one hidden layer and hyperbolic tangent commencement function for both hidden as a input layer is applied to all three models.

Table-VI gives information about the result of training and testing the final network to the hold out sample given below.

The relative error for each sale dependant variable into mean value of dependant variable is utilized like guessed value in every case.

The estimate algorithm stops because an error did not reduce after a step in the algorithms.

Table-VI shows independent variable significance analysis of ANN models for circular and non circular sprockets. It indicates normalized importance in which carry out sensitivity analysis, it gives input to the each predictor. The analysis is on the basis of combine testing and training sample.

By inserting the predictor variable values in an equation, response variable pulse is calculated. This calculated value is compared with experimental pulse. The coefficient of correlation between computed and experimental value with root means square error calculated.

Table-VI: Independent variable importance analysis of ANN models for circular and non circular sprockets

Model	Diameter of Wheel		Load		Length of crank	
	Importance	*Normalized Importance*	*Importance*	*Normalized Importance*	*Importance*	*Normalized Importance*
ANNC1	0.294	52.2%	0.564	100.0%	0.142	25.2%
ANNC2	0.465	100.0%	0.336	72.3%	0.199	42.7%
ANNC3	0.511	100.0%	0.351	68.7%	0.139	27.2%
ANNNC1	0.331	63.1%	0.524	100%	0.145	27.6%
ANNNC 2	0.498	100%	0.311	62.4%	0.191	38.3%
ANNNC3	0.475	100%	0.341	71.8%	0.184	38.8%

V. RESULT AND DISCUSSION

A. Regression Model of circular and non-circular sprocket of puller 1,2 and 3

Table-VII shows coefficient values of RA model for forward and backward path of puller 1. From RA models of puller the linear regression coefficients of responsible variable leading to minimum human energy are shown in table. It is depicted influential variable which contribute substantially in reduction of human energy consumption with all basic variable as input. For RAS1 and RAE 1, it is seen that the input variable load is the most influencing parameter to achieve the objective of minimum human energy. Similar result where obtain for puller 2 and puller 3.

It is concluded that for RA model, load is the most influential parameter and must be focus on archiving the objective of expending minimum human energy.

Table-VII: Independent variable importance analysis

Model	β1	β2	β3
RAS1	-0.3628	0.29411	-0.4092
RAS2	-0.3371	0.1146	-0.3791
RAS3	-0.5365	0.1121	-0.5197
RAE1	-0.2086	0.1889	-0.2693
RAE2	-0.3371	0.1146	-0.3791
RAE3	-0.08968	0.1121	-04158

Independent variable importance analysis shows standardized significance which performed sensitivity analysis. It likewise compute significance of every predictor in deciding the neural network. The analysis depends on combined training and testing sample. ANNS1 model clearly revealed that load (β2) is more sensitive than other variable

B. ANN model for circular and non-circular sprocket of puller 1, 2 and 3

Table-VIII display summary of ANN result by partition and in general including an error, a relative error or percentage of erroneous prediction. Stoppage rule is utilized for stopping training and its time. The error is the sum of the error when the identity hyperbolic tangent actuation work is provided on output layer. The range of SSE for training (0.0498) and for prediction (0.083) of the fitted model which is considerably on low side which pointed toward actually important model. Relative error or percentage of mistaken prediction is display as per dependant variable measurement test. If any dependant variable has scale measurement level, at that point average overall relative error (comparative with mean model) is shown. Relative error or percentage of improper prediction (0.059) for training and (0.011) for prediction are displayed for individual variable.

Table-VIII : ANN model for circular and non-circular sprocket of puller 1,2 and 3

Model	R	R^2	Adjusted R^2	SSE		Relative Error		RMSE	Sample	
				Training	Prediction	Training	Prediction		Training	Prediction
ANNC1	0.989	0.979	0.976	0. 498	0.083	0.059	0.011	2.168	18	9
ANNC2	0.948	0.899	0.896	0. 462	0.144	0.042	0.053	4.168	18	9
ANNC3	0.925	0.855	0.836	1.164	0.142	0.106	0.064	5.227	23	4
ANNNC1	0.924	0.854	0.835	0.219	0.188	0.021	0.603	4.0223	22	5
ANNNC2	0.978	0.957	0.952	1.158	0.462	0.136	0.054	1.9856	18	9
ANNNC3	0.917	0.840	0.819	0.078	0.065	0.009	0.021	4.7718	18	9

C. Experimentation of Circular and non-circular sprocket

Figure 5.1 shows that overall performance of non-circular and circular sprocket. Non-circular sprocket required minimum human energy as compared to the circular sprocket. Human energy is given in terms of pulses. Figure 5.1a, b and c shows comparison of puller 1 puller 2 and puller 3 combine data taken during experimentation.

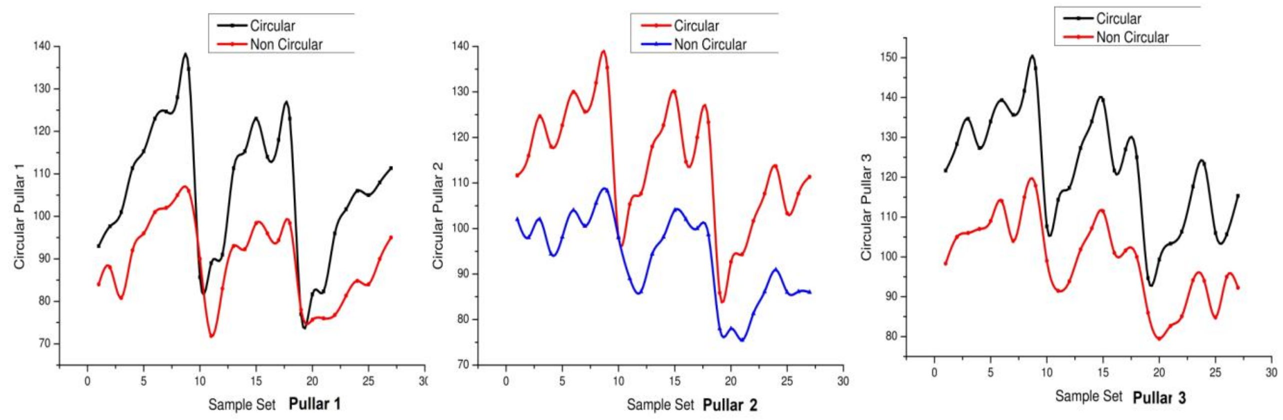

Fig. 3.Comparison of puller 1, puller 2, and puller 3 with non-circular and circular sprocket.

The energy of puller 1 of age 32 is utilized on a given path. Fig. 3 and Fig. 4 shows that overall performance of non-circular and circular sprocket of puller 1. The maximum pulse rate of puller 1 is beyond 130 for circular sprocket while for non-circular sprocket it is just up to 110 pulse rate for peak 1. For peak 2 the maximum pulse rate of puller 1 is beyond 120 for circular sprocket while for non-circular sprocket it is less than 100 pulse rate. For peak 3 the maximum pulse rate of puller 1 is less than 100 for circular sprocket while for non-circular sprocket it is up to 90 pulse rate.

It shows that puller 1 need less energy for non-circular sprocket than circular sprocket.

The energy of puller 2 of age 42 is utilized on a given path. Fig. 3 and Fig. 4 shows that overall performance of non-circular and circular sprocket of puller 1. The maximum pulse rate of puller 1 is beyond 140 for circular sprocket while for non-circular sprocket it is just up to 120 pulse rate for peak 1. For peak 2 the maximum pulse rate of puller 1 is nearly 140 for circular sprocket while for non-circular sprocket it is less than 120 pulse rate. For peak 3 the maximum pulse rate of puller 1 is less than 120 for circular sprocket while for non-circular sprocket it is up to 100 pulse rate. It shows that puller 1 need less energy for non-circular sprocket than circular sprocket.

The energy of puller 1 of age 47 is utilized on a given path. Fig. 3 and Fig. 4 shows that overall performance of non-circular and circular sprocket of puller 1. The maximum pulse rate of puller 1 is beyond 145 for circular sprocket while for non-circular sprocket it is just up to 120 pulse rate for peak 1. For peak 2 the maximum pulse rate of puller 1 is up to 140 for circular sprocket while for non-circular sprocket it is less than 120 pulse rate. For peak 3 the maximum pulse rate of puller 1 is less than 120 for circular sprocket while for non-circular sprocket it is up to 100 pulse rate. It shows that puller 1 need less energy for non-circular sprocket than circular sprocket.

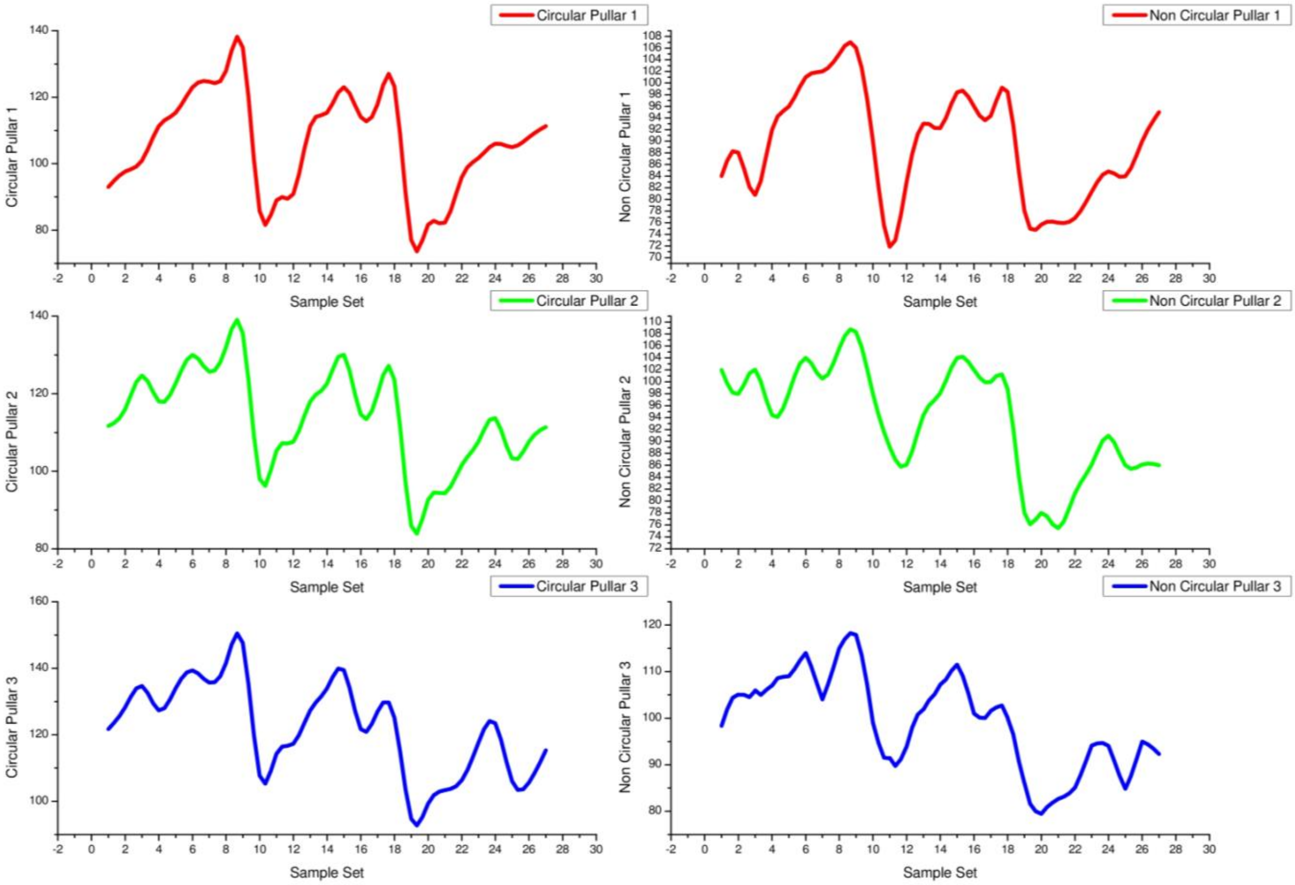

Fig. 4.Puller 1, Puller 2, and Puller 3 with non-circular and circular sprocket individually.

VI. CONCLUSION

For the present investigation, three different models of cycle rickshaw were used. The aim was to identity and optimizes input parameter that influences the consumption of human energy and performance the most. After running the experiment performing the statistical analysis, the following observations have been made:

- It is found that, for basic variables root mean square error (RMSE) and coefficient of correlations (R) obtained using ANN model for cycle rickshaw are more convincing. ANN model has emerged to be superior as compared to other techniques, namely RA both for circular and noncircular sprockets for three rickshaw pullers.
- ANN studies unveiled the benefaction of several factors to human-energy. However, load is the most prominent parameter to minimize human-energy as an outcome.
- RA of the experimental data unveiled that, input variable load is the most influential parameter to be focused on tor achieving the objective of expending minimum human energy by a rickshaw puller.
- Optimization of input variables using Min-Max principle for various regression models yielded the optimal solution at crank length 167 mm and wheel diameter 675mm for human energy for all linear regression models.

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