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Comparison Between Multiple Linear Regression (MLR) Model and Artificial Neural Network(ANN) Model for the Lean Practices of Manufacturing Industries (SMEs) of Gujarat

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Abstract

Lean Manufacturing practices are basically waste reduction perspective, in which value adding activities are focused over non value adding activities, however there are other advantages like process improvement, muda elimination, muri elimination but its main principal is work improvement through process flow and pull kanban.which finally results in increased productivity and key performance factor improvement like quality, cost, financial impact. Performance measures can only be controlled, if the critical factors are identified and explored among various process parameters. The objective of the paper is to compare the ANN base SPSS model with conceptual model and its linear regression model for lean manufacturing for SMEs. The comparison will gives the closeness of the data obtained for Model development and theory development .The residual indices were measured and equated to predict the performance measures. The operational level factors were explored for different performance measures of lean practices and their synaptic weightage for ANN was determined by activating hidden layer method in SPSS 20.

Keywords: Artificial Intelligence, Neural Networks, Productivity, SMEs (Small and Medium scale Manufacturing Enterprises), Waste

1. Introduction

Lean manufacturing is a way to achieve manufacturing excellence. Lean manufacturing is a philosophy, a production strategy and a set of techniques to meet customer requirements with a minimum of every resource. Lean manufacturing tools eliminate waste in the system and consequently reduce the cost of manufacturing. Lean manufacturing translates into manufacturing lead time reduction, WIP reduction, better space utilization, quality improvement, improved customer satisfaction and ultimately increased overall productivity. It drives the cost of manufacturing down and makes an organization competitive in the market and makes more profitable. Lean Manufacturing practice has got lot of attention as a world class manufacturing practice due to efficient and continuous improvement in day to day work.

Lean manufacturing practice or Toyota Production system started by Japanese automotive company under the strong leadership of its quality engineer Taichi Ohno in 1988, later on who was popular as a father of lean manufacturing, he had been implemented novel framework in manufacturing in the time of financial crisis and economical shortfall after World War II in Japan. Lean is all about mapping the value (anything which can produce money) and incorporating methods for minimising wastage and rework by utilizing efficient machines and active involvement of employees under the commitment

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of top management. From the origination of Lean thinking at Toyota Corporation, these principles have moved to other Japanese automotive manufactures and then to the American automotive companies as a benchmarking and breakthrough improvement techniques .

2. The Conceptual Model

As basis to eventually formulate the research hypotheses, 11 potential success factor and 8 performance measures Lean elements were identified from the literature study, and reported in the previous RPRs. These success factor elements are listed in Annexure A. Each potential success factor element identified has been linked to a core success element. The objective was to group the listed success factor element together into a final list of theoretical critical success factors to be empirically tested. The core success elements identified in Annexure A were than grouped together on theoretical grounds to formulate the potential critical success factors for successful lean implementation. Each theoretical core success element identified in Annexure A was grouped into the theoretical critical success factors for lean. This formed the basis for the development of the research questionnaire items. From each theoretical critical success factor a proposition was formulated. In this study the critical success factors for successful lean implementation served as the independent variables.

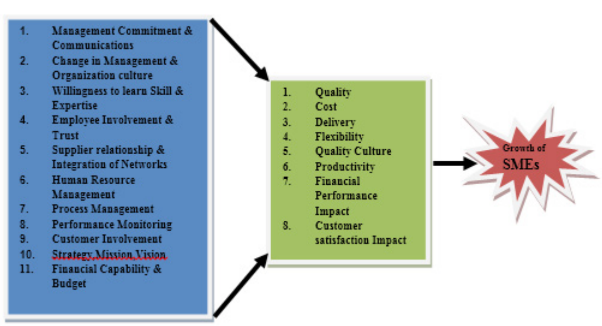


Figure 1. Research Model.

3. Data Collection

The questionnaire was developed from the research topic and questions. The questionnaire was designed using the approach of Watson and Frolick (1992) for structuring interviews with executives. The final questionnaire has total 20 questions some of which are subdivided in to sub questions. Question number 16 assesses operational level factors necessary for business performance which consist of total 53 sub questions rated on a six point scale. Also there is one question number 17 which consist of five sub questions to assess the operational performance rated on five point Likert's scale. Question number 18 consists of 21 sub questions to assess important skills required for business performance, which is assessed based on whether not very, moderately, very, and extremely important basis.

The data collection effort was divided into two stages. The first stage comprises pilot stage survey and the second is a final survey of total (299) Small and medium scale manufacturing enterprises of Gujarat and data gathering of performance at the different SMEs work interface through survey tool. The survey comprises of two sections, one is of critical factors and other is performance factors. Where managers, engineers, directors were asked to provide their opinion on likert scale for agreement or non-agreement based upon their experience pertaining to lean practices.

4. Artificial Neural Network Model

Manufactured neural system models depend on the neural structure of the mind. The cerebrum gains as a matter of fact thus do manufactured neural systems. Past research has demonstrated that counterfeit neural systems are appropriate for example acknowledgment and example arrangement assignments due to their nonlinear nonparametric versatile learning properties. As a helpful expository device, ANN is generally connected in dissecting the business information put away in database or information distribution center these days. One Basic stride in neural system application is system preparing. For the most part, information in an organization's database or information distribution center is chosen and refined to shape preparing informational collections. Simulated Neural System is generally utilized as a part of different branches of designing and science and their remarkable legitimate of having the capacity to estimated perplexing and nonlinear conditions makes it a valuable apparatus in Quantitative investigation. The genuine power and preferred standpoint of neural systems lies in their capacity to speak to both straight and on-direct connections and in their being demonstrated. Customary direct models are just deficient with regards to demonstrating information that contains non-straight qualities.

In this paper, one model of neural system is chosen among the fundamental system designs utilized as a part of building. The premise of the model is new structure as appeared in Figure 2. These neurons demonstration like parallel handling units. A manufactured neuron is a unit that plays out a straightforward scientific operation on its sources of info organic neurons and their one of a kind the neuron yield will be

$$v_k = \sum_{j=1}^{m} x_j w_{kj} + b_k$$

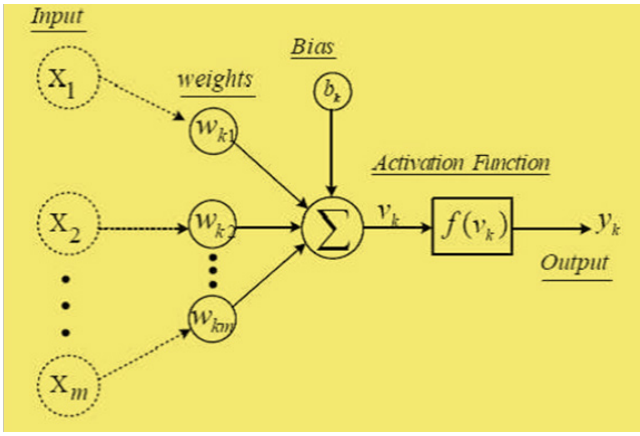


Figure 2. ANN Principal Schematic.

For the purpose of assessing the prediction performance obtained by the model, an index is used to measure the prediction accuracy and is defined as:

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y}_i)^2}$$

4.1 Remark

- For our analysis we used the ANN algorithm built into SPSS20 software. The algorithm Implements automatically the Multi-Layer Perceptron neural network with gradient descent learning.
- In addition the software displays the following useful information in the output:

i. "**Network Structure.** Displays summary information about the neural network."

ii "**Description. Displays** information about the neural network, including the dependent variables, number of input and output units, number of hidden layers and units, and activation functions."

iii. **Diagram**. Displays the network diagram as a non-editable chart. We note that as the number of covariates and factor levels increases, the diagram becomes more difficult to interpret".

iv. **Synaptic weights**. Displays the coefficient estimates that show the relationship between the units in a given layer to the units in the following layer. The synaptic weights are based on the training sample even if the active dataset is partitioned into training, testing, and holdout data. Note that the number of synaptic weights can become rather large and that these weights are generally not used for interpreting network results".

- **Network Performance**. Displays results used to determine whether the model is "good". We note that charts in this group are based on the combined training and testing samples or only on the training sample if there is no testing sample .
- **Model summary**. Displays a summary of the neural network results by partition and overall, including the error, the relative error or percentage of incorrect predictions, the stopping rule used to stop training, and the training time. The error is the sum-of-squares error when the identity, sigmoid, or hyperbolic tangent activation function is applied to the output layer. It is the cross-entropy error when the soft ax activation function is applied to the output layer. Relative errors or percentages of incorrect predictions are displayed depending on the dependent variable measurement levels. If any dependent variable has scale measurement level, then the average overall relative error (relative to the mean model) is displayed. If all dependent variables are categorical, then the average percentage of incorrect predictions is displayed. Relative errors or percentages of incorrect predictions are also displayed for individual dependent variables. Depending on preferences, numerous other network information can also be displayed .

5. Statistical Technique

Relapse strategy is a standout amongst the most generally utilized measurable systems [Mendenhall and Beaver et al 1994][7]. Different relapse examination is a multivariate measurable system used to analyze the connection between a solitary ward variable and an arrangement of free factors. The goal of the numerous relapse investigations is to utilize autonomous factors whose qualities are known to foresee the single ward variable. The impact of autonomous factors on the reaction is communicated numerically be the relapse or reaction work f:

$$y = f(x_1, x_2, \ldots, x_n; \beta_1, \beta_1, \ldots, \beta_n)$$

- y - Dependent variable
- x- Independent variable
- β1, β1, βn……..regression parameters (unknown!)
- f- The form is usually assumed to be known

i. $Y_1=0.143+0.86X_1+0.97X_2+0.131X_3+0.192X_4+0.142X_5+0.042X_6+0.026X_7+0.030X_8+0.116X_9+0.131X_{10}+1.039X_{11}+0.030$

ii. $Y_2=0.184+0.0756X_1+0.261X_2+0.009X_3+0.116X_4+0.961X_5+0.020X_6+0.154X_7+0.009X_8+0.131X_9+0.982X_{10}+0.883X_{11}+0.039$

iii. $Y_3=0.418+0.073X_1+0.429X_2+0.042X_3+0.066X_4+1.152X_5+0.014X_6+0.156X_7+0.036X_8+1.237X_9+0.580X_{10}+1.039X_{11}+0.088$

iv. $Y_4=0.634+0.707X_1+0.853X_2+0.211X_3+0.242X_4+2.174X_5+0.049X_6+0.149X_7+0.120X_8+1.899X_9+0.504X_{10}+0.005X_{11}+0.133$

v. $Y_5=0.065+2.328X_1+0.841X_2+0.107X_3+0.136X_4+0.455X_5+0.235X_6+0.011X_7+0.045X_8+0.408X_9+0.166X_{10}+1.039X_{11}+0.014$

vi. $Y_6=0.184+0.075X_1+0.261X_2+0.009X_3+0.116X_4+0.961X_5+0.020X_6+0.154X_7+0.009X_8+0.131X_9+0.982X_{10}+0.883X_{11}+0.030$

vii. $Y_7=1.708+0.287X_1+0.294X_2+0.109X_3+2.771X_4+1.177X_5+1.968X_6+0.361$

Table 1. Computer results for the MLR network model summary

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.998[a]	.996	.996	.04314
2	.997[a]	.994	.994	.05537
3	.984[a]	.968	.967	.12586
4	.984[a]	.969	.967	.19080
5	0.98[a]	0.96	0.96	.01957
6	.999[a]	.998	.997	.02930
7	.803[a]	.645	.638	.71576

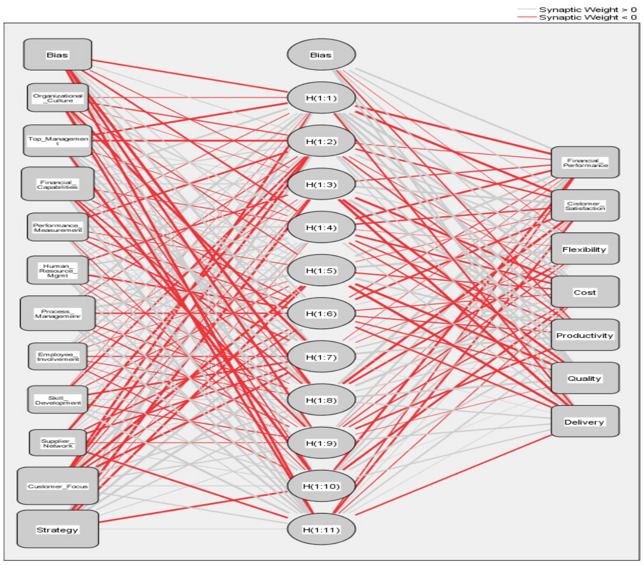
Table 2. ANN output table-error estimates

Model Summary			
Training	Sum of Squares Error		35.308
	Average Overall Relative Error		.047
	Relative Error for Scale Dependents	Y1	.006
		Y2	.005
		Y3	.009
		Y4	.008
		Y5	.286
		Y6	.005
		Y7	.008
	Stopping Rule Used		1 consecutive step(s) with no decrease in error
	Training Time		00:00:00.344
Testing	Sum of Squares Error		16.378
	Average Overall Relative Error		.067
	Relative Error for Scale Dependents	Y1-Factor	.006
		Y2-Factor	.005
		Y3-Factor	.011
		Y4-Factor	.013
		Y5-Factor	.367
		Y6-Factor	.010
		Y7-Factor	.011

The Table 2 and Table 3 shows a summary of the results obtained for the statistical and neural network analysis of the electricity data for the prediction of the productivity in SMEs. The forecasting ability of the two models is accessed using Mean Absolute Error (MAE), Mean Square Error (MSE), and Root Mean Square Error (RMSE). The results clearly show that Neural Networks, when trained with sufficient data and proper inputs, can better predict the Productivity. Statistical technique is well established, however their forecasting ability is reduced as the data becomes more complex

Table 3. ANN output table- path estimates

Parameter Estimates																			
Predictor		Predicted																	
		Hidden Layer 1											Output Layer						
		H (1:1)	H (1:2)	H (1:3)	H (1:4)	H (1:5)	H (1:6)	H (1:7)	H (1:8)	H (1:9)	H (1:10)	H (1:11)	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Input Layer	(Bias)	.324	.111	.099	.283	.110	.288	.379	1.039	.404	.213	.486							
	OC	.096	.225	.021	.258	.162	.036	.574	.049	.137	.155	.402							
	TM	.502	.499	.047	.067	.168	.259	.215	.760	.481	.704	.073							
	FC	.387	.193	.184	.147	.217	.182	.596	.254	.387	.036	.492							
	PM	.073	.443	.182	.308	.107	.179	.275	.041	.153	.077	.373							
	HRM	.091	.179	.284	.331	.049	.434	.280	.057	.046	.114	.300							
	PCM	.578	.128	.026	.330	1.163	.356	.143	.215	.188	.352	.446							
	EI	.071	.304	.032	.232	.055	.150	.238	.125	.021	.177	.106							
	SD	.005	.286	.038	.040	.149	.059	.464	.099	.214	.206	.494							
	SN	.052	.492	.038	.169	.008	.264	.342	.040	.115	.092	.387							
	CF	.456	.475	.097	.494	1.091	.241	.532	.298	.258	.130	.249							
	ST	.326	.373	.642	.009	.410	.486	.517	.260	.066	.464	.042							
Hidden Layer 1	(Bias)												.298	.187	.020	.170	.197	.298	.273
	H(1:1)												1.097	1.223	1.009	1.352	1.058	.530	.270
	H(1:2)												.117	.318	.267	.062	.238	.325	.180
	H(1:3)												.240	1.317	.146	.911	.975	.728	.741
	H(1:4)												.496	.340	.017	.432	.254	.227	.189
	H(1:5)												.590	.057	1.386	.264	.499	1.407	1.541
	H(1:6)												.130	.439	.111	.171	.218	.220	.322
	H(1:7)												.031	.058	.060	.261	.876	.015	.029
	H(1:8)												1.690	.870	.375	.969	.208	.828	.269
	H(1:9)												.275	.008	.189	.218	.357	.038	.271
	H(1:10)												.432	.318	.236	.428	.318	.002	.230
	H(1:11)												.187	.320	.035	.095	.235	.032	.267



Hidden layer activation function: Hyperbolic tangent
Output layer activation function: Identity

Figure 3. ANN model based on conceptual model.

Table 4. Comparison of models

	Nos Sample	MAE	MSE	RMSE
Regression	299	0.036	0.002	0.046
ANN	299	0.041	0.0019	0.052

6. Conclusion

In this paper, two different techniques for modeling and predicting the Lean Practices of SMEs implemented in Manufacturing SMEs: Neural Network and Statistical Technique of linear regression. The predicting ability of these models is accessed on the basis of "Mean Standard Error, Mean Average Error and Root Mean Square Error". After that we have learned from Table 4 that the statistic that Neural Networks beat Statistical technique in estimating. The ground of neural networks is very diverse and chances for future research exist in many parts, including data pre-processing and representation, architecture selection, and application (Azoff 1994)[1]. The next logical step for the research is to improve further the performance of Neural Networks, for this application, possibly through better training approaches, better architecture selection, or better input.

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