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Wind Turbine Manufacturer's Supply Chain- A Descriptive Study

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ABSTRACT

The main aim of this paper is to establishing the relationship between the inventory level and other cost of wind turbine companies because the past research does not create the causes and effect problems. So, the relationship between the operating cost inventory level has been managed with the help of the descriptive research. Initially different data has been collected from the 5 companies which includes both dependent and 8 different independent variables. From the variables different hypothesis has been formed for analysing the regression and log data in each industry. Finally the performance of the system is analysed using the analyzis of variance metrics with effective manner.

Keywords: Regression model, inventory level, Variables, Hypothesis.

1. INTRODUCTION

Supply chain [1] is plays an crucial role in various oragnizations for managing the employees, activities, information and resources involved in the product to enhance the turnover of the particular organization. In the supply chain, managing the relationship between the customer and ventror is placed an critical role because of the product flows, reveals, inventory movements and storage. So, the more activities such as purchase, transfer and inventories are has been performed in the industry to managing the relationship between the customers and ventors with efficient manner [2]. Then the most of the organization uses the inventory concepts to increase the turnover also managing the relationship between the parties in the company. Inventory [3] is one of special concepts in the research and management area in the production system which used to minimize the cost used in the company. In addition it used to taking the decisions in various applications such as manufacturing, supply chains, spare part allocation and the warehousing area.

During the management process, several problems has been occurred such as the dynamic programming, optimal control and so on. so, the inventory process has been optimized to reduces the problem present in the company. The essential optimization techniques is applied to manage the cost of the inventory model and the service levels in the company. Determining the optimum inventory for the required demand is of paramount importance. So, the different inventory optimization techniques [4] has been applied in terms of the multi product, multi supplier. Different optimization techniques such as the particle swarm optimization, genetic algorithm, ant colony [5] are applied to the inventoy level in the company to managing the relationship between the customers and suppliers.

From the above discussions there is no research was conducted so for in the literature review in wind turbine industries specially. So,this paper focuses on optimizing the wind turbine companies inventory methods. The optimization was done by collecting the data from the 5 different companies for the research. Since it was the first of its kind study it was done as a descriptive research.The relation between different parameters was established in this paper. From the five different companies, so many different parameters were collected. From this 8 different parameters were taken as dependent variables and one independent

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variable was established. These parameters were established based on the past research and experience. The hypothesis was established. The results out of these different industries were aggregated so that the industry aggregate relations are established. This would become a strong fundamental for further research to do in empirical research.

The remaining of the section organized as follows, section 2 deals that the various discussions about the deterministic and probabilistic inventory models and related methods. Section 3 discusses that the proposed scheme for industry analysis part and conclusion in the section 4.

2. LITERATURE REVIEW

There are many inventory models.The entire Inventory models help or support to find out the optimum level of an inventory to maintain to ensure smooth production. It is essential to balance the advantage of having inventory of resources and the cost of maintaining so as to determine and optimal level of inventory of resources. The two different type of inventory models such as deteriminstic and probabilistic model in the wind turbine companies. JafarRezaeia *et al.*, [6] discussing that the deterministic based inventory model in the multiple product and multiple suppliers in the company. In the company, each product cost and the quality has been monitored by continuous planning with the supplier in the horizontal manner. During the decision making process each buyer storage space is considered and the decision is carried out by the genetic algorithm.Bhuniaa *et al.*, [7] proposing the two different inventory models for solving the backlogged problem in the industry. During this process, the replenishment rate is considered as the fixed rate and the inventory is requested based on the demand which is commonly called as the Economic Lot Size or Economic Order Quantity Model. Then the performance of the system is analyzed using the two numerical examples which achieves the efficient result.

Some time the inventory models deal with the situation in which the demand is probabilistic. Normally, the developed models are categorized broadly under continuous and periodic review situation. This model includes both single period and multiperiod cases. Ingrid Farasyn [8] discussing the system like procter and gamble cross functionality to reduc the inventory investment. The inventory investment process lead to increase the savings which is achieved by two steps such as spreadsheet based inventory modesl and end to end supply chain. This model uses the inventory as the on demand basis in terms of the probabilistic method has bee used to manage the savings in the gamble system.Beamon *et al.*, [9] analzyign the multi-stage supply chain modeling and agenda improving the future research area. This research objective used to reduces the drawback present in the design, analyzis, manufacturing cost, shring resources of the manufacturing bases and the different product life cycles. Dimitris Bertsimas et al., [10] optimizing the supply chain problems by utilizing the stochastic demand in the discrete time. The method analyze the uncertainty of the each demands present in the supply chain without doing the any specific distribution in the policy. The developed optimal supply chain problem is compared with the dynamic programming which overcome the complex and robust problems in the supply chain.

Won Young Yun [11] discussing the optimal replacement strategy for reducing the replacement cost and operating costs in the rail sleeper strategies. So, the proposed system uses the finite horizon criteria for managing the operating cost in the rail system. Herbert J.Grunwald [12] research the Zero Inventory(ZI) and Just in Time (JIT) were the two buzz words that pretended to offer entirely new concepts industries and companies always strived for stocks close to zero inventory. Sergey Rumyantsev [13] discusses that the Classical inventory models offered variety of insights into the optimal way to manage inventories but these studies did not account for many practical considerations. In addition the author mentionthat the exploratory study aims to address the seissues using empirical data. Giri [14] discusses about economic manufacturing quantity problem for an unreliable production facility where the production rate is treated as a decision variable. Then the following section discusses that the schema analysis of the industry inventory levels by using the pareto analysis.

3. SCHEMA OF ANALYSIS PART

The inventory analysis consist of several activities such as games, suzlon and so on for each individuals which has the normal and log data. Then the different activities present in the industry has been shown in the following table 1. The table value has been analyzed using the pareto analysis.

Table 1
Pareto Analysis of Different Inventory Analysis

S.No	*Activities*	*Individual Form*		*Entire Industry*		
		Normal Data	*Log Data*	*Normal Data*		*Log Data*
1	Games	Corss Correlation	Cross Correlation	Games	Corss Correlation	Cross Correlation
		Regression Analysis	Regression Analysis		Regression Analysis	Regression Analysis
2	Suzlon	Corss Correlation	Cross Correlation	Suzlon	Corss Correlation	Cross Correlation
		Regression Analysis	Regression Analysis		Regression Analysis	Regression Analysis
3				Vestas	Corss Correlation	Cross Correlation
					Regression Analysis	Regression Analysis
4				Acciona	Corss Correlation	Cross Correlation
					Regression Analysis	Regression Analysis
				Win Wind	Corss Correlation	Cross Correlation
					Regression Analysis	Regression Analysis

During the pareto analysis different variables such as dependantanddependant variables has been used for individual firm which are listed in the table 2.

Table 2
List of Variables

S.No	*Dependant Variables*	*Independent Variables*
1	Inventory Level	The Cost of Goods Sold
2		Fixed Asset
3		Sales
4		Inventroy Holding Cost
5		Inventory Ordering Cost
6		Current Libilities
7		Relative Margin RatioSales – COGS)/ Sales [PAT]
8		Sales Growth (COGSb – COGSa)

The above variables [16] were selected based on the importance in contributing to inventory level. This was enhanced using Pareto tool.Then the list of variables are identified based on the performance which are short listed according to the impact and potential influence of the inventory. The variables are listed in the table 3.

From the above table3 shows that the different ordering costs such as ordering cost, communication expense, advertisement, travelling conveyance and selling admin expense are listed and the related sub categories also listed which is used to compare the inventory list with the related cost in the different environment. In addition the different category of the cost also included in the table 4.

Table 3
List of Ordering Cost

S. No.	*Cost Catogory*	*Sub- Catogory*
1	Ordering Cost	Expenses In Purchase
		Accounting
		Man Power Cost/Labor
		Money Spent In Sending Enquiries
		Receiving Quotations
		Company Placing /Typing Order
		Finalizing Orders
		Placing Orders
		Follow-Up Costs
2	Communication Expenses/Computer Software	Postage And Printing
3	Advertisement	Transportation
		Stationary
		Inspection
		Cost Of Settlement/Payment
		Cleaning Machine
		Calibrating Equipment
4	Quality Assurance Expenses	Performance Guarantee Expenses
		Performance Guarantee Expenses
		Training Staff
		Vehicle and Equipment Hire Charges
		Legal and Professional Charges
4	Travelling and Conveyance	Sales Commission
5	Selling And Admin Expenses	Provision For Operation, Maintenance And Warranty

Table 4
Holding Cost

S.No.	*Catogory Cost*	*Sub- Catogory*
1	Raw Material Cost (Including Those In Transit)	Interest On Capital Invested In Inventories
		Storage Space Cost
2	Rent	Land Lease And Rights
		Operating Lease Charges
3	Lease Rights	Electricity
		Power and Fuel
		Purchased
		Own Generation
		Materials Consumed in Operations and Other Expenses
		Total Consumption
		Stores and Spares
		Handling Cost
		WTG Installation Cost
4	Insurance	Insurance

contd. table 4

S.No.	*Catogory Cost*	*Sub- Catogory*
5	Taxes	Security
		Repairs and Maintenance
		Plant and Machinery
		Building
		Others
6	Operation And Maintenance Charges	Inventory Maintenance Costs
		Stock Checking
		Record Maintenance
		Monitoring Inventory
		Obsolescence Cost
		Design Change and Technology Up gradation Charges
		Deterioration of Quality
		Theft & Breakage (Provision For Liquidated Damages)
7	Labor	Freight Outward And Packing Expenses
		Blade Retrofit Expenses
		Cost Of Utilities
		Hidden Cost
8	Work In Process (WIP) & Contracts In Progress	Less: Provision For Inventory Included In WIP
		Net WIP

Table 5
Purchase

S.No.	*Catogory*	*Sub- Catogory*
1	Purchases	Inventories
2		cost of goods sold (COGS)
3		Sales
4		Accounts payable (AP)
5		Days of Accounts Payable (DAP)
6		Fixed Asset
7		Gross Margin (cogs-sales)/sales
8		Sales Growth (sales2- sales1)
9		Sales Growth 1 (COGS2-COGS1)
10		Profit After Tax (PAT)

Based on the ordering cost and related sub category the different purchase categories also included in the table 5. By using the above table values, the Pareto chart has been drawn which is shown in the figure 1. The pareto chart is used to analyze relationship between the different variables for analyzing the inventory level in the company.

Based on the above relationship between the inventory level and cost variables, the turbine company inventory level has been analyzed and optimized by using the following hypothesis formation process.

3.1.1 Hypothesis Formation

The following assumptions [17]were taken into consideration based on known information and previous experience.

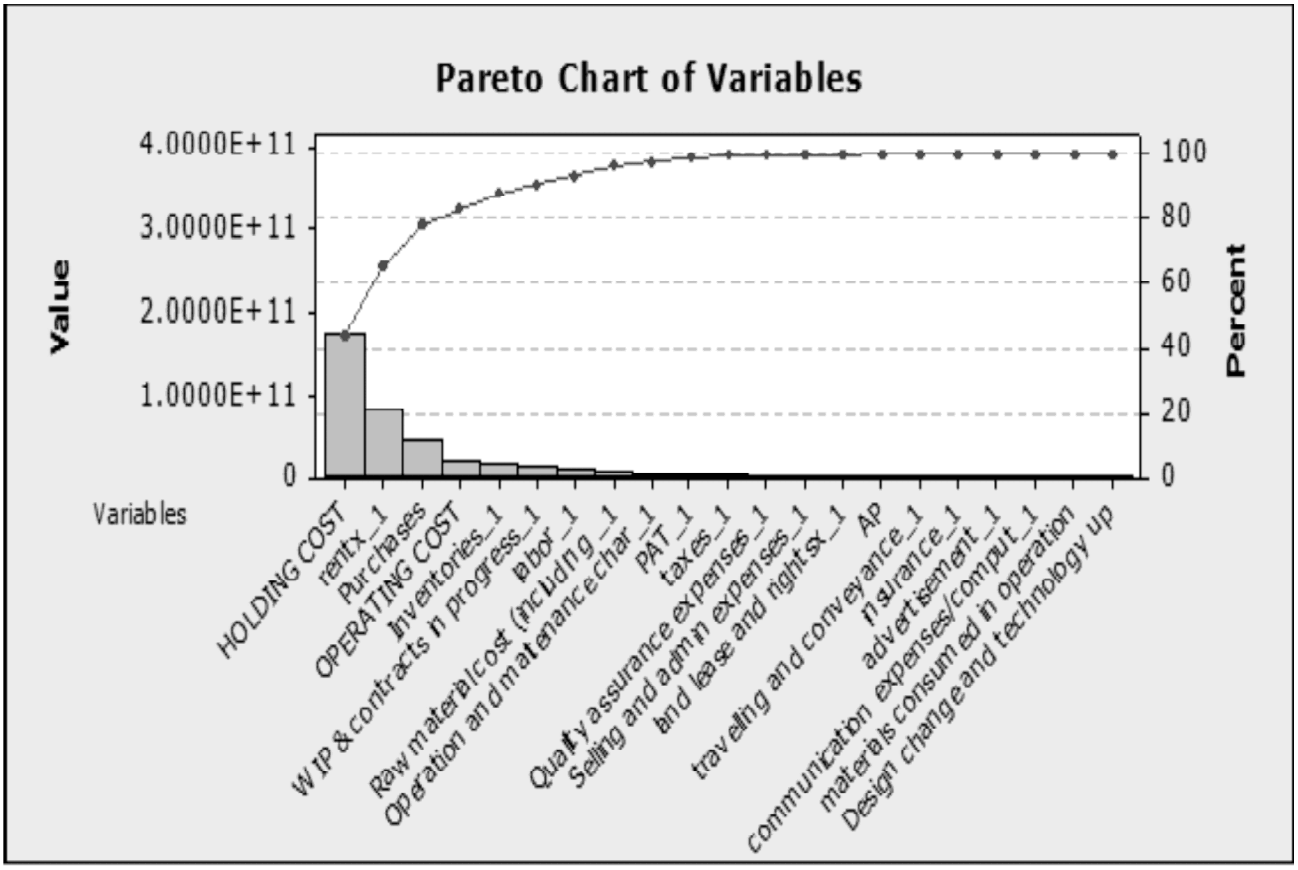

Figure 1: Pareto Chart for Variables

Hypothesis

1. Inventory level was positively associated with inventory holding cost
2. Inventory level was negatively associated with inventory ordering cost
3. Inventory level was positively associated with COGS
4. Inventory level was negatively associated with company size
5. Inventory level was associated with sales of the company
6. Inventory level was positively associated with product margin (PAT)
7. Inventory level was positively associated with procurement lead times [365/(4*COGS/AP)]

3.1.2. Proposed Model

In the proposed method the turbine company inventory level [18] has been optimized in the individual firm as follows,

Log (Inventories) = a + $b_1$log(COGS) + $b_2$log(Fixed Asset) + $b_3$log(Sales) + $b_4$log(Inventory Holding Cost) + $b_5$log(Inventory Ordering Cost) + $b_6$log(Current Liabilities) + $b_7$log(Relative Margin) + $b_8$log(Sales Growth) + $b_9$log(Sales shock)

3.2. For Entire Industry

The entire industry efficiency of the inventory level has been optimized by using the relationship between the normal aggregate cross correlation and the variable present in the industry which is discussed using the following table 6.

3.2.1. Normal Aggregate Crosscorrelation Between Variables For Industry

Table 6
Cross Correlation Between the Variables in the Industry

	Operating Cost	*Holding Cost*	*Cost of Goods Sold*	*Sales*	*DAP*	*Fixed Asset*	*Gross Margin (Cogs-Sales)/Sale*	*Sales Growth 1 (Cogs2-Cogs1)*	*PAT*	*Inventories*
Operating Cost	1									
Holding Cost	0.248	1								
Cost of Goods Sold	0.195	0.243	1							
Sales	0.259	0.17	0.123	1						
DAP	0.202	0.201	-0.068	0.032	1					
Fixed Asset	0.158	0.186	0.255	0.148	0.136	1				
Gross Margin (Cogs-Sales)/Sales	0.092	0.239	0.114	0.102	-0.005	0.056	1			
Sales Growth 1 (Cogs2-Cogs1)	-0.131	0.052	-0.129	0.117	0.068	-0.053	-0.004	1		
PAT	0.123	0.061	0.099	0.104	-0.041	-0.109	0.106	0.059	1	
Inventories	-0.195	0.14	0.129	0.196	0.124	-0.2	0.009	0.044	0.124	1

Interpretation

There was a high level of negative correlation between inventories and operating cost, whereas there was a positive correlation between inventories and holding cost. Also it could be interpreted that there was a significant relationship between inventories and COGS, sales, Gross Margin, DAP and it was positive.It was clearly seen that there was a negative correlation between inventories and Fixed Asset.

3.2.1.1. Normal Aggregate regression between variables across all firms

The normal aggregated regression between the variables has been analyzed in different firms and the related regression statistics is shown in the table 7.

Table 7
Regression Statistics

S.No	*Parameters*	*Statistics*
1	Multiple R	0.793
2	R Square	0.592
3	Adjusted R Square	0.554
4	Standard Error	0.002
5	Observations	222

By using the above table 7 regression statstics values for analyzing the relationship between the inventory levels present in the industry by using the ANOVA.

ANOVA

Analysis of Variance (ANOVA) is method to analyze the relationship between the group of variables in the firm by using the mean and the related variation values in the group. Based on the above table 7 values the regression and relationship between the values are analyzed which is shown in the table 8.

Analysis of Variance

Table 8
ANOVA Variance Analysis

Source	*DF*	*SS*	*MS*	*F*	*P*
Regression	9	1.48E+22	1.65E+21	2.9	0.013
Residual Error	213	1.46E+23	6.87E+20		
Total	222	1.60E+23			

Null Hypothesis

There is no significant relationship between variables.

Interpretation

The F test returned a fair value and it was greater than the table value 8. Thus Null hypothesis was rejected and also p-value was less than 0.05 which meant that null hypothesis should be rejected and the alternate hypothesis should be accepted. So there was a relationship between the variables of regression model. Also the relationship was significant between the variables are shown in the table 9.

Table 9
Relationship between the Variables

Predictor	*Coef*	*SE Coef*	*T*	*P*
Constant	2.29E+10	7362177262	3.12	0.002
Oprating Cost	-0.2288	0.1636	-1.4	0.016
Holding Cost	0.006096	0.008563	0.71	0.037
Cost of goods sold	0.01211	0.02146	0.56	0.007
Sales	0.04282	0.02347	1.82	0.032
DAP	15191899	16550311	0.92	0.016
Fixed Asset	-0.02362	0.01275	-1.85	0.005
Gross Margin	7.08E+08	880124069	0.8	0.042
Sales Growth	1.57E+08	1740009556	0.09	0.019
PAT	0.3002	0.2708	1.11	0.041

S = 26210621384 R-Sq = 59.2% R-Sq(adj) = 55.4%

Interpretation

1) It could be clearly interpreted that operating cost exhibits an inverse relationship with inventory level as the co-efficient is negative .Also the P-value is less than 0.05 which proves that the relationship is significant.

2) The sales, Sales growth and Gross Margin exhibit a positive relationship with inventory levels proving that they are linear function of inventory levels.

3) Fixed Assets exhibit a negative correlation with inventory level as the co-efficient is negative.

4) Holding cost also exhibit a positive relationship with inventory level. Similarly the cost of Goods sold also exhibits a positive relationship with inventory level and the p-value also shows that the relationship is significant.

5) The overall model fit is found using the adjusted R square value which is 55.4 %. This is a very fair value and the model is found to be stable throughout the industry.

The R-Square is the value representing that 59.2% of the variation in dependent variable are explained by the independent variables. This is meant to be an appreciable value implying that the model is good and reliable. The adjusted R-Square is 55.4 % meaning that there is less chances for errors to hinder the model's reliability.

3.2.1.2. Regression Analysis: Inventories versus OPERATING COST, HOLDING COST, ...

The regression equation isInventories = 2.29E+10 - 0.229 OPERATING COST + 0.00610 HOLDING COST + 0.0121 cost of goods sold + 0.0428 Sales + 15191899 DAP - 0.0236 Fixed Asset + 7.08E+08 Gross Margin (cogs-sales)/sales + 1.57E+08 Sales Growth 1 (COGS2-COGS1) + 0.300 PAT

Interpretation

There is a well established relationship between the operating cost and inventory level. For every increase in inventory level the operating cost declines and for every increase in inventory level the holding cost increases. Also the COGS established a fair relationship that for the raise in inventory level the COGS also increases. The sales growth parameter is also found to be positively significant with high co-efficient. So does the Gross Margin too. The days of accounts payable also increases along with the raise in the inventory level value is shown in the table 10.

Table 10
LOG Aggregate cross correlation between variables across all firms

	Operating Cost	*Holding Cost*	*Cost of Goods Sold*	*Sales*	*DAP*	*Fixed Asset*	*Gross Margin (Cogs-Sales)/ Sales*	*Sales Growth 1 (Cogs2-Cogs1)*	*PAT*	*Inventories*
Operating Cost	1									
Holding Cost	0.735	1								
Cost of Goods Sold	0.717	0.744	1							
Sales	0.719	0.702	0.661	1						
DAP	0.465	0.378	-0.325	0.31	1					
Fixed Asset	0.723	0.659	0.648	0.615	0.479	1				
Gross Margin (Cogs-Sales)/Sales	0.147	0.157	0.117	0.089	-0.058	0.067	1			
Sales Growth 1 (Cogs2-Cogs1)	-0.214	0.133	-0.195	0.1	0.276	-0.237	0.072	1		
PAT	0.613	0.628	0.631	0.682	0.236	-0.491	0.135	0.095	1	
Inventories	-0.685	0.648	0.635	0.63	0.372	-0.628	0.04	0.164	0.537	1

Interpretation

There was a high level of negative correlation between inventories and operating cost, whereas there was a positive correlation between inventories and holding cost. Also it could be interpreted that there was a significant relationship between inventories and COGS, sales, Gross Margin, DAP and it was positive.It was clearly seen that there was a negative correlation between inventories and Fixed Asset.

LOG Aggregate regression between variables across all firms- Using SPSS

The log aggregated regression between the variables across all the firms using the SPSS and the related regression statistics is shown in the table 11.

Table 11
Regression Statistics

Parameters	*Statistics*
Multiple R	0.738
R Square	0.56
Adjusted R Square	0.542
Standard Error	0.398
Observations	222

Analysis of Variance

Table 12
Analysis of Variance

Source	*DF*	*SS*	*MS*	*F*	*P*
Regression	9	8.27275	0.91919	30.14	0
Residual Error	213	6.49542	0.03049		
Total	222	14.76817			

Null Hypothesis

There was no significant relationship between variables.

Interpretation

The F test returned a fair value and it was greater than the table value 2.12. Thus Null hypothesis was rejected and also p-value was less than 0.05 which showed that null hypothesis should be rejected and the alternate hypothesis should be accepted. So there was a relationship between the variables of regression model. Also the relationship was significant between the variables.

Table 9
Relationship between the Significant variables

Predictor	*SE Coef*	*Coef*	*T*	*P*
Constant	3.1877	0.5683	5.61	0
log (Operating Cost)	-0.15706	0.05695	-2.76	0.006
log (Holding Cost)	0.12022	0.06911	1.74	0.003
Log (COGS)	0.15267	0.06935	1.74	0.034
log (Sales)	0.1329	0.07334	1.81	0.005
log (DAP)	0.03352	0.04563	0.73	0.021
log (Fixed Asset)	-0.09946	0.04726	-2.10	0.317
Log (Gross Margin)	0.03443	0.02483	1.39	0.079
Log (sales growth)	0.00597	0.03468	0.17	0.856
log (PAT)	0.04295	0.05838	0.74	0.316

Interpretation

1) It could be clearly interpreted that operating cost exhibited an inverse relationship with inventory level as the co-efficient was negative.Also, the P-value was less than 0.05 which proved that the relationship was significant.

2) The sales, Sales growth and Gross Margin exhibited a positive relationship with inventory levels proving that they were linear function of inventory levels.

3) Fixed Assets exhibited a negative correlation with inventory level as the co-efficient was negative.

4) Holding cost also exhibited a positive relationship with inventory level. Similarly, the cost of Goods sold also exhibited a positive relationship with inventory level and the p-value also showed that the relationship was significant.

5) The overall model fit was found using the adjusted R square value which was 54.2 %. This was a very fair value and the model was found to be stable throughout the industry.

The R-Square was the value representing that 56% of the variation in dependent variable were explained by the independent variables. This was meant to be an appreciable value implying that the model was good and reliable. The adjusted R-Square was 54.2 % meaning that there wereless chances for errors to hinder the model's reliability. Then the performance of the relationship is analyzed using the MINTAB which is represented as follows,

The regression equation waslog (Inventories) = 3.19 - 0.157 log (Operating Cost) + 0.120 log (Holding Cost) + 0.153 Log (COGS) + 0.133 log (Sales) + 0.0335 log (DAP) - 0.0995 log (Fixed Asset) + 0.0344 Log (Gross Margin) + 0.0060 Log (sales growth) + 0.0429 log (PAT)

4. CONCLUSION

There were many inventory models has been created in the past few years to minimizing the inventory cost also increasing the different service levels. The need to conduct the empirical research to test the predictions has been established in this research paper. For further research this would become a strong fundamental foundation.There was a well-established relationship between the operating cost and inventory level. For every 1% increase in operating cost, the inventory cost declined by 0.15% and for every 1% increase in holding cost, the inventory level increased by 0.22%. Also, the COGS established a fair relationship that for every 1% rise the inventory level increased by 0.15%. The sales parameter was found to be significant with an increase of 0.13% of inventory level for every increase of 1%. For every 1% increase in days of accounts payable, the inventory level increased by 0.03%. By an increase in 1% of the Fixed asset or the company size the inventory level decreased by 0.09%. For every 1% increase in the Gross margin the inventory level increased by 0.03%. The sales growth increased by 0.006% for every 1% rise in inventory level for which there was a lag. The profit also increased by 0.05%.

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