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SERVICES FOR SCIENCE AND EDUCATION

Exploring the Application of Blockchain Technology in the Supply Chain of the Automotive Industry

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ABSTRACT

The purpose of this study is to assess the impact of blockchain technology in the supply chain of the automotive industry and its effect on supply chain efficiency. A quantitative approach has been used by a self-administered questionnaire among 100 supply chain professionals predominantly from the automotive industry and to the blockchain professionals in other industries in Europe. The result of the investigation showed that there is enhancement of supply chain efficiency by the implementation of blockchain in the supply chain of the Automotive industry. In addition, based on the regression and correlation analysis, it concluded that data transparency, traceability, security of the data are significantly correlated with supply chain efficiency of the organization when blockchain technology is implemented. The study also examines the cost of implementation of blockchain technology which influences the decision-making process of adoption of blockchain technology for supply chain efficiency.

Keywords: Data transparency, Traceability, Security, Cost of implementation, Supply chain efficiency.

INTRODUCTION

Automotive sector is fragmented and is integrated into Global Value Chains (GVC) to reduce the cost of labour and to offshore certain processes to countries with low wages. Germany has also done that by shifting their production in central Europe and eastern Europe even when their final production is done in Germany. Supply chain disruptions is possibility due to unforeseeable circumstances like the COVID 19 and such fragmented sector can suffer a lot and will not operate smoothly (Connell Garcia et al., 2020). This research aims to identify the effects of blockchain implementation on variables like data transparency, traceability, security and cost of implementation and its effect on supply chain efficiency. This aim is to fill the gap by this research analysis and find the scope of implementation of blockchain in supply chain of automotive sector.

Research Questions

1. Does implementation of blockchain enhance data transparency and traceability of products and components in the supply chain of automotive industry?
2. Does blockchain help in the security of the data in the supply chain in the automotive industry?

3. Does cost of implementation of blockchain technology affect the organization's decision in integration of technology in their supply chains?

LITERATURE

Data Transparency in the Supply Chain Management

Bunzendahl (2023) focused on transparency in sustainable purchasing in the automotive industry and identified the transparency and the impact of it on sustainable purchasing using digitalization. Chi-Square test and Pearson correlation coefficient was used for analysis after conducting own survey for data collection and literature review was also used. Expert interviews with industry specialists were conducted to validate the results of the survey. The results suggested that digitalization created transparency which impacted in sustainable purchasing in the automotive industry. It also showed transparency in purchasing can elevate the procurement more sustainably.

Traceability in the Supply Chain Management

Dasaklis et al. (2022) analysed 72 peer-reviewed papers focusing on blockchain traceability and the various implementations of the technology. Descriptive analysis was done with defined steps and content analysis on the articles from 2018- 2021.Analysis gave overview of traceability systems which focused on food, pharmaceuticals, agriculture and electronics. Challenges noticed in the analysis were performance, cost of implementation, maturity of the technology, regulations regarding the data privacy. The research lacked real-life testing and the sustainability goals. Most of the literature focused on testing level implementations using Ethereum and Hyperledger.

Hastig and Sodhi (2020) focused on supply chain traceability systems on blockchain technology and identified business requirements and success factors for implementation. Thematic analysis was done of the literature including usage of blockchain in traceability systems. Compilation of literature was done to measure models on business requirements. Traceability systems displayed curtailing of illegal practices and enhanced sustainability too. Traceability of cobalt mining and pharmaceuticals was focused which prevented illegal practices.

Security of Data in Supply Chain Transactions

Kishnani, Madabhushi, and Das (2023) investigated blockchain's security in oil and gas supply chain by reviewing 124 academic papers and analyzed 21 literatures relevant to blockchain technology. Thematic analysis was done with database search and screening to explore the challenges in oil and gas operations.

Review indicated the security, immutability and privacy in oil and gas supply chain was enhanced by blockchain, thus increasing the efficiency. Challenges included the lack of implementation of blockchain technology in practical applications in the industry.

Karri, Mandapaka, and Pallati (2024) developed a secure product authentication system by using blockchain implementation to undertake anti-counterfeiting measures and integrated dynamic authentication checks for secured and transparent transactions. Challenges in counterfeit products in the e-commerce market were also addressed with the usage of blockchain technology. Ethereum's smart contracts were utilized for product verification and

transparency. The authenticity of the product was verified by the consumer using QR codes. Results showed increased security and mitigation of risks for authenticity and counterfeiting of fraudulent products and empowered consumers to authenticate the legitimacy of the products much more easily. Blockchain can help to combat frauds in healthcare, voting systems, online shopping and even banking due to increased integrity, transparency and security in supply chains.

Patil et al. (2023) detected counterfeit products using blockchain and QR code technology which enhanced security and authenticity in various industries. Distributed Ledger Technology and Smart contracts were formulated to detect counterfeit products. QR codes were integrated in blockchain for authentic verification of products and to enhance ownership tracking. Collaboration and trust were found to be increased in the supply chains and blockchain ensured data authenticity and integrity. It also eliminated the reliance on intermediaries to authenticate the products.

Cost of Implementation of Blockchain in Supply Chain

Zafar et al. (2022b) implemented permissioned blockchain for security of automotive supply chain management and evaluated monetary costs, memory and speed of the system during its execution. Hyper ledger fabric was used for development of distributed ledger platform. The results showed tamper-proof records and secured records in automotive supply chain management. The results showed that monetary cost of implementation was minimum as open-source resources were used, making it economically viable for companies to use and implement. Memory usage was also minimal as 346 MB was only needed for 1 million users making it very efficient.

Chen et al. (2022) analysed adoption of blockchain in global supply chains also considered the transaction cost theory. Data collection in this literature was done by Netnography to evaluate blockchain enabled platform system in Global Value Chain (GVC).

Supply Chain Efficiency

S.Yasmin & Devi (2023) conducted a Likert scale questionnaire based survey among 75 company executives in Indian automobile sector who had knowledge of blockchain to examine the challenges and opportunities of blockchain technology in Indian automotive industry and learnt from the response that there is high acceptance of Blockchain Technology usage in Supply chain integration and Sustainable Supply Chain Performance in Indian Automotive sector both from supplier and customer ends. The study reflected blockchain's ability to enhance supply chain sustainability and efficiency by increasing the coordination. Need for blockchain-based customer services in automotive sector was also highlighted in the literature. Oriekhoe et al. (2024) studied impact of blockchain on supply chains and analysed efficiency, transparency, also the challenges in the adoption of blockchain like the interoperability, doubts on scalability and the regulatory issues.

METHODOLOGY

This study adopted a quantitative research design and primarily made use of surveys to gather data from supply chain professionals mostly from the automotive sector but also was open to

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get data from the professionals from companies who have adopted blockchain in their supply chain.

Quantitative analysis was chosen for the study to understand the perspectives of the supply chain professionals regarding the blockchain technology, the trends and experiences related to usage and adoption of blockchain in the automotive supply chain.

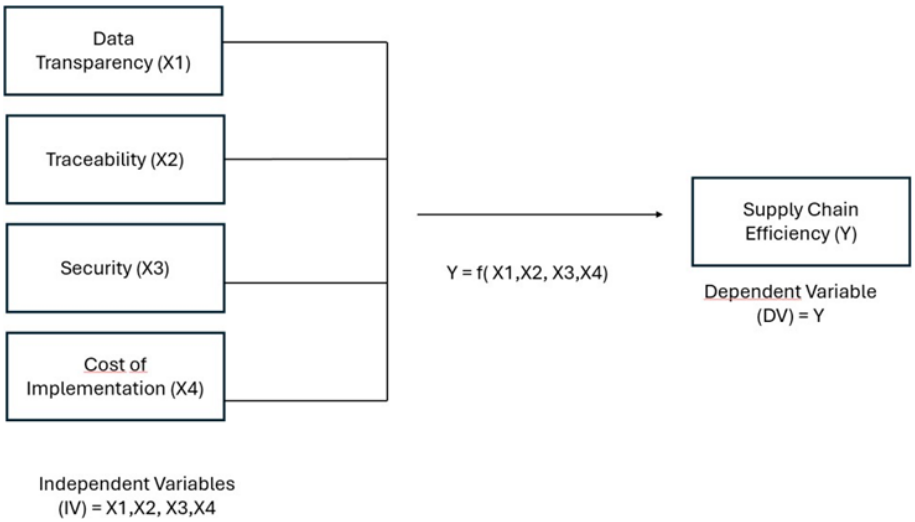

Figure 3.1: Research framework of this study

Figure 3.1 shows 5 variables in our research study, out of which 4 are independent variables and 1 is the dependent variable. The research framework illustrates that supply chain efficiency(Y) using blockchain in automotive industry has a significant relationship with data transparency(X1), traceability(X2), security(X3), cost of implementation(X4). This research study is done to find the relationship between these variables and deduce the results which would give a more meaningful insight into the usage of blockchain in supply chain of automotive industry.

Data Collection

The data collection process involved the distribution of questionnaire carefully among the selected supply chain professionals by constant monitoring and interactions with supply chain professionals with a background or a present in blockchain technology.

Most of them were connected through LinkedIn and had a brief conversation with them regarding the current state of blockchain technology in their respective companies which already gave very valuable insights even before the survey.

The questionnaire was distributed among professionals from BMW, Mercedes Benz, BMW, Volkswagen, Renault, Knorr-Bremse, Henkel etc. Professionals from these organizations and more were very helpful and made sure they gave their inputs to help in the analysis and were curious about the results.

Purposive sampling was done so that the data received had rich knowledge of blockchain and

supply chain which will make the data much stronger for a constructive analysis. The survey questionnaire was circulated to 145 professionals and out of them 100 professionals filled the form. The collection of responses was stopped after hitting the number 100 as the author got the adequate sample size for the analysis. The confidentiality of the respondents was took care of in the survey.

FINDINGS

The findings and analysis give valuable insights regarding the implementation of blockchain in supply chain and the dependency of the independent variables on dependent variables and the contributions of these variables together in achieving supply chain efficiency. The study highlights the different dimensions and challenges in the supply chain and the likeliness of blockchain technology to solve or eliminate the challenges with much better reliability and efficiency. Understanding the demography, the level of implementation of the blockchain in the industries and the opinions of supply chain professionals will give a much better understanding of the status. Along with this the survey, the survey process will help the researcher find out statistical data regarding the topic among the participants. Different analysis will be done in this chapter to evaluate the data set and get the results.

Regression Analysis

For analysis the author has used linear regression analysis. First step in this process was to calculate the average of all the 5 responses to all the questions given in the questionnaire to that single variable by an individual respondent. This was done to every variable and every respondent's average value that we got from the Likert scale of 1-5 is added into a single excel sheet as shown in the Figure 4.1. These average values of responses of each variable were labelled as Data Transparency, Traceability, Security, Cost of implantation which are the four independent variables of the analysis, and the last column was labelled as Supply chain efficiency which was the independent variable of the analysis. The regression analysis was done by use of this cleaned and optimized data sheet for an easy regression analysis

A	B	C	D	E
Data Transparency	Traceability	Security	Cost of implementation	Supply Chain Efficiency
1.6	1.6	2	2	2.4
4	3	4	3	3.6
3.4	3	3.2	3	3.2
5	4.8	5	4.2	4.2
3.4	3.8	2.8	3.4	4.2
3.4	3	2.4	3.6	3.2
3.4	3.6	4	3.2	3.6
4	3.8	3.8	3	3.6
4	3.8	3.6	3	3
5	4	4	2.8	3.6
3	3	3	3	3
4	3.6	4	3.2	3.6
3	3	3	3	3
4	4	4	3	3.4
3	3	3	3	3
4	4	4	2.8	4
3	3	3	3	3
3	3	3	3	3
3	3	3	3	3
3	3	3	3	3
4	3	3	2.8	3.2

Figure 4.1: Excel sheet image of Average of Variables

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SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.806152497
R Square	0.649881849
Adjusted R Square	0.635140032
Standard Error	0.370061592
Observations	100

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	24.14856969	6.037142	44.08424	7.14E-21
Residual	95	13.00983031	0.136946		
Total	99	37.1584			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	0.411383452	0.266853598	1.541607	0.126494	-0.118387922	0.941155	-0.11839	0.941155
Data Transparency	0.081602487	0.096651199	0.844299	0.400624	-0.110274403	0.273479	-0.11027	0.273479
Traceability	0.454791131	0.10982882	4.140909	7.49E-05	0.236753355	0.672829	0.236753	0.672829
Security	0.209084857	0.082161427	2.544806	0.012545	0.045973802	0.372196	0.045974	0.372196
Cost of implementation	0.161741477	0.09484544	1.705316	0.091403	-0.026550528	0.350033	-0.02655	0.350033

Figure 4.2: Excel sheet image of Regression Analysis

The regression analysis was done to find the implications of the four independent variables Data transparency, traceability, security and cost of implementation on dependent variable Supply Chain Efficiency. Regression analysis also helps to find the relationship between the variables and gives support to the research findings. Table 4-1 summarizes the regression statistics and gives output for the different co-efficient.

Table 4.1: Regression Statistics

Regression Statistics	
Multiple R	0.806152
R Square	0.649882
Adjusted R Square	0.63514
Standard Errors	0.370062
Observations	100

Interpretation and significance of each of the co-efficient is done as follows:

Multiple R:

It is a co-relation coefficient which indicates the linear relationship between the predictor variables and the response variables. The range of Multiple R from 0 to 1 indicates the linear relationship with 1 being the perfect linear relationship and 0 indicating no linear relationship. (Bobbitt, 2021) In this analysis, the output value of Multiple R is **0.806** which is closer to 1 show there is strong linear relationship between the independent variables and dependent variables.

R Square:

It is the co-efficient of determination and it is that proportion of variance in the response variable that can be explained by the predictor variable. The range of R-square goes from 0 to 1 in which 0 indicates that response variable cannot be explained by predictor variables at all while 1 indicates that predictor variables can perfectly explain the response variable with no error.

In this regression analysis, the output value of R Square is **0.6498** which indicates that **64.98%** variance in the Supply Chain Efficiency (SCE) can be explained by data transparency, traceability, security and cost of implementation in the supply chain of the organisation.

Adjusted R Square:
It is modified version of R-square which is just adjusted based on number of predictors or independent variables in the model. Value of adjusted R square is always less than R Square. It is useful to compare the fit of regression models which are different to each other.
In this analysis, the output of Adjusted R Square came to **0.6351**

Standard Error of the Regression:
In this analysis, value of standard error is **0.3700** which shows dependent variable Supply Chain Efficiency (SCE) is 0.3700 points away from the regression model based on data transparency, traceability, security and cost of implementation. This indicates that the research study model could be trusted as the error is inclined towards less value.

Observations:
Observations is the total number of observations in the dataset. This analysis is done with **100** respondents which is the number of total observations.

Table 4.2: ANOVA table

ANOVA					
	df	SS	MS	F	Significance F
Regression	4	24.14856969	6.037142	44.08424	7.14E-21
Residual	95	13.00983031	0.136946		
Total	99	37.1584			

Interpretation and significance of the ANOVA table as shown in Table 4-2 is done below as follows

Regression Degrees of Freedom:
It is equal to number of regression variables subtracted by 1. In this research study, there are 5 total variables including independent and dependent variables minus 1. Here the regression degree of freedom is 5-1= **4**.

Total Degrees of Freedom:
It is number of observations minus 1. In this analysis with 100 observations the total degrees of freedom are 100-1=**99**

Residual Degrees of Freedom:
It is calculated by subtracting regression degree of freedom from total degrees of freedom which is 99-4=**95**

Significance F(P-value):
It is one of the most important values in the table. It is important to gauge if the overall regression model is significant. If the p-value is less than the common significance level, then it

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could be stated that the regression model is suitable for data than the model with no independent variables. In this analysis the output shown in table for Significance F is 7.14E-21 which is equal to '**0.000000000000000000000714**'. P-value in this research is significantly lower than common significance level 0.05 which means the regression model is statistically significant and the model fits with the considered independent variables.

Table 4.3: Regression Analysis Results

	Coefficients	Std. error	t-stat	p-value
Intercept	0.4114	0.2669	1.5416	0.1265
Data Transparency	0.0816	0.0967	0.8443	0.4006
Traceability	0.4548	0.1098	4.1409	0.00007
Security	0.2091	0.0822	2.5448	0.0125
Cost of implementation	0.1617	0.0948	1.7053	0.0914

Interpretation and significance of Regression model as shown in Table 4-3 is as follows:

Intercept:
Intercept is a baseline or starting point for dependent variable when the independent variables are set to zero. It helps to understand the impact of independent variables on dependent variables (Southekal, 2024). The value of intercept in this analysis is **0.4114.**

Other two important numbers in the table are '**coefficients'** and '**p-value'** of the independent variables. P-value is also known as probability value. Low P-value indicates high statistical significance. Now coefficients and p-value of each independent variables will be considered for analysis.

Data Transparency:
The coefficient of data transparency is positive but its p-value **0.401** is not that significant**.** This indicates the positive effect of data transparency on supply chain but the value from the data doesn't seem to be that significant.

Traceability:
The coefficient of traceability is positive, and its p-value is **0.00007** which is highly significant. This suggests that if traceability of the products is increased in the supply chain of the industry through adoption or implementation of blockchain than it might lead to elevated levels of supply chain efficiency. This analysis supports traceability as independent variable a very appropriate choice for the research.

Security:
The coefficient of security is positive, and its p-value is **0.0125** which is highly significant. This indicates that there's scope of increased security of data and communication in supply chain with the implementation of blockchain increases. This output of p-value helps in supporting the research and security turns out to be valuable independent variable.

Cost of Implementation:
The coefficient of cost of implementation is positive and its p-value is **0.091** slightly significant

but not that significant as the number is greater than common significance level 0.05. This shows cost of implementation variable doesn't show as much relationship with supply chain efficiency compared to the variable like traceability and security.

Correlation Analysis of Different Variables

Correlation analysis is also done by the author to find the relationship between different independent variables which will also help in the research analysis and might give interesting insights regarding the interdependency of these variables like data transparency, traceability, security and cost of implementation with each other and their relationship with dependent variable supply chain efficiency which has already been discussed in the above section using regression analysis. But this correlation will give more strength to the research analysis. Correlation analysis was done using Excel software and is shown in Figure 4.3 below. Correlation coefficient ranges from -1 to 1, 1 means a perfect positive correlation and -1 means perfect negative correlation and 0 means no correlation between the variables.

	Data Transparency	*Traceability*	*Security*	*Cost of implementation*	*Supply Chain Efficiency*
Data Transparency	1				
Traceability	0.792024928	1			
Security	0.685568189	0.718379073	1		
Cost of implementation	0.474735374	0.539022934	0.56619609	1	
Supply Chain Efficiency	0.67515633	0.768009713	0.701878081	0.552953387	1

Figure 4.3: Excel file of Correlation analysis

Noticeable and significant correlation variables are analysed from the Figure 4.3 are highlighted

Table 4.4: Correlation between Data Transparency and Traceability

	Data Transparency	Traceability
Data Transparency	1	
Traceability	0.792024928	1

From table 4.4, the independent variables of data transparency and traceability has a strong positive correlation indicating that with the increase of data transparency there is proportional increase of traceability in the supply chain when blockchain is implemented. The scatter plot in Figure 4.4 also supports the above results.

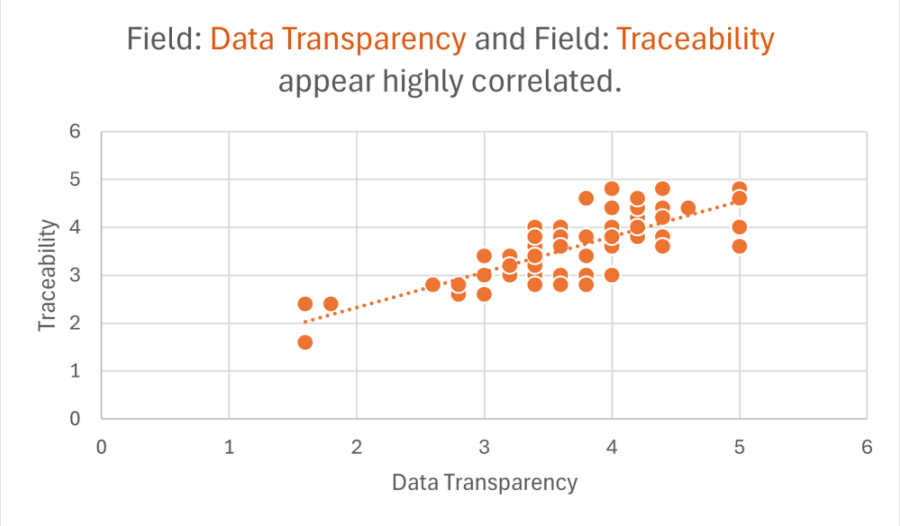

Figure 4.4: Scatter Plot: Data Transparency vs Traceability

Table 4.5: Correlation between Traceability and Security

	Traceability	Security
Traceability	1	
Security	0.718379073	1

From table 4.5, the independent variables of traceability and security has a strong positive correlation indicating that with increase in security of data and communication, traceability of goods and commodities in supply chain will increase proportionally with the implementation of blockchain. From Figure 4.3 it is also clear how supply chain efficiency (dependent variable) has strong positive correlation with independent variables of data transparency, traceability and security while it has comparatively less positive correlation with cost of implementation. This suggests how blockchain enhances data transparency, traceability and security of the supply chain and makes it efficient in the long run irrespective of the initial implementation costs.

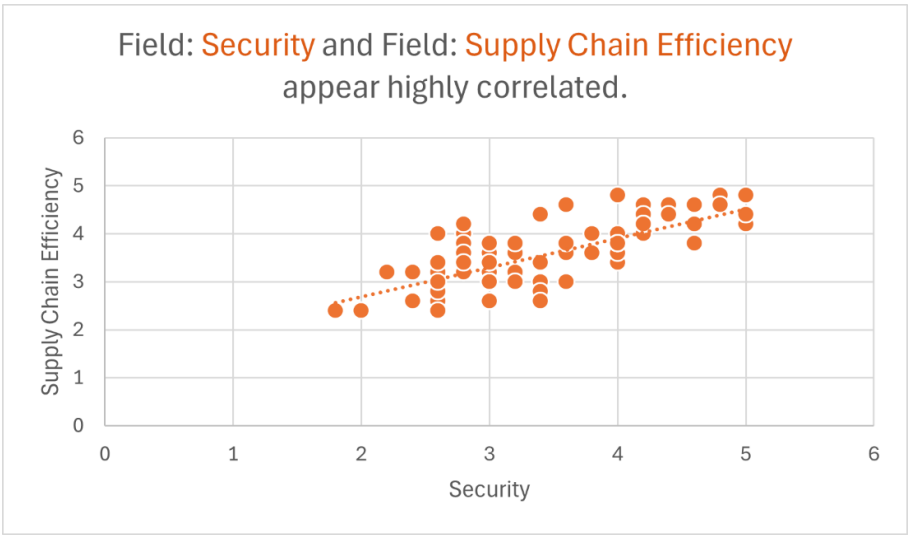

Figure 4.5: Scatter Plot: Security vs Supply Chain Efficiency

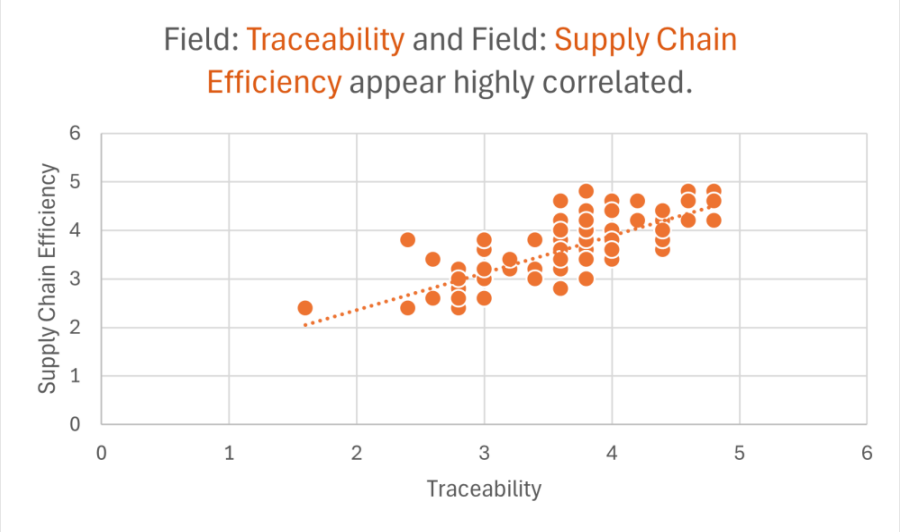

Figure 4.6 Scatter Plot: Traceability vs Supply Chain Efficiency

Scatterplot graphs in figure 4.5 and figure 4.6 shows the high correlation of Supply chain efficiency with security and traceability. These graphs also act as basis and evidence to answer the research questions.

CONCLUSION

Blockchain technology is in the process of continuous adoption by various industries now and automotive industry is one of the most crucial benefactors of this technology advancement. Automotive industry is also in a transitional phase with the increased number of electric vehicles manufacturing year by year which leads to more expansion of supply chain and the need for more resilient and efficient supply chain.

Digital Transformation is what everyone is striving for in every industry and the one who jumps into it first always has the upper hand with the optimization that these technology offers. This research has identified the core challenges of supply chain in the automotive industry and has researched on key factors like data transparency, traceability, security and cost of the implementation collectively to measure its impact on supply chain efficiency in the automotive industry.

The research involved analysis by quantitative methods by taking real time data and from professionals who are in the center of blockchain transition. Many of the companies have conducted their pilot tests for a year and two. This was identified because of the interaction with supply chain professionals who were ready to take part in the analysis.

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