# Chaos Theory in Supply Chain and Inventory Management of Automobile Industry

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***Abstract*-** We live in a volatile environment, where firms and various organisations thrive for survival. Firms rely on technology, product innovation to compete in an uncertain environment. Firms which do not adapt to changes are more likely to face higher risks in terms of growth. Core sectors such as manufacturing firms, FMCG firms, Consumer electronics depend on supply chain for sustainability. Firms which face uncertain environment are more likely to face supply chain disruptions. The COVID-19 pandemic, 2008 Financial crisis, Suez Canal-2020 crisis have exposed the vulnerability of various firms. Hence it becomes necessary to leverage technological tools as well as innovation to improve supply chain as well as reduction of losses during uncertainties. In this work we have studied and analysed various models for supply chain in automobile sector. The model examines the most important variables during extreme uncertainties like the COVID -19 pandemic. It also studies the seasonality, trend for a 10 year period time line of data. Our research helps the supply chain identify certain gaps prevalent in the most vulnerable times of any economy.

***Index Terms*-** Chaos Theory, Supply Chain Management, Research Design

## 1. INTRODUCTION

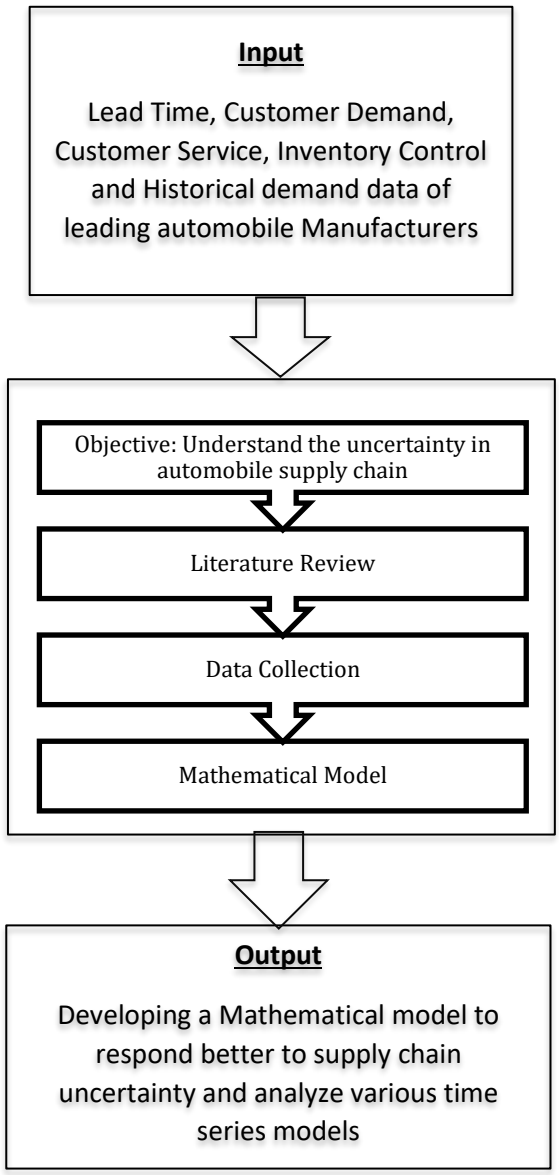
Today's market has become a very competitive place also known as VUCA environment. It is as volatile and uncertain as it ever was. However, trade-offs between pricing, labour cost, inventory carry cost and transportation cost has become even more complex (Sharma, 1997). It is now found out that the success of an organisation is dependent on the performance of another organisation, thus resulting in a collaborative environment (Richard Wilding,1998). Hence supply chain has emerged as one of the competitive.
Driving associations are starting to move from a firm against firm business methodology to a gracefully chain against flexibly chain methodology (Bowersox et al., 2003) elevating the significance of powerful gracefully chain the board. As a result, gracefully chains are getting exceptionally mind boggling and their executives exceptionally troublesome and testing (Hakansson and Snehota, 1995). One key quality that appears to separate the most proficient gracefully chain networks from their less profitable partners is the union connections what's more, collective nature of the effective organizations (MacBeth, 2002).

The research problem includes Studying a set of uncertainties in supply chains caused by factors such as Customer demand, Service, Inventory control policy and forecasting, and Lead time, Environmental factors and studying the trends and seasonality associated with each mathematical model

**Developing the Research Framework**

It has the following variables of interest:

- Lead Time
- Customer Demand
- Customer Service
- Inventory Control (Forecasting)



Lead time is the time to order, handle, manufacture and deliver the final product. The focus is to reduce the lead time because increased lead times lead to bullwhip effect. Inventory Control is preventing stock out and maintaining economic balance between the costs incurred and the costs saved by holding the material in stock. Understanding the fluctuations in Customer demand is important (constant, seasonal demand, trends) and is essential to understand uncertainty and reduce costs such as inventory costs. Customer service is everywhere along the supply chain. It affects when products are sold to the customer and when products are delivered. The general understanding is that better customer service leads to retention of customers and even promotions by customers leading to better demand. This also leads to increase in uncertainty across the supply chain.

Understanding the automobile industry and supply chains, trends, collection and analysis of data are the steps to develop a mathematical model to understand uncertainty. Eliminating uncertainty is not possible but the model will help understand how to respond better to the uncertainty in the supply chain.

**Research Objective:**

Studying a set of uncertainties in supply chains caused by factors such as Customer Demand, Service, Inventory control policy and forecasting, and Lead time, and studying the trends and seasonality associated with each mathematical model

**Literature Reviews:**

To expand the base of supply chain knowledge Chaos Theory Principles are applied to certain Supply Chain functions. The Chaos Theory principles are used in examining forecasting, product design and inventory management challenges faced by supply chain practioners. Chaos Theory provides valuable insights for effective management of inventory and it helps understand Supply Chain ambiguity. The inventory management structure is mapped to the related Chaos Theory Principles. [ Drew Stapleton Joe B. Hanna Jonathan R. Ross]

The systems used within the supply chain lead to oscillations and uncertainties and further lead to buffer. Inventory Management and Supply Chain display some of the key characteristics of the Chaotic System which generates patterns, invalidates the reductionist view and undermines computer accuracy. The characteristics are mapped to Inventory management to stimulate some of the effects. [Richard D. Wilding]

Logistics and Inventory systems have episodes of Chaotic behaviour studying the non-linearity. The Chaos Theory in Logistics and Inventory Management involves concepts of attractor, bifurcation, fractal, fluctuation and it suggests that the future can't be learn by studying about the past too much because if History is the sum of complex and nonlinear interactions among people and nations then it does not repeat itself. [Andrzej Rzeczycki]

Variability in orders or inventories in supply chain systems is generally thought to be caused by exogenous random factors such as uncertainties in customer demand or lead time. The Inventory and supply chain dynamics are observed under various conditions such as demand pattern, ordering policy, demand-information sharing, and lead time. The degree of system chaos is quantified using the Lyapunov exponent across all levels and it is characterized by using classical beer distribution model with some modifications in it. [H. Brian Hwarng, Na Xie]

Several researchers have developed a framework to sustain the supply chain system of a firm.(Hau Lee) from the California Review Management has developed a framework model which includes both demand uncertainty and supply uncertainty as a variable. The research also includes the study of the bullwhip effect in a supply chain for a chocolate and nut company (Nabisco and Wegmen). The bull whip effect was carried out at Barilla's Distribution Centre. After several simulations and theoretical frameworks, several conclusions were made.

The fact being that with innovation, there lies a danger of disruption in the supply chain, thus a drawback of increased operational costs. Products with shorter life cycle adds pressure to the already dynamical supply chain system.

(Drew Stapleton et al.) Have made significant theoretical research in the field of supply chain systems. The researchers have tried to explain linkage between chaos theory and supply chain management. The researchers have defined chaos theory as 'Chaos theory is an explanation of the behaviour of a system that can be described by nonlinear equations where the output of one calculation is taken as the input of the next.' The paper addresses the various elements which affect the supply chain system like rapid development and implementation of technological advancements, globalization of markets and competition, and aggressive and sometimes risky competitive strategies. Government policies like tax rates, import tariffs and reserved economy , opening up adds uncertainty to the whole system. However, the research paper has introduced an interesting variable which is the product design. It is stated that , under chaos theory the product design proves to be a very crucial variable in the system. It goes by the logic that for a specified product, the customer demand forecasts are accurate, thus making easier predictions and lowering the inventory level.

(Richard Wilding, 1998) has managed to model the randomness in a supply chain system. The research paper analyses three new variables namely, Deterministic chaos, parallel interaction and amplification. The research involves algorithms to study the forecasting of demands, optimum inventory cover level in a limited period of time. The researchers have emphasized on the interaction between the suppliers and manufacturers. The interaction has been measured by calculating the percentage of time the company or assembler would be stopped due to the interactions. The increased variability between the forecast and actual demand results in both suppliers and the assembler experiencing increased stoppages due to interactions. The 2nd variable being the demand amplification stresses on the bullwhip effect. Thus the author stresses on the need for batch processing, rationing the storage and dynamic iterative forecasting. The research concludes by stating that long term forecasting may not be useful, since the market never achieves the equilibrium state(constant demand), hence leading to systematica disturbance in the system.

Further (L.F. Escudero et al.) have developed a mathematical framework model for optimization of a manufacturing, assembly and distribution supply chain. The focus point on being automotive sector but not limiting to itself. Several mathematical operations have been used to reduce the problem's dimensions. It works on the approach that supply chain systems have a high degree of sensitivity towards initial conditions. Hence a model is developed to assess initial constraints and then a generalised model for the rest of the time period. It considers time period based analysis. Four variables time period, service level, cost and stochastic parameter(uncontrollable variables) have been used. It works on the quantative techniques of minimizing the cost while maintaining the operational efficiency. A separate average time from the model is deducted where policy are issued by the governments thus reducing sensitivity of the supply chain and increasing the efficiency.

(Chunxiang Guo et al.) have analysed the effect of supply chain system of automobile sector in China because of macro-economic variables. It heavily emphasis on building a network model on the definition on robustness. The main objective of the research paper is to build the right network of supply chain in order to optimize the cost and be prepared when an uncertainty rises. A network system was built based on several assumptions like the flowrate of the components was constant, the places of manufacturing sites were fixed. The model will be built on scale and the capacity of warehouses, optimal selling network, which had all customer demand satisfied. . The aim of the study lied in determining optimal channel structure and taking uncertain parameters into account.

Rohit Kumar Singh and Sachin Modgil in their paper on "Assessment of Lean Supply Chain Practices in Indian Automotive Industry"have conducted a study with the purpose of exploring the effect of lean practices on performance measures in automotive industry and identify the lean criteria that can have significant impact on automotive supply chain. The identified lean practices can serve as a template to enhance the performance of a supply chain. The present study offers a multi-criteria decision-making approach to identify the effective performance practices in automotive lean supply chain. The decision-making trial and evaluation laboratory (DEMATEL) was applied on a matrix of observed values and the actual effect of proposed practices was observed. Further it was confirmed with the help of fuzzy-Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR; that means multicriteria optimization and compromise solution, with pronunciation). The criteria which had the most impact are proposed for achieving the future goals of leanness. It was found that among the lean criteria considered, quality management, information management and customer management practices influence the key performance measures more than others. Although DEMATEL and fuzzy-VIKOR were applied for situation leading to setting up of priorities of factors that considered affecting automotive manufacturer, the proposed methodology can be applied in diverse industrial settings. The present study may help decision-makers to device the appropriate strategy in identifying major practices that influence the lean supply chain.

Krasimir Markov and Pavel Vitliemov wrote "Logistics 4.0 and supply chain 4.0 in the automotive industry". They explored the Industry 4.0 technologies. They provide real benefits to the plants where they are implemented such as performance improvement, costs and delays reductions. The automotive plants are among the factories that could implement most of these technologies. Industry 4.0 can affect all of the processes which happen in the automotive industry manufacturing plants – engineering, production, logistics, management, etc. Analysis of all of the processes in one article is too complex task and due to this the paper is focused only on logistics and supply chain. The aim of this article is to investigate the potential possibilities for implementation of Logistics 4.0 and Supply Chain 4.0 in the automotive industry plants, in particular in Bulgaria. It consists of two groups with proposals and assumptions. The survey was conducted by 12 automotive industry logistics experts who are on 6 different logistics positions. The results show that the production visibility (assembly lines connected to internet) and blockchain technologies have the biggest values to the logistics and supply chain. But the cybersecurity and faulty data are the main challenges in front of them.

Authors A. Chandak , S. Chandak and A. DalpatiDespite co-wrote "Analysis of the Impact of Supply Chain Flexibility on Supply Chain Performance: An Empirical Study in the Indian Automotive Industry". They researched the fact that intensive research has been done in supply chain management (SCM) a little research has been done so far in which this issue is discussed with respect to a single sector in India. This research in the field of supply chain management is mainly concentrating on the impact of supply chain flexibility (SCF) on supply chain performance (SCP). This research is an attempt to bridges the gap and deficiency on the research done previously in this issue and particularly about the relationship between supply chain flexibility dimensions on supply chain performance. Hence, the first and foremost objective of this study is to find how supply chain flexibility (SCF) dimensions are related to supply chain performance (SCP) dimensions. Furthermore, efficient and effective supply chain flexibility is directly related to improving supply chain performance. This research is mainly concentrated on Indian automobile industry which is in current scenario one of the fasted growing and one of the major contributors of GDP growth in India. The researchers find the type of relationship of supply chain flexibility dimensions with supply chain performance dimensions. This research is based on research done by Fantazy et al. (2009), in his research he suggested that further investigation can be made on his research in a different geographical region. To widen understanding on this topic and to go after the recommendation of the preceding research, this research closely related to Fantazy et al. (2009), and this research is done on the Indian automotive industries which in the current situation have much importance.

Model is built to simulate the dynamic evolution of consumption-driving supply chain system of automobile industry (Jun-yan Sun, Wei-ping Fu, Wen Wang, Dan Yao) on the geographic information system (GIS) map using agent based model (ABM) and discrete event modelling method.

For the construction of the model-the GIS map is introduced to show the dynamic evolution of the supply chain. By establishing using a hybrid modelling method combining the

ABM with the discrete event modelling method, the model reflects the operating processes of all agents in the microcosmic level so as to preferably present the overall procedure of the supply chain. By building the information agents and environment agents, information is exchanged among all agents so as to preferably reflect the information flow and environmental factors of the supply chain. This simulation model lays a foundation for studying the evolutionary and emergence mechanisms of the supply chain.

To verify the model is correct and reasonable, the sale volumes of all agents are analysed and the changes and mutual relationships of main parameters of all agent nodes. These main parameters include the sale volumes, orders, inventories (finished inventory and parts inventory), in transit inventory and WIP. As for the simulation analysis, the simulation model is analysed from two perspectives: the complex network and the CAS. The authors discuss the simulation process in the macrocosmic and microcosmic levels. From the complex network perspective, the supply chain network displays the scale-free and small-world characteristics and the distribution of node degrees coincides with the power-law distribution by analysing the relationships among nodes in the supply chain network. In addition, by analysing the power spectra, the phase spaces and Lyapunov exponents of distributors and manufacturers, it proves that the supply chain is in the chaotic motion. Besides, the supply chain belongs to a nonlinear dynamic system with the typical nonlinear characteristics of CAS. To overcome the shortcomings of the model, the following works are expected to be carried out in the future: the model shows the functions in the departments including demand, purchasing, production and inventory, while it does not establish corresponding agents for the functions. Apart from considering the consumers purchasing behaviour the influence of macroeconomic, microeconomic and policy factors.

The main purpose of the research (Tunay Aslan) is to investigate nonlinear dynamics in bullwhip effect and search chaotic behaviour. In the paper, a generalized supply chain model is simulated with safety stock regulations to expose the bullwhip effect. A seasonal demand model which fits Poisson distribution is utilized to generate orders from customers to retailers, continuously to distributors and a single factory. Using largest Lyapunov exponent analysis, orders are reconstructed in phase space and investigated chaotic behaviour variations. It is assumed that increasing fluctuations of demand cause chaos and unpredictability, it is seen that predictability increases in bullwhip effect. In chaotic research aspect, demands from customers are still more chaotic than orders reach to the factory. This paper provides a novel approach to supply chains with comparing dynamics of demands and orders to identify which exhibits more chaotic behavior. It presents a supply chain model and seasonal Poisson data generation in this paper. As results of the simulations reached bullwhip effect and searched whether the bullwhip exhibit chaotic behavior. Hence largest Lyapunov exponent is numerical indicator of chaos presence, by the method of phase space reconstruction, after calculating the embedding dimension and delay, analysis of the largest Lyapunov exponents of supply chain orders. Simulation results prove that chaotic behaviour of the system decreases while moving on supply chain from retailers to factory. Largest Lyapunov exponents differ significantly after 3650 days of iterations and 10 repetitions. Generated seasonal retailer's demand data has more unpredictability and chaotic behaviour while it has less fluctuation. Orders to distributors and to factory lead the system to behave less chaotic while more frequent and amplified oscillations are taking place.

Supply chains are dynamic that is there exists uncertainties such as demand uncertainty, production uncertainty, lead time uncertainty. A system of chaos is often characterized by a number of distinct features like non randomness and nonlinearity, sensitivity to initial conditions - a small change in initial conditions can have a large effect on the evolution of the system. In this paper, we are presented with the model of retailers demand (Junhai Ma and Yun Feng). In simulation of the interaction, the behaviour of the system exhibits deterministic chaos with consideration to system constraints. Space-reconstructed method - this paper calculates the minimum embedding dimension and the maximal Lyapunov exponent of retailer's demand model. The result shows that the model is chaotic. Because of the simulation, the model exhibits different behaviours as the initial condition varies. The system keeps disturbed all the time by various factors and the disturbance could be amplified in this way. The simulation model discussed in this paper can inflect that the real supply chain is much more complex and its behaviour is much more complicated.

Supply chain of Indonesian Automotive Industry can be described from the component product industry as a supplier to consumer. Single Agent Brand in the supply chain automotive industry is a tier that has a dominant effect on supply chain automotive activities, so the wrong strategy selection in this tier can deliver a fatal effect on the majority tier of the supply chain automotive industry. This strategy can result in a violation of Indonesian law regulation. One of strategy that is likely to conflict with law regulation in Indonesia is a vertical restraint. This article (Levinia Dian Laraswati, Rina Wiji Astuti, Murman Budijanto, Yuniaristanto, Wahyudi Sutopo) discussed the evaluation of supply chain business strategy related to the indication of vertical restraint based on dealer and customer point of views. The result of this research proves that there are vertical restraints based on evaluation of resale price maintenance, territorial restriction, tying, and exclusive dealing, increase in competition condition has led to a variety of vertical restraint which allows the emergence of unfair competition in the Indonesian Automotive Industry. Vertical restraint itself is a contract made in a form of incorporation of linked companies to restrict competition in the field of business or industry. There are four kinds of vertical restraint in Indonesian regulation, such as Resale Price Maintenance, Exclusive Dealing, Tying, and Territorial Restriction. There is indication for all vertical restraints but only two vertical restraints that perceived consumer's disadvantage - territorial restriction and exclusive dealing. The price of the product, dealers' afterdemand service, dealer's location and dealer's

quality of service are as some factors that influence consumers in determining the car in the first purchase. There are some effects of vertical restraint strategy on consumer's behaviour that is complicate the customer's mind, provides benefits and convenience for consumers who want to purchase a car and makes it difficult for the consumers to compare the prices and product quality. Mapping study of regulatory issues and barriers to enter into the existing industry are needed as future research to capture an integrative supply chain analysis.

(SCM global corp) in their research have mentioned that the supply chain system is highly non linear system. It states that the supply chain are sensitive to initial conditions. It stresses on the butterfly effect has a huge impact on the system. A combinations of attractors(dependent variables) and constraint optimization would lead to near equilibrium, even if minor changes are induced in the system. They have explained the whole system through Lorenz equation stating that the constraints would meet at a single point which denotes the optimum value of the each constraint.

## METHODOLOGY

### Description of Research Design and Procedures Used

For Our Research Methodology, we are taking a qualitative approach. This method is not only about "what" people think but also "why" they think so. Qualitative research methods are designed in a manner that help reveal the behaviour and perception of a target audience with reference to a particular topic. There are different types of qualitative research methods like an in-depth interview, focus groups, ethnographic research, content analysis, case study research that are usually used. The results of qualitative methods are more descriptive and the inferences can be drawn quite easily from the data that is obtained.

### Sources of Data

Our preferred method for data collection is Secondary Research. Secondary research includes research material published in research reports and similar documents. These documents can be made available by public libraries, websites, data obtained from already filled in surveys etc. Some government and non-government agencies also store data that can be used for research purposes and can be retrieved from them. Secondary research is much more cost-effective than primary research, as it makes use of already existing data, unlike primary research where data is collected first hand by organizations or businesses or they can employ a third party to collect data on their behalf. Secondary sources will be put into use to collect the data from Automobile industries based on the factors to determine their uncertainty.

### Sampling Procedures

Database Selection and the First Search Phase: The Websites such as Researchgate, Strategic Management Journal, The Journal of Industrial Economics, Industrial Engineering Journal, and Global Business Review were used to select a list of papers to be studied for the Literature Review. The title, abstract, and keywords in the websites were used to search for the defined keywords. In this step of our literature search, 20 - 25 papers were identified that fit into our profile. From which 18 papers were selected for the Literature Review.

### Defining Sampling Framework and Identifying Research Designs

Sampling Procedure: We have chosen to employ Likert Scale to measure the attitudes of the responses that we receive for our circulated questionnaire. A Likert scale assumes that the intensity/strength of an attitude is linear, i.e. on a continuum from strongly disagree to strongly agree, and makes the assumption that attitudes can be measured.

We have compiled a questionnaire that determines the importance variables that are responsible for determining uncertainties present in the supply chain. We have circulated the questionnaire among industry professionals in various companies.

### Data Collection

We have developed a questionnaire for the research paper. The focus of this survey is to collect data regarding the variables of interest in determining the uncertainty in supply chains. For developing the questionnaire, we had to understand the variables associated with uncertainty in supply chains. The major variables of interest – Supplier uncertainties and risks the objective is to understand whether the organisation relies on few dependable suppliers and certifies them for quality an organisation includes its key suppliers in its planning and goal setting activities (forecasting and production planning)

### Data Analysis

The data will be collected based on the questionnaire circulated to organizations. The likert scale has been used for preparing the questionnaire and the qualitative data will be collected based on the responses.

Type of data – primary data (data will be taken based on the responses from members actively involved in the supply chain).

### Methods for Analysis –

Ranking and Multi Criteria Analysis: Multicriteria analysis (MCA) may be a family of methods commonly implemented by decision support systems (DSS) to match alternative courses of action on the idea of multiple factors, and to spot the simplest performing solution. These methods include techniques to structure the choice problems, improve transparency, enhance result and visualisation, etc. A characteristic feature of multicriteria approaches is that the evaluation is predicated on variety of explicitly formulated criteria, i.e., 'standard of judging', that provide indications on the performance of the alternatives with reference to variety of objectives. The standards, which are typically represented by considerable mutual difference in nature, are expressed by appropriate units of measurement. The character of MCA makes it particularly suitable for decision problems in impact assessment and sustainability appraisal. This sort of decision

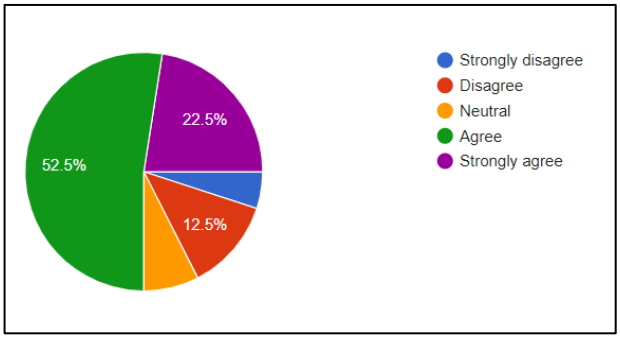
problems involves multiple objectives and multiple criteria, which are typically noncommensurable and sometimes conflicting. Accuracy and Validity of Data: Once we have gathered enough responses we will determine the accuracy and the validity of the data.

## 2. ANALYSIS

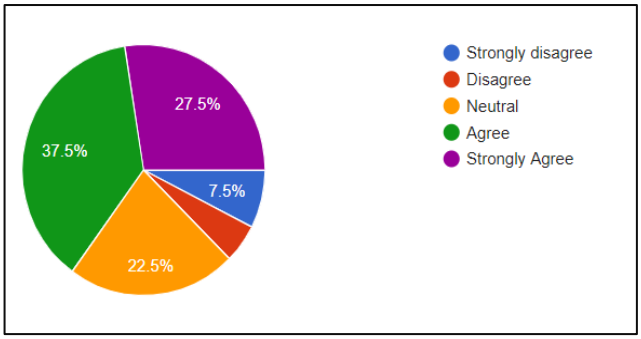
We performed a Survey Analysis whose results are shown below:

**Logistic uncertainties and risks (LUR)**

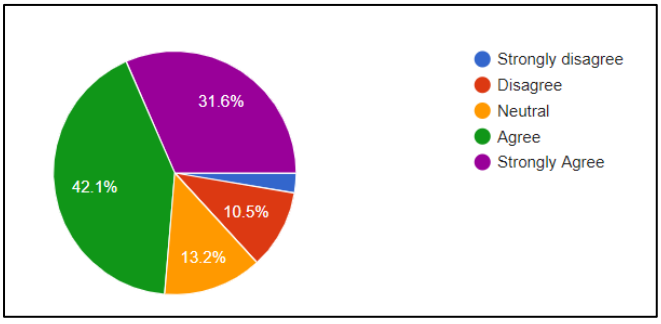
1. (LUR) Your organisation relies on few dependable suppliers and certifies them for quality




2. Your organisation includes its key suppliers in its planning and goal setting activities

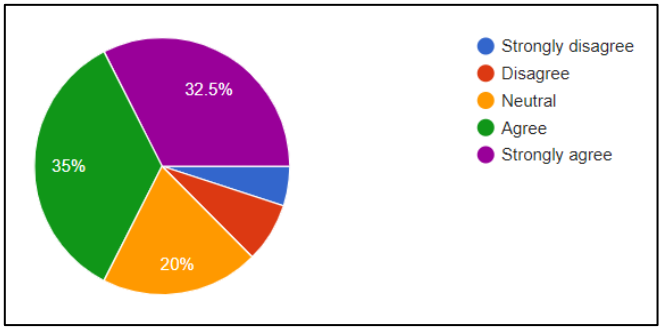



3. (LUR-2)Your organisation pushes suppliers for shorter lead times

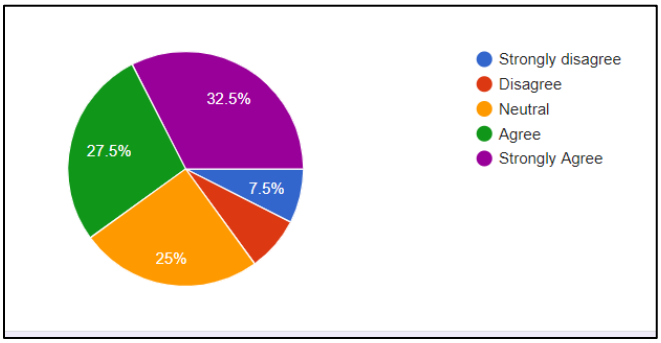



**Information uncertainties and risks (IUR)**

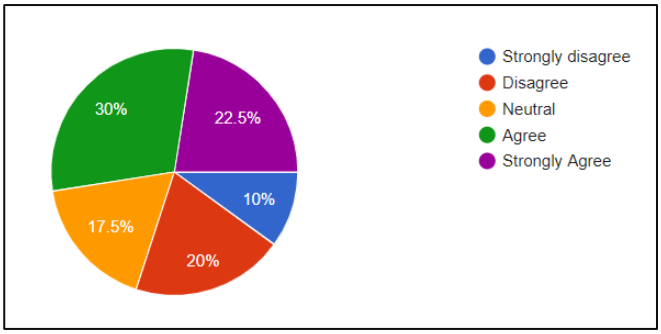
4. (IUR) Your organisation and its trading partners exchange information that helps establishment of business planning



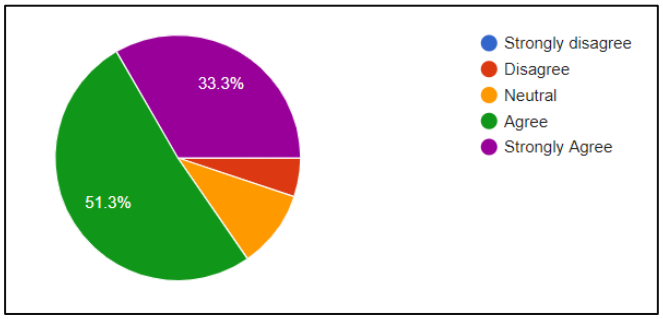

5. (IUR-1)Your organisation and its trading partners keep each other informed about events or changes across the supply chain that may affect the other partners




6. (IUR-2)Our supply chain members share research and development costs and results with each other

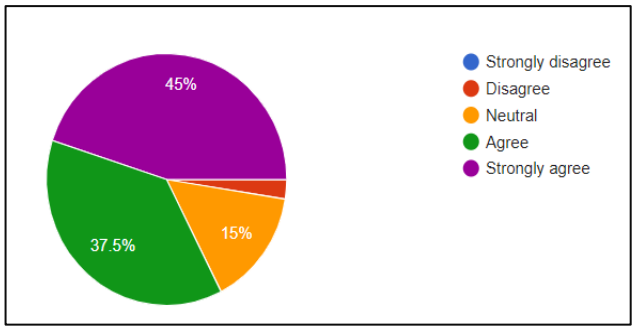



7. (IUR-3) Firms in our supply chain create a compatible communication and information system



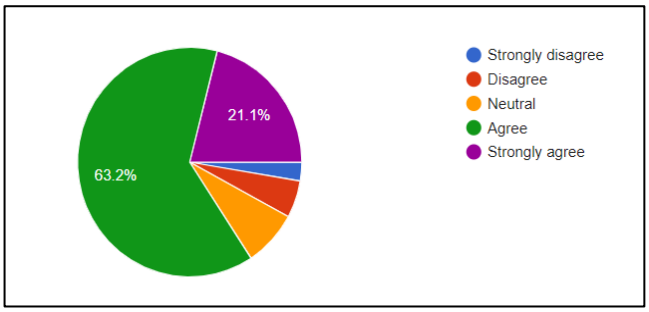

**Customer uncertainties and risks (CUR)**

8. (CUR) Your organisation has frequent follow-up with its customers for quality/service feedback

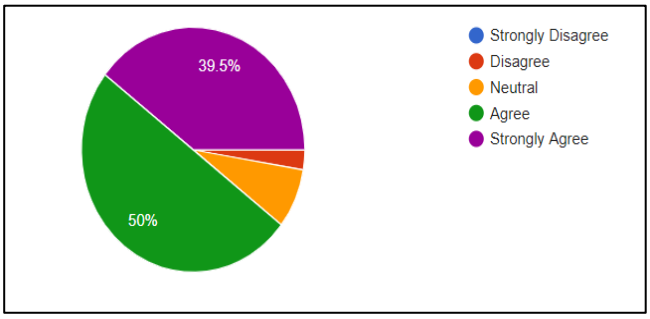



**Environment uncertainties and risks (EUR)**

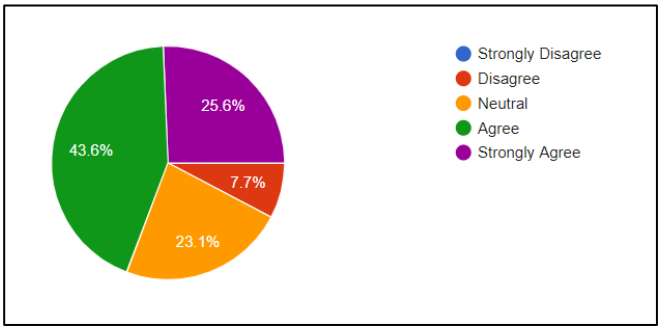
9. (EUR-1) Your organization has the ability to respond to and accommodate the periods of poor manufacturing performance (machine breakdown) and poor delivery performance




10. (EUR-1) Your organization has the ability to respond to and accommodate demand variations such as seasonality

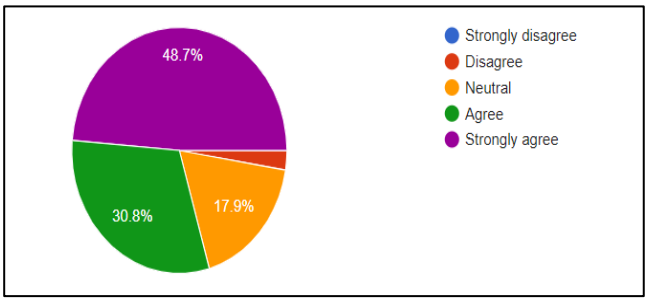



11. (EUR-2)The inventory acts as a buffer against uncertainty in the supply chain

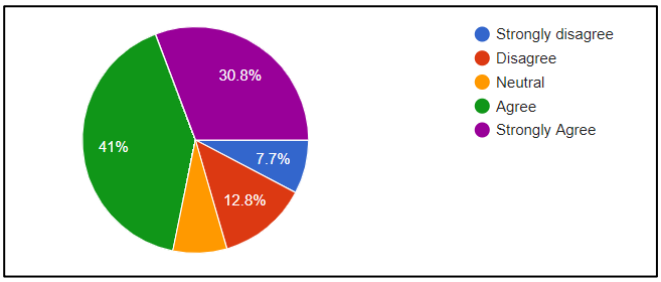



**Organization and Location** (OL)

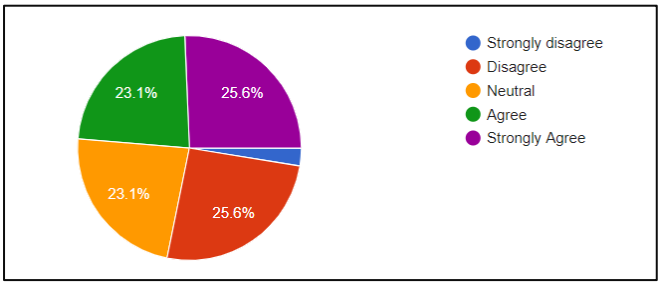
12. (OL) Your organisation has continuous quality improvement programs



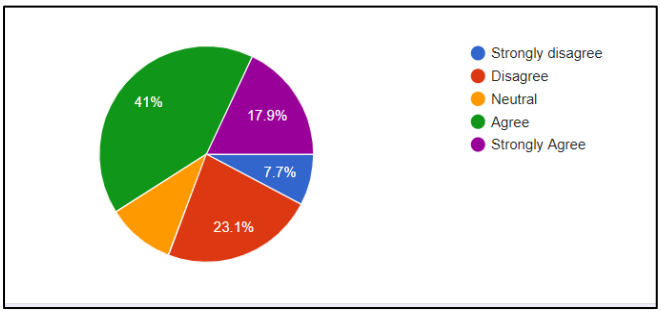

13. (OL-1) Your organisation produces only what has been ordered by customers (pull production system)



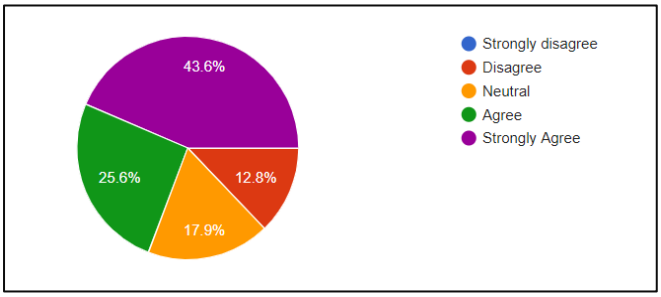

14. (OL-2) Your organisation's production process modules can be rearranged so that customization can be carried out later at distribution centres




15. (OL-3) Your organisation delays final product assembly activities until customer orders have actually been received




16. (OL-4) Your organisation's goods are stored at appropriate distribution points close to customers in the supply chain




We collected a total of 113 responses from our survey (responses collected from industry professionals actively involved in the supply chain)

**Regression Analysis:**

Using the data accumulated by the Questionnaire through the survey, we collected data in the form of Likert scale. Which was then converted to a numeric metric for proper analysis. The conversion was:

1- Strongly Agree

5- Strongly Disagree

Using this conversion scale, the data was loaded from an excel sheet to python for further regression analysis. This data is then divided into X data variables consisting of all the question variables except EUR2 which is the Y data variable. The data is trained using train_test_split from sklearn.model_selection library. Regression is then performed on this data using LinearRegression() from sklearn by importing linear_model. The model is then fit and the coefficients are found. Our variance value or R-squared coefficient is 0.69. Using regression analysis, it was possible to set up a predictive model using the X data variables of the survey that explain 69% of the variance in Y data variable. For reference the image is attached below.

| SUMMARY OUTPUT | |
|---|---|
| | |
| Regression Statistics | |
| Multiple R | 0.836165 |
| R Square | 0.699172 |
| Adjusted R Square | 0.644805 |
| Standard Error | 0.518171 |
| Observations | 99 |

| | Coefficien | Standard Error | t Stat | P-value |
|---|---|---|---|---|
| Intercept | 1.977403 | 0.646238767 | 3.059864 | 0.002982 |
| LUR | -0.08169 | 0.063076311 | -1.29516 | 0.198857 |
| LUR | 0.118713 | 0.090509842 | 1.311606 | 0.19327 |
| LUR | 0.362828 | 0.081855592 | 4.432535 | 2.83E-05 |
| CUR | 0.323766 | 0.10658207 | 3.037711 | 0.003186 |
| IUR | -0.02851 | 0.07575991 | -0.37634 | 0.707621 |
| IUR | -0.27581 | 0.095632409 | -2.8841 | 0.004999 |
| IUR | 0.448619 | 0.076973381 | 5.828233 | 1.03E-07 |
| IUR | -0.04413 | 0.118741626 | -0.37161 | 0.711128 |
| OL | -0.2608 | 0.09524953 | -2.73805 | 0.007561 |
| OL | 0.120293 | 0.09614093 | 1.251217 | 0.214371 |
| OL | 0.101434 | 0.052562236 | 1.92979 | 0.057049 |
| OL | 0.019173 | 0.068960463 | 0.278036 | 0.781676 |
| OL | -0.87038 | 0.108623509 | -8.01279 | 6.14E-12 |
| EUR | 0.007003 | 0.119917759 | 0.0584 | 0.953571 |
| EUR | 0.57787 | 0.079486134 | 7.270077 | 1.81E-10 |

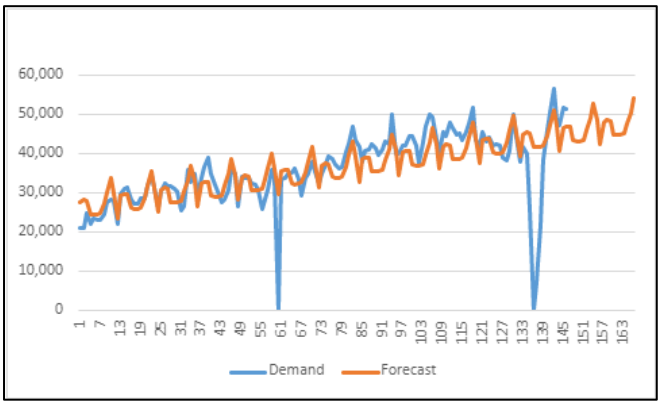
| ANOVA | | | | | |
|---|---|---|---|---|---|
| | df | SS | MS | F | Significance F |
| Regression | 15 | 51.79520455 | 3.453014 | 12.86033 | 7.18E-16 |
| Residual | 83 | 22.28560353 | 0.268501 | | |
| Total | 98 | 74.08080808 | | | |

**Automobile demand Data (2009-2021)**

We acquired the automobile demand data for the years 2009-2021 from the company website. Our next step is the analysis. We applied forecasting models to the acquired data, forecasted the future demand and chose the best and accurate model (model which has the least sum of squared errors). To forecast the demand, it is essential to understand the trends (upward or downward) and seasonal aspects that are associated with the product (automobiles). We will be using moving averages and time series analysis to smooth out seasonal data and better understand the trend and seasonality characteristics of the given data. If per period growth is independent of the current demand value, the additive trend model will outperform the multiplicative trend model. If per period growth is an increasing function of current demand, the multiplicative trend model will probably outperform the additive trend model.

**Forecasting Techniques:**

1. Additive Modelling




| | A | B | C |
|---|---|---|---|
| Base | | 26399.15 | |
| Trend | | 131.3137 | |
| | | | |
| | | | |
| | 1 | 1142.717 | |
| | 2 | 1516.711 | |
| | 3 | 1223.702 | |
| | 4 | -2294.86 | |
| | 5 | -2614.43 | |
| | 6 | -2709.91 | |
| | 7 | -2495.64 | |
| | 8 | -231.283 | |
| | 9 | 2580.987 | |
| | 10 | 6205.256 | |
| | 11 | 2096.776 | |
| | 12 | -4420.04 | |
| | | | |
| Mean | | 0 | |

To calculate the forecasted(predicted) demand - Base + Trend*Period Number + Seasonal Index for month

Base - The base is the best estimate of the level (without seasonality) of monthly automobile demand at the beginning of the observed time period (1st January 2009). Base = 26399.15017

Trend - The trend is the best estimate of the monthly rate of increase in automobile demand.

Trend = 131.3137 which indicates the automobile demand (in units) are increasing at the rate of 131.3137 per month.

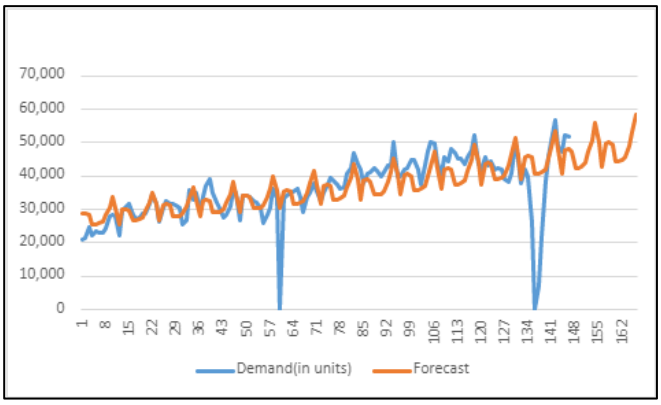
Seasonal Index - Each month of the year has a seasonal index to reflect if automobile demand during the month tends to be higher or lower than average.

In October the Seasonal Index is 6205.256 which means the demand are 6205.256 units higher than an average month.

In December the Seasonal Index is -4420.037 which means the demand are 4420.037 units lower than an average month.

We have the demand data, the corresponding month numbers, and with the help of the formula (additive model) we calculate the forecasted values, the error, squared error and the sum of squared errors. we perform a number of iterations to minimize the sum of squared errors and obtain the most accurate model. therefore, we can also forecast the future demand.

2. Multiplicative Model




To calculate the forecasted(predicted) demand - Base * (Trend^t) * (Seasonal Index for Month)

t - period no.

Base - The base is the best estimate of the level (without seasonality) of monthly automobile demand at the beginning of the observed time period (1st January 2009). Base = 27544.69

Trend - 1.0035 which indicates that the automobiles demand are increasing at the rate of 0.35% per month and 4.28% per year.

Seasonal Index - The seasonal index for a month indicates the percentage by which automobile demand for the month is above or below an average month.

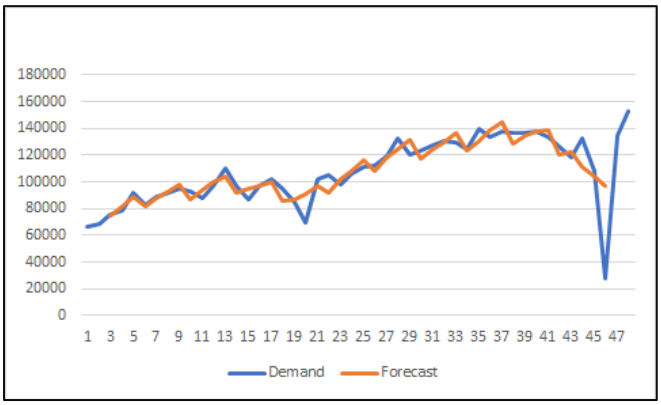
October has a seasonal index of 1.18 which indicates the automobile demand for October is 18% more than a average month

June has a seasonal index of 0.918 which indicates the automobile demand for June is 8.2% less than a average month

This forecasting model is nonlinear forecasting model because we are raising the trend to a power and multiply rather than adding terms involving the seasonal indices.

We have the demand data, the corresponding month numbers, and with the help of the formula (multiplicative model) we calculate the forecasted values, the error, squared error and the sum of squared errors. We perform a number of iterations to minimize the sum of squared errors and obtain the most accurate model. Therefore, we can also forecast the future demand using the formula.

3. Ratio to moving Average (RTMA)




| Quarter | Seasonal Index | Normalized |
|---|---|---|
| Q1 | 1.047852092 | 1.057855 |
| Q2 | 0.929184762 | 0.9380549 |
| Q3 | 0.975150945 | 0.9844598 |
| Q4 | 1.009988843 | 1.0196303 |
| | | |
| | | |
| | | |
| | | |
| | | |
| SSE | 6882337975 | |

Ratio to Moving Average method focuses on estimating a time series trend and seasonal indices and generate forecasts of future values of the time series.

The important steps for RTMA -

We will estimate the deseasonalized level of the series during each period using

centered moving averages

Fit a trend line to your deseasonalized estimates

Determine the seasonal index for each quarter and estimate the future level

of the series by extrapolating the trend line

Forecast future demand by re-seasonalizing the trend line estimate

Seasonality = Actual demand/ Centered Moving Average in this forecasting model, we have taken the quarterly demand data. then we take the 4 period moving average, then the centered moving average where we have deseasonalized the data.then we calculate the seasonality = Actual demand/ Centered Moving Average. then we forecast the quarterly demand by using the formula - product of centered moving average and seasonality.

Further future centered moving average can be evaluated using - intercept + slope*period no.

**SSE**

Additive model - 6.48E+09

Multiplicative model - 6.55E+09

RTMA - 6.88E+0988

we compared the three models and we found that additive model has the least SSE(sum of squared errors) and therefore we can conclude that the additive model is most relevant for the forecasting of demand in automobile supply chain.

## 3. SUMMARY

From the Linear Regression analysis we found that of the 16 variables of interest from the survey, 6 variables had significant importance (based on the P-value). Those are: LUR-3, CUR, IUR-2, IUR-3, OL-1 and OL-5. Using regression analysis, it was possible to set up a predictive model using the X data variables of the survey that explain 69% of the variance in Y data variable.

We also did a comparative study using the three models (additive, multiplicative and ratio to moving average model) and we can conclude that the additive model (model with the least sum of squared errors) is most relevant and accurate to forecast the demand in the automobile supply chain.

## 4. RECOMMENDATIONS

Supply chains are associated with uncertainty especially due to the current pandemic at hand and therefore to understand and overcome this uncertainty companies should pay utmost attention to the five variables of interest that affect the supplychains (Logistic, information, environment, customer, organization and location uncertainties and risks).

## 5. LIMITATIONS

Certain factors such as political environment, technological factors and population size have not been taken into consideration due to their dynamic variability.

## 6. FUTURE SCOPE

Various modelling techniques such as vector auto regression, auto regression and integrated moving average could also be used to forecast demand.

## 7. REFERENCES

1. Statistics for Management. *Levin and Rubin (2013)*
2. Research Methodology. *Deepak Chawla and Neena Sondhi (2018)*
3. https://www.researchgate.net/publication/333719893_Management_of_Uncertainty_In_Supply_Chain