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Various Complexities Involved in Supply Chain, Effective and Efficient Ways to Mitigate it

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Abstract: The upsurge of global supply chain trends in recent years not only depicts the robust market, but also the supply chain efficiencies and complexities. The term supply chain complexity refers to the condition of inter-connectedness and inter- dependencies across a supply chain network where a change in one element can disrupt other elements in the network. This study explains different complexities, transparency and efficiency involved in the supply chain network in industries such as retail, electronics, fast-moving consumer goods, e- commerce, automotive, chemical and healthcare and different ways to mitigate it. The key complexity factors are production Transportation, logistics, location, information and inventory. Complexities represent the uncertainties in supply chain which includes factors such as time, cost, prediction errors, and randomness. These can be effectively eliminated or reduced by using various tools and advanced technologies such as time series analysis, block chain technology combined with IOT.

IndexTerms **- Supply chain, Complexities, Time series analysis, Block Chain, IOT**

I.INTRODUCTION

In the course of this paper we would like to discuss different complexities involved in different industries like retail and fast-moving consumer goods, e-commerce goods chemical, automotive and electronics and health care. In the previous section we have defined supply chain complexity. It is very much necessary to identify and understand the drivers or factors to successfully manage the complexity in the supply chain management. In the next sections of the paper, we would like to discuss how we would identify and measure the complexities and different strategies and solutions to reduce, manage or prevent it which would deal to better performances and higher customer satisfaction. The solution to deal with different complexities can be extracted from different good practices of supply chain complexity management, a decision matrix can assist decision makers in identifying solutions to different complexities involved in a supply chain. To maintain a balance between internal, interface and environmental varieties and help different industries in dealing with the complexity in supply chain a common framework is needed.

II.LITERATURE REVIEW:

Complexity in a supply chain grows, as client necessities, competitive surroundings and enterprise requirements change, and as the organizations in the supply chain shape strategic alliances, engage in mergers and acquisitions, outsource capabilities to third parties, undertake new technologies, launch new products/services, and amplify their operations to new geographies, time zones. [1]. We are able to distinguish among three kinds of supply chain complexity: static, dynamic and decision making. even as static (structural) complexity describes the structure of the supply chain, the type of its components and strengths of interactions; dynamic (operational) complexity represents the uncertainty within the supply chain and includes the elements of time and randomness. The static-dynamic difference has been normally used to observe complexity in production systems. [3]

From the static factor, the supply chain system is made from excessive wide variety of factors, range and interactions, and considering all of them while making a decision is going past the capacity of the human choice maker. From the dynamic factor, the fact that the system is dynamic, non-predictable, and non-linear adds another layer of complexity to decision making within the supply chain. As a result, complexity of decision making inside the supply chain is associated with the volume and nature of the information that have to be considered when making a supply chain associated decision. [2] The achievement in handling complexity of a system isn't always most effective decided via the extent of its complexity, however additionally with the aid of the degree of our manage and have an effect on over the gadget. Distinct procedures can be adopted to address the complexity drivers thinking about the degree of manipulate over the device (e.g., for the internal-static drivers techniques can be: product modularization, decreasing the product variety, mass customization, enterprise technique re-engineering). The next phase affords a greater targeted dialogue of the strategies for handling supply chain complexity.

The reviewed practices represent distinct supply chains starting from retail and FMCG to chemical, automotive and electronics all of which contain a spread of complexities. Inside the retail and FMCG supply chains the primary complexity drivers are high type of products and SKUs, variation in demand, version in capacity necessities, a complicated network with excessive variety of providers and distribution factors which can be additionally geographically dispersed. These deliver chains depend upon collaborative planning and forecasting, well described approaches, and visibility into many details (e.g. stock stages, shipments, promotions, POS records) in the entire supply chain network.

In chemical supply chains, most important complexity drivers are complicated supply chain network, geographical dispersion, converting laws, regulations and directives, transportation structure, mode selection and specifically policies on dangerous materials and their transportation manner. Those supply chains are confronted particularly with operational complexity and the answer to conquer their troubles lies in standardization of products, cargo methods and many others. [4]

Automobile supply chains are characterized through high quantity and type of components even though lean practices permit reduction of stock and streamline data and material flows, there is still want for flexibility and responsiveness in automobile supply chains. As a consequence, the answers within the reviewed cases are aimed at enhancing performance and responsiveness through pull based totally replenishment, data sharing and centralized logistics operations. Those adjustments ended in reduced inventories throughout the supply chain, decreased lead times and advanced customer support tiers as meant. [5]

In electronics supply chains, the complexity drivers have a tendency to be mostly static in nature, together with excessive range of SKUs, extensive variety of complicated products, excessive quantity and style of providers and customers and a complex deliver chain network, bundled with demand and market uncertainties. In one of the reviewed cases, Motorola Inc., redecorate of product to lessen complexity of the supply chain changed into used as a strategy. Motorola devised measures of product complexity in terms of supply chain effects and redesigned their products every time they have got higher complexity than their competitors' products. [6]
This paper introduces a specific degree of static structural complexity for standard and assembly supply chain networks. Its contributions could be seen in together constant domain names. A primary, it's far within the exploration of existing and the unconventional indices for SC structural complexity evaluation and eventual configuration design software. A second advantage may be discovered in figuring out certain concepts for creating of the distinct varieties of supply chain network models. However, it needs to be also underline that we identified few deficiencies at some point of our exploration and became omitted critical parameter - geographic dispersion of supply chain subjects. [7]

Dealing with SC complexity entails the coordination and manage of the upstream, mid-move and downstream flows of products and services via the organization to be able to attain several goals inclusive of lowering prices, growing overall performance, reaching a better consumer satisfaction, improving profitability and improving the reliability of verbal exchange. SC turns into extra complicated. While an employer has to deal with big variety of suppliers/ companions. consequently, dealing with complexity becomes an essential project in such corporations. Control of complexity first calls for identification and then controlling of drivers that drives SC closer to complexity. However, before identification, it's far vital to understand what a complexity driving force is. Many drivers impact SC complexity and could be labeled based totally at the starting place of drivers. [8][9] [10]

Identification of drivers that cause complicated supply chain is the first and essential crucial undertaking to triumph over the complicated scenario that arises within supply chain network. According to this paper, complexities of deliver chain has been divided into 3 classes this is internal, external and Interfacial complexity.

Internal complexity: Internal complexity is related to the difficulties that is generated inside various entities of organization. It is able to expand to encompass merchandise, system, in addition to, related to the component of business enterprise itself. Discern 1 indicates all the drivers that is associated with internal complexity. Those drivers can be similarly categorized into both strategic or tactical issue. Strategic troubles are the only that needs to be addressed at the better degree inside the control hierarchy. However, tactical problems have to be dealt at the lower level. One of the most important motive force of internal complexities inside a SC is the heterogeneous demands that stands for variety. For instance, customization of merchandise has grown to be a norm in many segment of organizations due to the particular product demanded by the consumer. However, customization requires a number of diversity in merchandise and the availability of product plans and packages. Product diversity in addition to product customization calls for special ability set, various forms of resources and the corporation has to attempt for non-stop product development. therefore, the difficulty of customization needs to be addressed at strategic stage taking into account available sources, talent set and employee motivation. Similarly, the organizational shape, which includes departments and its employer are a first-rate instance of organizational elements that have an effect on the complexity if no longer organized to excellent match the enterprise scenario.

The alternative key driving force of internal complexity is worried with the operational difficulty. That is a dominant source of complexity now not most effective as an internal motive force however also at the interface between the SC companions. The operational trouble can be associated with production method, facts and verbal exchange system used or advertising and marketing and sales. The manufacturing techniques can notably affect the internal complexity of SC, particularly, in coordinating making plans and scheduling of manufacturing technique and managing logistics and transportation needs. The range in manufacturing method and its complexity are at once proportional to SC complexity. As this sort of complexity lie in the corporation, relatively, it can be controlled with little attempt.

External Complexity: External complexity lies outside of the company boundary. This sort of complexity is immediately stricken by environmental factors, including technology alternate and the motion of competitor upon which enterprise do not have to manage over it. The competitor could have a dominant impact at the external complexity, when you consider that they can increase the service or product quicker and extra efficaciously with the aid of imposing advanced technologies at which the enterprise is not aware off. The external complexity motive force can result in expanded operational costs, put off and problem within the control of cooperation between companions.

The drivers of external complexity may be further labeled in terms of issue they are associated with. The drivers are associated either to market difficulty or societal difficulty. Drivers related to marketplace trouble includes complexity because of changing client want, movement of competitor, technological innovation, and product life cycle. alternatively, societal issue encompass laws related to local, domestic and global jurisdiction. It also encompasses trendy and regulations imposed with the aid of diverse enterprise, in addition to, legal and political issues. As all of the drivers of external complexity lie past the control of SC companions, managing the complexity due to such driving force may be tough.

Interfacial complexity: In among internal and external complexity, some drivers in the interface of supplier and client which create complexity. these drivers are essentially associated with supply and call for issues and entails flow of facts and fabric. Drivers associated with interfacial complexity can further be divided from the factor of view of operational and strategic problems. Operational issues consisting of unsuitable synchronization of system and records between companions, as well as, incompatible partners and use of incompatible facts gadget between companions create chaos and confusion. Further, amplification of demand due to flawed forecasting from a downstream to an upstream SC has been recognized in an enterprise from long time. Amplification consequences into growing swing inside the stock even as shifting in addition upward the chain. Such bullwhip impact will increase the complexity inside the chain for handling uncooked cloth and system planning.

Other than operational issues, strategic issues together with range of providers, their places, variety of customers and the lifestyle of agency may also affect the extent of complexity. Having more than one providers is taken into consideration as a way to reduce the deliver dangers in terms of price and reliability. But, this is not usually real as growth in the range of providers for identical aspect might also motive problem in assembly affecting the assets of getting homogeneous product. degree of flexibility, decision making manner and level of innovation and many others is significantly laid low with the subculture embraced with the aid of the employer. Having SC partners embracing distinctive tradition may also result into conflicting factor of view with special stage of transparency, thereby ensuing into complexity. As interfacial complexity arises between the partners, it's far practicable to a degree and relies upon closely on their level of cooperation.

According to reference [11], to control complexity well it is essential to measure complexity drivers the use of a proper methodology in order that the agency can apprehend how large it's far reference [12], discusses the use of entropy method to display and measure the complexity of producing machine. In addition, it is feasible that addressing one driving force of complexity may cause another new driver or can also growth the level of severity of a current complexity driver. Therefore, expertise the level of severity of every complexity driver and their interaction effect is crucial. in keeping with this studies work, the modern-day studies might be extended to broaden a quantitative version which could measure the extent of complexity exerted by using the drivers. This can assist company to categorize complexity drivers based totally on their effect compared to others. Further, the following road of studies may be to develop a technique that enables to understand the interaction effect of one driving force over others. [13] [14]

The extra complicated the system turns into, the more is the need for a model to control its complexity. consequently, to enhance the flows in a deliver chain, superior tools and techniques are evolved and broadly adopted within the practice such as the supply Chain Operations Reference model (SCOR), Collaborative planning, Forecasting and Replenishment (CPFR), quick response (QR), efficient consumer response (ECR), vendor managed inventory (VMI), as well as Lean-Agile projects. Since its introduction in 1996, the SCOR model has been advanced on a normal basis with the aid of the Supply-Chain Council and is extensively followed by means of industry. The model is primarily based on five core supply chain control approaches: plan, source, make, deliver, and return; and its scope spans 3 degrees of deliver chain process element: process, process kind, and process detail (Stewart 1997; Supply-Chain Council 2008). The SCOR model presents a common framework to seize supply chain procedures and enables corporations to communicate supply chain practices, measure overall performance objectively, identify supply chain performance gaps and expand improvement targets. In flip, it enhances the capacity of the companies to understand and address the dynamic and complicated behavior of supply chains. QR, ECR and VMI are time based competition methods that focus on decreasing the level of inventory in the supply chain and enhancing the replenishment accuracy and frequency based totally on real product usage and stock level records provided by the customer. They inspire the collaborative control of facts flows and data technologies. these automatic replenishment tools make contributions to complexity management efforts in that they lessen the range of choice ranges and conflicts. An advanced automated replenishment initiative is the CPFR, which provides a formalized tenet for creating collaborative relationships between parties through co-controlled methods and shared statistics with the intention of increasing the overall performance inside the deliver chain. Different from different computerized replenishment tools CPFR unites call for making plans and deliver making plans beneath a coordinated business plan, for that reason it promotes cease-to-stop visibility, collaborative making plans, and collaborative selection-making. Doing so, CPFR reduces uncertainty in the supply chain processes and creates a possibility for lowering complexity. The main idea in the back of these tools is the want to be responsive, in which agility appears to be the solution. Agility and leanness can't be thought in isolation. as a consequence, introducing leagiley, which positions the decoupling factor according to the traits of the lean and agile paradigms. In leagile paradigm, upstream of the decoupling point the methods are designed to be lean (level scheduled) and downstream of the decoupling factor the tactics are designed to be agile. Lean and agile or leagile paradigms

assist the included supply chain wherein the data and material flows are simplified, streamlined and optimized, and lead times and waste are decreased. Furthermore, the leagile paradigm contributes to complexity management by means of permitting lean thinking, which promotes eliminating muda. [15] [16] [17] [18] [19] [20]

III. Methodology

Basically, there are four important steps to handle complexity in supply chain. Those four steps are identification of drivers, measuring the level of complexity, analyzing the complexity measure and then finally using strategy to control complexity. This flow cycle allows to undertake precise practices as vital to manage the complexity. Many motive force creates complexity in SC. these drivers affect productivity, price, lead time and conflict among SC partners, which may have extensive impact at the pleasure degree of entire stakeholder within the chain. similarly, complexity may additionally act as an obstacle in the realization of agile SC. therefore, it is vital to take some actions or organization ought to broaden a few solution methods to overcome this complexity.

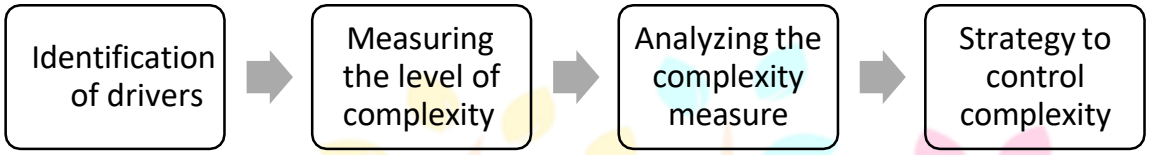

Fig 1: Basic Methodology to counter Complexities

Supply chain complexity may be measured in lots of distinctive ways but there may be no standard way to measure supply chain complexity. If there was a manner to measure this and also we had visibility of the whole thing that was going on across our supply chain then clearly we could take steps to simplify commercial enterprise approaches, consolidate technologies and introduce progressed efficiencies right throughout our downstream supply chain. A few methods an organization can take up to identify and measure the complexity in supply chain is by measuring performance of the organization by using score model. Other methods include expert's advice, entropy method and customer feedback. After identifying the complexity in SC it falls into three broad categories those are Internal, External and Interfacial SC complexity driver. Figure 2,3,4 show different complexities in supply chain.

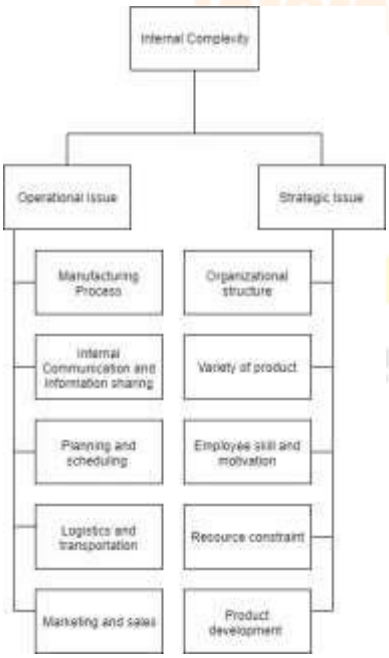

Fig 2: Internal Complexity

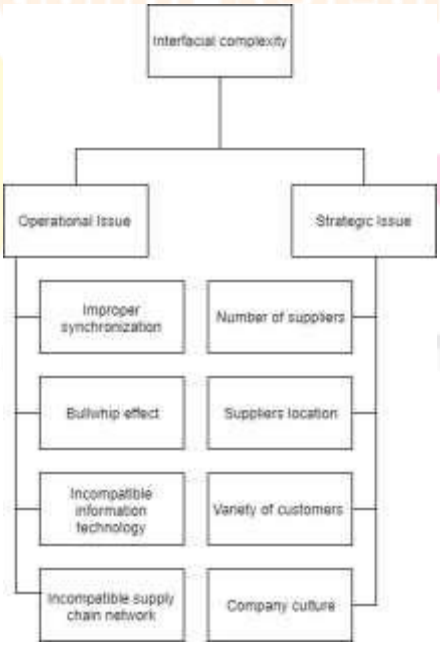

Fig 3: Interfacial Complexity

Fig 4: External complexity

One of the emerging technologies in the industry 4.0 is blockchain. Blockchain along with IoT(internet of things) can sucessfully mitigate some of the complexities involved in supply chain. Some of the complexities listed above like internal communication and information sharing, logitics and transportation which come under operational issue under internal complexity of organization. These comeplexities can disrupt the entire supply chain particularly in coordinating, making plans and scheduling of manufacturing technique and managing logistics and transportation needs.

Under interfacial complexity, operational issues like improper synchronization of system and records between companions, as well as, incompatible partners and use of incompatible facts gadget between companions create chaos and confusion. Strategic issues together with range of providers, their places, variety of customers and the lifestyle of agency may also affect the extent of complexity. Generally, the organization tend to have more than one providers is to reduce the deliver dangers in terms of price and reliability. But, this is not usually real as growth in the range of providers for identical aspect might also motive problem in assembly affecting the assets of getting homogeneous product. Having SC partners embracing distinctive tradition may also result into conflicting factor of view with special stage of transparency, thereby ensuing into complexity.

These complexities can be sucessfully eliminated by using the blockchain technology with the assist of some cryptographic key. Every accountable people on the nodes of the blockchain community is provided with a private key and the public key is shared with all of the other individual. As quickly as the future owner of cryptocurrency (digital tokens or virtual representation of a few different asset) stocks his/her public key to the original owner, the transaction gets initiated. This transaction receives packaged with other expecting transactions which in turn creates a “Block”. Now there's an opportunity that many blocks are created on the equal time through distinct nodes. To decide which block need to be the following block in the blockchain a mathematical puzzle changed into brought, which is also called “proof of labor”. After the location of the “block” is determined, it is further dispatched forward inside the blockchain system’s community of taking part computer systems which evaluates the transactions and determines the validity of the database via mathematical calculations. This level is referred to as the verification stage wherein assessment is achieved primarily based on agreed-upon guidelines when consensus has been performed. The confirmed blocks are then time-stamped with a cryptographic hash, which additionally has a connection with the previous block’s hash. This forms an immutable “chain” of data. In any case of those stages, the transaction is finished. Figure 5 indicates the basic go with the flow diagram of simple blockchain diagram. [21]

Fig 5: Brief Block Diagram of the Blockchain [21]

1. Transaction**:** Two parties decide to exchange a unit of value (digital currency or information) and initiate transaction.
2. Block**:** Packaged with other pending transaction thereby creating a block. The block is sent to the block chain system's network of participating computers.
3. Verification**:** Participating computers evaluate and through mathematical calculations determine whether the transactions are valid.
4. Hash: Each Verified blocks are time stamped with a cryptographic hash.
5. Execution**:** The unit of value moves from one party to other.

Further in the course of the paper would like to concentrate on bullwhip effect which falls under the interfacial complexity. Bullwhip refers to the increasing swings in stock in response to shifts in client call for as one actions further up the supply chain. The causes of bullwhip effect can broadly be categorized into two categories that is behavioral and operational causes.

Behavioral factors are human elements influencing the conduct in supply chains are in large part unexplored. But, studies advocate that humans with increased want for protection and security seem to carry out worse than risk- takers in a simulated supply chain environment. people with excessive self-efficacy revel in much less problem dealing with the bullwhip-impact inside the supply chain. Some of the behavioral causes are –

1) Misuse of base-stock policies
2) Mis-perceptions of feedback and time delays
3) Panic ordering reactions after unmet demand
4) Perceived risk of other players' bounded rationality Some of

the operational causes are –

1) Dependent demand processing
    i) Forecast errors
    ii) Adjustment of inventory control parameters with each demand observation
2) Lead time variability (forecast error during replenishment lead time)
3) Lot-sizing/order synchronization
    i) Consolidation of demands
    ii) Transaction motive
    iii) Quantity discounts
4) Trade promotion and forward buying
5) Anticipation of shortages
    i) Allocation rule of suppliers
    ii) Shortage gaming
    iii) Lean and JIT style management of inventories and a chase production strategy Some of the

methods to mitigate the bullwhip effect are –

1. Collaborate with clients and suppliers

Another approach to enhance supply chain effectivity is through better collaboration with customers and providers. when groups work with clients to apprehend their plans and forecasts, they are able to construct promotions and seasonality into the forecast after which offer extra insight to their suppliers to help save you the buildup of useless stock due to the bullwhip effect.

Supply chain control software frequently has talents to resource in collaboration. supplier portals, EDI transactions, occasion alerts and task portals are a number of the maximum not unusual methods to increase visibility and collaboration.

2. Enhance forecast accuracy

Despite the fact that a enterprise tries to come to be more demand pushed, it nonetheless want a forecast to plot long lead time objects or to cover call for from new clients, new merchandise or in-house promotions. while it's a given that a forecast can be inaccurate, there are steps that could improve accuracy. ensuring which you use the proper set of rules to project demand is one way to boom accuracy; taking input from income and clients is every other.

3. Allow speedy selections with visibility and perception

The maximum essential benefit of deliver chain management applications is the visibility and perception they offer. without the proper degree of insight, a deliver chain supervisor must depend on guesswork or guidelines of thumb to make choices. The result will almost always be sub-optimization of the deliver chain that results in better charges, extra inventory, and slow deliveries.

4. Adopt a call for driven deliver chain management approach

Call for pushed deliver chain management is one of the most effective approaches to reduce the bullwhip effect. it's miles a recognized fact that maximum forecasts are erroneous, so while real call for materializes it's miles almost certain to differ from forecast quantities. This causes companies to vicinity emergency orders on providers. with out effective communication, those providers' deliver chain management systems will overreact, putting off a sequence reaction of excess stock that increases cost and slows speed. In evaluation, a call for driven deliver community can have much less ordinary stock and be more responsive.

The keys to effective deliver chain management are visibility, open communication, and fast access to statistics and insight. With those 5 attributes, your deliver chain might be extra powerful, and you may have minimized the hazard of extra inventory as well as inventory shortages. with out them, you'll feel the sting of the bullwhip impact.

There are usually two types of forecasting, subjective and objective forecasting. Subjective methods are sales force composites, customer surveys, jury of executive opinion, delphi method.

Objective forecasting techniques are those in which the forecast is derived from an analysis of information. A time series technique is one that uses only past values of the phenomenon we are predicting. Causal models are ones that use facts from resources aside from the series being predicted.

In time series analysis we attempt to isolate the patterns that arise most often. These include the following: Trend, seasonality, cycles and randomness. In time-series method there are moving average, exponential somothing, regresion analysis, double expontial smoothing.

IV Analysis

A real time data sets of sales of Apple and Samsung tablets were collected from third quarter of 2011 to third quarter of 2018 and t-test was conducted in Minitab 18.

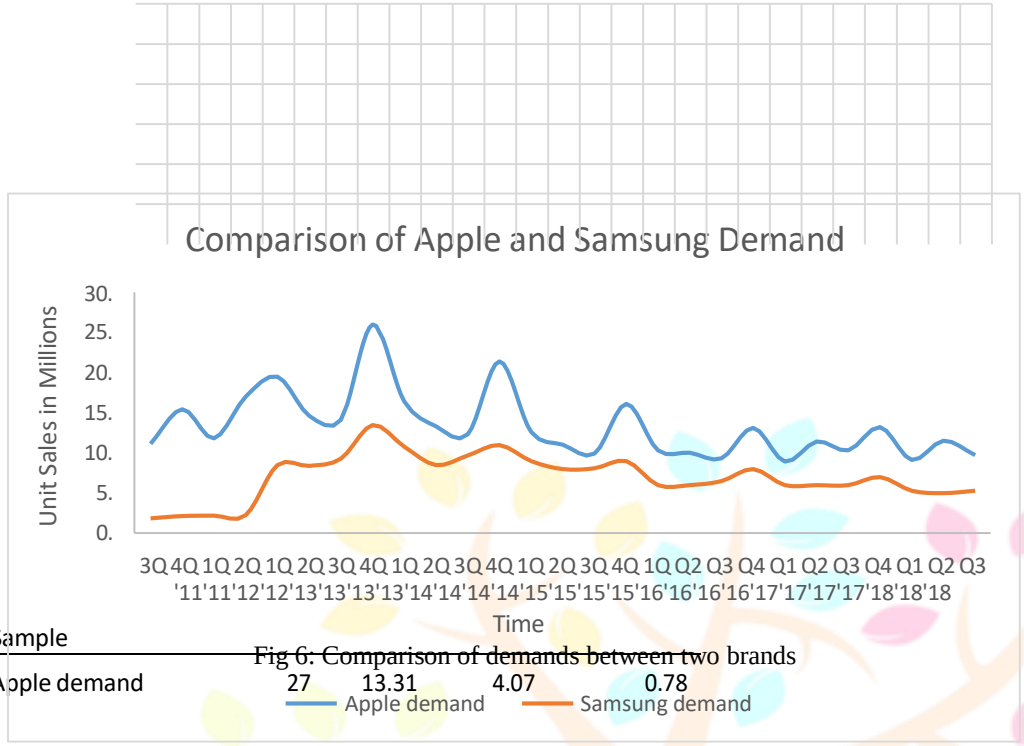

Fig 6: Comparison of demands between two brands

Sample				
Apple demand	27	13.31	4.07	0.78
Samsung demand	27	7.01	2.87	0.55

Estimation for Difference

Difference	95% CI for Difference
6.298	(4.369, 8.226)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.57	46	0.001

Fig 7: Test results of 2 sample T-test

From the t-test we can see that P-value is less than signifance level and therefore we can reject the null hypothesis and say that the two data sets are significantly different and their means differ at the 0.05 level of significance and hence forcasted in Holt Winter's model using excel and Arima model using Python jupyter platform to mitigate the bullwhip effect.

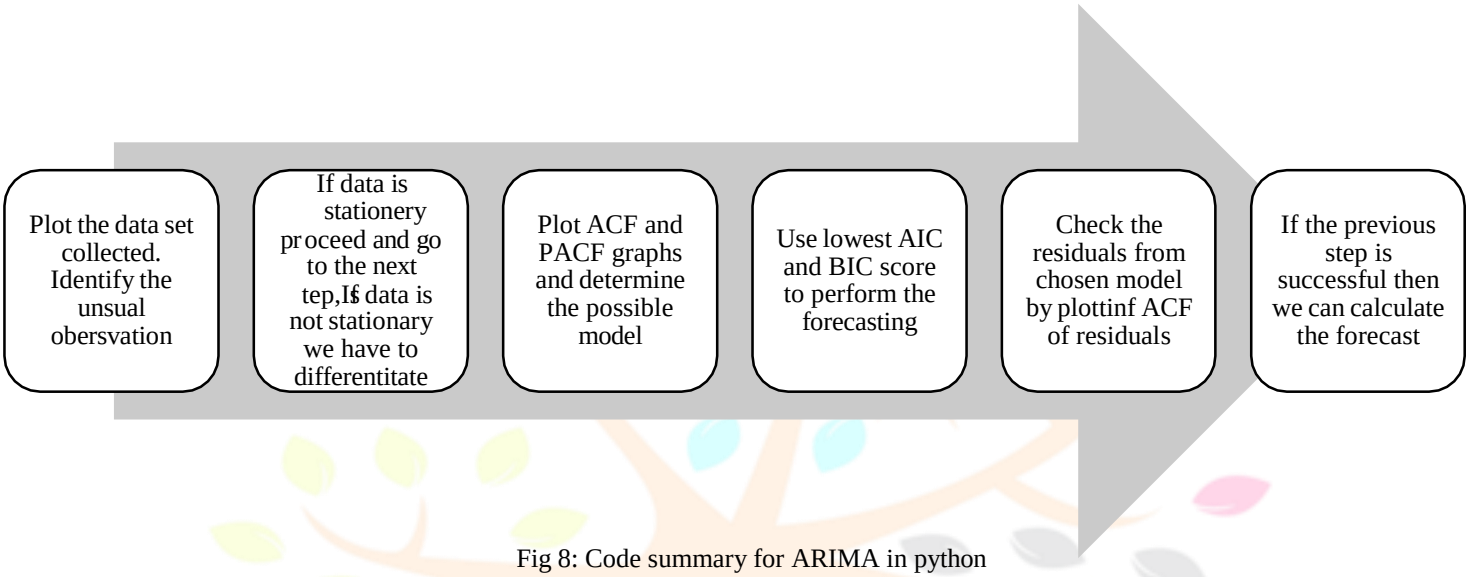

Fig 8: Code summary for ARIMA in python

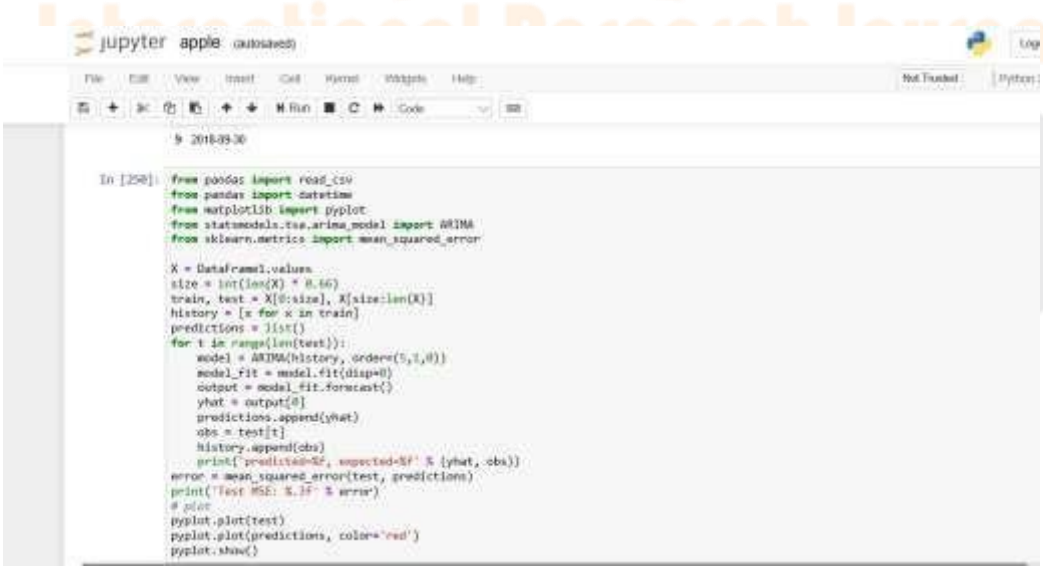

Fig 9: Partial code for ARIMA model in Python

V. RESULTS AND DISCUSSION

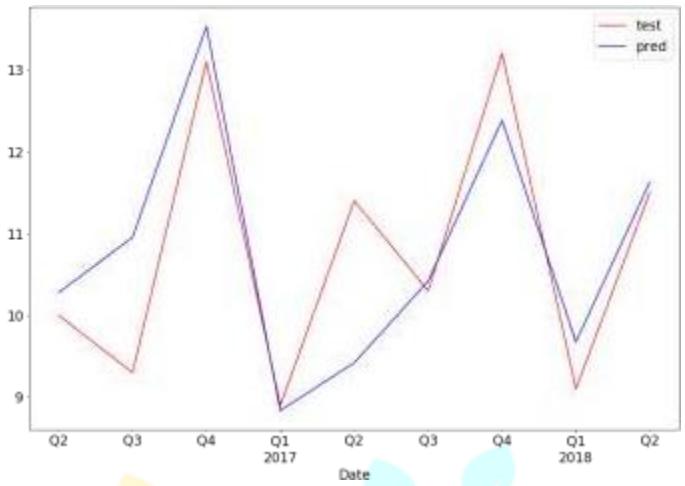

Fig 10: ARIMA Rolling Forecast For Apple Demand

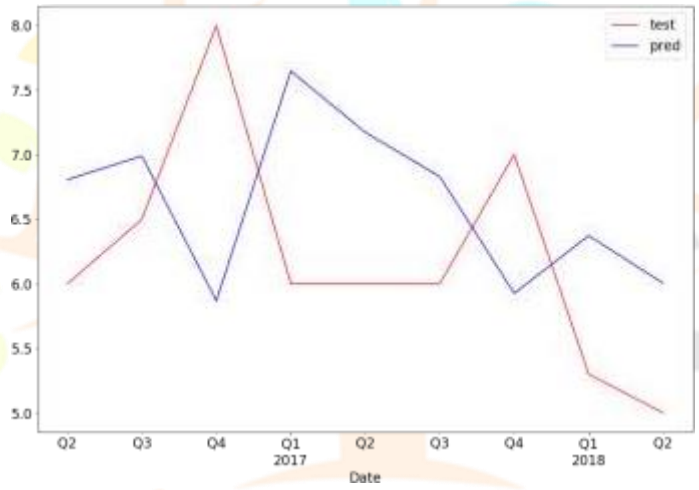

Fig 11: ARIMA Rolling Forecast For Samsung Demand

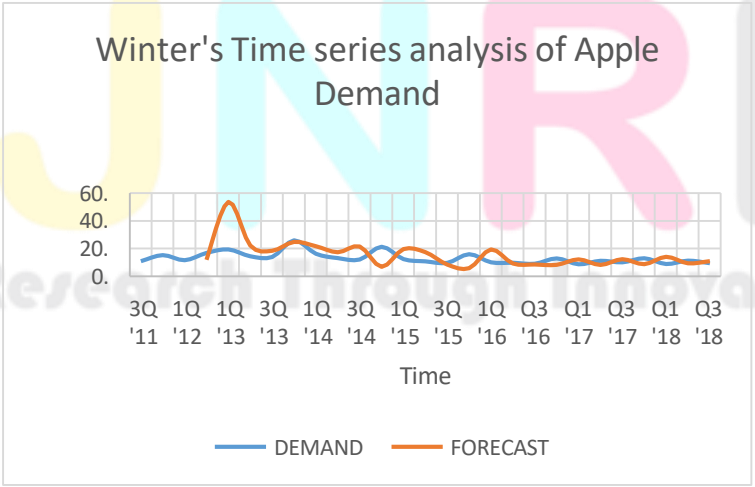

Fig 12: Winter's Time series analysis of Apple Demand

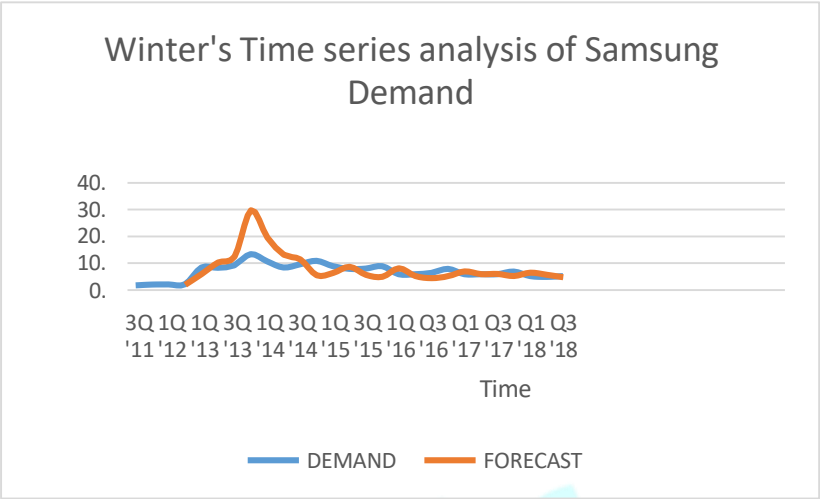

Fig 13: Winter's Time series analysis of Apple Demand

Brand	MAD	MSE	MAPE
Apple	6.1	83.71	43.3
Samsung	2.82	19.74	30.84

Table1: Forecasting accuracy in Winter's model

Brand	MSE
Apple	0.896
Samsung	1.356

Table 2: MSE (Mean squared error) in ARIMA model

VI Applications

In the paper various complexities involved in supply chain were discussed and how we can successfully mitigate them through using blockchain technology along with IOT and forecasting time series models like Holt's winter and ARIMA model were also discussed to counter act the bullwhip effect. Blockchain technology is not just limited to cryptocurrencies, it can also be used in supply chain activities. The issues faced in supply chain management can be reduced by the use of block chain technology because of the speed, transparency, immutability and an effective means of measurement of the outcomes and performance. The most beneficial industry in supply chain would be the automotive and the food sector. Blockchain helps in being more trustworthy and transparency among the parties in the entire supply chain. Blockchain technology can help in being more responsive. This technology can be great tool for traceability, that is any quality issues are found in the product it would very easy to trace the suppliers.

By using time series analysis, it was seen that we can predict the product demand at any early stage and thereby it can help us in planning effectively from purchasing the right amount of raw materials from various vendors, to the right amount of workforce needed. It can also help in marketing and getting the product into the markets. This reduces a major complexity, bullwhip effect in entire supply chain, it also effectively reduces inventory holding costs or any delays involved.

VII Conclusion

In the course of paper, various complexities involved in supply chain were discussed and various ways to mitigate them. More concentration was given to the bullwhip effect and how through forecasting, time series analysis we can successfully eliminate the effect was seen. A real time data sets of Apple and Samsung tablets were collected from third quarter of 2011 to third quarter of 2018 and t-test was conducted in Minitab 18 to know the variance between the two data sets. Using the past sales data it was then forecasted in ARIMA model using python and Holt' winter model using excel. From the graph and results table we can see that if a data set has trend, seasonality, cycles and randomness then ARIMA is more accurate than Holt's Winter model. Further, by the use of blockchain technology in supply chain was also discussed and how by using this technology along with IOT we can reduce time, delays and cost and human error. Apart from this it also enhances transparency among all the parties involved in supply chain. Blockchain also helps in achieving robust cybersecurity measure which in turn enhances the trust and security.

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