AI in Supply Chain Management for Automotive Industry

Submitted in partial fulfillment of the requirements
of the degree of

BACHELOR OF ENGINEERING

in

INFORMATION TECHNOLOGY

by Group No: 34

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2020-2021

CERTIFICATE

This is to certify that the project entitled " AI in Supply Chain Management for Automotive Industry" is a bonafide work of

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Project Report Approval for B.E

Project report entitled **AI in Supply Chain Management in Automotive Industry** by

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is approved for the degree of **“BACHELOR OF ENGINEERING”** in **“INFORMATION TECHNOLOGY”**

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Date:

Acknowledgement

We state that the work embodied in this project titled “AI in Supply Chain Management in Automotive Industry” forms our own contribution to the project work carried out under the guidance of Mr. Mukesh Israni . We would like to express our sincere gratitude to our supervisor and project guide Mr. Mukesh Israni for consistently guiding and mentoring us throughout the course of the project. We thank him for his valuable feedback and suggestions which inspired us to inculcate innovative ideas in our project.

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Abstract

The economic and social importance of the automotive industry explains the need for researching improved ways of organizing and managing the diverse processes involved in the production of motor vehicles. Automotive industry has hundreds of suppliers and thousands of spare parts units. Due to globalization, the automotive supply chain has been undergoing tremendous changes and the industry has been exploring innovative methods to reduce operating cost, lead time and inventory to sustain their growth in the market. With the expansion of sourcing partners, streamlining customer requirements, inventory management, accurate forecasting, better suppliers' relation, coordination and cooperation across supply chain, better visibility and control over the process and reduction of lead time is being achieved by the organizations.

Managing inbound logistics remains another key concern for OEMs as well as auto component players, driven more by challenges related to reliability of data, lead time and absence of quality logistics players on the upstream side. The project attempts to capture the innovative supply chain practices in the Automobile Industry, identify key challenges involved in integration and implementation of supply chain, and suggest strategies to overcome the challenges for optimum leverage.

In any business, a supply chain is used to manage the flow of goods and services, money, or information from the start of a product to the end consumer. As new technology is developed, the way companies transfer information and goods, both intercompany and to partners along the supply chain, changes constantly. Artificial intelligence, or AI, is one of these emerging technologies that is reshaping the supply chain for every industry, specifically manufacturing within the automotive industry. In a manufacturing environment within the automotive industry especially, AI can use the data collected by the machines and staff to reduce bottlenecks, improve supplier and customer relationships, and improve delivery, all while learning, refining, and streamlining the process.

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Chapter 1

Introduction

1.1 Introduction

Supply Chain Management can be defined as the management of flow of products and services, which begins from the origin of products and ends at the product's consumption. It also comprises movement and storage of raw materials that are involved in work in progress, inventory and fully furnished goods. The main objective of supply chain management is to monitor and relate production, distribution, and shipment of products and services. This can be done by companies with a very good and tight hold over internal inventories, production, distribution, internal productions and sales.

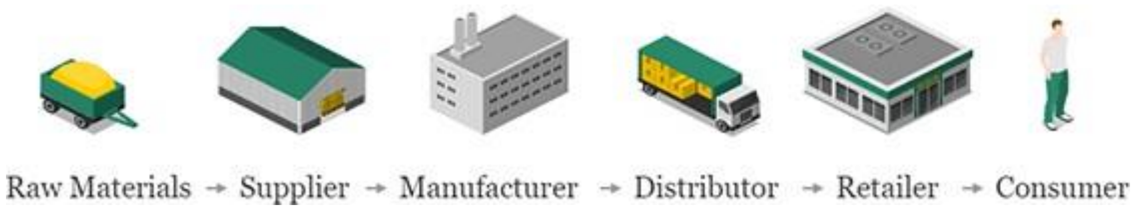


figure 1.1 Supply chain management

In the above figure, we can see the flow of goods, services and information from the producer to the consumer. The picture depicts the movement of a product from the producer to the manufacturer, who forwards it to the distributor for shipment. The distributor in turn ships it to the wholesaler or retailer, who further distributes the products to various shops from where the customers can easily get the product. Supply chain management basically merges the supply and demand management. It uses different strategies and approaches to view the entire chain and work efficiently at each and every step involved in the chain. Every unit that participates in the process must aim to minimize the costs and help the companies to improve their long term performance, while also creating value for its stakeholders and customers. This process can also minimize the rates by eradicating the unnecessary expenses, movements and handling. Here we need to note that supply chain management and supply chain event management are two different topics to consider. The Supply Chain Event Management considers the factors that may interrupt the flow of an effective supply chain; possible scenarios are considered and accordingly, solutions are devised for them.

AUTOMOBILE SUPPLY CHAIN-Supply chain develops from Porter's value chain. Supply chain is defined as an integrated net structure where the core enterprises control the flows of information, materials, and capital from the supplier, manufacturer, distributor, and retailer. Supply chain management is the integration of key business processes from end-users through original suppliers that provide products, services, and information that add value for customers and other stakeholders [2]. The automobile industry supply chain is a representative supply chain organization structure mode. Automobile industry in accordance with its own production and development laws forms its own industry structure. The automobile industry forms supply-manufacture-sale-service supply chain structure by means of new production research and development, design, raw materials supply, components processing, assembler, distribution and after-sales service. In this chain, the added value of each link has a great difference.

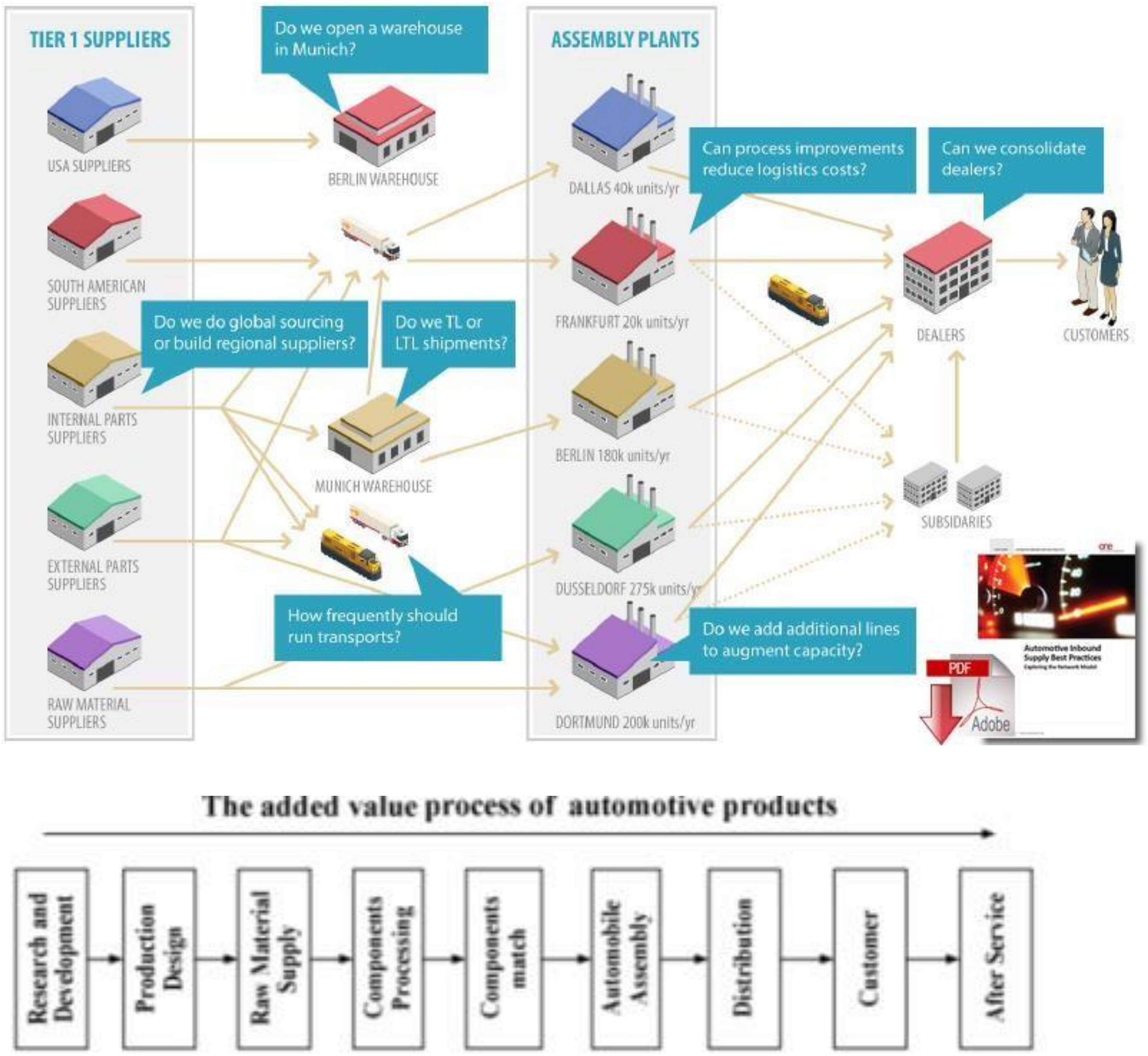


figure 1.2 automotive supply chain

Fig. 1 just introduces one supply chain's added value process, with the tendency of globalization of supply chain, supply chain pays more attention to collaboration and relationship between internal enterprises and external enterprise, because it is not only a chain of materials and added value, but a network chain based on the core enterprise. In the supply chain, each enterprise is a node; every company in the supply chain is cooperative with each other. The whole system of supply chain harmonious

1.2 Aim and Objectives

The Automotive industry is an ever-growing industry with an estimated major growth in the near future with product functionality quickly evolving from cruise control to self-driving vehicles, advanced autonomous systems that can make informed decisions that protect passenger safety, conserve fuel, reduce emissions, manage maintenance, and maintain comfortable conditions inside the vehicle. Organizations can now increasingly harness vast amounts of data from both digital and physical assets into their supply chain business processes and leverage AI and machine learning (ML) to make faster and better decisions for superior customer experiences and a competitive advantage. By applying AI and ML to this data, companies can gain "predictive visibility," or the ability to sense a disruption before it happens. Once organizations have sensed this potential disruption, they can then use prescriptive analytics to create appropriate risk mitigation plans. Organizations must recognize they need to radically transform their operating models to achieve greater visibility, sense and predict disruptions more accurately, and respond with speed and agility, while also protecting profit margins.

The aim of the project is to implement the use of AI in the Supply Chain of Automotive Industry and improve/solve some of the issues such as

Optimize the Speed of the Supply Chain, analyze timings and handovers as products move through the supply chain. It can compare this data to benchmarks and historic performance to identify potential holdups and bottlenecks and make suggestions to speed up the supply chain,

Forecast Likely Demand From Customers combine the data to predict demand for specific goods and help to manage the sourcing and manufacture of those products,

Manage Suppliers and Documentation analyze the types of contracts, documentation and other areas that lead to the best outcomes from suppliers and use those as a basis for future agreements and administration and

1.3 Scope

Increased demand in the last decade has put pressure on the existing automobile manufacturers to quickly adopt global standards and practices. Technological developments are at a lighting speed and so to keep up with the demands and improve their system to be better and fit in the existing fast paced world is a must.

The scope of our project is to cover the major areas of the supply chain management of the automotive industry to streamline their process and in the near future automate most of their processes. Advancements in their system are still at a very slow paced as compared to the fast growing demands. Our project aims to handle such reductances to leave room for the companies to solve other important factors.

Chapter 2

Review of Literature

2.1 Domain Explanation

Historically, Production required highly skilled workers and a lot of time. Automakers generally had many suppliers, and coordination across the supply chain was poor. The problem with this system was that few cars could be produced by any one automaker, and vehicles tended to be quite expensive**(Womack, Jones, & Roos, 1990).**

Shortly afterwards, the concept of mass-production was developed by Henry Ford. His original idea was to make all of the parts in his cars interchangeable and easy to assemble. Next mass-production strives for shorter vehicle manufacturing times. The result of mass-production was that manufacturers wanted to build as many cars as possible, and defects had to be dealt with in a separate rework area. To keep the line going at all times required high inventory levels, many workers, and a lot of rework**(Womack et al., 1990)**

Lean production came about in the mid 20th century, largely from practices developed at Toyota, and other automakers today have adopted the concept to varying degrees. It is about teamwork within the manufacturing plant, coordination along the **supply chain**, and the elimination of waste in the pursuit of perfection. If any defects are found or a worker has a problem, the rest of the team can help to fix the problem. Coordination along the supply chain is necessary in order to reduce inventory levels using a Just-In-Time (JIT) system. This istrue for both suppliers and customers, because in lean production the supply chain shifts to a pull from a push system. The elimination of waste is what gives lean producers the continuous ability to improve. Less defects mean less rework. Lower inventory levels mean less invested capital and greater flexibility in the case of disruptions such as receiving a load of defective parts**(Womack et al., 1990).**

One of the current trends in the automotive industry is the move to more modular production. In context to the automotive industry, this means building larger subassemblies of the vehicles before the assembly stage. Two examples of this are I" tier suppliers building an entire instrument panel or vehicle interior. Modularity has three levels, modularity in design, modularity in manufacturing, and modularity in organization.**(Camuffo, 2000)** While this change is likely to reduce costs and improve flexibility, there are also other implications that need to be considered with the introduction of modularity.

Modularity in design is about developing a system that is composed of a set of subsystems, or modules. Each of these modules is independent from each other. This requires that each module has an interface that can directly work with other modules. Also, there has to be an evaluative system to assess the design specifications of the module and to determine product flaws**(Camuffo, 2000).**

Modularity in manufacturing entails developing methods to simplify production and assembly processes. This can be done by creating teams that work on sets of tasks independently 10 of one another. This includes testing and sub-assembly of modules, and outsourcing some of the design and assembly tasks to suppliers **(Camuffo, 2000)**.

Finally, modularity in organization is about flexibility. The key here is to be able to adjust machinery in a timely and cost effective manner to change production output to accommodate changing consumer demands. This requires careful planning and standardization of layout, equipment, and technology. Essentially, each assembly team within a manufacturing plant is an "organizational module" which develops a single module. Ideally, this makes it easier to spread organizational structure across all of the manufacturing plants within an organization **(Camuffo, 2000).**

The introduction of modularity into the automotive industry is forcing a change in the supply chain. Auto manufacturers are now looking to consolidate their suppliers in an effort to reduce complexity along their supply chain, and to improve efficiency. Improved efficiency can be gained in this way by having better collaboration with suppliers and involving them in the product development process.It is estimated that about 12% of the world's population own a vehicle, and that global industry growth is at 20% every decade. The majority of this growth will come from emerging markets, primarily China, India, Russia, and Brazil **(Howell & Hsu, 2002).**

2.2 Supply Chain Management in Current industries

Companies have traditionally used business intelligence gathering systems to monitor the performance of highly complex order-to-cash (OTC) processes. However, these systems mostly rely on root cause or post-mortem data analysis to identify gaps in the order fulfillment cycles. With rapid advancements in analytics and machine learning (ML), companies can now proactively examine transactional data in near real time and use the insights derived to plug the gaps and revenue losses—the impact can be as high as 10% in some industries.

ML-based methodology can be used to address two major problems – late shipment delivery and high volume of return orders.

Operational inefficiencies in supply chain management can often lead to potential revenue losses, increasing costs, and poor customer service – ultimately diminishing ports. For instance, marine shipment from the United States to Singapore sometimes takes more than 60 days instead of the scheduled 40 days. This uncertainty triggers a series of business and operational issues. Typically, the delays are due to known causes, such as multiple loading and unloading points, congestion along the route, varied quality policies, process bottleneck, and so on.

The order-to-cash cycle, a key process in supply chain management, sees many uncertainties. These include:

1. Inadequate inventory to fulfill demand

2. Supply shortages and logistical uncertainties

3. Huge backlog of orders

4. Demand variation

5. Communication gaps among stakeholders

6.Variation in quality levels of inventory

7. Varied performance indicators used at customers endn Delivery of products not ordered for

The root causes of these variables differ on a day-to-day basis and are difficult to forecast using predefined rules. ML that allows real-time analytics and action points can play an important role in understanding these challenges and predicting them well in advance.Having a layer of analytics on top of standard OTC processes can enable data-driven actions in real time. ML uses algorithm models that can process large volumes of data very quickly—something that is not possible through manual methods. This approach can drive operational efficiencies, reduce revenue losses from return orders, and improve customer satisfaction with on-time delivery.

Indian Automotive Industry

According to India Brand Equity Foundation (IBEF), with an annual production of 23.37 million vehicles for the financial year 2014-15, the Indian auto sector is seen as one of the biggest in the world following a growth of 8.68 per cent over the previous year. The automotive industry accounts for 7.1 percent of India's GDP.

As per the recent report by IBEF, Indian auto industry has produced overall 14.25 million vehicles which inclusive of commercial vehicles including trucks and buses, passenger vehicles including cars, three wheelers and two wheelers during the period April - October 2015 period as against 13.83 million vehicles during April-October 2014, showing a higher growth of 3.07 per cent year
on-year.

The report indicates that India is also becoming a prominent automotive exporter and expects strong growth in the near future. There was a 15 per cent growth in automobile exports in the financial year 2014-15, compared to the last year. In April-October 2015, overall automobile exports also grew to 5.78 percent over the same period last year. In addition, several initiatives taken by the Government of India and the Indian automotive players are expected to make India a leader in the two wheeler and four wheeler market in the world by 2020.

Now, the Indian Government encourages foreign investment in the automotive sector and 100 per cent Foreign Direct Investment (FDI) is allowed under the automatic route. In order to take advantage of the rising demand, during the last year many automotive manufacturers have initiated heavy investments in various segments of the industry. According to the information published by the Department of Industrial Policy and Promotion (DIPP), the auto industry has attracted foreign direct investment worth US$ 13.48 billion during the period April 2000 to June 2015.

The Indian automotive sector has the potential to generate annual revenue up to US$ 300 billion by 2026. According to the Automotive Mission Plan 2016-26, jointly executed by the Society of Indian Automobile Manufacturers (SIAM) and the Indian Government, the auto sector has the potential to create 65 million additional jobs and contribute more than 12 per cent to India’s GDP.

After connecting with the supply chain management consultant at **Capgemini** Invent, **Mr. Abhinay Kalva** said that he hasn’t seen much advancements in the field of supply chain in automotive industries with respect to ML & AI and they usually depend on OEM’S(Original equipment manufacturer) for taking care of the supply chain.

Mr. Dhanesh More, Assistant Manager Supply Chain Management at **Mahindra & Mahindra Limited** [Automotive, Farm Equipment and Agri Business] said that Machine Learning is a new field in SCM specially in automotive sector and it involves a lot of practical things which aren’t taken in considerations in software terms but software use can be done to boil down to fewer examples.He also said currently they use a 3rd party software which takes care of their supply chain.

2. 3 Need of Change in SCM

Operational inefficiencies in supply chain management can often lead to potential revenue losses, increasing costs, and poor customer service – ultimately diminishing ports. For instance, marine shipment from the United States to Singapore sometimes takes more than 60 days instead of the scheduled 40 days. This uncertainty triggers a series of business and operational issues. Typically, the delays are due to known causes, such as multiple loading and unloading points, congestion along the route, varied quality policies, process bottleneck, and so on. The order-to-cash cycle, a key process in supply chain management, sees many uncertainties. These include: n Inadequate inventory to fulfill demand and Supply shortages and logistical uncertainties and Huge backlog of orders on Demand variation in Communication gaps among stakeholders. The root causes of these variables differ on a day-to-day basis and are difficult to forecast using predefined rules. ML that allows real-time analytics and action points can play an important role in understanding these challenges and predicting them well in advance.

Modern, international supply chains generate vast amounts of complex data. Machine learning can analyze this information and use the findings to enhance supply chain management (SCM). Having a layer of analytics on top of standard OTC processes can enable data-driven actions in real time. ML uses algorithm models that can process large volumes of data very quickly—something that is not possible through manual methods. This approach can drive operational efficiencies, reduce revenue losses from return orders, and improve customer satisfaction with on time delivery.

Need Of Scm In Automobile Industry

Supply chain management is a systematic process and an approach to manage and control the supply of materials and parts from raw materials suppliers, through the producers of finished goods and ultimately delivering to end consumers. Supply chain management has severely affected the manufacturing businesses in multiple ways from availability of raw material, costs of goods manufactured, infrastructure of the company and communication between suppliers and customers.

In the past few decades, automotive businesses have discovered new manufacturing methods, technologies and business strategies that enabled them to reduce the cost and to compete in different and challenging markets. Strategies and systems like Just-In-Time, Kanban, Lean manufacturing, Total Quality Management (TQM), Total Productive Maintenance (TPM), 5S, and other systems were implanted with heavy investments. Companies started practising quality systems like ISO9001, ISO/TS16949, ISO 14000, six sigma etc. With the result of this, these automotive companies have reduced their manufacturing cost to a great extent and now these companies are more focussing on effective supply chain management to decrease the operational cost and to enhance their market share and profits.

Today, there is fierce competition in Indian automotive industry with a large number of players and products, the product life cycles are shortening, and operating margins are shrinking. There is continuous improvement in technology coupled with ever increasing customer needs and expectations, heightened with regard to product quality, product availability, on time delivery, sales services and timely availability of information, etc. Further continuing innovation in communication systems and transportation facilities like mobile phone networks, internet and intranet systems, mobile apps and overnight delivery practices, etc., increased the need for a well organized and effective supply chain management in the automotive industry. As the number of companies in automobile sector are increasing, competition forces prices to decline, flat sales, putting a premium on efficiency to maintain profitability and sales growth which calls for effective integration of front-end and back-end operations of automobile companies which can all be possibly done only with the implementation of Supply Chain Management practices in these sectors.

SCM supports product ordering, replenishment, inventory control and more importantly, better control over logistic management, merchandising and marketing operations. SCM also facilitates demand forecasting, customer data analysis, customer relation management which can be effectively used in replenishment of product, production scheduling, order processing, order delivery, etc., which will further help in smooth functioning of automobile companies. So, the study of supply chain management in the automobile industry is the need of the hour.

Why Supply chain improvement is required in Automotive industry

All the way at the far end of the supply chain, when an automobile reaches its end consumer, it looks like they're buying one large item. But automotive manufacturers know differently—they know that each car on the road is really composed of about 20,000 different parts, and all of them had to come from somewhere. After being sourced, they had to be stored, allocated for various production plans, brought to the production plant, and assembled into a road- worthy vehicle that someone could drive off the lot at their local car dealership.

This rundown barely gets into the real complexities of the automotive supply chain, and yet it should at least suggest the high degree of complexity that would be involved in true supply chain optimization. Given the number of moving parts, it would be ridiculous to expect a single supply chain planner with an Excel spreadsheet to create a supply stream that was even remotely optimized. In the past, for practical purposes this has meant that a fair amount of waste was baked into the structure of the automotive industry—but with the advent of digitization and the rise of Industry 4.0, it's increasingly possible to create value chains that reduce waste and ward off disruptions.
Businesses that integrate modern technologies in their supply chain can enhance service levels while reducing up to 30 percent of costs. While creating a future-ready supply chain, auto companies need to be on top of the latest trends that are shaping the industry. For instance, ever changing international trade policies, the continuous evolution of environmental and safety regulations, and even cybersecurity issues are all contributing to the auto supply chain puzzle. The modern supply chain must evolve to meet new demands and supply chain challenges, and supply chain managers need to plan ahead to keep everything flowing smoothly. A combination of consumer expectations, more routes to market, international complexities and other factors creates significant challenges throughout the supply chain network.
Following are the problems in supply chain industries currently

1. Increased Costs Throughout the Supply Chain

Profit margins are under pressure as costs creep up throughout the supply chain network. These costs come from many areas, and a lack of visibility and accountability for reducing them can result in rising operational expenses. Major contributors to increased costs include:

- Rising price of fuel to transport goods by road, sea or air
- Increasing commodity prices raising the cost of raw materials
- Higher labor costs from suppliers and manufacturers
- Complex international logistics leading to higher charges for storage, transfer and management of products.

2. Supply Chain Complexity Due to Multiple Channels to Market

Consumers buy products across multiple channels, and as routes to market increase, the underlying supply chain must adapt. Supply chain managers need to develop variations on supply chain processes to address each of the channels:
Supply chain managers must manage multiple supply chains, third parties and other

organizations to ensure a good end customer experience, regardless of how they order and receive products.

3. Consumer Demands Drive Need for Improved Speed, Quality and Service

Consumers have never had more choice, and every industry is facing disruption. Every touchpoint with an end user needs to be focused on providing excellent products and services. Quality and speed are becoming as important as pricing when it comes to purchasing goods: The most successful products are those that meet consumer requirements of quality, availability and price. The underlying supply chain is vital to meeting those needs.

4. Risk in the Supply Chain Creates Pressure

International complexity, environmental changes, economic pressures and trade disputes all put pressure on the supply chain. This pressure can easily turn into risks and issues that snowball throughout the network, causing significant problems:

Supply chain managers must develop contingencies and mitigating action plans to prioritize and eliminate risks and manage issues when they occur.

5. The Impact of Supply Chain Volatility

Volatility and complexity don't just create problems at a specific point in the supply chain, instead the impact can ripple throughout the entire infrastructure. Supply chain managers must deal with these issues promptly before they create delays, backlogs, bottlenecks and other issues. Instead, supply chain managers need to understand the major issues impacting supply chains around the world and create strong reporting and management plans to resolve issues quickly. Much of this will be down to predicting problems before they happen, building robust contracts and relying on strong relationship management, collaboration and prioritization to minimize the impact

Artificial Intelligence in Supply Chain

• According to the Accenture digital operations survey, organizations are rapidly digitizing their supply chain to distinguish and drive revenue growth.

• The report also says that 85% of businesses integrate AI in their supply chain by next year. • The main objective behind integrating AI is that it plays a vital role in optimizing business processes and establishes an agile supply chain.

• Assimilating Artificial Intelligence (AI) in Supply Chain eventually results in redefining an ecosystem where supply-chains link themselves to generate impeccable flow of products and information end-to-end.

Chapter 3

Design and Implementation

3.1 Methodology

The supply chain process of an automotive industry is highly complex and requires high number of labor and analysis to carry forward the smooth management. To keep up with the demands of the ever increasing customers and the technological advancements, our project aims at automating some important processes in the supply chain and incorporate the latest technology to make the company ready for future trends and changes. Below the Supply chain processes is summarised where apart from the basic structure that includes supplier, plant, warehouse, logistics and retailer addition of processes such as demand forecasting, material requirement planning, order management would help boost up the entire system. It would provide the company to be prepared of the future advances, cut down on cost and much more. Our solution aims to help the companies achieve this.

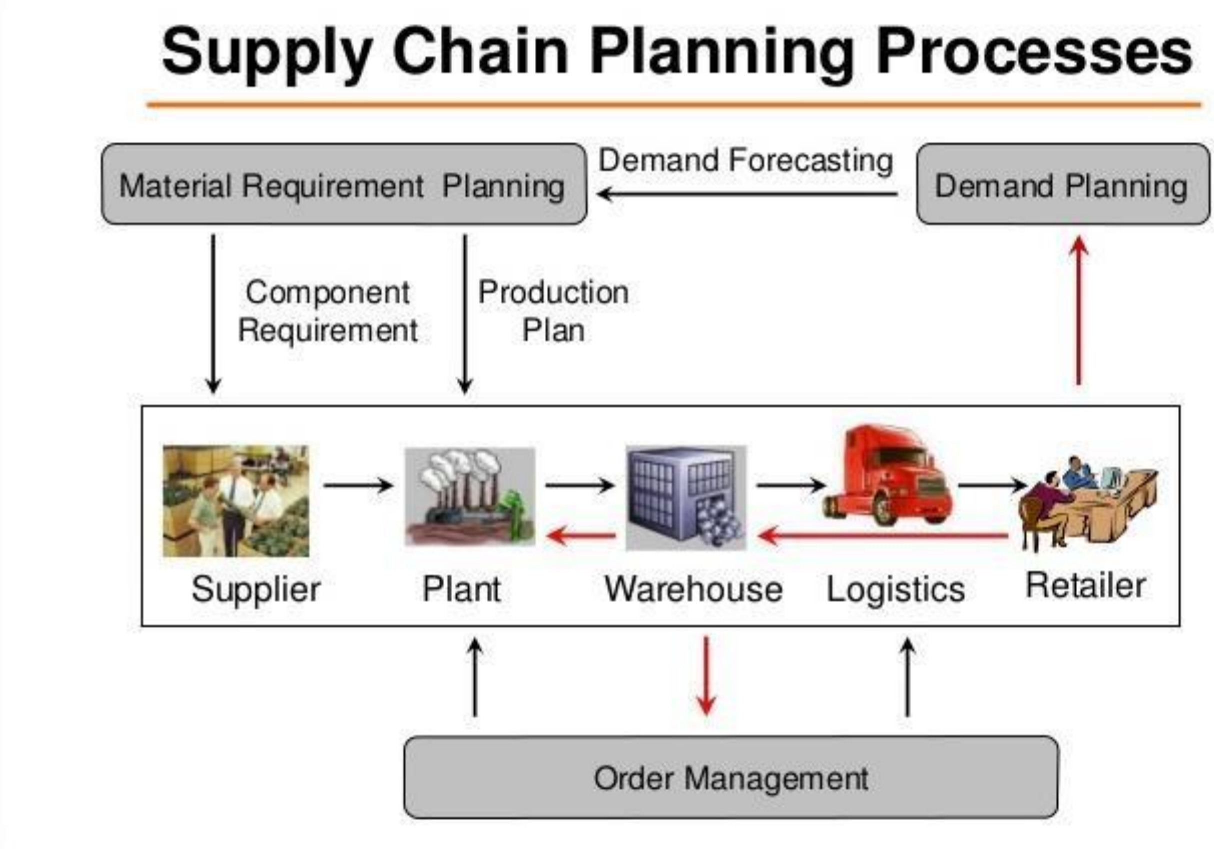


figure 3.1 supply chain planning process

The solution consists of parts to tackle different problems and also advance the system to make it ready for the changing market. Our main focuses lies in three domains in the supply chain process such as:

A. **Demand Forecasting**
   Demand Forecasting is the process in which historical sales data is used to develop an estimate of an expected forecast of customer demand. To businesses, Demand Forecasting provides an estimate of the amount of goods and services that its customers will purchase in the foreseeable future.
B. **Sourcing and Outsourcing**

Sourcing and Outsourcing includes the supplies transported from the warehouse to the plant and also transporting of the finished products. Predictive analysis is used to find the optimal distance that has been travelled and received items from.

C. **Invoice Data Analysis**
Data obtained from the invoices by sourcing and outsourcing can provide important insights about the finances of the company which in turn can help companies make important decisions, it helps in finding the best possible modes of shipment for faster and convenient delivery.

3.2 Part A - Demand Forecasting

AI-lead supply chain optimization software amplifies important decisions by using cognitive predictions and recommendations on optimal actions. This can help enhance overall supply chain performance. It also helps manufacturers with possible implications across various scenarios in terms of time, cost, and revenue. Also, by constantly learning over time, it continuously improves on these recommendations as relative conditions change.

Dataset having 913000 rows and 4 columns is selected which contains important fields such as sales by date and item along with the quantity of the items, these help to make predictive forecasting of the demand according to the trends of the customers and market state.

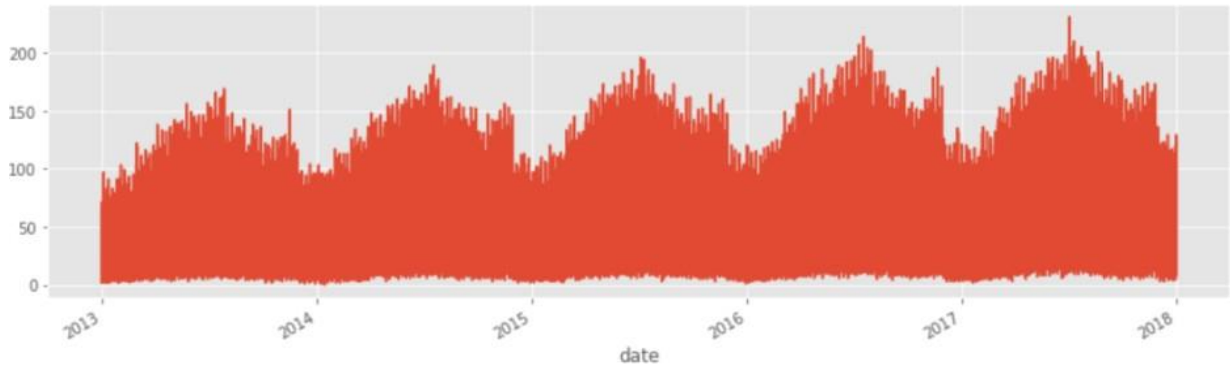


figure 3.2 evaluation over 5 years

The figure gives us a simplified evaluation of the sales over the years, which would help the company make informed decisions for future by studying these trends and what factors are affecting the decline of sales or increase of sales.

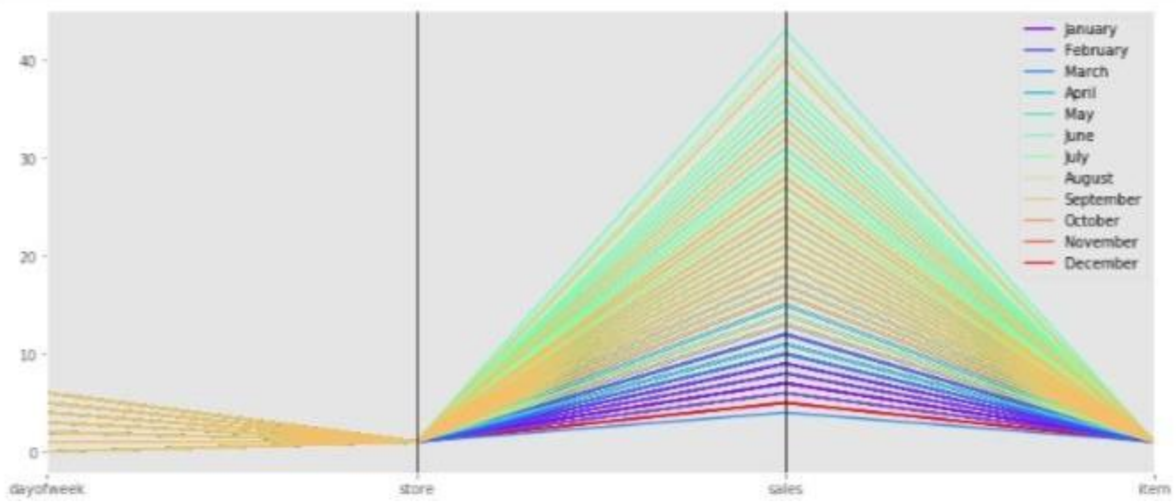


figure 3.2 weekly analysis

Daily analysis of sales according to the store and item can be found out which helps the company understand the consumer trend of when most customers are likely to buy the item from which store and also which items have a higher likelihood of being sold off.

Next, data is processed for further analysis to find out insights into the patterns of the sale and analzing with respect to items in the store, days of the week, and other factors.

3.2.1 Models

Using **One Hot Coding** we have split the column which contains numerical categorical data into many columns depending on the number of categories present in that column.
The new refined dataset is then used to run models such as Linear, XGBoost, Decision Tree Regressor , Random Forest Regressor, and others

Linear Regression

Linear regression is useful for finding relationship between two continuous variables. It looks for statistical relationship but not deterministic relationship. Relationship between two variables is said to be deterministic if one variable can be accurately expressed by the other.The core idea is to obtain a line that best fits the data. The best fit line is the one for which total prediction error (all data points) are as small as possible. Error is the distance between the point to the regression line. LinearRegression fits a linear model with coefficients to minimize the residual sum of squares between the observed targets in the dataset, and the targets predicted by the linear approximation.
Linear Regression model gives a Rscore is 0.6558538493142778.

XGBoost

XGBoost is an optimized distributed gradient boosting library designed to be highly efficient, flexible and portable. It implements machine learning algorithms under the Gradient Boosting framework. XGBoost provides a parallel tree boosting (also known as GBDT, GBM) that solve many data science problems in a fast and accurate way. XGBoost is a decision-tree-based ensemble Machine Learning algorithm that uses a gradient boosting framework. In prediction problems involving unstructured data (images, text, etc.) artificial neural networks tend to

outperform all other algorithms or frameworks. However, when it comes to small-to-medium structured/tabular data, decision tree based algorithms are considered best-in-class right now.
Mean Absolute Error is 0.12240535.
XGBoost model gives rscore is 0.9233099242965672.

Decision Tree Regressor

Decision tree regression observes features of an object and trains a model in the structure of a tree to predict data in the future to produce meaningful continuous output. Continuous output means that the output/result is not discrete, i.e., it is not represented just by a discrete, known set of numbers or values. Decision tree builds regression or classification models in the form of a tree structure. It breaks down a dataset into smaller and smaller subsets while at the same time an associated decision tree is incrementally developed. The final result is a tree with decision nodes and leaf nodes. A decision node has two or more branches, each representing values for the attribute tested. Leaf node represents a decision on the numerical target. The topmost decision node in a tree which corresponds to the best predictor called root node. Decision trees can handle both categorical and numerical data.
Mean Absolute Error : 0.1710087944488003
rscore is 0.8446189984842214

Random Forest Regressor

A Random Forest is an ensemble technique capable of performing both regression and classification tasks with the use of multiple decision trees and a technique called Bootstrap and Aggregation, commonly known as bagging. The basic idea behind this is to combine multiple decision trees in determining the final output rather than relying on individual decision trees. Random Forest has multiple decision trees as base learning models. We randomly perform row sampling and feature sampling from the dataset forming sample datasets for every model.

Mean Absolute Error : 0.1710087944488003

rscore is 0.9092196878110362

3.2.2 Time Series Analysis

A time series is simply a series of data points ordered in time. In a time series, time is often the independent variable and the goal is usually to make a forecast for the future. Time series is a sequence of observations recorded at regular time intervals.
Depending on the frequency of observations, a time series may typically be hourly, daily, weekly, monthly, quarterly and annual. Sometimes, you might have seconds and minute-wise time series as well, like, number of clicks and user visits every minute etc.

We further analyze how the sales varies across all the items of the store.

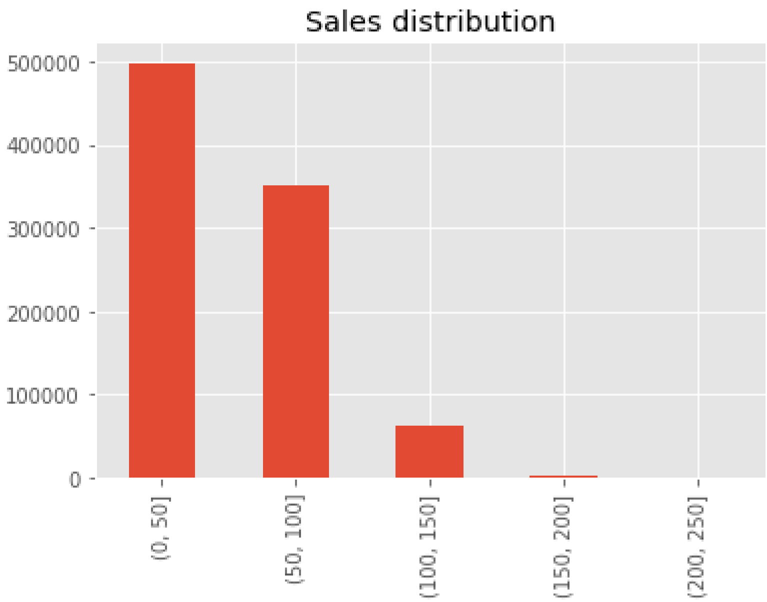


figure 3.2.1 sales distribution

As we can see, almost 92% of sales are less than 100. Max, min and average sales are 231, 0 and 52.25 respectively. So any prediction model has to deal with the skewness in the data appropriately.

According, we have also found out the average sales per store that the stores with ID 2 and 8 have higher average sales than the remaining stores and is a clear indication that they are doing good money.
Whereas store with ID 7 has very poor performance in terms of average sales.

	item	avg_sale
14	15	88.030778
27	28	87.881325
12	13	84.316594
17	18	84.275794
24	25	80.686418

Similarly, analysis of sales vary across the items and we found out that the sales are distributed uniformly across and top items with highest average sale are 15, 28, 13, 18 and with least average sales are 5, 1, 41 and so on.

Sales across a span of five years are analysed to help find a pattern in the sales of the items.

Light GBM model

Light GBM is a gradient boosting framework that uses tree based learning algorithm.

LightGBM grows trees vertically while other tree based learning algorithms grow trees horizontally.
It means that LightGBM grows tree leaf-wise while other algorithms grow level-wise. It will choose
the leaf with max delta loss to grow. When growing the same leaf, leaf-wise algorithm can reduce more
loss than a level-wise algorithm. The algorithm stops when the validation score doesnot improve anymore.
Root mean squared error is 0.1549782667240093
rscore is 0.9253940011830566

Below are the feature importance and prediction:

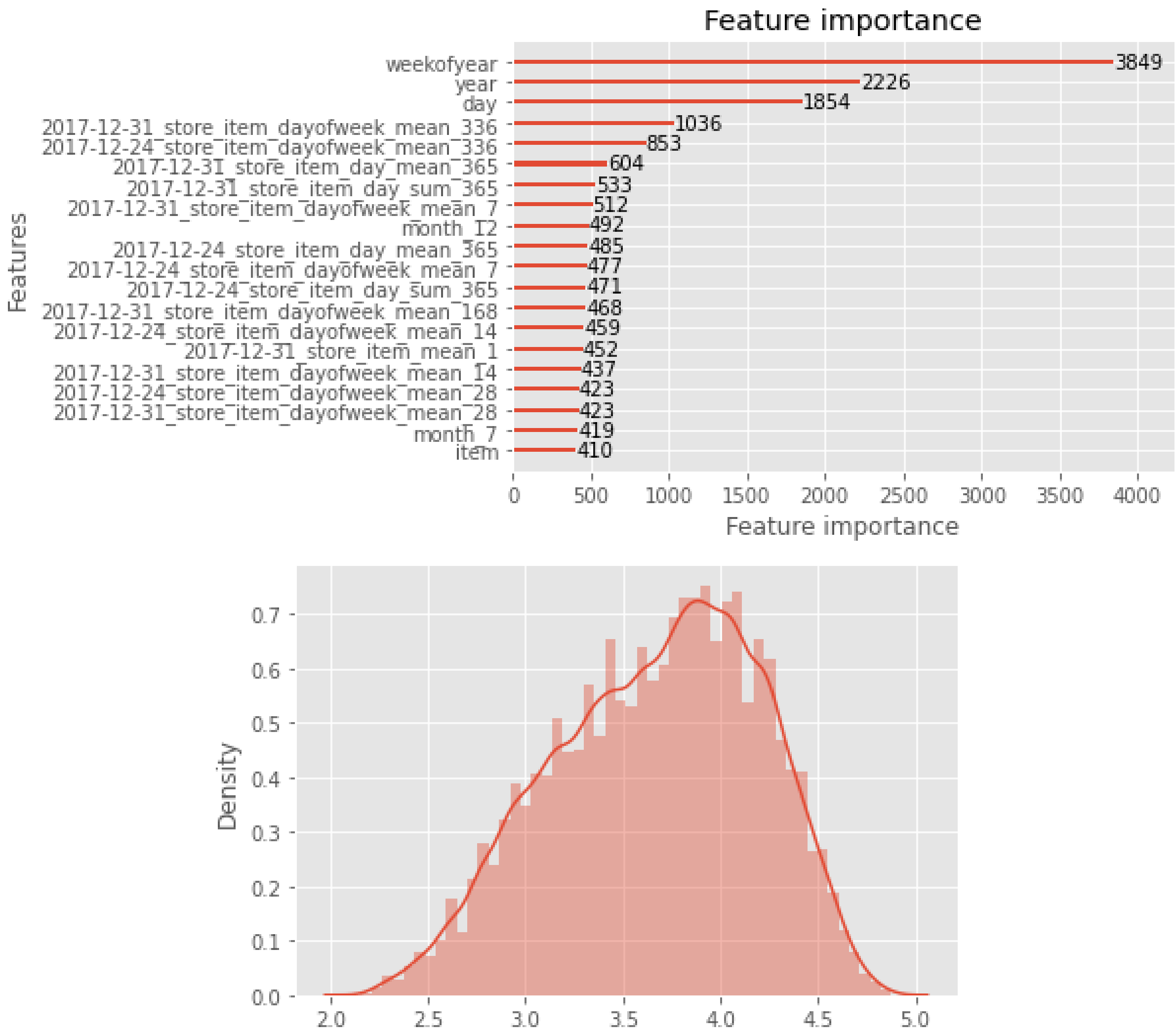


figure 3.2.2 LightGBM model results

Arima Model

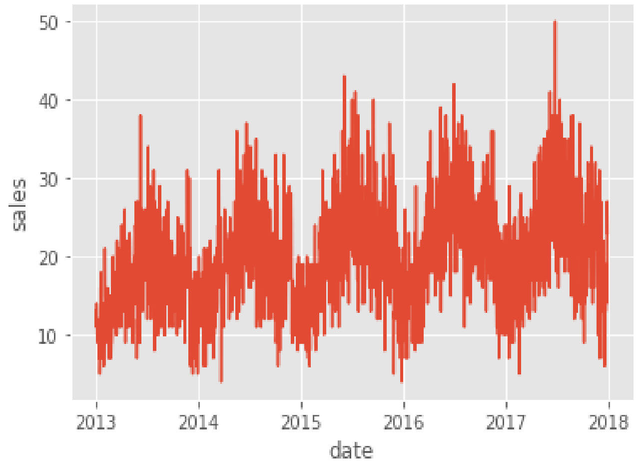
Autoregressive integrated moving average is a forecasting algorithm based on the idea that the information in the past values of the time series can alone be used to predict the future values.

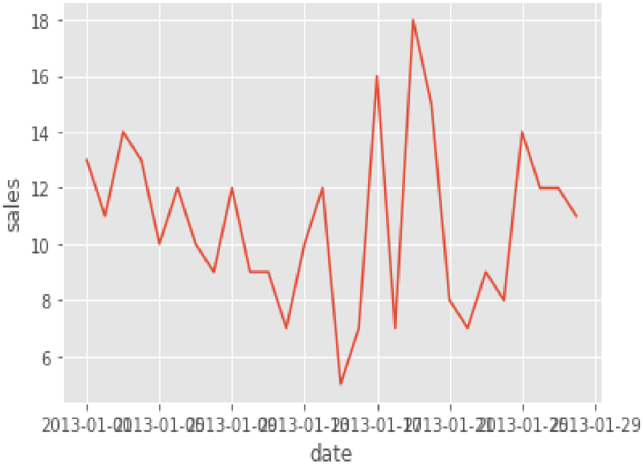
It is actually a class of models that 'explains' a given time series based on its own past values, that is, its own lags and the lagged forecast errors, so that equation can be used to forecast future values. Using ARIMA model, you can forecast a time series using the series past values. It is a linear regression model that uses its own lags as predictors. models are fitted to time series data either to better understand the data or to predict future points in the series (forecasting). ARIMA models are applied in some cases where data show evidence of non-stationarity in the sense of mean (but not variance/autocovariance), where an initial differencing step (corresponding to the "integrated" part of the model) can be applied one or more times to eliminate the non-stationarity of the mean function (i.e., the trend). When the seasonality shows in a time series, the seasonal-differencing could be applied to eliminate the seasonal component.

In our implementation we have found out if there are any missing values and to better understand the data we elaborate as month and weekly wise as given below.

	date	store	item	sales	year	month	day	weekday
0	2013-01-01	1	1	13	2013	1	1	1
1	2013-01-02	1	1	11	2013	1	2	2
2	2013-01-03	1	1	14	2013	1	3	3
3	2013-01-04	1	1	13	2013	1	4	4
4	2013-01-05	1	1	10	2013	1	5	5

The seasonality, trends and outliers are found and plotted as given below:





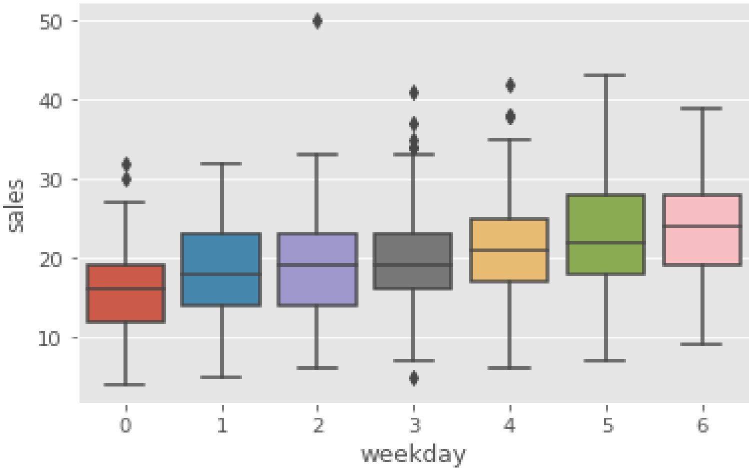
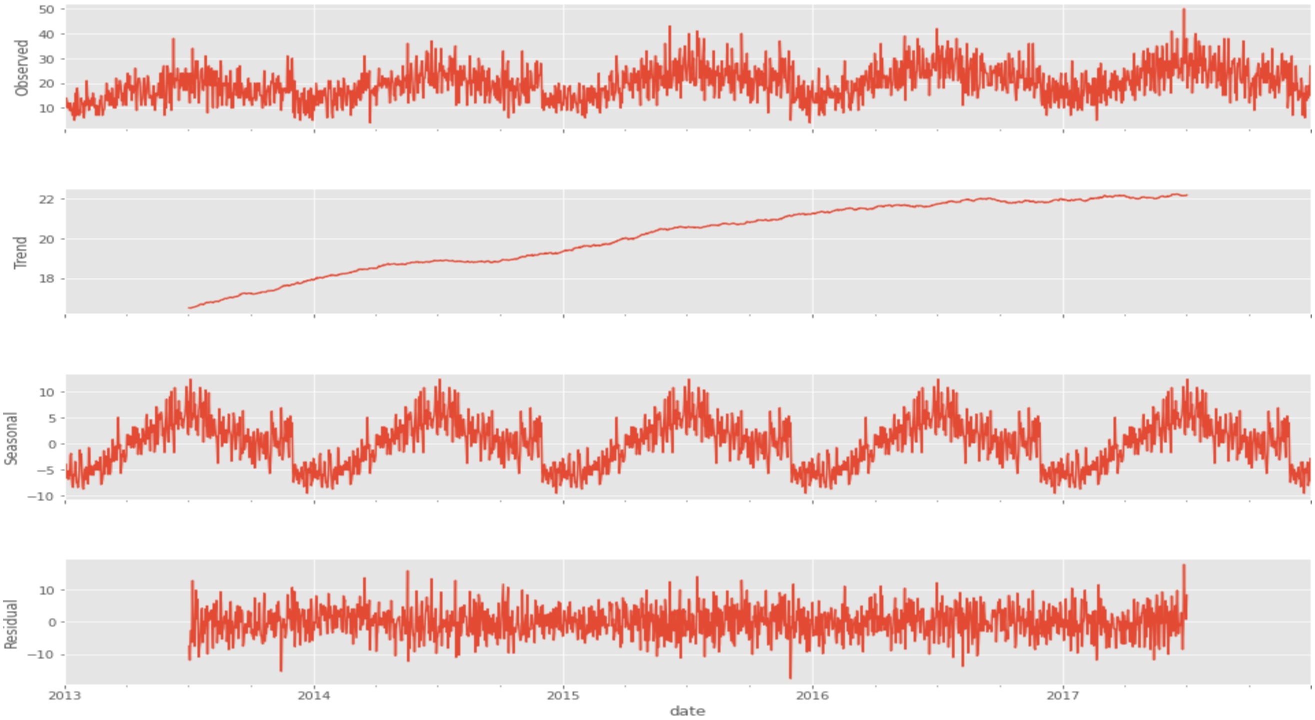
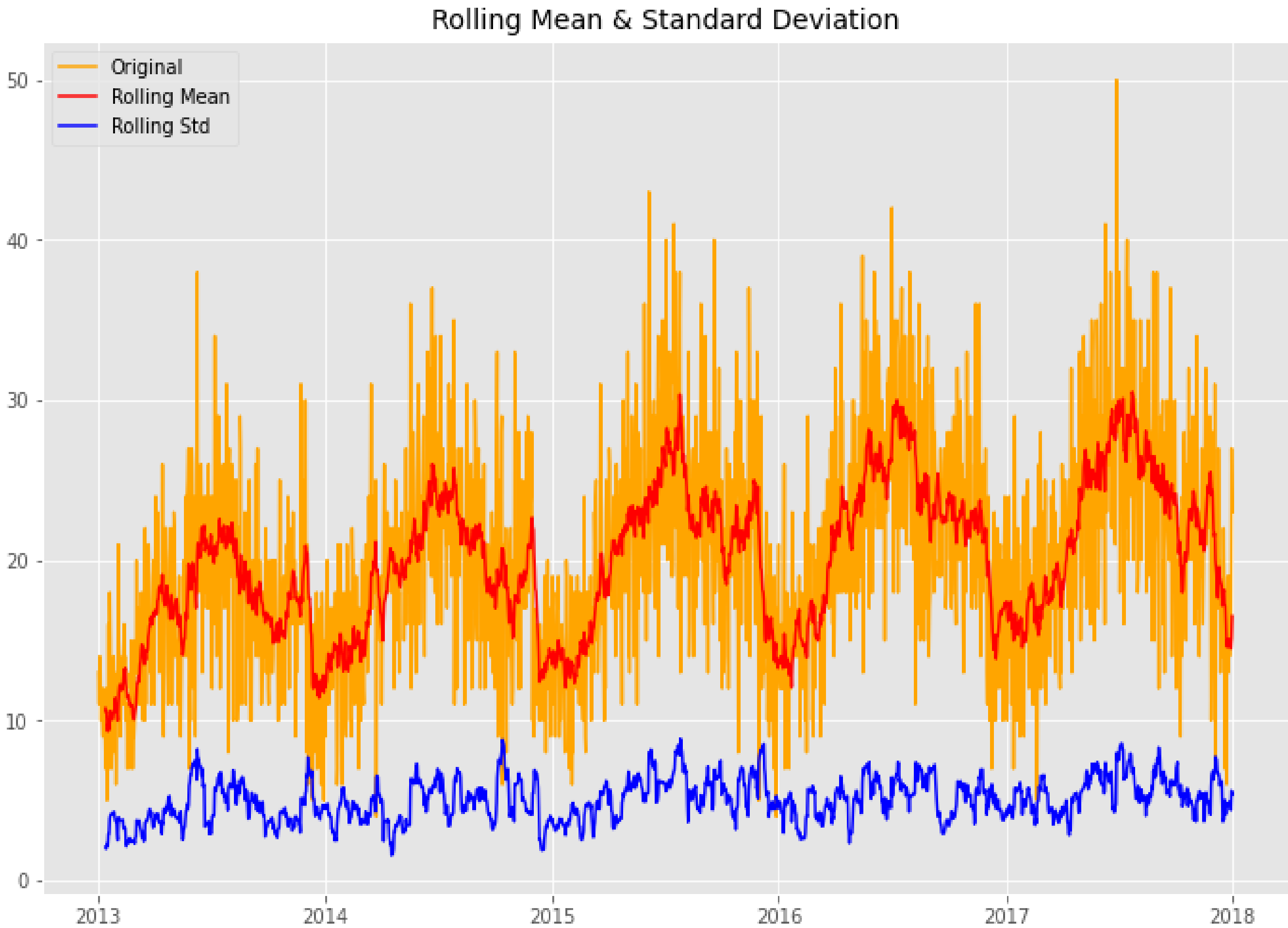


figure 3.2.1.1 ARIMA model results

The additive model is most appropriate if the magnitude of the seasonal fluctuations or the variation around the trend-cycle does not vary with the level of the time series as in our case.



Dickey-Fuller test was performed to find out whether the series is stationary or not. As, the smaller p-value, the more likely it's stationary. Here our p-value is 0.036. It's actually not bad, if we use a 5% Critical Value(CV), this series would be considered stationary. But as we just visually found an upward trend, we want to be more strict, we use 1% CV. p-value = 0.0361. The series is likely non-stationary. After reducing the trend and seasonality, we get the p-value as 0.0000. The series is likely stationary.



ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function)

Autocorrelation is a calculation of the correlation of the time series observations with values of the same series, but at previous times. Partial Autocorrelation, on the other hand, summarizes the relationship between an observation in a time series with observations at previous time steps, but with the relationships of intervening observations removed.Here we can see the ACF and PACF both has a recurring pattern every 7 periods. Indicating a weekly pattern exists.

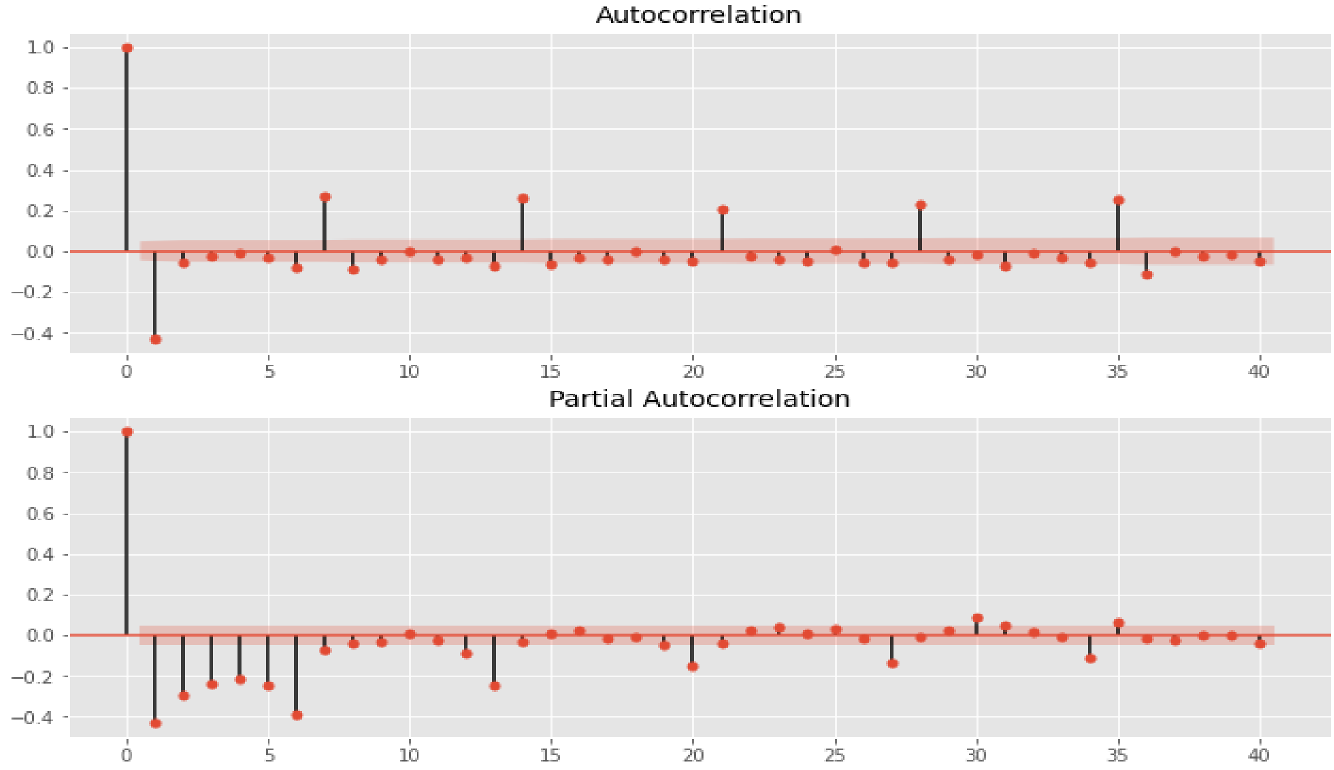
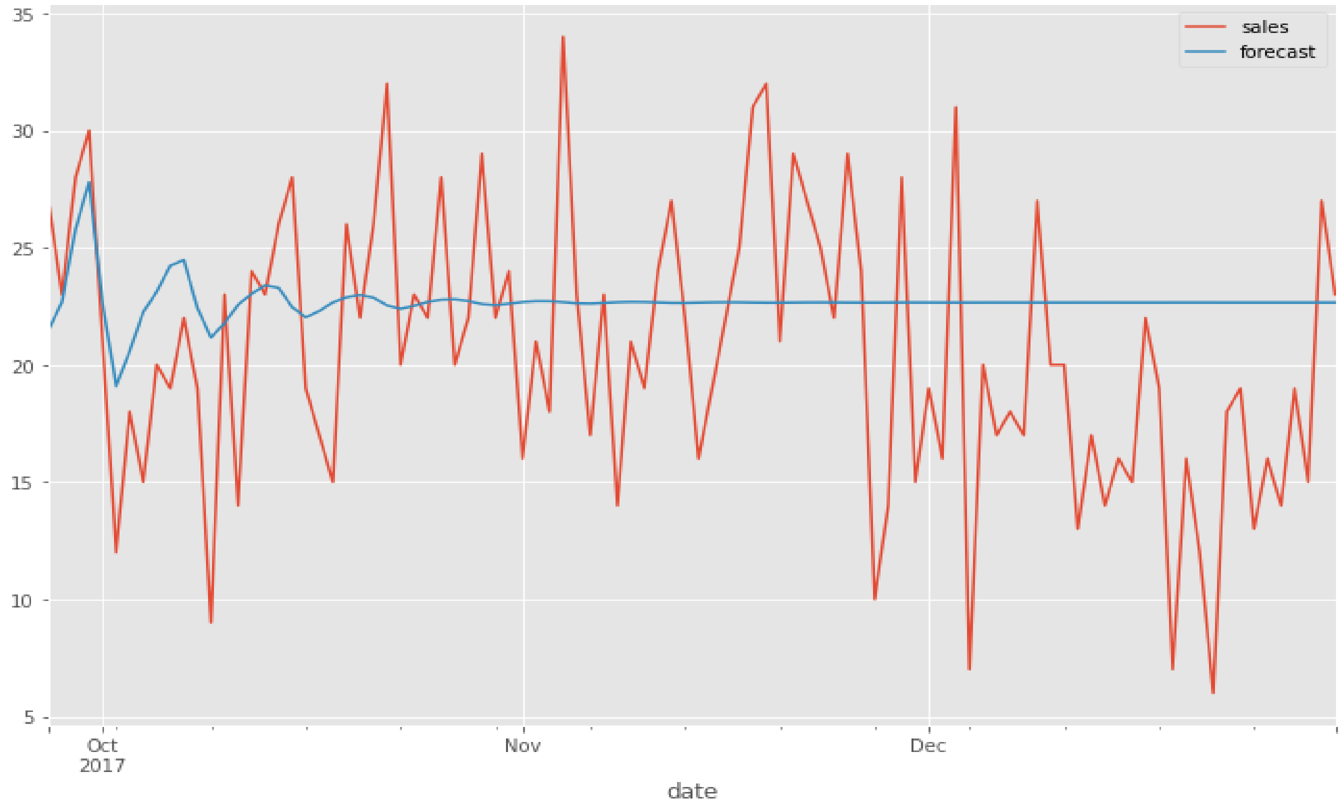


figure 3.2.2 ACF and PACF results

SARIMA Model

ARIMA, is one of the most widely used forecasting methods for univariate time series data forecasting, but it does not support time series with a seasonal component. The ARIMA model is extended (SARIMA) to support the seasonal component of the series. SARIMA (Seasonal Autoregressive Integrated Moving Average), method for time series forecasting is used on univariate data containing trends and seasonality. SARIMA is composed of trend and seasonal elements of the series.



3.3 Part B - Sourcing and Outsourcing

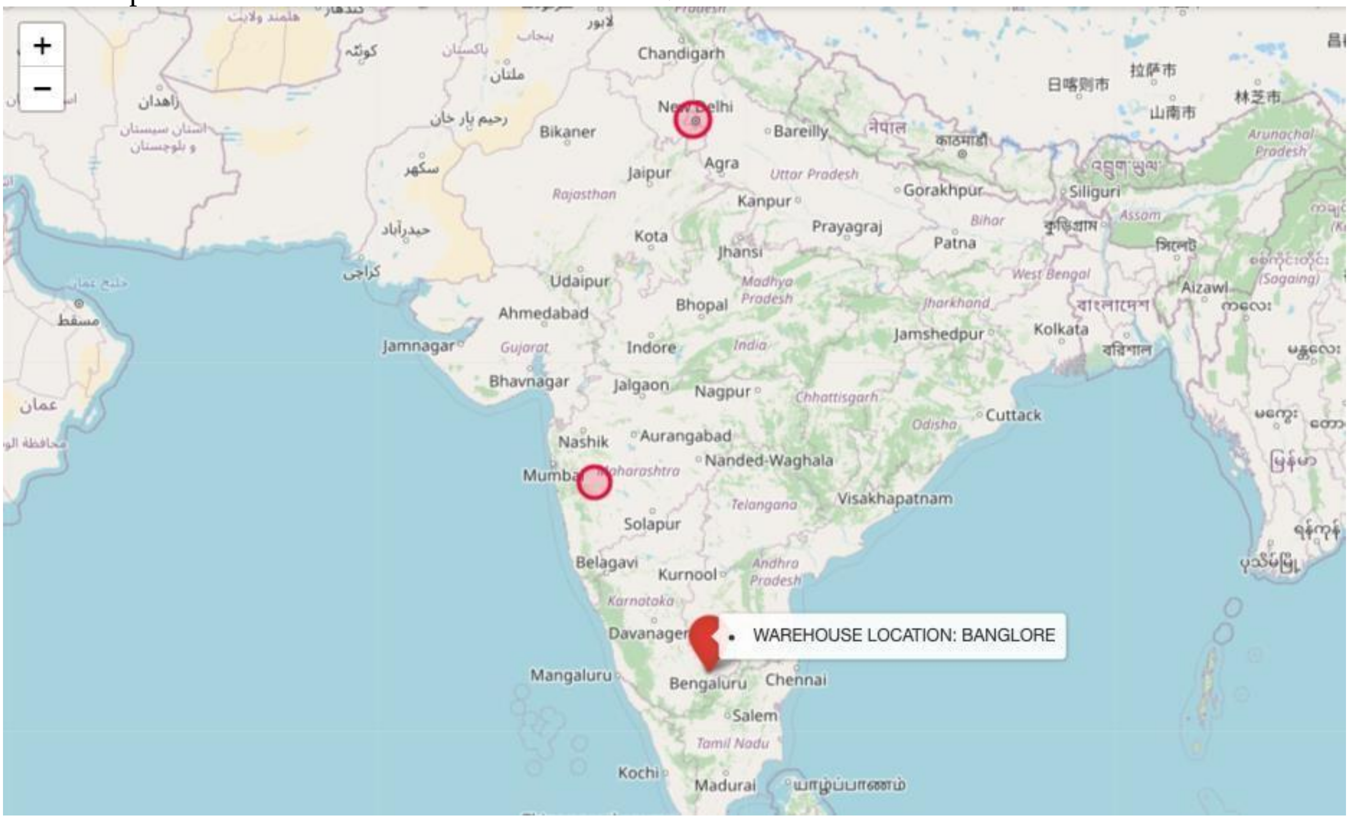
In fields like logistics, transportation, air travel, and more, these calculations deliver a key component for examining the fastest, shortest, and most efficient routes between two locations. For logistics, where distance and time can be the difference between profits and losses, finding the shortest possible point between two locations can greatly improve travel times and reduce wasted resources. More importantly, it can help calculations that feature several moving parts.

For instance, an airline that has to fly between two locations with a layover can find the most efficient path to fly, reducing jet fuel use, time that a single airplane is occupied, and increase the number of flights possible in a day. Even for delivery services, it can assist companies with planning the best possible routes for their teams to travel while reducing overall transit times, improving delivery speeds, and generating revenues.

While pen and paper calculations are time-consuming and not entirely necessary understanding how to calculate distances using latitude and longitude can help any company identify better routes to cut down the distances their planes, ships, cars, and teams must travel.
The calculation can be useful when trying to determine the distance for logistical purposes (ie delivery service, flights, distance between customers, etc).
Distance of between the origin and destination 301.17000641409464

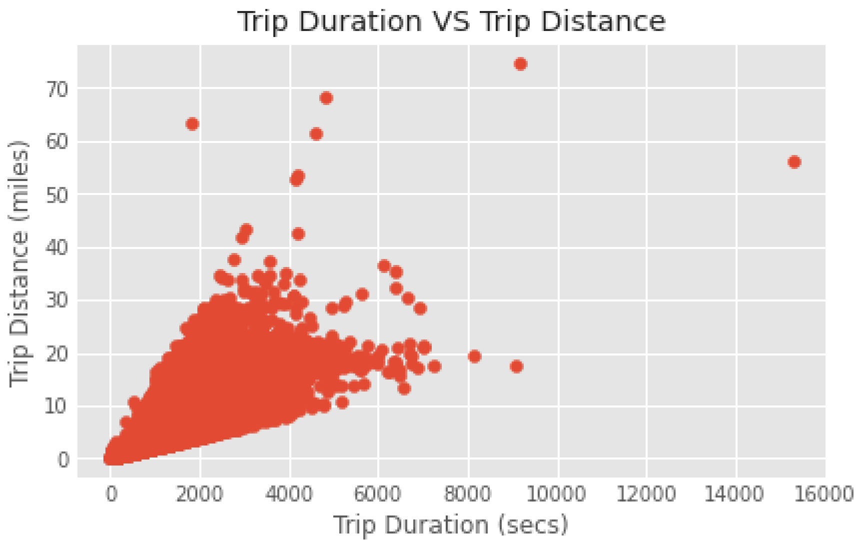
	State	District	Latitude	Longitude
0	Andaman and Nicobar	Andaman Islands	12.382571	92.822911
1	Andaman and Nicobar	Nicobar Islands	7.835291	93.511601
2	Andhra Pradesh	Adilabad	19.284514	78.813212
3	Andhra Pradesh	Anantapur	14.312066	77.460158
4	Andhra Pradesh	Chittoor	13.331093	78.927639

The latitudes and Longitudes have been removed to help with finding the distance between the warehouse and the place where the required part is available. Here, taking the example of finding the part "Brakes" where the user inserts just the name of the item and can view where the item is available and the quantity of the item available, which is Delhi that can be located on the map when hovered over the name of the area.



Trip Duration Prediction

The purpose of this modelling is to accurately predict the trip duration of taxi's. To make predictions we will use several algorithms, tune the corresponding parameters of the algorithm by analysisng each parameter against RMSE and predict the trip duration. To make our prediction we use RandomForest Regressor, LinearSVR and LinearRegression.
Based on the acquired dataset we have found out some insights which can be further used to increase optimality.



Models

The models are used to predict the estimated trip time to the actual time, which can help us choose the model which gives the highest accuracy.

a. Linear Regression

Linear regression is a linear approach to modelling the relationship between a scalar response and one or more explanatory variables.
accuracy 0.7805781859765831
Mean Absolute Error : 170.7867109199458
rscore is 0.7805781859765831

b. Bayesian Regression

Bayesian linear regression considers various plausible explanations for how the data were generated. It makes predictions using all possible regression weights, weighted by their posterior probability.
accuracy 0.780553392432325
Mean Absolute Error : 170.94139274017988
rscore is 0.780553392432325

c. Decision Tree Regression

Decision tree builds regression or classification models in the form of a tree structure. It breaks down a dataset into smaller and smaller subsets while at the same time an associated decision tree is incrementally developed. The final result is a tree with decision nodes and leaf nodes.
accuracy 0.7072930124263475
Mean Absolute Error : 179.71852584942945
rscore is 0.7072930124263475

d. KNN Regression

KNN regression is a non-parametric method that, in an intuitive manner, approximates the association between independent variables and the continuous outcome by averaging the observations in the same neighbourhood.

accuracy 0.7509285383054066
Mean Absolute Error : 168.74404283801874
rscore is 0.7509285383054066

e. Random Forest Regression

Random forests or random decision forests are an ensemble learning method for classification, regression and other tasks that operates by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean/average prediction (regression) of the individual trees.Random decision forests correct for decision trees' habit of overfitting to their training set. Random forests generally outperform decision trees, but their accuracy is lower than gradient boosted trees. However, data characteristics can affect their performance

Mean Absolute Error : 142.01376535875664
rscore is 0.8264000477212416
accuracy 0.8264000477212416

3.4 Part C - Invoice Data Analysis

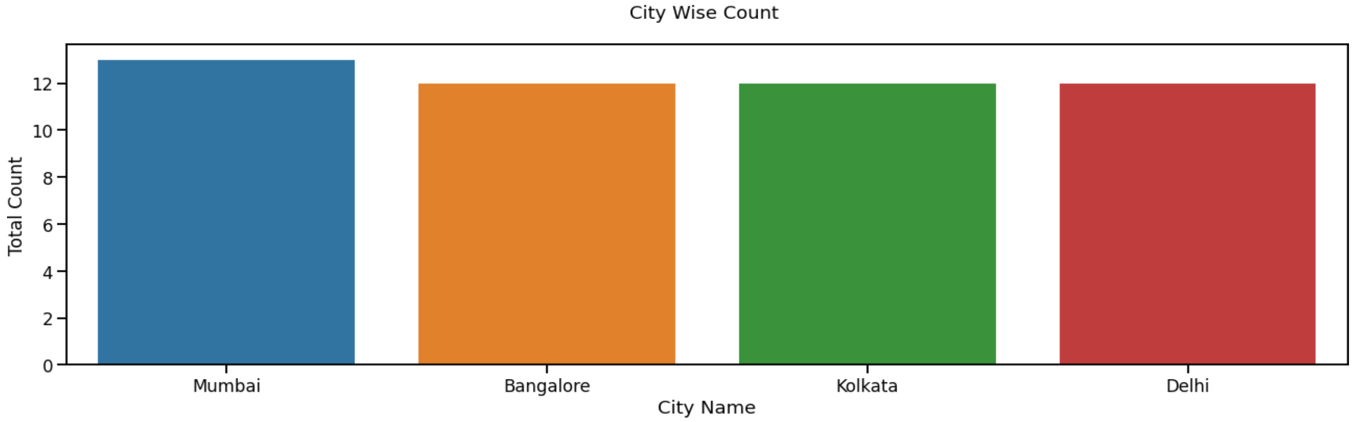
The real complexities of the automotive supply chain, and yet it should at least suggest the high degree of complexity that would be involved in true supply chain optimization. Given the number of moving parts, it would be ridiculous to expect a single supply chain planner with an Excel spreadsheet to create a supply stream that was even remotely optimized.

Designed to help automotive companies with the management of their critical documents from creation to approval, publishing to archiving, and deleting it permanently from the system. Solution comes with the extended capability to schedule approval, archival, and managing documents well in advance. An organization can collaborate with users for review of the document. Moreover, the users get notifications about the same.

Correct and seamless operation of the assembly plants and sales points of any automobile manufacturer greatly depends on the efficiency of their document processes. After all, as in any other sector, business documents and data need to be transferred quickly, efficiently and securely. The invoicing process needs to be managed by an advanced system that supports high volumes of data and rapid transactions, in order to ensure a secure, flexible and high- capacity process and keep the corresponding costs to a minimum.

Our solution has used a dataset which has fields such as Freight Cost (Rupees) , Shipment Mode , Manufacturing Site, and others.

The Number of Transactions are found out per city



Freight cost is seen to be highest Banglore and lowest in Mumbai; and total pack price is seen to be maximum in the cityv of Delhi and lowest in the city of Mumbai.

Analysis with respect to Different Shipment Mode

Analysis has helped us figure out the best possible shipment mode for future requirements.

a. Air Shipment mode

The Max Air Shipment Mode is : 270
The Min Air Shipment is : 20
The Mean Air Shipment is : 75.0

b. Truck Shipment Mode

The Max Truck Shipment Mode is : 240
The Min Truck Shipment is : 20
The Mean Truck Shipment is : 112.0

c. Ship Mode

The Max Ship Shipment Mode is : 240
The Min Ship Shipment is : 100
The Mean Ship Shipment is : 157.14

Quantity with respect to Region and Item

Financial Debit can be found out by calculating the transaction of all the invoice left to clear, through our analysis we can find fast and user friendly data about the debit and credit.
Total Transaction amount (in Rupees) 30521852054.40518

Chapter 4

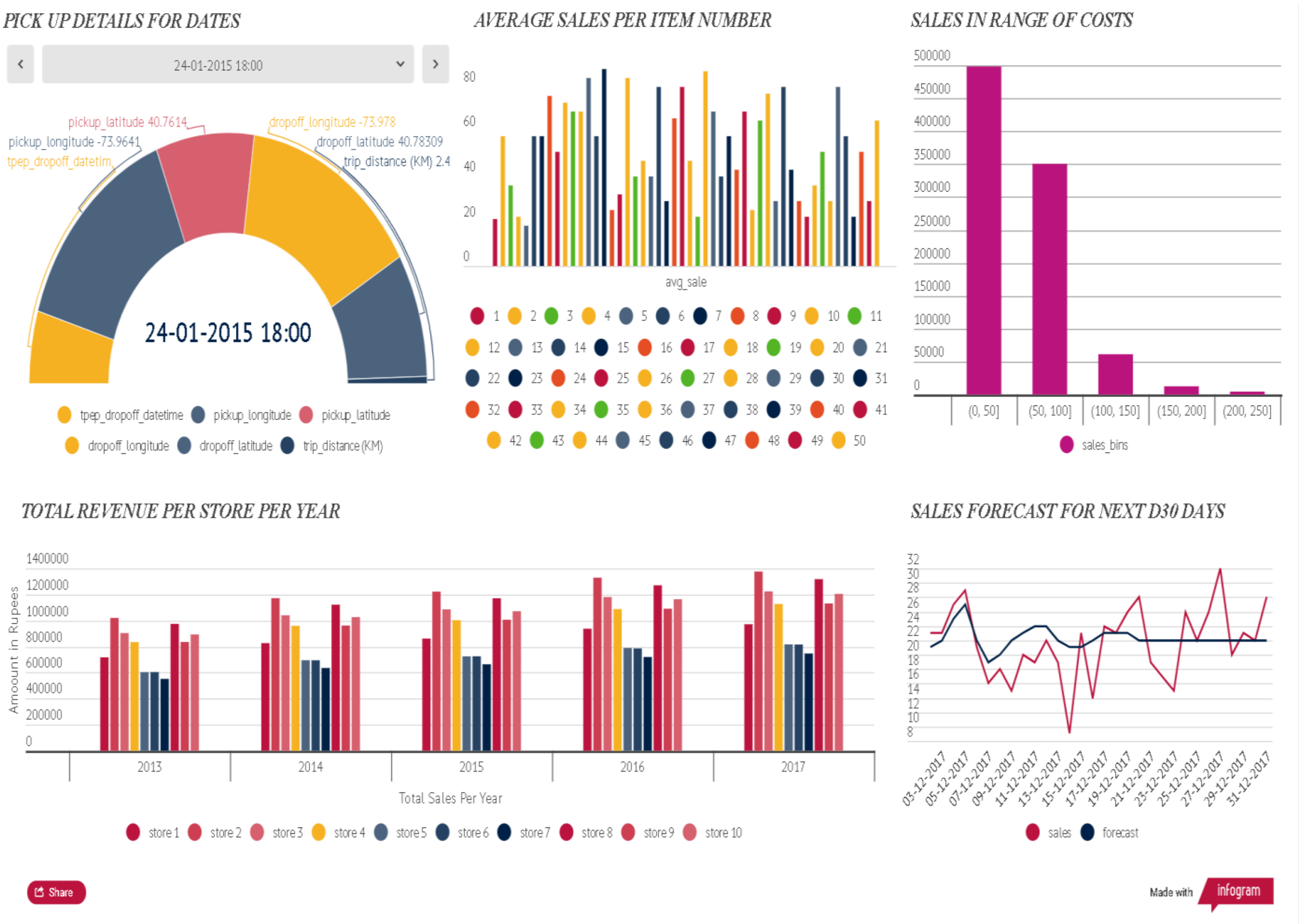
GUI implementation and Results

4.1 GUI implementation

A data dashboard is an information management data tool that visually tracks, analyzes and displays insights, metrics and key data points to monitor the health of a supply chain management system,business, department or specific process. They are customizable to meet the specific needs of a department and company. Behind the scenes, a dashboard connects to your files, attachments, services, but on the surface displays all this data in the form of tables, line charts, bar charts and gauges. A data dashboard is the most efficient way to track multiple data sources because it provides a central location for businesses to monitor and analyze performance. Real-time monitoring reduces the hours of analyzing and long lines of communication that previously challenged businesses.

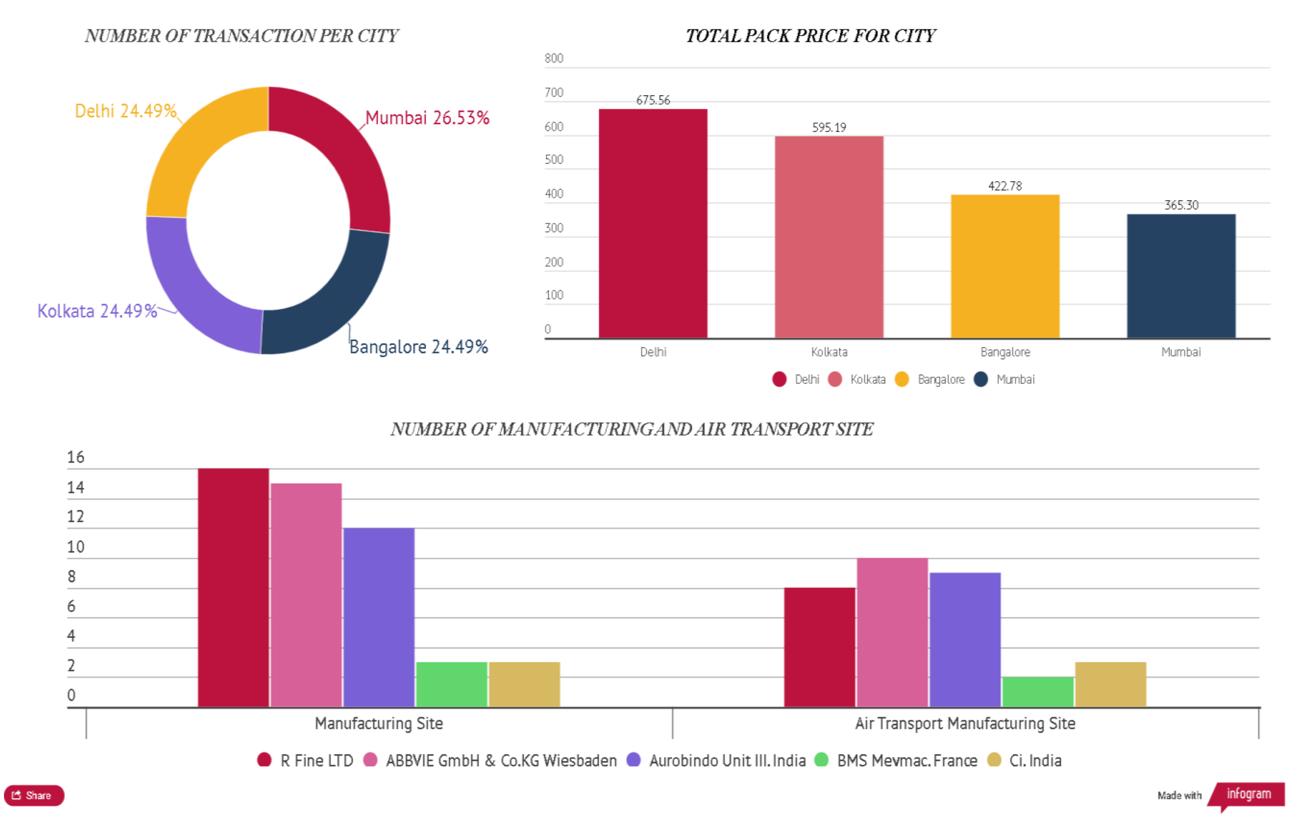
Dashboard mainly focuses on the questions emerging by the supply chain management system which needs to implement production according to the current trends.

What’s our Sales Revenue? Where is our Sales Revenue compared to where it should be?
How many signups has the management system done this week? Was it more or less than last week?
What is the share of sales per month? Has there been an increase in Revenue per month?
What does our profit margin look like? Is it on target?



By taking raw data from a number of sources and consolidating it before presenting it in a tailored, customized dashboard, data dashboards can help make sense of your company's most valuable data and empower you to find actionable answers to your most burning business questions.

In doing so, your business will be data-driven, and as a direct result – more successful.



Dashboards present interactive data visualizations

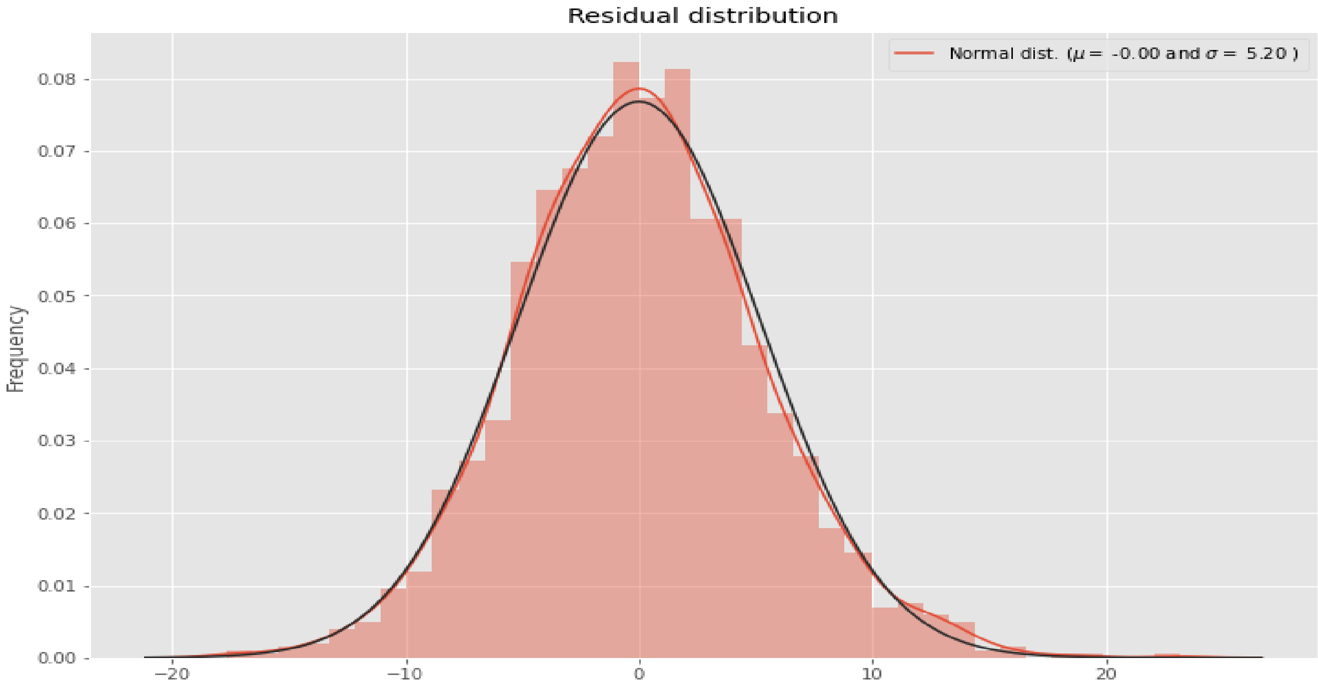
Data is visualized on a dashboard as tables, line charts, bar charts and gauges so that companies can track the health of their production against benchmarks and goals. Data dashboards surface the necessary data to understand, monitor and improve your business through visual representations. Depending on how you decide to design your dashboard, even straightforward numerical data can be visually informative by utilizing intuitive symbols, such as a area chart for given revenue per month vs amount of volume of sold, bar graph with sales per unit helps to visualize which product has highest sales and which has the lowest, gauge with target shows where are revenue sales has reached for achieving our target, a table line graph which shows the number of signups,orders,sold unit,profit margin with the exact value provided by analyzing our data which can indicate the direct comparison with sales per month per unit.

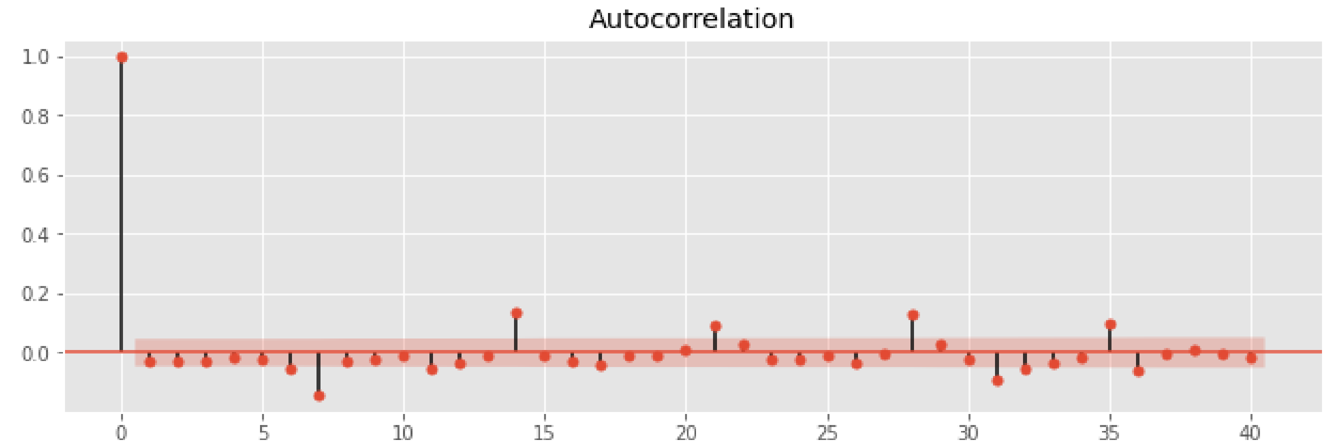
4.2 Results

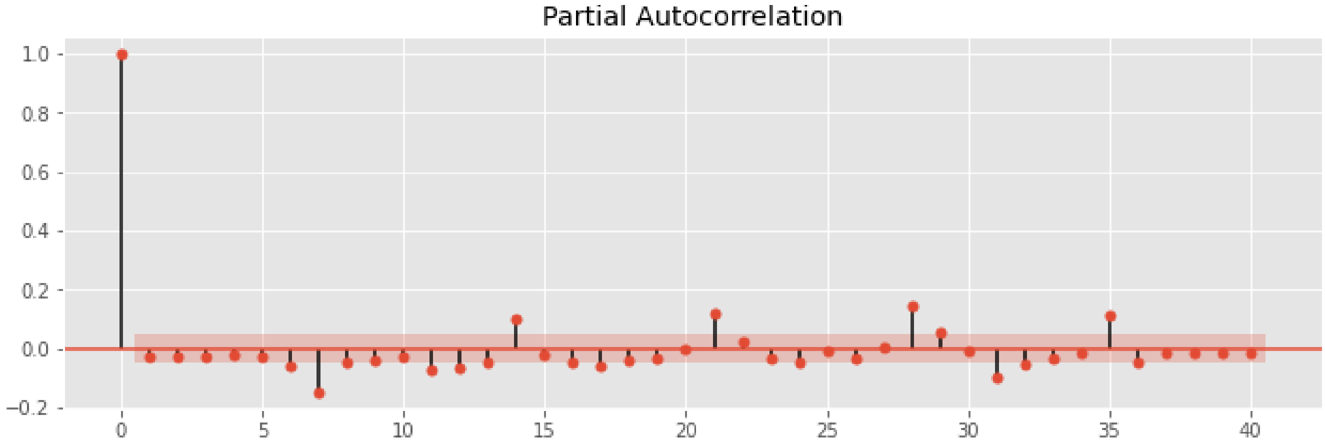
ARIMA Model

```
                             ARIMA Model Results
==============================================================================
Dep. Variable:                D.sales   No. Observations:                 1825
Model:                 ARIMA(6, 1, 0)   Log Likelihood               -5597.668
Method:                       css-mle   S.D. of innovations              5.195
Date:                Tue, 25 May 2021   AIC                          11211.335
Time:                        12:39:32   BIC                          11255.410
Sample:                    01-02-2013   HQIC                         11227.594
                         - 12-31-2017
=================================================================================
                    coef    std err          z      P>|z|      [0.025      0.975]
---------------------------------------------------------------------------------
const             0.0039      0.025      0.152      0.879      -0.046       0.054
ar.L1.D.sales    -0.8174      0.022    -37.921      0.000      -0.860      -0.775
ar.L2.D.sales    -0.7497      0.026    -28.728      0.000      -0.801      -0.699
ar.L3.D.sales    -0.6900      0.028    -24.665      0.000      -0.745      -0.635
ar.L4.D.sales    -0.6138      0.028    -21.950      0.000      -0.669      -0.559
ar.L5.D.sales    -0.5247      0.026    -20.132      0.000      -0.576      -0.474
ar.L6.D.sales    -0.3892      0.022    -18.064      0.000      -0.431      -0.347
                                    Roots
=============================================================================
                  Real          Imaginary           Modulus         Frequency
-----------------------------------------------------------------------------
AR.1            0.6842           -0.8982j            1.1292           -0.1464
AR.2            0.6842           +0.8982j            1.1292            0.1464
AR.3           -1.0869           -0.5171j            1.2037           -0.4293
AR.4           -1.0869           +0.5171j            1.2037            0.4293
AR.5           -0.2714           -1.1477j            1.1794           -0.2870
AR.6           -0.2714           +1.1477j            1.1794            0.2870
-----------------------------------------------------------------------------
```

Normal test Results pvalue=0.0002710536340863827



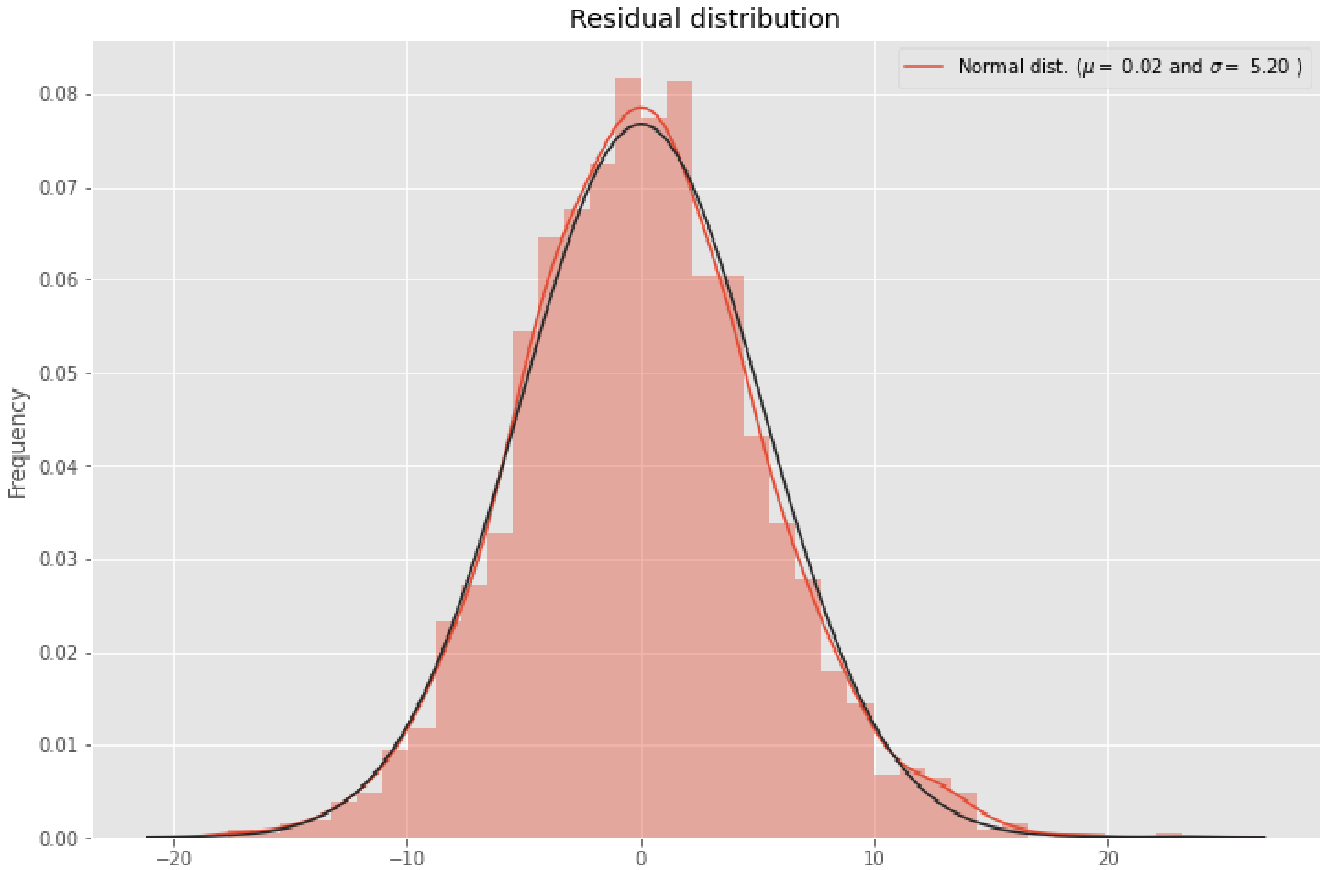


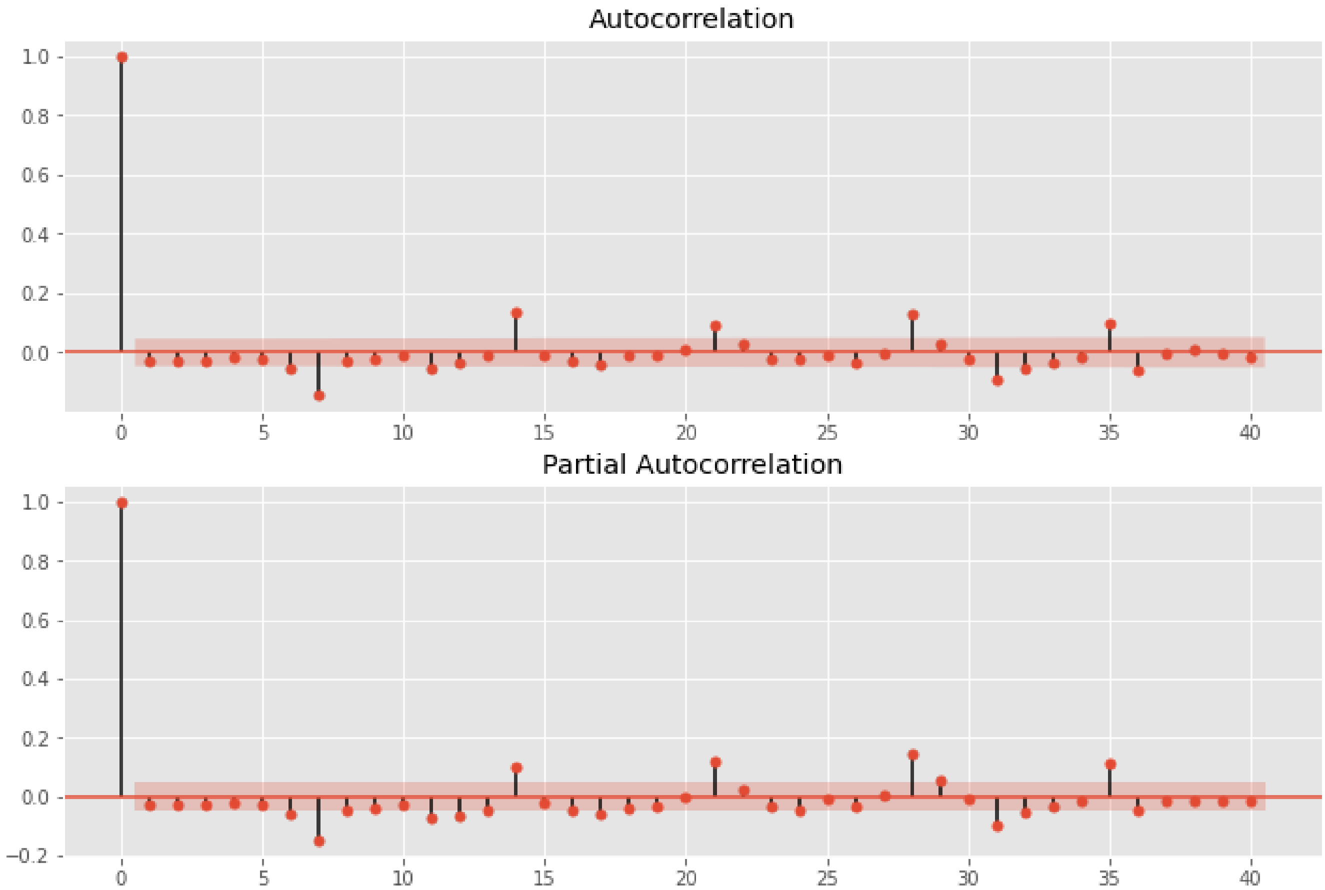


Normal test Result
statistic=16.426387689817304
pvalue=0.0002710536340863827

SARIMA Model

```
                               Statespace Model Results
==========================================================================================
Dep. Variable:                    sales   No. Observations:                    1826
Model:                 SARIMAX(6, 1, 0)   Log Likelihood                  -5597.679
Date:                  Tue, 25 May 2021   AIC                             11209.359
Time:                          12:39:36   BIC                             11247.924
Sample:                      01-01-2013   HQIC                            11223.585
                           - 12-31-2017
Covariance Type:                    opg
==========================================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------------------
ar.L1         -0.8174      0.021    -39.063      0.000      -0.858      -0.776
ar.L2         -0.7497      0.025    -30.480      0.000      -0.798      -0.702
ar.L3         -0.6900      0.026    -26.686      0.000      -0.741      -0.639
ar.L4         -0.6138      0.027    -22.743      0.000      -0.667      -0.561
ar.L5         -0.5247      0.025    -21.199      0.000      -0.573      -0.476
ar.L6         -0.3892      0.021    -18.819      0.000      -0.430      -0.349
sigma2        26.9896      0.817     33.037      0.000      25.388      28.591
===================================================================================================
Ljung-Box (Q):                      205.88   Jarque-Bera (JB):                        19.53
Prob(Q):                              0.00   Prob(JB):                                 0.00
Heteroskedasticity (H):               1.41   Skew:                                     0.15
Prob(H) (two-sided):                  0.00   Kurtosis:                                 3.40
===================================================================================================
```





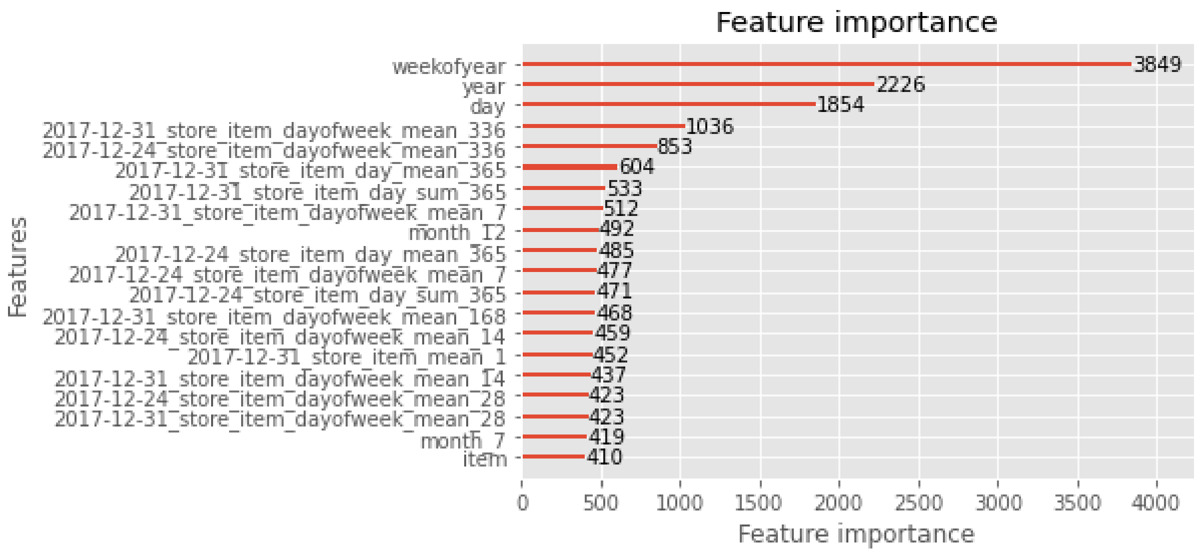
Normal test Result
statistic=16.742690143436878
pvalue=0.00023140408921805145
MAPE: 33.01 %
SMAPE: 25.07 %

The study concludes with some case studies why specific machine learning methods perform so poorly in practice, given their impressive performance in other areas of artificial intelligence. The challenge leaves it open to evaluate reasons of poor performance for ARIMA/SARIMA and LSTM models, and devise mechanisms to improve model's poor performance and accuracy. Some of the areas of application of the models and their performance is listed below: ARIMA yields better results in forecasting short term, whereas LSTM yields better results for long term modeling. Traditional time series forecasting methods (ARIMA) focus on univariate data with linear relationships and fixed and manually-diagnosed temporal dependence. Machine learning problems with a substantial dataset, it is found that the average reduction in error rates obtained by LSTM is between 84–87 percent when compared to ARIMA indicating the superiority of LSTM to ARIMA.
The number of training times, known as "epoch" in deep learning, has no effect on the performance of the trained forecast model and it exhibits a truly random behavior.
LSTMs when compared to simpler NNs like RNN and MLP appear to be more suited at fitting or overfitting the training dataset rather than forecasting it.
Neural networks (LSTMs and other deep learning methods) with huge datasets offer ways to divide it into several smaller batches and train the network in multiple stages. The batch size/each chunk size refers to the total number of training data used. The term iteration is used to represent the number of batches needed to complete training a model using the entire dataset.

LSTM is undoubtedly more complicated and difficult to train and in most cases does not exceed the performance of a simple ARIMA model.

The sales predictive analysis to forecast the demand using various models are given below:

Model	rscore
Linear regression	0.6558538493142778
XGBoost	0.9233099242965672
Decision Tree Regressor	0.8446189984842214
Random Forest Regressor	0.9092196878110362



Trip duration Prediction

Model	Accuracy	Mean Absolute Error	rscore
Linear Regression	0.7805781859765831	170.7867109199458	0.7805781859765831
Bayesian regression	0.780553392432325	170.94139274017988	0.780553392432325
Decision Tree Regression	0.7072930124263475	179.71852584942945	0.7072930124263475

KNN regression	0.7509285383054066	168.74404283801874	0.7509285383054066
Random forest Regressor	0.8264000477212416	142.01376535875664	0.8264000477212416

Random Forest Regressor gives the maximum accuracy of 82.64%

Chapter 5

Conclusion and Future work

5.1 Conclusion

Businesses that integrate modern technologies in their supply chain can enhance service levels while reducing up to 30 percent of costs. While creating a future-ready supply chain, auto companies need to be on top of the latest trends that are shaping the industry. For instance, ever changing international trade policies, the continuous evolution of environmental and safety regulations, and even cybersecurity issues are all contributing to the auto supply chain puzzle. Technology has come a long way, and advancements in AI and ML make it possible for automotive companies to analyze vast amounts of data to predict events, spot trends and anomalies, analyze any correlations between patterns and variables, understand the ramifications of different response options, and provide recommendations. Now, with the ability to analyze outcomes (including consumer insights and past behavior) and adjust supply parameters, companies can make faster and better decisions and provide better visibility, speed, and automation to address the growing complexity. And they can do so profitably. By leveraging the power of AI, automotive companies can now take advantage of the digital revolution to create a fully connected, automated supply chain that gathers information, performs sophisticated analysis, and takes strategically correct action with no human intervention. Whatever a company's current stage in its supply chain evolution, it is essential to remember that achieving full autonomy is an ongoing process, beginning with single technology implementations in critical areas of the business. But the end benefits—including increased supply chain visibility, reduced expenses, higher performance, increased efficiency, revenue growth, improved margins, and higher shareholder value—make the journey to full autonomy worthwhile.

In conclusion, artificial intelligence is redefining the supply chain, especially within the automotive industry. AI is helping companies streamline processes, schedule production, manage supply risk, minimize supply chain disruption, reduce language barriers, improve customer service and quality control, and improve demand forecasting. With these benefits, there will be quite a few challenges companies will have to face to get the most out of the new technology. The biggest challenges being faced today include a lack of computing power, high cost, the long implementation process, the complexities of language and social cues, the lack of data scientists and other analysts, sharing data, legacy systems, and security concerns. As this technology continues to evolve and grow, more applications of AI will be developed, while the challenges will continue to progress. The sooner automotive companies start implementing AI, the sooner they can start improving processes, produce more efficiently, and save money from a range of different areas of the business. Companies will improve customer service, which strengthens the relationships between the consumer and the OEM, which encourages repeat customers. Stronger bonds can be formed between the OEM and their suppliers, which encourages joint development and overall growth.

5.2 Future work

The development and proliferation of driverless cars or assisted driving is perhaps one of the greatest innovations on the horizon in today's automotive manufacturing industry. Yet even so, AI has the potential to impact the automotive manufacturing supply chain in equally profound and interesting ways beyond the idea of the driverless car. In fact, AI has the potential to be a truly disruptive force in the way automotive manufacturing companies produce vehicles and how the consumer interacts with the end product.
With AI as an increasingly common technology platform, the automotive industry is set to experience significant changes in the coming years in terms of production and supply chain management. As vehicles become more integrated, individualized, and complex, manufacturing companies will have to leverage more lean methods of production and supply chain logistics to keep pace with the demands of such a variant-rich industry.

By the year 2020, industry analysts estimate more than 250 million vehicles will be connected to the internet. These vehicles will be equipped with a myriad of sensors, embedded connectivity platforms, geo-analytical capabilities, and other methods of incorporating Big Data as a baseline of operations. As such, the Internet of Things principle will become a critical link in integrating these disparate systems into a unified operating platform.It means manufacturers will have to work more closely with software developers and other players in the software industry to successfully integrate these smart systems into new vehicles and ensure effective communication between these systems. This means the potential for new partnerships and an expansion of existing partner networks, which can result in exciting business opportunities but also more complex networks with new partners in disparate parts of the world.

In today's supply chain, many of the plant's actions are reacting to what is happening around them. For instance, if a machine breaks down, the production schedule must be re-made to accommodate this stop in production. This is very reactive; employees must quickly determine the best solution to minimize delays and money lost. On the other hand, proactive planning allows employees to start planning for potential problems before they occur, so a recovery plan is finalized and can be set in place much sooner. With an increase in AI implementation in the supply chain, manufacturing firms are going to be able to shift from very reactive planning to proactive decision making. As AI is being developed and further implemented, employee's duties and responsibilities are being shifted to help accommodate this. "Artificial intelligence technology serves as an advisor that can make connections based on all relevant data, from internal systems and external like social and news feeds, weather, traffic, and other sources, from learnings caused on prior resolutions, and from any notes your collaborators may choose to upload for future reference" ("The AI Journey: Artificial Intelligence and the Supply Chain").

As AI starts to take over more of the manual or tedious tasks, staff are going to be responsible for more managerial responsibilities. Staff will rely on the recommendations from the AI systems, and as the system learns more things will continue to change. Automation is going to play a large part in the future of the automotive industry, and many companies have been and continue to implement more machine-based processes to support manufacturing. With an automated process, there is much smaller room for error for critical steps. Human error is a large concern for many manufacturing settings, so if the process is created to rely on automation to ensure the correct procedures are being followed consistently, the overall part quality will greatly improve. In addition to quality, speed is another big benefit of automation in a manufacturing setting. If a machine can do the same five steps over and over again even a second faster than a human, think about how much time can be saved on a daily or weekly basis. Automation is becoming more and more fundamental in any automotive process, which will only continue as robotics continue to advance.

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