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Research paper

A Data Warehouse Based Modelling Technique for Stock Market Analysis

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Abstract

The objective of this paper is identifying a warehouse model to build an analytical framework and analyze different important parameters which directly impact the changes of share market. We identify parameters that represent different viewing windows and perspectives towards stock market performance and movement trends. We categorize and define many intrinsic as well as external factors that may affect stock market as a whole. Sensex and Nifty are used as the pulse of Indian stock market. In this paper, we focus on defining a suitable OLAP model which can cater all the parameters that affect share market. We also identify different applications of this analytical model for forecasting information to help decision making.

Keywords: *Analytical Processing; Data Warehouse; Lattice of cuboids; Prediction and forecasting; Stock Markets*

1. Introduction

Data warehouses (DW) have been used by almost all the businesses for their decision support systems as well as in strategic business intelligence systems. It helps organize, store and analyse huge amount of day to day transactional data in a systematic way that is much different from operational database systems. Data warehouses usually stores data in de-normalized form for high performance during complex ad hoc business queries. Data warehouse technology includes Extract-Transform-Load (ETL) processes for data cleansing, data integration from many different databases as well as other manual systems and online Analytical processing (OLAP)[16]. OLAP stands for analysis techniques with functionalities such as summarization, consolidation and aggregation, as well as the ability to view information from different angles. The term OLAP was first coined by Codd. He presented 12 guidelines to evaluate OLAP systems and emphasized the main characteristic of OLAP [1]. OLAP tools conceptually model the information as multidimensional cubes.

Stock market is a secondary market place where shares or stocks of different listed companies are traded. In Indian context any person having an authorized trading account from any depository participants can take part in buying or selling of stocks. Share prices of stocks vary throughout the day as well as throughout time depending on a lot of factors. Basic working of stock market depends on the individual perception on the future price of some company's share. Few people foresee an uptrend in stock valuation so they buy at current price level to sell it in future with a profit earning. Again, in the same time a few people assume that share price will fall in future so they sell at current price level and in future they may buy again at a lower price. There are internal as well as external factors that affect stock prices. Some of the internal factors may be operating ratio, work order received, high demand of produced goods, technically advanced assembly line, profit margin of the company etc. External factors can be those factors which are out of the company's control such as change in government policy, subsidy, political instability, big events like Olympics, world cup etc. But most common attribute is the balance between supply and demand of some stock that determines its price on day to day basis. In a normal day there are sellers as well as buyers for stocks due to different perception of the future stock price. In future any one category of people will benefit and other has to incur loss. So there has been many efforts spent on predicting future stock price movement analysis and a lot of different data mining and statistical analysis has been tried with mixed success. Some of the simple tools that are widely used to analyse future price from historical price movement data are: 30 days moving average; 200 days moving average, weighted average etc.

In this paper at first, we discuss on Indian share market and different relevant terms of Data warehouse and OLAP tools which are used in this research work. The main focus of this paper is to build a data warehouse model which can work with different parameters (dimensions) for analysing the movement of share market. The model will further show how the analysis is possible with the different combinations of identified dimensions. Here we also consider the abstraction of some of the dimensions and also include these abstractions in our proposed methodology for analysis purpose.

In the following subsections we discuss related terms used in stock market as well as DW and OLAP technology.

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1.1. An Overview of Indian Share Market

The Bombay Stock Exchange (BSE) is one of the oldest stock exchanges in India and one of the top stock exchanges globally with respect to the number of listed companies and market capitalization. The BSE 30 or the SENSEX is a stock market index of 30 well established and financially sound companies listed on BSE. The 30 component companies which are some of the largest and most actively traded stocks are representative of various industrial sectors of the Indian economy. It is published since 1st January 1986 and regarded as the pulse of the domestic stock markets in India [2]. The NIFTY 50 index is national stock exchange of India's benchmark stock market index for Indian equity market. Most of the stocks belong to BSE SENSEX are also in NIFTY 50. The shares are chosen such a way so that it covers almost all industry sectors and tracking its performance will give analogous result of whole stock market.

2.2. Data Warehouse and OLAP

A data warehouse is a subject-oriented, integrated, non-volatile, and time-variant collection of data in support of management's decisions [3]. The information stored in a DW is usually exploited by OLAP tools as it provides quick answers for queries that aggregate great amount of detail data to analyse trends and patterns. OLAP tools conceptually model the information as multidimensional data cubes where data is divided into facts and dimensions. Dimensions are the business users' perspectives on which analytical trend or pattern analysis will be based. Facts are the main events or transactions whereas dimensions provide the context to the facts. Facts are numerical measures. The fact table contains names of facts, or measures as well as keys to each of the related dimension tables.

A concept hierarchy defines a sequence of mappings from detailed concepts into higher level abstractions. Hierarchies allow the user to start from a detailed view of data and reach to abstracted view by roll-up operation and the reverse operation is called drill-down where the detailed data is fetched from the abstracted data. Concept hierarchy can be of total order or of partial order (aka lattice). In a location dimension where attributes such as street, city, pin, state etc. are related by a total order (street<city<state<country). An example of a partial order for the time dimension based on the attributes like day, week, month, quarter and year is "day< {month<quarter; week} <year".

The cubes in a DW can be stored in a multidimensional database by following either a so called Relational OLAP (ROLAP) and/or a so-called Multidimensional OLAP (MOLAP) approach. ROLAP systems use relational databases to store data and achieve good query performance, better scalability. It also supports frequent updates well. ROLAP implementations typically employ star or snowflake schemas, both of which store data in fact tables and dimension tables. Star and snowflake schemas differ in how they manage dimensions, and selecting any of them mainly depends on the required properties of the modelled system. A star schema has one table for each dimension. Snowflake schemas contain one table for each dimension level to avoid redundancy, which may be advantageous in some situations. The dimension tables each contain a key, a column holding textual descriptions of the level values, and possibly columns for level properties. Tables for lower levels also contain a foreign key to the containing level.

1.3. Lattice of Cuboids

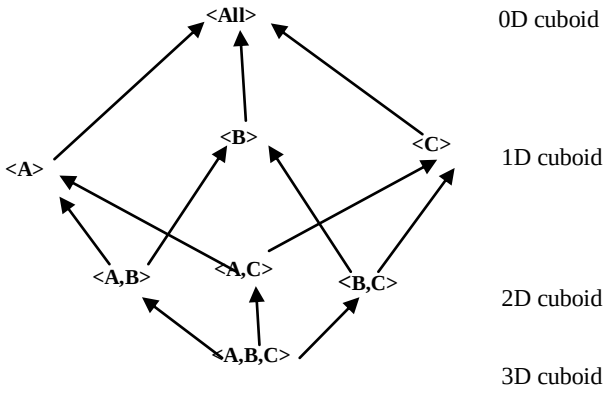


Fig. 1: A lattice of Cuboid showing all possible aggregation on all 3 dimensions

If there are 'N' numbers of dimensions then the fact table would contain the primary key of all of all these 'N' dimension tables. The instances of fact table are represented as base cuboid which is an N-dimensional cuboid. All possible combinations of the cuboids could be generated from this base cuboid. Rollup operations generate a new cuboid through dimension reduction. Rolling up an N-dimensional cuboid we get (N−1)-dimensional cuboids. After repetitive application of Roll-up operation on intermediate cuboids would finally generate 0-D cuboid or apex cuboid. It is denoted by <All>. All these roll-up operations generate a set of total 2N cuboids that collectively corresponds to a lattice structure and is known as lattice of cuboids in DW literature [4]. The following is a figure of 3-D data cube, consist of three dimensions A, B and C where each cuboid represents different degree of summarization [5],[6]. As this lattice of cuboids form of three dimensions, numbers of generated cuboid are 23 that is total of 8 cuboids (Figure 1).

2. Related Work

There are number of researches done on Stock price prediction as well as prediction of stock exchange index movement using data mining and statistical analysis. Good reviews of stock market forecasting methods were discussed in [7]. Author has identified three different categories of analysis namely fundamental analysis, technical analysis and the efficient market theory. Researchers in [8] used OLAP and data mining to find out long-term and short-term rules influencing oil price underlying time series in data warehouse and carry out dynamic risk decisions according to the useful patterns, relations and information. To test any of the above models, good quality pre-processed data with multiple perspectives is of prime importance. Data warehouses provide a way to store pre-processed, properly aggregated and multi-dimensional data on a specially designed database schema that can be used for OLAP analysis. J. Han introduced the concept of OLAP mining [9] where with the availability of data cubes and cubing operations, mining can be performed on any of the layers of abstraction. One can first perform cubing operation to select a portion of data and then select the dimension abstraction level and then apply data mining techniques on it. For example, user may first select business industry sector = telecom and then year = 2015 and gets a sub cube ready for data mining. Relevance cube or R-cube [10] is proposed to contextualize corporate warehouse data with text mining of related news articles using Information retrieval techniques. This concept helps to understand impact of some big event (such as Iraq war in 1990) or corporate results on stock prices etc.

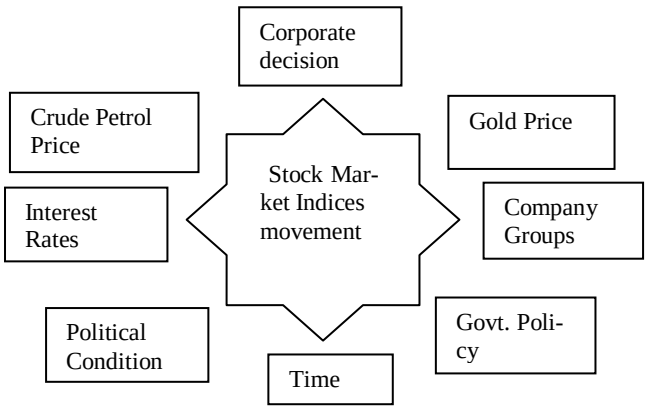


Fig. 2: Logical Schema for Stock Market Analysis with Fact and Dimension Entities

Authors in [11] have analysed co-movement of Taiwan and Hong Kong stock market indices for future investment portfolio. They have built a star schema to store different market indices, their performance, date of observation, frequency of observation etc. They have done association rule-based analysis, cluster analysis with k-means algorithm to analyse the data store in the star schema. They have used only selected parameters particularly required for their analysis purpose. Authors in [15] also used historical sectorial index values to predict future movement using lagged correlation and association rule mining. Both the works focused on data mining rather than modelling the warehouse for analytical processing. However, in the existing research work we have not identified any literature which deals with multiple parameters based generic schema model associated with share market at a time. We address the problem from data warehouse point of view so that an analytical framework could be proposed to simultaneously work with several parameters. In our proposed DW model for share market analysis we will consider many different perspectives and variables that affects share prices and data will be stored in such a way that investor will be able to concentrate on a smaller part of data based on his selection criteria. Huge stock price data will be aggregated based on different parameters as well as abstraction levels. Our aim is to design a generic model for building a DW that can be used for different kind of knowledge discovery based on the diverse business requirements.

3. Proposed Framework to Analyze Stock Market by Forming Suitable DW Schema

In the previous section we have discussed several significant research works in analyzing share markets. However, we could not find any research work on DW models which work with several associated parameters at the same time. Therefore, we identify absence of a data model which provides an integrated framework to analyze the relationship of multiple parameters. In this research work we try to conceptualize a suitable data model which able to present different factors or parameters associated with share market as a single integrated framework.

In the proposed framework we identify every factor or parameter as a dimension for OLAP analysis. With the help of these dimensions we construct the fact table based on Star schema modelling. The proposed model is presented in subsequent sections.

3.1. Dimensions for Share Market Analysis

In this section we identify different dimensions with respect to their impact on share market analysis. These dimensions have been identified by studying different economic surveys as well as Share market analysis reports from a macro-economic view [7][8][11][12][13]. A good survey of different input parameters, datasets with duration of data collection as well as methods used for stock market analysis is presented in [12]. Depending on the direct and indirect as well as near term and long-term effects of these items, we evaluate suitable dimensions for the share market analysis using DW. Now we discuss about the impact of every identified dimension in share market.

Time: Time is an inevitable dimension for any data warehouse. DW stores historical data, hence present data can easily be compared with older data. Past trend analysis as well as historical moving averages can only be calculated with data stored across time dimension. Any stock exchange index movement is captured throughout the day in terms of 'opening points', 'closing points',' intraday low', 'intraday high' etc. For any analysis on these 'day level' granular data will require hours, minutes and even seconds to be considered in the time dimension. It is assumed that historical data holds the key to future prediction, so for any real useful analysis of share market data time becomes an important perspective to the analysis.

Company Groups: This could be for all the companies enlisted in the share market or the companies which form the Sensex, Nifty, BSE 100 or any other index. The data stored in this dimension could be the range of aggregated profit/loss of all the companies, aggregated profit/loss industry wise, aggregated based on public sector and private sector companies, % of change in turnover etc. This dimension will allow us to analyse comparative performance of different index as well as different sectors, industries etc. Again, investors normally calculated some technical parameters to understand a company's fundamentals. Such measures are price to earnings ratio (PE), price to book value ratio, dividend yield (dividend earned/ current stock price), market capitalization (can be grouped into large cap, mid cap and small cap), overall debt in the market etc. For all such understandings grouping of companies become indispensable part of the analysis framework.

Rate of Interest: The increase in interest rate causes Sensex or Nifty to go down and increase in interest rate causes them to go up. Interest rates have cascading effects on share indices. There are a few categories of benchmark interest rates that are revised by Reserve Bank of India (RBI) at a regular interval. When Prime Lending Rate (PLR) increases home loans, car loan etc. becomes dearer hence real estate and automobile companies suffer with less demand and lower profit. So, these two sectors lower the indices. Again, when Reserve Bank of India (RBI) reduces Repo rate i.e. the rate of interest at which RBI lends money to the banks, banks have easy access to money and companies get loans easily, hence industry grows. Again, bond's and debenture's interest rate are inversely related to the savings interest rate. When bank rate increases, investors used to stack their money into term deposits in banks and hence companies lose the opportunity to get easy money through bonds. We see every time RBI makes any changes to any of the key interest rates share market indices are affected instantly.

Price of Petrol/Diesel: Price hike of petrol/diesel directly / partially impact in increasing cost of products hence less sale. Thus, generally results in fall of share market. Fall in Crude oil price reduces dollar cost for importing countries like India, but for oil exporting countries such as Iran, Saudi Arabia their earning reduces and subsequently they reduce spending. India is one of the largest oil-importing country. It has to bear the effect of international crude price changes as well. A study shows [13] that effect of crude price on stock market return depends on the data consolidation time period considered for analysis. They found that increase in oil price have a positive impact on stock market returns for daily and monthly data; while decrease in price have positive and significant impacts for monthly data in emerging economies. With the incorporation of this dimension all the above-mentioned scenarios as well as many more unknown patterns can be analysed.

Price of Gold: Gold is a precious yellow metal that has its intrinsic value to every country in the world. Most of the countries reserve large amount of gold. It is also used to pay for imported goods when exchange value of currency falls. In times of national crisis, gross failures of large banks, depreciation in paper money value and in times of high inflation i.e. negative real interest rate, investors consider gold as a concrete asset and safe haven and like to invest in gold because often there is a little chance of getting better returns in the stock market due to a fragile economic and

Govt. Policy Decisions: Govt. policies changes due to political agenda of the ruling party as well as priority and focus of the government. Some of the Indian examples include subsidy on domestic LPG cylinder, subsidy in urea production, special rebate to software companies, massive rail and road construction initiative, green energy generation etc. All of the above decision affects profits and in turn share price of companies belong to that sector. Our point is to make it clear that stock prices as well as index

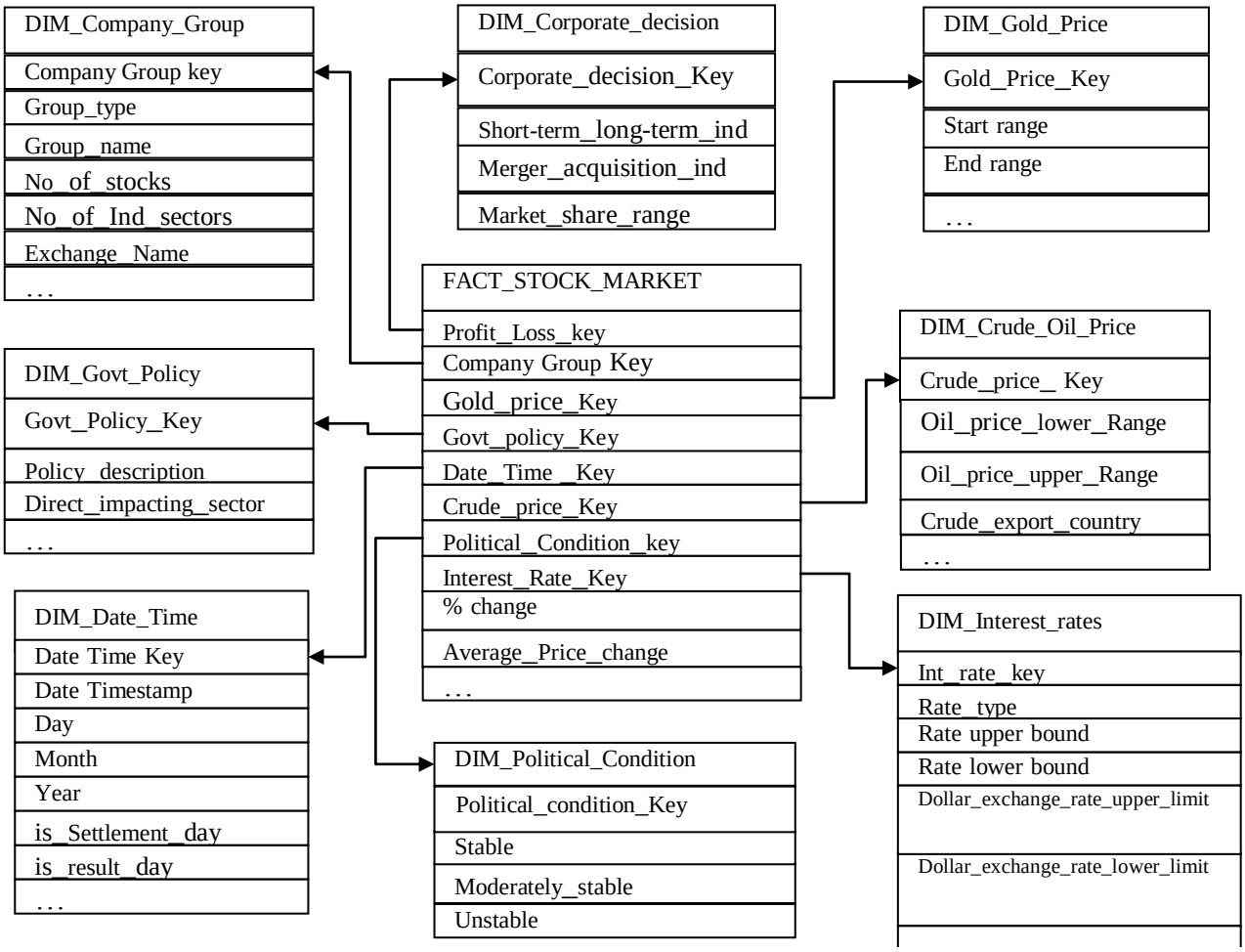


Fig. 3: A model generic DW schema for stock market analysis

financial position [14]. In India gold is purchased even for the rituals, gifts and other purposes even the price hike may not lead to decrease in sale. Recently gold bonds have been introduced with certain interest rates and minimum buy amount in paper form. It allows an investor to invest in gold to hedge equity market risk at the same time without physically buying or selling gold.

Industry/Corporate Decisions: Some business decisions such as acquisition of companies, merger of companies, new investment may result in agility to share market; whereas manpower reduction, shutdown of factories or companies causes negative impact to the share market. Tata Steel's takeover on Corus in 2007 made it worlds' fifth largest steel company. When Tata motors decided to buy JLR (Jaguar and Land Rover, a UK based automobile company with historic brand value) it affected its stock prices in short term as well as in long term. In domestic mergers ICICI bank's acquisition of Bank of Rajasthan at about Rs 3000 crore helped it to enhance its market share across the Indian boundaries especially in northern and western parts. However, measuring the impact of it directly is not easy. We can make a categorization based on the amount invested for acquisition.

movement is highly related with govt. policy decisions and for any parameterized analysis of index performance must consider policy decisions taken from time to time. But these policy decisions are not regular and systematic phenomena that can be predicted or factored easily in all scenarios. So, if some perspective analysis requires special consideration of policy decisions then that should be done separately with manual input.

Political Condition: Political stability of state is the most important deciding factor for management before setting up new facility or enhancing existing production capacity. Transparent business processes, different approvals, cooperation from administration and ministers help businesses to grow. If central or state government does not have majority in both the houses of parliament then even passing of important reform bills fails. Any kind of political instability paralyses the administration which in turn hinders ease of doing business. There are issues like land acquisition, corporate facilities, water, road, electricity, tax exemption etc. Due to political situation sometimes, newly elected government does not continue the facilities to the businesses promised by earlier govt. A stable govt. with well-defined policies and agenda

always encourages business. The BSE Sensex hits an all-time high of 25375.63 points on May 16, 2014 when Lok Sabha election results were announced and one of the political parties got a clean majority.

Now based on the dimensions identified we present a logical view of fact and dimension entities in Figure 2.

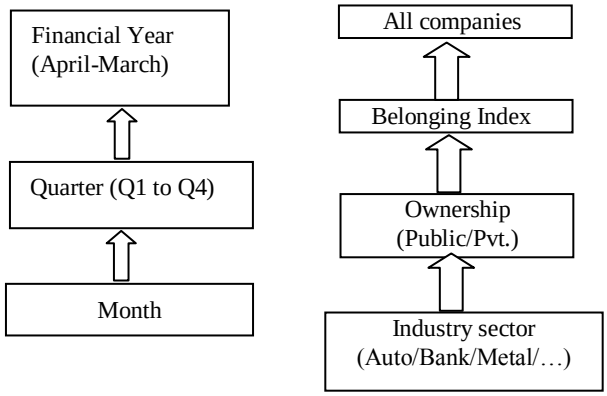


Fig. 4: Concept Hierarchy on (a) Time (b) Company

3.2. Schema of Share Market Warehouse

It is obvious from above discussion that the first five dimensions namely Time, company group, Interest Rate of Bank, Price of crude Petroleum, and gold price would surely be in the warehouse as these factors are frequently changing. Therefore, we model our DW as a star schema with only first 5 identified dimensions as other dimensions require separate treatment and manual knowledge gathering. Political volatility or govt. policy decisions normally mutate share market instantly where as other more common normal parameters helps to evolve it gradually. Evolution can be analyzed in a systematic way but mutation cannot. Hence, we consider those dimensions that are systematic in nature and design the star schema for it. For the sake of completeness, we have shown all 8 identified dimensions in the schema in Figure 3. Dimensions like govt. policy, political condition and significant industry/corporate decisions normally very less frequent events and their impact is also instantaneous most of the cases. So, unless we want to specifically investigate effects of such events, they can be assumed to be constant or non-affecting day to day prices of the stocks in short term. Hence for most of the analysis first 5 dimensions will suffice.

3.3. Concept Hierarchies of the Selected Dimensions

In this section we identify some domain bound concept hierarchies present in the selected dimensions. Time dimension can start with each second or minute and can extend up to lifetime of a listed company. Concept hierarchy is to be defined on the Time dimension and as per requirement it could be in the form of Quarter, Month, Week, Day etc. In Indian stock market all businesses use financial year starting from 1st April and ends on 31st march in the subsequent year. Company related details such as profit/loss; NPA (Non-Performing Assets), balance of payment, debt amount, dividend paid etc. are disseminated quarterly and then aggregated yearly. Also, market analysts generally compare all those quantities on a quarter-on-quarter, or year-on-year basis. This makes a total order of concept hierarchy where we have base cube granularity as monthly data and can roll up from monthly values to quarter and that to a financial year. This is shown in Figure 4(a).

Different group of companies make an index like Sensex or Nifty etc. in any stock exchange. These indices again consist of stocks of companies from many different sectors. Some of the Industry sectors can be like automobile, banks, Information Technology, Metal sector, Real estate etc. Company grouping can also be done based on ownership of the company and can be a govt. owned or private limited company. This dimension hierarchy is shown in Figure 4(b).

Some of the fields in a model interest rate dimension table is shown in the schema where rate_type contains values like 'Base Rate', 'PLR', 'Repo Rate', 'CRR' etc. value_start_range and value_end_range contains the corresponding interest value's upper and lower bound. Important to note that Cash reserve ratio (CRR) is a specified minimum fraction of the total deposits of customers, which commercial banks have to hold as reserve either in cash or as deposits with the central bank. Repo rate is the rate at which the central bank of a country (RBI in India) lends money to commercial banks in the event of any shortfall of funds. Depending on the value range of repo rate and reverse repo rate market environment is divided into 'high interest regime', 'moderate interest regime' and 'low interest regime' where 'low interest regime' favours business activity but also encourages inflation or price hike of essential commodities.

Petroleum prices often can be aggregated based on % change over a time or price-slabs and this can be incorporated in dimension table as a range of values with upper and lower limit for each range. Also, dollar amount spent on importing crude oil can also be made part of the dimension table. In a similar fashion dimension for gold price can be modelled.

3.4. Lattice of Cuboids for Share Market

The lattice of cuboids corresponding to this system would consist of among 32 cuboids (If 5 dimensions considered), 64 cuboids (for 6 dimensions), 128 cuboids (for 7 dimensions) or 256 cuboids (for 8 dimensions) without any concept hierarchy on any dimension. Now let's consider the case when some of the dimensions have concept hierarchies defined with certain number of levels of abstraction. In such a case total number of cuboids in the lattice of cuboid is given by:

$$T = \prod_{i=1}^{N} (Li + 1)$$

Where Li is the numbers of levels associated with dimension i and N is the number of dimensions present.

If we consider 3 abstractions (Figure 4(a)) on time dimension and 4 abstractions (Figure 4(b)) on company dimension then total numbers of cuboids would be $2\times2\times2\times2\times2\times2\times4\times5 = 1280$.

It is evident from above example that the numbers of cuboids grow exponentially when compute total cuboids along with the concept hierarchies of the given dimension. Actually, few of them are important in stock market analysis. These cuboids are usually computed when they are referred in the user queries. Accessing the target cuboid with defined dimension hierarchy involves many numbers of calculations. Initially the base cuboid is computed. It corresponds to fact table and is at the lowest level of lattice of cuboids. If none of the dimension maintains concept hierarchy one base cuboid is formed. However, there could be multiple numbers of base cuboids, if at least one of the dimensions contains concept hierarchy. The cuboids at the higher level are formed by the roll-up operation on lower level cuboids. If the abstraction on concept hierarchy is different in the generated cuboid then roll-up or drill-down operation needs to be performed on the concerned dimension [4].

4. Conclusion and Future Work

Here we have analysed individual dimension with the historical data of that dimension and market indices (Sensex / Nifty). The result of analysis on individual dimension can be aggregated or integrated to analyse the impact for every cuboid. Therefore, we

could assign a weightage on every cuboid based on the impact of it on share market. Further analysis might help us to realize different weightages of the cuboids when share index goes up or down. That is based on different growth rate (positive or negative) of index the weight of the cuboids may vary. Different statistical methodologies can be applied on the data to predict and measure the abnormalities as well as trends. Virtual data warehouse mechanism can also be incorporated for special/emergency conditions and events. With enhanced domain knowledge newer business dimensions can be incorporated into the system. Further, data mining-based technology may also be applied on individual dimension for data cleaning, transformation prediction etc.

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