*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

# Machine Learning in Business Intelligence

**Mr. Kopelo Letou[1*], Dr. S.Thiyagarajan[2,]**
[1*]Computer Science and Engineering, St. Joseph University, Chümoukedima, Nagaland,India. E-mail:kopsystem@gmail.com
[2]Computer Science and Engineering,St.Joseph University, Chümoukedima, Nagaland,India. E-mail:tyagarajin@yahoo.com

***Abstract:-***The purposed of this research have the fivefold: First We did in-depth deliberate studies on Business Intelligence (BI) and Machine Learning (ML) technology to provide overview of the state-of-art of its scopes and challenges. Second, to understand and identify knowledge gaps BI that the problems of business can be solve in optimal through the techniques and algorithms of ML. Third, we have developed conceptual framework of adaptive business intelligence model to solve the problems of businesses by incorporating a characteristics, techniques, algorithms and technology of machine learning. The key concept was to developed Business Intelligence Machine (BIM) which was the whole system of adaptive business intelligence models in-order to automate business processes, intelligent decision making and obtain optimal business desire goal. Fourth, a systematic review was done on Business Intelligence and Machine Learning along with their chronological and evolution of terminologies, technologies, techniques, algorithms, classifications, analytics, capabilities and Business Intelligence Machine applications. Fifth the paper proposed adaptive business intelligence model which was the solution to existing business intelligence. Machine learning engine is the heart and soul component of adaptive business intelligence model. Business intelligence machine can solve real world business problems with minimal human involvement, more accurate, more speed, quick response and better decision making in business as compare to existing of business intelligence systems functionalities. In this research paper, we have open look_forward ways to future research directions on the related areas of Business Intelligence from non_adaptive model to adaptive BI model using machine learning technology to solve real world business problems. Different machine learning techniques and algorithms can overcome the existing challenges of business intelligence systems.

***Keywords:-****Business, Intelligence, Business Intelligence (BI), Machine Learning (ML), Adaptive BI Model, ML Engine, Business Intelligence Machine (BIM).*

## I. Introduction

In this modern era rapid growing of artificial intelligence (AI), machine learning (ML) technology is the solutions of business problems face in this real world. Business is part and partial of our daily life may it be individual or company or industry or firm either we like it or not, it will co-exist with the existing of life. ML is the heart and soul of AI component. Artificial intelligence is software to mimic aspects of human intelligence including perceiving, planning, reasoning, learning, predicting, et cetera. The novelty of this paper was that ML revolutionized and reshaping various aspects of the old decades terminologies of business intelligence and machine learning. Machine learning technology involve in business intelligence is a new way to solve the current problems of businesses. The problems of businesses are solves by adopting from non-adaptive or primitive or conventional methods of business intelligence to adaptive business intelligence model using machine learning techniques and algorithms. There is in need of machine learning technology in business intelligence to solve real world business problems, quick business decision making, better service to firms and customers, automate resolve operational business problems, quick automate response to market trends without delay, more accurate estimation, better prediction on business's operational activities and to obtain maximum profits from businesses. In this first session we discussed the chronicle and evolution of Business Intelligence and in the second session we discussed the chronicle and evolution of Machine Learning.

### 1.1 Chronicle and Evolution of Business Intelligence

Business Intelligence (BI) is constantly changing with time and space. (Power Daniel J. 2004), mentioned that BI began from Decision support systems (DSS) during the late 1950s and early 1960s, the pioneers, Peter Keen and Charles Stabell, stated the concept of decision support which was extracted from the theoretical studies of organizational decision-making [1]. (Hiremath Rupa & Patil Pradip. 2016), in 1989 the concept of a Knowledge Discovery and Data Mining (KDDM) process model was originally discussed during the first work shop on Knowledge Discovery in Databases (KDD)[2].(PowerD.J.2007), early 1990, Bill

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

Inmon and Ralph Kimball worked on DSS built using relational database technologies. Ralph Kimball was known as "The Doctor of DSS" and Bill Inmon was known as the "Father of the data warehouse". Inmon defined decision support system (DSS) as "a system used to support managerial decisions. Usually DSS involves the analysis of many units of data in a heuristic fashion. As a rule, DSS processing does not involve the update of data". Inmon and Kimball focused on building data-driven DSS [19].

(Abell´o Alberto and Romero Oscar.1993), in1993 Edgar F. Codd, S.B. Codd, & C.T.Salley coined the term On-line Analytical Processing (OLAP) [3]. (Breslin Mary. 2004), in 1990 Inmon Bill coined the term Data Warehouse in his seminal work Building the Data Warehouse [4]. (Davis Gary Alan & Woratschek Charles R.2015), the term Business Intelligence (BI) was originally coined by Richard Millar Devensin 1865.He used the term BI to describe how a banker Sir Henry Furnese profited by receiving and acting upon information about his business before his competitors could; in this case information was the key component in decision making. Collecting, refining and acting upon information retrieved is still the basis of the definition of BI used today [5]. (Luhn H. P.1958), the term BI was used by IBM researcher, Hans Peter Luhn.In1958 he used Webster's dictionary definition of intelligence as the ability to apprehend the interrelationships of presented facts in such away as to guide action towards a desired goal [5],[6],[7]. And he defined the term business as a collection of activities carried on for whatever purpose, it be science, technology, commerce, industry, law, government, defense, et cetera. [6].The term business is beyond making money profit businesses but applications base activities domain in any organizations or company or industry or firms. (Gupta Anand Ramesh 2017), Hans Peter Luhn IBM computer scientist is known as the "Father of Business Intelligence."[23]. (Elena Cebotarean. 2011), in 1989 Howard Dresner (later a Gartner Group analyst) proposed BI as an umbrella term to describe "concepts and methods to improve business decision making by using fact-based support systems". And Forrester defined, "Business Intelligence is a set of methodologies, processes, architectures, and technologies that transform raw data into meaningful and useful information used to enable more effective strategic, tactical, and operational insights and decision-making."It gives an opportunity to business users to take better business decisions ahead of its business adversaries.[7],[45].(Sutton Richard S. 2020), in 1997 John McCarthy defined "Intelligence is the computational part of the ability to achieve goals in the world."[22]. Current state of Business Intelligence (BI) has been an increasing impact on decision making, business management and performance in the cooperative firms or industry, et cetera. In general, business intelligence is the process of transforming various types of business data into meaningful information and finally intelligence that can help in decision making at all levels and improve business performance to optimal desire goals. In the context of Machine Learning, the term Business Intelligence can be defined as a adaptive business intelligence model encompass of processes, components, products and machine learning technology which extract business data from large datasets and transformed it into intelligence in problem-solving, decision-making, achieve desire's optimum goal in business and control its actions. Some common functions of BI machine include ad-hoc queries, reporting, Online Analytical Processing (OLAP), business data mining, complex event processing, business performance management, benchmarking, text mining, descriptive analytics, diagnostic analytics, predictive analytics, prescriptive analytics, preventive analytics, cognitive analytics and data visualization. Applications of Business Intelligence (BI) are used in banking, educational institutions, finance, insurance, retail industry, manufacturing industry for planning, risk analysis, marketing, forecasting, et cetera.

### 1.2 Chronicle and Evolution of Machine Learning

The journey of machine leaning was not an easy one which took place with enormously testing and experimentation of programming machine learning models. Some of the prominent pioneers of Machine Learning were Alan Turing, Arthur Samue and John McCarthy. (Turing A. M. 1950), in his paper "Computing Machinery and Intelligence" 'the Imitation Game' is known as 'Turing test'. He proposed to consider the question "Can machines think?" or can a machine win the game? Or can a machine do what human can do? It was proved in some areas that machine like IBM's Deep Blue do better than human, made history in 1997 when it became the first machine to beat a reigning world chess champion. (Bowen Jonathan Peter. 2017), Alan Turing is known as the 'Father of modern computing' [24], [25]. Samuel A. L. (1959), was the first person to coined term machine learning in 1959. The two approaches to the problem of machine learning are the Neural Nets and the Switching Nets. The Neural Nets once trained it does not require reprogramming for each new application whereas the Switching Nets requires reprogramming for each new application. He devise computer that can be programmed that was created servant programmed using machine learning so that it will learn to play a better game of checkers than its creator master's programmed the person who wrote the program. The Samuel Checkers-playing

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

Program appears to be the world's first self-learning program. The first operating checker program for the IBM 701 was written in 1952.The first program with learning was completed in 1955 and Arthur Samuel is often considered the 'Father of machine learning'.[26].(Mahesh Batta.2018), Arthur Samuel defined Machine learning as the field of study that gives computers the ability to learn without being explicitly programmed [29]. (J. McCarthy, M.L. Minsky, N. Rochester, and C.E. Shannon 1955), intelligence proposal was initiated by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon, during Dartmouth summer research project on Artificial Intelligence 1955. John McCarthy was the first to coined term Artificial Intelligence (AI) and he is considered as the Father of Artificial Intelligence. (Grewal Dalvinder Singh. 2014), John McCarthy defines AI as the science and engineering of making intelligent machines.[27],[28].The current state of machine learning technology is the biggest and crucial players in artificial intelligence to solve the real world problem of businesses in any company, industry or firm, et cetera. (Mahesh Batta 2018), defined machine learning (ML) as the scientific study of algorithms and statistical models that computer systems use to effectively perform a specific task without being explicitly programmed.[29].Machine learning is the scientific study of techniques and algorithms to develop adaptive machine learning models that can learn from large dataset and improve performance tasks automatically overtime with more dataset without explicit instructions. Some of the applications of machine learning are applying in business intelligence, retail industry, manufacturing industry, iron and steel industries, cotton and textile industries, healthcare industry, pharmaceutical industry, banking industry, insurance industry, finance industry, et cetera.

## 2. Related work

In this session of related work, first we discussed the definitions, functions, architecture, applications, challenges and issues of business intelligence. And the next session we discussed machine learning definition, machine learning types, techniques and algorithms.

### 2.1 Business Intelligence

We discussed the definitions, functions, architecture, applications, challenges and issues of business intelligence. Here, Business Intelligence is referred to as BI. Today's Business Intelligence (BI) is still in the phase of development what actually BI was supposed to deliver to various stakeholders. (Gilad Benjamin & Gilad Tamar. 1986), stated BI is a process; its input is raw data and it send result is intelligence [8]. (Ghoshal S. & Kim, S. K. 1986), stated BI as the collection and analysis of information on markets [9]. (Lönnqvist Antti. & Pirttimäki Virpi. 2006), BI can be term as an organized and systematic process by which organizations acquire, analyze, and disseminate information from both internal and external information sources significant for their business activities and for decision making [10]. External information are indirect data outside the organization like databases, competitive intelligence from external environment and internal information are the direct collected data within the internal system. (Rouhani Saeed & et al. 2012), stated BI is a set of abilities, tools, techniques and solutions that help managers to understand business situation. They defined business intelligence system as a data-driven DSS that primarily supports querying of an historical database and production of periodic summary reports [11]. (Mudau Thanyani Norman, & et al. 2024), Business Intelligence (BI) systems are a class of information systems combining tools and infrastructure (e.g., OLAP, data warehouses, dashboards, and query tools) for data management, analysis, and reporting [43]. (Pavkov Sanja, Poščić P., & Jakšić Danijela. 2016), in their paper stated that the core functions of BI were to answers business questions like what is happening in the business environment, why that is happening, what needs to be done, how to do something and what will happen next [12].(Elena Cebotarean. 2011), term business intelligence system also called as Decision Support System (DSS). And Conventional business intelligence system mainly used ETL, DW, OLAP, decision support system (DSS) [7]. However, decision support system and business intelligence system are different. (Jr Sprague Ralph H. 2011), DSS is a class of information system that draws on transaction processing systems and interacts with the other parts of the overall information system to support the decision making activities of managers and other knowledge workers in the organizations. The relationships between Electronic Data Processing (EDP), Management Information System (MIS), and DSS show that DSS was only one of several important technology subsystems for improving organizational performance, and that DSS development efforts must carefully integrate with these other systems [42]. However, (Dedić Nedim & Stanier Clare. 2017), stated that BI was referred as a philosophy, strategies, processes, applications, data, products, technologies and technical architectures used to support the collection, analysis, presentation and dissemination of business information [13]. (Foley Eric & Guillemette Manon G.2010), stated BI as s a combination of processes, policies, culture, and technologies for gathering, manipulating, storing,

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

and analyzing data collected from internal and external sources, in order to communicate information, create knowledge, and inform decision making. The typical classical Business Intelligence architecture Fig. 1 comprises of Extract-Transform-Load (ETL) tools; Data Warehouse (DW), Data Marts (DM), Operational Data Store (ODS), Online Analytical Processing (OLAP), data mining and front-end dashboard tools [14].

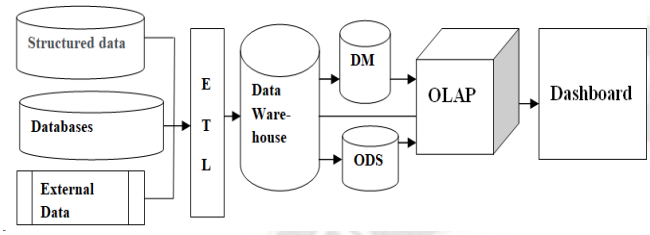


**Fig.1 Classical Business Intelligence architecture**

(Reinschmidt Joerg & Francoise Allison. 2000; Anand Nitin. 2014), Extraction, Transform and Load (ETL) focuson three processes as Extraction is the process of identifying and collecting relevant data from different sources; Transformation is the process of converting data using a set of business rules (such as aggregation functions) into consistent formats for reporting and analysis. Data transformation process also includes defining business logic for data mapping and standardizing data definitions in order to ensure consistency across an organization. Data loading is the process of loading the data into the data warehouse after the data is transformed [20],[21]. A Data Warehouse (DW) is a database where data is collected for the purpose of being analyzed. The defining characteristic of a data warehouse is its purpose. Most data is collected to handle a company's on-going business. This type of data can be called" operational data". The systems used to collect operational data are referred to as On-Line Transaction Processing (OLTP). A data warehouse collects, organizes, and makes data available for the purpose of analysis — to give management the ability to access and analyze information about its business. This type of data can be called "informational data". The systems used to work with informational data are referred to as On- Line Analytical Processing (OLAP). A data mart contains a subset of corporate data that is of value to a specific business unit, department, or set of users. An Operational Data Store (ODS) is a database designed to integrate data from multiple sources for additional operations on the data, for reporting, controls and operational decision support. On-Line Analytical Processing (OLAP) is a category of software technology that enables analysts, managers and executives to gain insight into data through fast, consistent, interactive access to a wide variety of possible views of information that has been transformed from raw data to reflect the real dimensionality of the enterprise as understood by the user. Data mining is the process of extracting valid, useful, previously unknown, and comprehensible information from data and using it to make business decisions. A BI dashboard is a business intelligence tool which allows users to track, analyze and report on key performance indicators and other metrics. BI dashboards typically visualize data in charts, graphs and maps which helps stakeholders understand, share and collaborate on the information [20]. (Shatat Abdallah, Altahoo Mariam & Almannaei Munira. 2024), Business Intelligence (BI) is a critical in enhancing decision-making processes, operational efficiency, and positive outcomes such as improved customer service, stronger customer relationships, increased profitability, and lower failure rates. [15]. (Shariat M. & Hightower J.R. 2007;Shollo Arisa & Kautz Karlheinz. 2010), term BI as a composition of processes to collect data and analyse, technology to facilitates BI functions and products is the knowledge obtained from it [16],[17]. (Ranjan Jayanthi. 2009), stated BI considered in a broad category of applications and technologies for gathering, providing access to, and analyzing data for the purpose of helping enterprise users make better business decisions [18].(Power, D.J. 2007), Howard Dresner of the Gartner Group in 1989 describes BI as a set of concepts and methods to improve business decision making by using fact-based support systems. BI is sometimes used interchangeably with briefing books, report and query tools and executive information systems. Business Intelligence systems are data-driven DSS [19]. (Reinschmidt Joerg & Francoise Allison. 2000), mentioned that Business intelligence is not business as usual, it's about making better decisions easier and making them more quickly. BI transforms information into knowledge. Business Intelligence is the application of putting the right information into the hands of the right user at the right time to support the decision-making process [20].

### 2.2 Challenges and Issues of Business Intelligence

(i).Over the past years many researchers have defined many definitions of 'business intelligence' since the term business intelligence was first coined in the year 1865 by Richard Millar Devens. However, there was no consensus or standard definition of business intelligence to till today.

(ii) Usually data flow and control flow uni-directional in the conventional business intelligence system. In the modern business intelligence system, there can be a multi-directional

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:*** *25 July 2023* ***Revised:*** *12 September 2023* ***Accepted:****30 November 2023*

flow of data and control communication.

(iii) Usually business intelligence models are non-adaptive models as it used the technologies and tools of decision support system (DSS), data warehouse, online analytical processing (OLAP) and data mining. Nevertheless, machine learning techniques and algorithms can be use in business intelligence for developing adaptive models.

(iv) Usually business intelligence system handle structured data. However machine learning techniques and algorithms can handle different types of data types like structured data, semi-structured data and unstructured data.

(v) There is lack of automate service in business intelligence system, as it is non-adaptive business models. There can be better performance of automate service in business intelligence system by developing adaptive business intelligence models using machine learning techniques and algorithms in business intelligence system.

(vi). Conventional business intelligence system analyzes business data descriptive analytics and business data predictive analytics. However, there can be further refine business data analytics like diagnostic analytic, prescriptive analytic, preventive analytic and cognitive analytic using machine learning techniques and algorithms.

(vii) Business intelligence system usually handles offline data from the databases. However, online or real time data can be adhered by incorporating different mechanism in the business intelligence system.

(viii) Business intelligence systems are usually rigid. It is better for the business users to have flexible and user friendly business intelligence system.

(ix) Business intelligence systems are usually lack in automates business data preparation. There can be automating business data preparation by using machine learning techniques and algorithms.

(x) There is lack of automate intelligent decision making in business intelligence system. However, using machine learning techniques and algorithms can adhered and enhance automate intelligent decision making in business intelligence system.

(xi) There is technological challenge in business intelligence. However, machine learning technology is the solution to the existing business intelligence.

(xii) There were knowledge and methodology gaps in existing business intelligence system and therefore, we recommended machine learning techniques and algorithms in business intelligence machine.

### 2.3 Machine Learning

There are many research papers and articles published on the applications of machine learning technology that solve real world problems. In this session, we discussed machine learning definitions, machine learning types, techniques and algorithms. The ultimate solution for business intelligence in solving businesses problems is machine learning techniques and algorithms. (Mitchell Tom M. 1997), defined machine learning as the study of algorithms that allow computer programs to automatically improve through experience [30]. (Sah Shagan. 2020), according to him machine learning is the study of computer algorithms that provides systems the ability to automatically learn and improve from experience [34]. (Janiesch Christian, Zschech Patrick & Heinrich Kai. (2021), stated in their paper that machine learning is a computer program's performance improves with experience with respect to some class of tasks and performance measures. Conventional ML utilizes neural networks with an input layer, one or two 'hidden' layers, and an output layer [31]. (Chahal Ayushi and Gulia Preeti.2019), defined Deep Learning (DL) is a set of algorithms of machine learning which uses multiple layers that corresponds to different level of abstraction to each level. Deep learning utilize deep neural networks with an input layer, three or more 'hidden' layers, and an output layer [32]. There are five fundamental types of machine learning as shown in Fig 2. Supervised learning, unsupervised learning, semi supervised learning, reinforcement learning and deep learning. All types of machine learning can be implement from these five fundamental machine learning. Neglecting any of this fundamental machine learning will jeopardize the effective and efficiency of machine learning in solving the real world complex business problems.

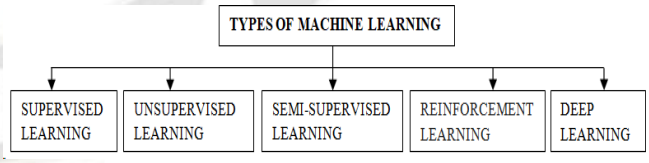


**Fig. 2 Types of Machine Learning**

(i). Supervised Learning: In supervised learning, algorithm builds a machine model from a set of data that contains both the input features and desired output. (Sarker Iqbal H. 2021), supervised learning is considered as task-driven approach [33]. There are usually two techniques or methods i.e., regression techniques and classification techniques to build a supervised machine model based on the problem/task of the supervised learning as shown in Fig 3.

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:*** *25 July 2023* ***Revised:*** *12 September 2023* ***Accepted:****30 November 2023*

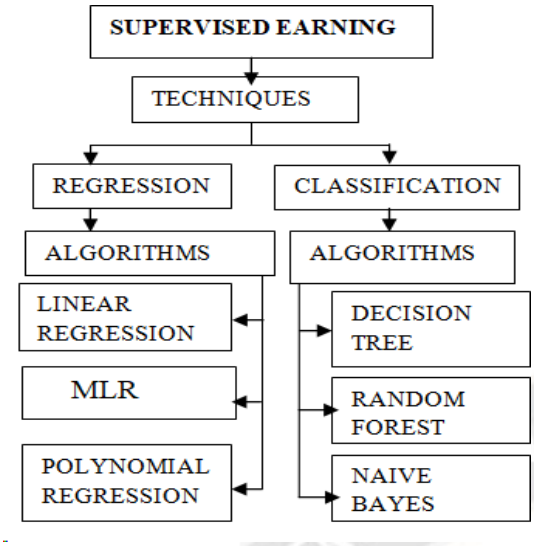


**Fig. 3 Supervised Learning**

Regression techniques and algorithms are applied to regression problem. A regression problem is when the output variable is a real or continuous value, numerical outputs such as forecasting sales or temperatures. It tries to fit data with the best hyperplane that goes through the points. It helps in establishing a relationship among the variables by estimating how one variable affects the other. There are several types of regression techniques, each suited for different types of data and different types of relationships. The main types of regression techniques and algorithms are: linear regression, polynomial regression, Multivariate Linear Regression (MLR), etc. The equation for simple linear regression is: $Y=\beta0+\beta1X$, Y is the dependent variable, X is the independent variable, $\beta0$ is the intercept and $\beta1$ is the slope. Classification techniques and algorithms are appliedto classification problems. Classification problems are supervised learning problems wherein the training data set consists of data related to independent and response variables (label), which require the given data set to be classified in two or more categories data into discrete classes or labels. For example, whether a person is suffering from a disease X (answer in Yes or No) can be termed as a classification problem. It predicts the class of the dataset based on the independent input variable. Class is the categorical or discrete values. The main types of classification techniques and algorithms are: Decision trees, Random forest, Naive Bayes, etc. The difference between the regression and classification is only due to the output value. While classification divides the dataset into classes, regression is used to output continuous values. The algorithms and evaluation metrics used also differ; classification employs metrics like precision, recall, accuracy, confusion matrix, F1-score and receiver operating characteristic (ROC) curve while regression uses Mean Squared Error (MAE), Mean Absolute Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE) and R- Squared.

(ii). Unsupervised Learning: (Sah Shagan. 2020), unsupervised learning is applied when the data is available only in the form of an input and there is no corresponding output variable [34]. (Sarker Iqbal H. 2021), unsupervised learning is known as data-driven process [33]. The two main techniques of unsupervised machine learning are clustering and association rule learning as shown in Fig 4.

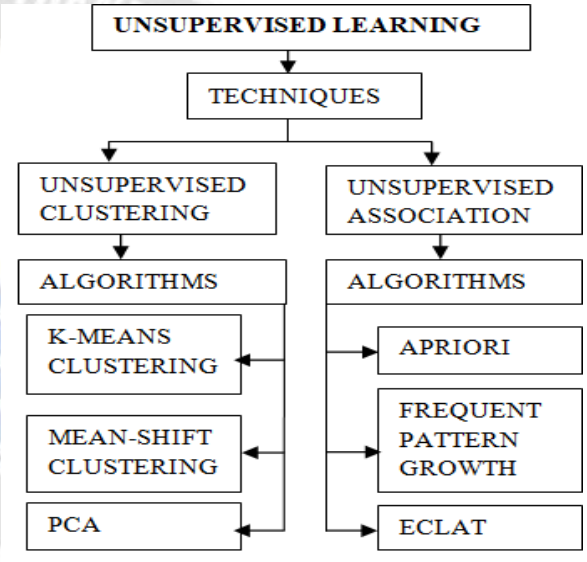


**Fig. 4 Unsupervised Learning**

In clustering technique, where the data are grouped on the basis of some similarity inherent among them and then used to predict output for unseen inputs [34]. Some of the clustering algorithms are k-means clustering algorithm, mean-shift clustering algorithm, Principal Component Analysis (PCA) algorithm, etc.

In association rule learning technique is also known as association rule mining is a common technique used to discover associations in unsupervised machine learning. This technique is a rule-based ML technique that finds out some very useful relations between parameters of a large data set. Some of the association rule learning algorithms are apriori algorithm, Frequent Pattern Growth (FP-Growth) algorithm, Equivalence Class Clustering and bottom-up Lattice Traversal (ECLAT) algorithm, etc.

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

(iii) Semi-Supervised Machine Learning: (Mahesh Batta. 2018), Semi-supervised machine learning is a combination of supervised and unsupervised machine learning methods [29]. (Sarker Iqbal H. 2021), Semi Supervised Learning (SSL) is known as hybridization driven approach as it used supervised and unsupervised learning approach which operates on both labeled and unlabeled data [33]. The techniques used in semi supervised learning are semi supervised regression, semi-supervised classification and semi supervised clustering as shown in Fig 5.

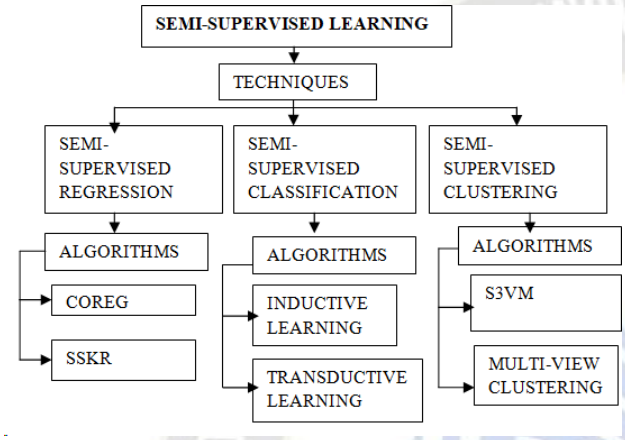


**Fig.5 Semi-Supervised Learning**

(Sah Shagan. 2020), the algorithms are trained using a combination of labeled and unlabeled data. In a semi-supervised learning, there is a small amount of labeled data and a very large amount of unlabeled data. A basic procedure involved is that first similar data is clustered using an unsupervised learning algorithm and then existing labeled data is used to label the rest of the unlabeled data [34]. (Kostopoulosgeorgios K, Karlosstamatis, Kotsiantissotiris & Ragosomiros. 2018), stated that Semi-Supervised Regression (SSR) refers to the case where the output variable is real-valued [35]. Some algorithms of SSR are Co-Training Style Semi-Supervised Regression (COREG) algorithm, Semi-Supervised Kernel Regression (SSKR) algorithm and others. Semi-Supervised Classification (SSC) refers to the case where the output variable is discrete. Most of the studies about Semi Supervised Learning (SSL) deal with classification problems, with a view to predicting a label from a finite set of class labels [35]. Some algorithms of semi-supervised classification are inductive learning algorithm, transductive learning algorithm and others. (Cai Jianghui, Hao Jing,Yang Haifeng, Zhao Xujun & Yang Yuqing. 2023), Semi-Supervised Clustering (SSC) is a technique integrating semi-supervised learning and clustering analysis, incorporates the given prior information (e.g., class labels and pair wise constraints) into clustering to guide the clustering process and improve the performance [36]. Some of the Semi-Supervised Clustering (SSC) are Semi-Supervised Support Vector Machine (S3VM), Semi-Supervised Multi-View Clustering and others. (Grira Nizar ,Crucianu Michel & Boujema Nozha. (2005), mentioned that similarity information are used by unsupervised clustering, in many cases a small amount of knowledge is available concerning either pair wise (must-link or cannot-link) constraints between data items or class labels for some items. Instead of simply using this knowledge for the external validation of the results of clustering, one can imagine letting it "guide" or "adjust" the clustering process, i.e. provide a limited form of supervision. The resulting approach is called semi-supervised clustering [37].

(iv). Reinforcement Learning: (Sarker Iqbal H. 2021), stated that Reinforcement Learning (RL) is a machine learning process that allows an agent to learn by trial and error in an interactive environment using input from its actions and experiences. It is also known as environment-driven approach. Reinforcement learning used Markov Decision Process (MDP) to make sequentially decisions. A RL problem typically includes five key elements such as the agent, states, actions, rewards, and optimal policies. [33]. (Sah Shagan. 2020), during the learning process, an artificial agent gets either rewards or penalties for the actions it performs. Its goal is to maximize the total reward [34]. Depend upon the nature of reinforcement learning task whether there is an environment model or not, RL techniques and algorithms can be classified as model-based RL or model-free RL or hybrid RL as shown in Fig 6.

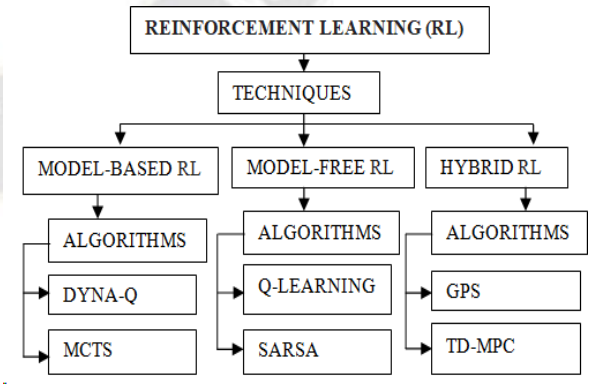


**Fig. 6 Reinforcement Learning (RL)**

(Sarker Iqbal H. 2021), stated that Model-based RL is based on learning a transition model that enables for modeling of the environment without interacting with it directly whereas

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:*** *25 July 2023* ***Revised:*** *12 September 2023* ***Accepted:****30 November 2023*

model-free RL methods learn directly from interactions with the environment [39].Some Model-based RL algorithms are Dyna-Q, Monte-Carlo tree search (MCTS) and others. (Liu Yiyang,Yan Shuaihua, Zhao Yang, Song Chunhe & Li Fei. 2022), stated that Model-free reinforcement learning algorithm directly improves the policy or estimates the value function according to the data sampled by agents and environment interaction. Some algorithms of model-free reinforcement learning are classical Q-Learning, State–Action–Reward–State–Action (SARSA), temporal-difference algorithms and other [38]. (Pinosky Allison, Abraham Ian, Broad Alexander, Argall1 Brenna & Murphey Todd D. 2022), stated that Hybrid RL is a systematically combining model-based and model-free learning methods. Predictive models is model-based learning and experience-based is model-free learning [40]. Some Hybrid RL algorithms are Guided Policy Search (GPS), Temporal Difference Learning-Model Predictive Control (TD-MPC) and others.

(v). Deep Learning: (López Osval Antonio Montesinos, López Abelardo Montesinos & Crossa José. (2022), defined Deep Learning (DL) as a generalization of Artificial Neural Network (ANN) where more than one hidden layer is used, which implies that more neurons are used for implementing the model. For this reason, an artificial neural network with multiple hidden layers is called a Deep Neural Network (DNN) and the practice of training this type of networks is called deep learning (DL), which is a type of machine learning where a multilayered (deep) topology is used to map the relations between input variables (independent variables) and the response variable (out-come). An artificial neural network is a system composed of many simple elements of processing which operate in parallel and whose function is determined by the structure of the network and the weight of connections, where the processing is done in each of the nodes or computing elements that has a low processing capacity [41] Deep learning is the core component of machine learning as it's a deep neural networks that can be use to mimic human brain's functionality. (Sarker Iqbal H. 2021), DL techniques broadly into three major categories deep networks for supervised or discriminative learning (also known as supervised deep learning) that is utilized to provide a discriminative function in supervised deep learning or classification applications. Some of Supervised Deep Learning are Artificial Neural Network (ANN), Convolutional Neural Networks (CNN or ConvNet), Recurrent Neural Networks (RNN), etc. Deep networks for unsupervised or generative learning (also known as unsupervised deep learning) that are used to characterize the high-order correlation properties or features for pattern analysis or synthesis, thus can be used as pre-processing for the supervised algorithm. Some of the deep networks for unsupervised learning are Generative Adversarial Network (GAN), Deep Belief Network (DBN), etc. And deep networks for hybrid learning (also known as hybrid deep learning) that is an integration of both supervised deep learning and unsupervised deep learning model and relevant others. Some of the algorithms of hybrid deep learning are Deep Transfer Learning (DTL), Deep Reinforcement Learning (DRL), etc. as shown in Fig. 7 [39]

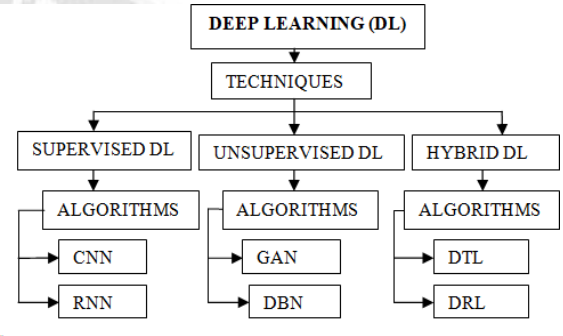


**Fig. 7 Deep Learning (DP)**

## 3. Research Methodology

We have developed conceptual framework for machine learning in adaptive business intelligence model. This adaptive business intelligence model have data visualization, data sources, Extraction - Transformation - Load, data warehouse, and machine learning techniques and algorithms. Data Visualization (DV) is nothing but a graphic representation of business data. It represents business data in visual form like plots, graphs, charts, infographics, animations, etc that were generated from business intelligence machine. It make easier for the business user to identify any deviation of patterns, outliers, trends in business data. Business users utilizes data visualization to hindsight, insight and foresight from business data, access to business data, communicate between business user and business data to considers the best decision as generated by business intelligence system. Data sources is the originates position of business data and these business data are to be used further for refining data, creating information, derive knowledge and connect it from information, intelligence acquire from knowledge and then finally used it for decision making. There are different data types and they are structured data type, unstructured data type and Semi-structured data type. In Fig. 8 Data sources consist of OLTP database, Databases and external data act as data sources. Extraction- Transformation- Load (ETL); Business data extraction is the process of collection of business data from

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

business data sources and to be move business data to data warehouse. Business data transformation is the process of selection of entity, attribute, and occurrence, separation or concatenation of business data or records, normalization or denormalization business data or record, aggregation business data or records, conversion business data or records and enrichment to create a new field or fields in the output record. And business data load is the process that moves integrate transformed business data to data store that is data warehouse. Data Stored is repository of integrated business data. Data warehouse is the storage of aggregates business data that have been transferred from business data sources through ETL and that further process it by machine learning techniques and algorithms for analysis of business data. Machine learning operation is the practice of planning, designing, building business data pipelines and adaptive machine learning models, and deployment of Business Intelligence Machine to solve complex business real-world problems.

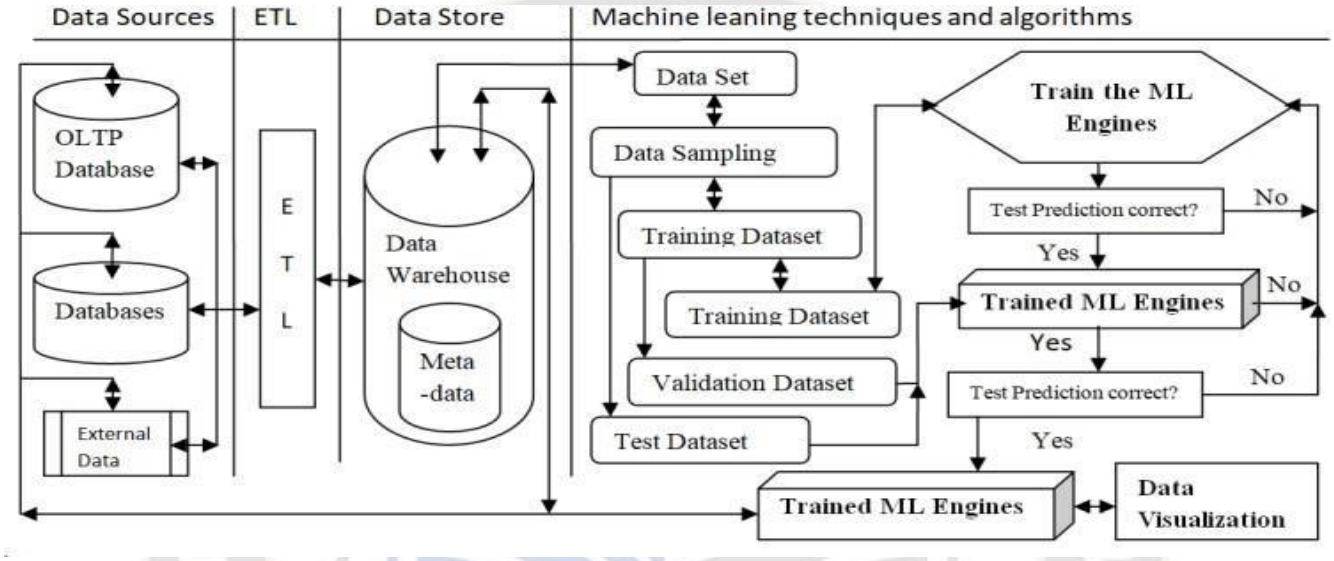


**Fig 8. Conceptual framework for machine learning in adaptive business intelligence model**

Machine learning techniques and algorithms were used in adaptive business intelligence model as shown in Fig 8. Machine learning is the core component of adaptive business intelligence model.

Adaptive Business Intelligence Models (Adaptive BI Model) are a set of machine learning engines use for optimal and intelligent decision making. Such models are business intelligence descriptive model, business intelligence diagnostic model, business intelligence predictive model, business intelligence prescriptive model, business intelligence preventive model. In other words, adaptive business intelligence models are machine learning models that can be used for business activities management and decision making in any of the industry or institutional or firms. Machine Learning engines (ML engines) are machine learning techniques and algorithms that learn from large dataset to build descriptive, diagnostic, predictive, prescriptive and preventive analytics for optimal decision making in adaptive business intelligence models. In other words, machine learning engines are machine learning techniques and algorithms that learn from large dataset and improve its performance as it exposed to more data without explicit programmed that turn data set into intelligence for decision making in adaptive business intelligence models. Each ML engines address specific business problems.

**3.1 Basic steps for development of machine learning in adaptive business intelligence model: -**

(i) Define the objectives and desired out comes for each machine learning engines i.e., descriptive analytics engine, diagnostic analytics engine, predictive analytics engine, prescriptive analytics engine and preventive analytics.

(ii) Aggregate business data and integration business data from different data sources and performs data exploration.

(iii) Business data preparation from data sources by Extraction, Transformation and Loading data (ETL) to data warehouse which are needed in machine learning engines.

(iv) Perform business data sampling.

(v) Business data is partition in to training dataset, validation dataset and test dataset.

(vi) Select which machine learning engine to train as per the tasks.

(vii) Select which machine learning techniques and algorithms are needed for the specific selected business intelligence model.

(viii) Evaluates each business intelligence model performances from training dataset, validation dataset and test dataset. After that new unknown business data is apply to the final business intelligence model.

**3.2 Analytics Engines:-**

Below we have discussed various analytics engines. Analyzes different types of analytics on business data to get hindsight, hindsight, foresight and apply different machine techniques and algorithms, strategies, tactics, policies for different types of decision making for different business activities and consider the best the decision.

**(a). Descriptive analytics engine:** Descriptive analytics engine is the machine learning techniques and algorithms that extract historical past business data and current business data to identify trends and present summary relationships that have occurred in business. Descriptive analytics engine first extracts business data from large datasets through machine leaning and then transformation and cleansing it for exploratory business data analysis to analyze historical business data that generate various business reports like operational report, statistical report, general trends, patterns, performance and present summarize past events that have occurred in business in business data visualizations or dashboard.

Machine learning techniques of supervised learning, unsupervised learning and semi- supervised learning apply in descriptive analysis engine for outlining, classifying, and drawing out information to get the answers for what had happened in past and present. The purposed of descriptive analytics engine is to answer/addresses 'what has happened in the past and present?'

**(b). Diagnostic analytics engine:** Diagnostic analytics engine is the machine learning techniques and algorithms that extract historical past business data and current business data and also used descriptive analytics engine to determine the causes of unusual trends and correlations between variables. Diagnostic analytics engine used descriptive analytics that aims to uncover the underlying causes and factors behind observed trends and patterns. It involves machine learning techniques of exploration, investigation to identify abnormal patterns, detect of unusual trends, explain anomalies and outliers, and analysis to determine "why" behind specific outcomes or events.

Machine learning techniques of supervised learning, Unsupervised learning and semi-supervised learning applying in diagnostic analysis engine for outlining, correlation, regression, clustering, classifying, and drawing out information to get the answers for 'why did it happened in the past and present?' and the root cause behind that. The result of business data analysis is comprehended in business data visualization. The purposed of diagnostic analytics engine is to determine 'why did it happened in the past and present?'

**(c). Predictive analytics engine:** Predictive analytics engine is the machine learning techniques and algorithms that extract historical past business data and current business data to predict the probability future outcome of business activities. Predictive analytics engine use historical past and present business data, descriptive analytics, machine learning techniques and algorithms like regression, classification, clustering, association, neural networks, time series analysis to find patterns or relationships and then extrapolating these relationships to predict the probability future outcome of business activities.

Drawing out information to get the answers for 'what will happen if certain conditions change?' in the future. The result of business data analysis is comprehended in visualization. The purposed of predictive analytics engine is to determine "what-if", 'what will happen?', "What might happen next?" in the future?' It gives a chance of foresight recommendation to improve the operations of businesses or warning risk assessment to correct the fraud, error, abnormal, etc.

**(d). Prescriptive analytics engine:** Prescriptive analytics engine is the machine learning techniques and algorithms that extract historical past business data and current business data to prescribe the foresight recommendations of business activities for optimal best decisions. Prescriptive analytics engine use historical past business data and current business data, descriptive analytics, diagnostic analytics, predictive analytics, machine learning techniques and algorithms like regression, classification, clustering, association, neural networks to find trends, patterns or relationships and then extrapolating these relationships, used generated prediction and foresighted recommendations for optimal best decisions the probability future outcome of business. Based on the foresighted recommendations for optimal best decisions, prescriptive analytics engine generates the best prescription on possible outcomes to handle similar future business activities for optimal best decisions.

It's try to determine the effect of future decisions. It gives insights what to do. Drawing out information to get the answers for 'what should a business do about it?' in the

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

present and future. The result of the prescriptive analytics engine is comprehended in business data visualization.

The purposed of predictive analytics engine is what action to should be taken. It gives a chance of recommendation for prescription to choose the optimal best decisions business activities. Prescriptive analytics engine address 'what should a business do to address a problem?'

**(e). Preventive analytics engine:** Preventive analytics engine is the machine learning techniques and algorithms that extract historical past business data and current business data to prevent, avoid and control undesirable business activities actions from desirable business optimal goals.

Preventive analytics engine extract historical past business data and current business data, used descriptive analytics engine, diagnostics analytics engine, predictive analytics engine, prescriptive analytics engine, machine learning techniques and algorithms like regression, classification, clustering, association, neural networks, deep learning to find patterns, trends, relationships and then extrapolating these relationships to generate preventive measures to act before an anomaly business activities occurs from undesirable optimal goals.

It needs to combine retrospective earlier stages of analytics, introspect with real-time data interoperability to prevent, avoid and control any undesirable business activities risks. Drawing out information to get the answers for 'what to do to prevent, avoid and control business activities from happening?'. The result of the preventive analytics engine is comprehended in business data visualization.

The purposed of preventive analytics engine is to determine 'how should we do from happening?' It gives a chance of recommendation to prevent, avoid and control from undesirable goals. Preventive analytics engine address 'what to do to prevent, avoid and control business activities from happening?' Preventive Analytics engines are used in business intelligence machine to curb any business activity that is not in line of desire optimal goals.

**(f). Cognitive analytics engine:** Cognitive analytics engine is a deep learning techniques and algorithms that tries to mimic the human brain's functionality to learn, unlearn and relearn of business activities for optimal decision-making in business. This Cognitive analytics model was still not develop.

The sequence of degree of difficulty level and value increases respectively as follow from descriptive analytics engine, diagnostic analytics engine, predictive analytics engine, prescriptive analytics engine, preventive analytics engine and then finally cognitive analytics engine.

Business intelligence processes from business data to decision making as shown in Fig 9.

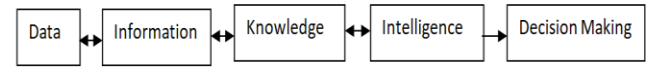


**Fig 9. Business intelligence processes from business data to decision making**

Data refers to raw facts, figures, and symbols. Information is a meaningful and usable data. Information are organized in a very systematic way. Knowledge is the acquire information. Intelligence is a adaptability to acquired knowledge, apply knowledge, capability to make decision and control its action.

The term intelligence was included in the line of business intelligence processes from data to decision making. Intelligence occurred after acquired knowledge and before decision making in business environment. Decisions are taken based on outcome of various stages of business data analytics which determine historical past business data, present business data and future business data which result in hindsight, insight and foresight.

In the context of Machine Learning, the term Business Intelligence can be defined as a adaptive business intelligence model encompass of processes, components, products and machine learning technology which extract business data from large datasets and transformed it into intelligence in problem-solving, decision-making, achieve desire's optimum goal in business and control its actions.

The whole system of adaptive business intelligence models is known as business intelligence machine (BIM). Business Intelligence Machine is a business data driven, components driven, process driven, machine learning models driven and decision making driven.

### 3.3 Business Intelligence Machine Utilities

The main purpose of Business Intelligence Machine are to achieve desire's optimum goal in business, quick business decision making, better service to firms and customers, automate resolve operational business problems, automate response to market trends without delay, more accurate estimation, better prediction on business's operational and to obtain maximum profits from businesses.

*International Journal on Recent and Innovation Trends in Computing and Communication*
*ISSN: 2321-8169 Volume: 11 Issue: 11*
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:**30 November 2023*

**Table 1. Business Intelligence Machine Utilities**

| **Area of Business Intelligence Machine Utilities** | **Purposes** |
|---|---|
| Retail Industry, Defence Industry Cotton & Textile Industry, Farming Industry, Manufacturing Industry, Iron & Steel Industries, Oil and Natural Industry, Mineral Industry, Information Technology Industry and others. | • Automate required summary of the products, order, shipping, pending, purchased, sales, stock and inventory.<br>• Automate business operations.<br>• Automate stock management to meet the demand<br>• Automate diagnostic of anomaly of any products.<br>• Automate products purchases performance management.<br>• Automate products sales performance management.<br>• Automate risk management of products that does not produce good result based return on investment (ROI).<br>• Automate financial management.<br>• Automate human resources management.<br>• Automate analyzing business data in real-time and status of customer's preferences and trends.<br>• Automate price optimization by offering incentive and discounts.<br>• Automate predict products shortages and replenish their inventory proactively.<br>• Automate logistics and distribution of products.<br>• Automate marketing and inventory management.<br>• Automate personalization service to customers based purchase history.<br>• Automate forecast demand products by customers.<br>• Automate forecast supply product to customers.<br>• Automate decision making in pricing, marketing, supply and demand chain, maximum profit to the businesses without effecting to customers, et cetera. |
| Healthcare Industry, Pharmaceutical industry, Educational Institutions, et cetera. | • Automate patient's past and present business data summary.<br>• Automate required summary of the products, order, shipping, pending, purchased, sales, stock and inventory.<br>• Automate business operations.<br>• Automate diagnostic on patient's data.<br>• Automate prediction the consequence of patient based on patient's data with space and time.<br>• Automate prescription of medicines to patient based on the patient's diagnostic and prediction result.<br>• Automate logistics to physicians and patients.<br>• Automate the status of the patients from patient's data.<br>• Automate stock management to meet the demand.<br>• Automate products or equipments purchases performance management.<br>• Automate products or equipments sales performance management.<br>• Automate risk management of products or equipments that does not produce good result as per the return on investment.<br>• Automate financial management.<br>• Automate human resources management.<br>• Automate supply and demand chain of products and equipments.<br>• Automate decision making to patients and physicians as per the history record patient's diseases, et cetera. |

| | |
|---|---|
| Banking Industry,<br>Automobile and aviation Industry,<br>Telecommunication Industry,<br>Insurance Industry,<br>Finance Industry, et cetera. | • Automate required bank and customer banking data summary.<br>• Automate update of different bank transactions.<br>• Automate decline loans or any schemes to defaulter customers.<br>• Automate detect anomaly in the bank transactions.<br>• Automate business operations like credit management.<br>• Automate prediction the consequence of customers based on customer's history records.<br>• Automate incentive and benefits to outperformance customers.<br>• Automate insurance claims, policies and premium covered.<br>• Automate logistics to bankers and customers.<br>• Automate the status of the customers from customer's business data.<br>• Automate financial management to meet the demand of customers.<br>• Automate risk management of customers.<br>• Automate customer profiling and human resources management.<br>• Automate optimize marketing.<br>• Automate personalization service to customers.<br>• Automate decision making to customers and industries as per the history record business data, et cetera. |

## 4. Findings

(i) In the context of Machine Learning, we have defined business intelligence as a adaptive business intelligence model encompass of processes, components, products and machine learning technology which extract business data from large datasets and transformed it into intelligence in problem-solving, decision-making, achieve desire's optimum goal in business and control its actions.

(ii) There were knowledge and methodology gaps in existing business intelligence system. Hence, we proposed conceptual framework of 'Adaptive Business Intelligence Model' used machine learning techniques and algorithms. The whole system of adaptive business intelligence models is known as business intelligence machine.

(iii) Automate service and management in business intelligence machine.

(iv) Business intelligence machine have multi-directional flow of data and control communication.

## 5. Conclusion

In this research paper, we have discussed various challenges of existing BI and we have developed conceptual framework for machine learning in adaptive business intelligence model. We have found that machine learning techniques and algorithms is the solution for the business problems and challenges in business intelligence. Machine learning engines are machine learning techniques and algorithms that learn from large dataset to build descriptive, diagnostic, predictive, prescriptive and preventive analytics for optimal decision making in adaptive business intelligence models. Machine learning engine is the heart and soul components of adaptive business intelligence model. Business intelligence machine can learn and solve real world business problems with minimal human involvement, more accurate, more speed, and better decision making in business as compare to existing of business intelligence systems functionalities. Future research directions, various types of machine learning techniques and algorithms have been classified for further investigation and implementation in business intelligence. To build cognitive analytics engine or model, we need to explore and exploit deep learning techniques and algorithms. To handle various data types of structured, unstructured, semi-structured, flow of data and control in multi- directional communication from back-end and front-end while implementing adaptive business intelligence model. The applications business intelligence machine are very vast and large, the only limits is human understanding on the problems of business intelligence. Some of the applications of business intelligence machine are retail, hospital, transport, education, revenue, industry, market, bank, big data, etc.

## 6. References

1. Power Daniel J. (2004). "Decision Support Systems: From the Past to the Future,"AMCIS2004 Proceedings. 242, from http://aisel.aisnet.org/amcis2004/242.
2. Hiremath Rupa & Patil Pradip (2016). "A Study- Knowledge Discovery Approaches and Its Impact with Reference to Cognitive Internet of Things (CIOT)," International Journal of Information Sciences and Techniques (IJIST) Vol.6, No.1/2.

3. Abell´o Alberto and Romero Oscar (1993). "On- Line Analytical Processing," Universitat Polit`ecnicade C atalunya, https://www.essi.upc.edu/~aabello/publications/09.encicl opedia.pdf
4. Breslin Mary. (2004). "Data Warehousing Battle of the Giants: Comparing the Basics of the Kimball and Inmon Models," Business Intelligence Journal.
5. Davis Gary Alan & Woratschek Charles R (2015)."Evaluating Business Intelligence/ Business Analytics Software for Use in the Information Systems Curriculum," Information Systems Education Journal (ISEDJ), ISSN: 1545- 679X.
6. Luhn H.P.(1958)."A Business Intelligence System," IBM Journal2(4):314.doi:10.1147/rd.24.0314.
7. Elena Cebotarean (2011). "Business intelligence" https:// www.scientificpapers.org/wp-content/files/1102_Business_intelligence.pdf
8. Gilad Benjamin., Gilad, Tamar.(1986)."SMR Forum: Bus inessIntelligence-The Quiet Revolution," Sloan Management Review, 27(4), 53–61.
9. Ghoshal S., & Kim, S.K.(1986)."Building Effective Intelligence Systems for Competitive Advantage," Sloan Management Review, 28(1), 49–58.
10. Lönnqvist Antti. & Pirttimäki Virpi. (2006). "The Measurement of Business Intelligence ,"Information Systems Management, 23(1),32-40.
11. Rouhani Saeed, Asgari Sara & Mirhosseini Seyed Vahid . (2012). "Review Study: Business Intelligence Conceptsand Approaches," American Journal of Scientific Research ISSN1450-223X Issue 50 (2012), pp. 62-75
12. Pavkov Sanja, Poščić P., & Jakšić Danijela. (2016). "Business Intelligence Systems Yesterday, Today and Tomorrow - an Overview," Zbornik Veleučilištau Rijeci, Vol4 (2016.),No.1,pp. 97-108
13. Dedić Nedim & Stanier Clare. (2017). "Towards Differentiating Business Intelligence, Big Data, Data Analytics and Knowledge Discovery, "Springer International Publishing LNBIP285,pp.114–122,2017.DOI:10.1007/978- 3-319-58801-8_10.
14. Foley Eric & Guillemette Manon G.(2010)."What is Business Intelligence?," International Journal of Business Intelligence Research, 1(4), 1-28,
15. Shatat Abdallah, Altahoo Mariamand Almannaei Munira (2024)."The Impact of Business Intelligence on Decision-Making Process and Customer Service, "ASU International Conference in Emerging Technologies for Sustainability and Intelligent Systems (ICETSIS).
16. Shariat M. & Hightower, J.R.(2007). "Conceptualizing Business Intelligence Architecture, "Marketing Management Journal (17:2), Fall2007, pp 40-46.
17. Shollo Arisa & Kautz Karlheinz. (2010). "Towards an Understanding of Business Intelligence," AC IS2010 PROCEEDINGS Paper 86.
18. Ranjan Jayanthi. (2009). "Business Intelligence: Concepts, Components, Techniques and Benefits," Journal of Theoretical and Applied Information Technology Vol. 9, No.1, pp 60-70
19. Power D.J.(2007),"A Brief History of Decision Support Systems," http://dssresources.com/history/dsshistory.htmlversion4.0', viewedon03 March2024
20. Reinschmidt Joerg & Francoise Allison.(2000)."Business Intelligence Certification Guide, "International Technical Support Organizatio,www.redbooks.ibm.comSG24-5747-00.
21. Anand Nitin. (2014)."ETL and its impact on Business Intelligence, "International Journal of Scientific and Research Publications,Volume 4, Issue 2,ISSN 2250-3153.
22. Sutton Richard S.(2020)."John McCarthy's Definition of Intelligence," Journal of Artificial General Intelligence 11(2) 66-67, 2020 , DOI: 10.2478/jagi-2020-0003
23. Gupta Anand Ramesh.(2017)."Business Intelligence: Concepts, Components Tools, Techniques, Benefits and Challenges, "IJARIIE-ISSN(O)-2395-4396 Vol-3 Issue-3
24. Turing A. M. (1950). "Computing Machinery and Intelligence, "Minda Quarterly Review of Psychology and Philosophy. VOL. LIX. NO. 236. Pg 433-460.
25. Bowen Jonathan Peter. (2017)."Alan Turing: Founder of Computer Science, "Engineering Trustworthy Software Systems (pp.1-15) DOI:10.1007/978-3-319-56841-6_1.
26. Samuel A.L.(1959)."Some Studies in Machine Learning Using the Game of Checkers, "IBM Journal of Research and Development (Volume:3, Issue:3,July1959) https://ieeexplore.ieee.org/document/5392560DOI: 10.1147/rd.33.0210
27. J. McCarthy, M.L. Minsky, N. Rochester, and C.E.Shannon (1955). "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence," http://jmc.stanford.edu/articles/dartmouth.html

28. Grewal Dalvinder Singh (2014). "A Critical Conceptual Analysis of Definitions of Artificial Intelligence as Applicable to Computer Engineering, "IOSR Journal of Computer Engineering (IOSR-JCE) e-ISSN: 2278-0661, p- ISSN: 2278-8727 Volume16, Issue 2, Ver.I,PP09- 13. 1.
29. Mahesh Batta. (2018). "Machine Learning Algorithms- A Review, "International Journal of Science and Research (IJSR) ISSN: 2319-7064
30. Mitchell Tom M. (1997). "Machine Learning, "McGraw Hill, ISBN:0070428077
31. Janiesch Christian, Zschech Patrick & HeinrichKai (2021). "Machine learning and deep learning,"https://link.springer.com/content/pdf/10.1007/s12525-021-00475-2.pdf
32. Chahal Ayushi and Gulia Preeti.(2019). "Machine Learning and Deep Learning," International Journal of Innovative Technology and Exploring Engineering (IJITE E), ISSN: 2278-3075 (Online), Volume-8 Issue-12.
33. Sarker Iqbal H. (2021). "Machine Learning: Algorithms, Real-World Applications and Research Directions," SN Computer Science Vol.(0123456789) https://link.springer.com/article/10.1007/s42979-021-00592-x
34. Sah Shagan.(2020). "Machine Learning: A Review of Learning Types, "https://www.preprints.org/DOI:10.20944/preprints202007.0230.v1
35. Kostopoulos Georgios K, Karlos Stamatis, Kotsiantis Sotiris & Ragos Omiros. (2018). "Semi-supervised regression: A recent review," Journal of Intelligent & Fuzzy Systems 35(1):1-18
36. Cai Jianghui, Hao Jing, Yang Haifeng, Zhao Xujun & Yang Yuqing. (2023), "A review on semi- supervised clustering, "Information Sciences Volume 632, Pages 164-200
37. Grira Nizar, Crucianu Michel & BoujemaNozha.(2005). "Unsupervised and Semi-supervised Clustering: A Brief Survey," A Review of Machine Learning Techniques for Processing Multimedia Content, Report of the MUSCLE European Network of Excellence (6th Framework Programme)
38. Liu Yiyang, Yan Shuaihua, Zhao Yang, Song Chunhe & Li Fei. (2022). "Improved Dyna- Q:A Reinforcement Learning Method Focused via Heuristic Graph for AGV Path Planning in Dynamic Environments,"Drones, https://doi.org/10.3390/drones6110365
39. Sarker Iqbal H.(2021)."Deep Learning: A Comprehensive Overview on Techniques, Taxonomy, Applications and Research Direction," SN Computer Science https://doi.org/10.1007/s42979-021-00815-1
40. Pinosky Allison, AbrahamIan, Broad Alexander, Argall1 Brennaand Murphey Todd D. (2022). "Hybrid control for combining model-based and model-free reinforcement learning, "The International Journal of Robotics Research, Vol. 42(6) 337–355
41. López Osval Antonio Montesinos, López Abelardo Monte sinos & CrossaJosé. (2022)."Multivariate Statistical Machine Learning Methods for Genomic Prediction," Foreword by Fred van Euwijk ISBN 978-3-030- 89009- 4,https://doi.org/10.1007/978-3-030-89010-0
42. Jr Sprague Ralph H. (2011)."A Framework for the Development of Decision Support Systems,"MIS Quarterly,Vol. 4, No. 4 (Dec., 1980), pp. 1-26
43. Mudau Thanyani Norman, Cohen Jason and Papageorgiou Elmarie (2024)."Determinants and consequences of routine and advanced use of business intelligence(BI) systems by management accountants," Information and Management, Published by Elsevier B.V.https://doi.org/10.1016/j.im.2023.103888