Integrated Big Data Analytics Conceptual Framework for Information Sharing across the fast-moving consumer goods industry

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***Abstract*—Industrial revolution 4.0. (I.R.4.0) has augmented the number of cyber-physical systems that generate, store and process data at an unprecedented rate hence, requiring big data (BD) and big data analytics (BDA) technologies to foster this. Based on this evolution in data science, this paper has presented a framework depicting intial results for both privacy and effective sharing of integrated BD in the fast-moving consumer goods (FMCG) supply chain (SC). The FMCG consist of complex and dynamic entities, wherein, physical goods and information exchange occur and generate massive amounts of data, classified as big data (BD), which is siloed, fragmented, etc. and requires BD technologies to be processed. The absence of information integration and data defusion deprives the FMCG SC of opportunities to achieve and maintain balanced demand and supply, reduce inventory holding costs and improve logistic efficiency. The utilization of technologies such as Hadoop to process and integrate the massive amounts of BD provides streamlined processes, information, and reduced operational costs. Information integration and fusion throughout the diverse SC to achieve accurate, timely and reliable data/information was been presented in this paper using an integrated framework.**

Keywords: Integrated Big Data Analytics, Data Defusion and integration, Hadoop, Fast-Moving Consumer Goods Industry

I. Introduction and Background

The emergence of industrial revolution 4.0. (I.R.4.0.), which involves the latest technology applications, such as the Internet of Things (IoT), cloud computing, blockchains, and big data (BD) [1] has amplified the number of cyber-physical systems that generate, store and process data at an unprecedented rate and requiring big data (BD) and big data analytics (BDA) techniques, technologies and methods[2] to explore the data from multiple sources [3] and foster data integration and collaboration in the fast-moving consumer goods FMCG supply chain (SC) value network facilitating data-driven decision-making [4].

The FMCG SC consist of complex and dynamic entities, wherein, physical goods and information exchange occur [5], physical material, financial and data/information flows connecting entities in both upstream and downstream directions [6] while generating massive and diverse amounts of data/information, through the utilisation of sensors, RFIDs, etc. which is regrettably, fragmented, siloed and intrinsic to each stakeholder in the FMCG SC value network. The availability of advanced data fusion and integration technologies embedded on BD platforms provides various techniques, competencies and focus (e.g., others are designed for batch processing and others for real-time analytics [7] to assist in achieving a predictable, cost-effective, balanced demand and supply of FMCGs throughout the SC value network. The massively generated data sets are progressively in higher volumes (i.e. large amounts of data generated from different sources, which have been expanding at any time continuously [8], velocities (refers to the speed of data generation and delivery, which can be processed in batch, real-time, nearly real-time, or streamlines, with a variety of structured, unstructured and semi-structured data (refers to the rate at which the data is produced and processed [3] and variety (i.e. several types of structured, semi-structured, and/or unstructured data collected from different sources such as sensors, social networks, or any kind of monitoring activities that can be digitized [2], the aforementioned 3 V's qualifies the data generated by the FMCG SC to be classified as big data (BD).

The absence of an information sharing and integration conceptual model across the FMCG SC value network results in a myriad of operational inefficiencies such as the bullwhip effect, increased operational costs, loss of sale and increased inventory holding, etc. The bullwhip effect refers to the phenomenon where order variability increases as the orders move upstream in the supply chain [9] which is a result of information distortion throughout the FMCG SC value network. Inventory holding acts as a buffer to mitigate unexpected situations and not to be totally out of stock, unfortunately, inventory holding accrues costs (i.e. cost of capital, cost of storage and handling of the inventory, and cost or risk (insurance, pilferage, obsolescence etc., and in literature, is often mentioned that the holding costs, observed in the industry, ranging from 5 – 45%, which gives an average of 25% [10] and is further exacerbated by the absence of information sharing and integration across the SC value network.

There is an increasing demand for the adoption of BD technologies [11] [12] to achieve information flow, collaboration and integration across the FMCG SC. Furthermore, there is substantial evidence that BD technologies may lead to increased efficiency, reduce cost, etc., and also integrate the data resources in the SC (Song, Fisher, Wang and Cui, 2016) to help gain insights, arrive at data-driven decisions, positively change SC performance, supplier integration, based on BD (Moktadir, Ali, Paul and Shukla, 2019) and BDA technologies (Gunasekaran, Kumar Tiwari, Dubey, and Fosso Wamba, 2016).

It is with the above background, that a need to develop a BDA conceptual framework to encourage data/information integration and flow across the FMCG SC value network utilises the main three analytics of BDA with the ultimate goal of reducing various FMCG SC costs to a minimum baseline

II. BIG DATA ANALYTICS CONCEPTUAL FRAMEWORK BASIS AND OVERVIEW.

Over the years there have been several types of research on BDA capabilities, technologies, etc., limited empirical studies have investigated the benefits of BDA technologies in the FMCG SC integration and information fusion [13], also very little is known about key BDA capabilities for FMCG SC (Arunachalam et al., 2018) and fewer studies propose systems that aim to improve the information flow, fusion and integration in the SC [14]. Companies globally are seeking ways to establish [15] information integration and fusion throughout the diverse SC to achieve accurate, timely and reliable data/information. It is a documented fact, that data analytics capabilities have a positive effect in enhancing the utility of the massively generated data by the entire SC value network. This BDA conceptual framework seeks to document and detail the information fusion & integration, and application of BDA across the FMCG SC value network. SC entities are interconnected in various forms; including physical (e.g., raw materials, etc.), information and financial flow [4], and data visibility provides a need for a "Big Data Analytics Conceptual Framework" for the FMCG SC, refer to Figure 1. "The strategic use of data analytics is to provide up-to-date information to make decisions and respond appropriately". The advancement of mass data technologies and the adoption of automation in the SC value network forces data/information integration and availability across the value network.

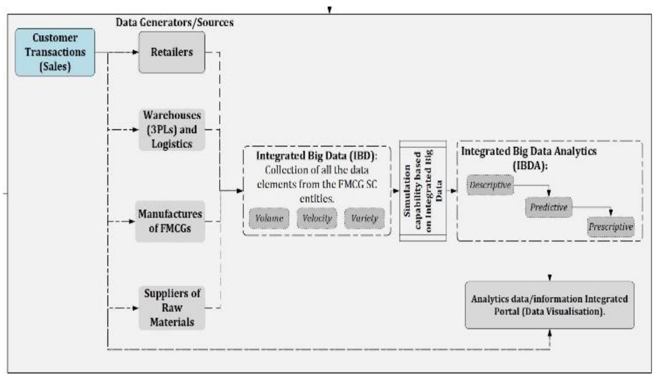

Figure 1: Big Data Analytics Framework (Source: Self Constructed)

The Big Data Analytics "conceptual" framework integrates information flow across the FMCG SC value network to improve operational efficiency and/or achieve seamless computation of various data behaviors.

The various transactional data/information of the various FMCG SC entities will be captured and stored on the entities' internal technological databases. The captured and stored data/information can be real-time, batch, etc. On the agreed basis of data downloading to the "Big Data Technology (BD Technology)", the data/information will be extracted and loaded to the BD technology. The computation capability of the BD technology will process data/information, in batch, real-time, near real-time and stream, etc. as by BD computation capabilities.

The extracted and loaded data/information onto the "IBD technology" will then be "processed' (utilising the various processing computation capabilities for the various V's). On completion of processing the data/information, the processed data/information will then be extracted, transformed and loaded onto the "simulation capability". The "simulation capability" (this refers to a computation technology specialising in developing scenarios) will then perform a scenario (e.g., if there is a shortage of certain raw material for a specific entity, no availability of delivery trucks, etc.). On completion of the simulation, the simulated data/information scenario will be extracted and loaded to the BDA capability.

The BDA capability will extract the loaded data/information and perform the various sequential analytics and generate a prescriptive analysis. Each stage of the analytics (i.e., descriptive, predictive and prescriptive analysis) will be "stored" on the BDA database for future computation combinations. The prescriptive analysis outcome/results will be extracted and loaded onto the "Analytics data/information Integrated Portal". The main function of the "Analytics data/information Integrated Portal" is to record, and store all the prescriptive analytics outcomes. The "Analytics data/information Integrated Portal" will extract and load all the prescriptive analysis and analytics. There will be contractual agreements amongst entities on information agreements. Following agreed rules of information sharing and integration, all the entities will have "access" to the "Analytics data/information Integrated Portal" by the "click of a button" and the applicable prescriptive analysis of the scenario will be provided. If there is no record of the scenario, a new simulation process will be performed.

III. BIG DATA ANALYTICS CONCEPTUAL LOGICAL FLOW.

The flow of data/information across the BDA conceptual framework will utilise descriptive statistics utilised to provide summarized information on the characteristics and distribution of data elements in more datasets to provide the degree of dispersion as they are useful in today's era of BD [16]. The conceptual framework refer to Figure 2, is formulated based on data analytics capabilities, which enhances the utility of the mass amounts of data that can be collected and communicated through SC continuously [15].

IV. APPLICATION AND UTILISATION OF THE CONCEPTUAL FRAMEWORK IN THE FMCG SC VALUE NETWORK.

Over the years the SC industry has been evolving at a rapid rate with an increase in the use of automation, data processing

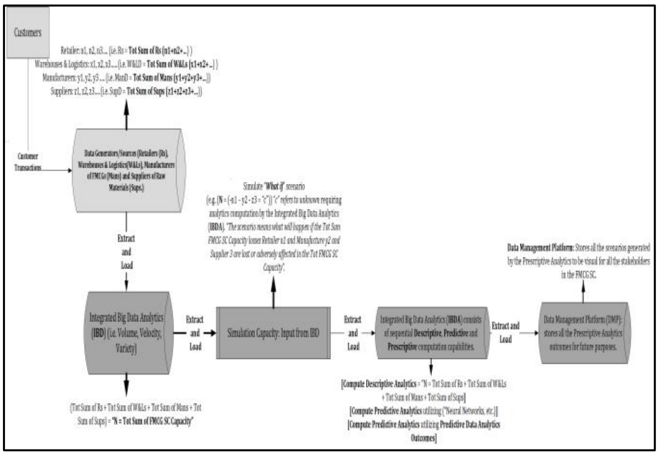

Figure 2: Conceptual Logical Flow.

and exchange [11] exacerbated by industrial revolution 4.0., (I.R. 4.0.), the COVID-19 pandemic, has had a devastating impact on SC [17] and war between Russia and Ukraine, their total effects have had the prolonged effects and are still prevailing in most industries (including the FMCG) and full recovery is not envisaged soon. The aforementioned has fostered information integration [18] critical to the varied sources of data/information. There is an increasing trend in adopting BD and BDA technologies in industries such as retail, manufacturing, etc. [2], which makes information sharing, and integration critical in the improvement of operational efficacy, cost reduction and financial improvement. furthermore, there is substantiated evidence supporting the assertion that BD and BDA technologies have a positive effect on various factors (e.g., business performance, cost reduction, etc.). It is the goal of this conceptual framework to optimally integrate the data/information generated to achieve a streamlined, cohesive data/information availability. Based on this, technologies such as Apache Hadoop (i.e., an open-source tool used by companies to provide the latest solutions in warehouse data as well as the processing of data work out will be inexpensive and efficient [19].

V. Integrated Big Data (IBD) and Analytics (IBDA).

Integrated BD (IBD), refers to the computational collation capabilities to store, manage, etc. data/information from all the interlinked data/information from all the data generators/sources. BD offers substantial value, new opportunities [20] and operational excellence for existing SC practices [21] and can create better decision-making mechanisms [22] and has extended technological capabilities to store, manage, process, interpret and visualize the amount of data [23]. The IBD utilises the existing BD computational, technological capabilities, etc. to achieve an integrated platform for the entire FMCG SC by performing data assessment and computing (according to volume, velocity and variety) and BD technologies which provide all the necessary computing and data processing capabilities for data-intensive and data-driven applications. Once the assessment and computing of the data/information have been completed and the data/information will be ready to be loaded.

BDA can be used as an innovative tool and enhance FMCG SC performance [24] in general. The function of IBDA is to systematically perform sequentially descriptive (application in the development of effective and summarizing reports on raw data that is easy for human interpretation [4], predictive (helps in the "Prediction" of what might happen in the future using existing data set information [25]) and computational algorithms [26] and prescriptions (which combines both the tools and techniques that include algorithms, business rules, computational modelling and machine learning procedures [27]) across a variety of data sets. The IBDA in the conceptual framework, will process and compute the necessary analytics (namely, descriptive, predictive and prescriptive) and generate the optimum prescriptive recommendation/solution while the recommendations will be loaded onto the "Analytics data/information Integrated Portal" for storage and data visualisation [28] for future reference (or reuse) purposes.

VI. Customer Transaction (Sales).

At the point-of-sale (POS), goods are predominantly scanned using the stock keeping number (SKU) to collect and collate the products purchase details, through the scanning of the SKU transaction with the datasets consisting of important details (e.g., the number of goods, set or type of products bought, time of purchase, frequency of purchases, customer loyalty programmes, etc.) are collected and stored. The data collected from transactions are recorded to be eighty-eight (88%) percent [4] captured and stored in different varieties (i.e., structured, semi-structured and unstructured) [29].

VII. Data Generators/Sources

Data generators/sources refer to entities (i.e., Retailers, Warehouses (3PLs) and Logistics, Manufacturers of FMCGs and Suppliers of Raw Materials) where information and material flow are linked [4], at various levels and stages of their operations due to high levels of BD adoption [2] and have flooded the FMCG SC with a massive amount of data since various sensors, electronic devices, and digital machines [30] are used and cannot be processed using traditional technologies [31].

VIII. Integrated Simulation Capacity (ISC).

The use of simulation in the BDA conceptual framework is to enable each stakeholder to provide its unique outcome. A simple conceptual model is to be followed and translated into computer codes [32]. The conceptual model will organically grow as the complexity of simulations is needed for IBDA. The simulated scenario (i.e., "what if") will be captured, stored, extracted from the ISC and loaded onto the IBDA for analytics. It must be noted that there is a gap in simulation studies making use of transactional data [33].

IX. Analytics Data/Information Integrated Portal.

Digital connection is a proven approach to achieving enterprise integration, transformation, and collaboration [34], and the "Analytics data/information integration portal", supports the statement, by integrating all the related data sets. All the generated recommendations/solutions will be loaded onto the "Analytics data/information Integrated Portal" for data visualisation. This portal will be visual to all the data generators/sources and any other authorised individuals.

X. SECURITY, PRIVACY AND CONFIDENTIALITY.

The benefits of BDA are so great that there are just as many new privacy and security issues amplified by the 3Vs concerns being created [35] and confidentiality. Privacy and security of BD are gaining momentum in the research community (Cuzzocrea, 2014), by proposing and implementing strong protection mechanisms that enable getting benefits from BD without risking security and privacy [36]. Industries are focusing too much on the advantages offered by BDA (e.g., Hadoop, etc.), and too little on the concerns related to security and privacy protection [36]. The conceptual framework takes note of data/information security, privacy and confidentiality elements in its pursuit of digital integration of data/information across the FMCG SC.

XI. THE BENEFITS OF THE CONCEPTUAL FRAMEWORK.

The FMCG SC is engulfed with various data/information-related challenges and these challenges hinder various advancements in the FMCG SC. The era of BDA is progressing and those that are not adopting it will either fall behind, lose competitiveness or worst case, close business. The benefits of the framework include the following underlisted:

XII. FUSED AND INTEGRATED DATA/INFORMATION VIEW.

The amount of BD computing technologies [37] in the FMCG SC has created a data-rich environment driven by different data generators/sources. These data generators/sources include human beings, sensors, RFIDs, data warehouses, robots, etc. all these artefacts enable the framework to enable data fusion (i.e., the process of fusing multiple records representing the same view of the FMCG SC into a single and consistent data [38] and integrated the data/information to improve information [39] and enable the BD computational capabilities and technologies to achieve fused and integrated data/information resulting in positive operational and business performance [40] on a proactive rather than a reactive scenario.

XIII. REDUCE OPERATIONAL COSTS.

The adoption and utilisation of BDA is appropriate for cost efficiency, and cost reduction [4] and a clear and systematic strategy toward BDA can provide a good return on investment (ROI) [41]. The warehousing sector act as a buffer for unforeseen circumstances. However, inventory holding is costly. The data/information from the IBDAP will be almost real-time and provide a snapshot of the current and predicted overall situation. All of the data generators/sources will have the same view of data/information. Furthermore, the stakeholder companies will be provided with predicted information to adjust their enterprise resource plan (ERP) accordingly.

XIV. IMPROVED FMCG SC DATA/INFORMATION PROCESSING.

BD has modified information processing technology and analysis methods and has been widely used [42] and enables entities to effectively deploy technologies to capture, store and analyse data [43] in either batch, near real-time, real-time or stream [3] frequency. Sourcing and consolidating data/information from various sources is time-consuming, costly and requires further processing. The conceptual framework will facilitate the collection and processing of various data sets throughout the FMCG SC and utilise the BD and BDA processing computational technologies through streamlined datasets.

XV. DATA QUALITY, PRIVACY, INTEGRITY AND SCALABILITY.

The enormous and complex data/information generated by the entities in the FMCG SC requires smart, scalable [44] and quality data extraction with a certain level of privacy [45]. Earlier studies have shown that BDA quality factors are consisting of data quality [46]. The quality of data to be generated by the framework will be defined by the different entities and the collection method be improved over time. Entities in the FMCG SC compete and data/information is one of their strategic competitive advantages hence, a need for data anonymity [45]. BDA can act as a critical technology to manage and integrate data [47]. The sources of data origin will be specified accordingly to preserve data integrity at each source [48]. Even though data scalability is a known technical challenge for BDA [4], computational technologies are advancing at a reasonable rate.

XVI. RISK ASSESSMENT, DATA-DRIVEN DECISION-MAKING AND MANAGEMENT.

BDA practices are necessary to mitigate risks [50]. FMCG SC faces a variety of risks daily (e.g. out-of-stock, consumer needs changes, economics, etc.) and the BDA conceptual framework seeks to optimise BD and BDA capabilities to improve areas such as risk assessment [47]. BD techniques are used to conduct an assessment of risks and solve them by utilising rules based on operational data [51] while also accessing the probability of occurrence of a problem and its impact [4]. Intuition-based decision days are slowly diminishing and will soon be not applicable as the usage of BDA has a positive impact on decision-making quality [49].

XVII. CONCLUSION.

Information integration transcends these days and there is a reasonable justification to extend this across the FMCG SC to add a layer of knowledge to the existing one. The BDA conceptual framework adds to the existing data analytics, data integration, data fusion and data visualization to achieve an integrated FMCG SC. The continuing advancements of BD and BDA capabilities afford the FMCG SC abundant opportunities to explore technologies such as Hadoop data analysis and predictive analytics to include and depict practical information in the most visually appealing way possible. The BDA conceptual framework anticipates the capabilities of BD and BDA to provide an abundance of potential and act as an added value in the era of BD and BDA.

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