AN INTEGRATED APPROACH USING FUZZY LOGIC AND IOT FOR SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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Abstract - The impact and transition in the physical structure and economic ties of the Supply Chain (SC) for the Internet of Things (IoT) technology is comprehensive and deep. Business models affect the utilization of resources and the supply chain process, leading to several management issues. The paper provides a decision support mechanism to choose suppliers and the technology by predicting the demand. The first phase of the method offers a forum for community decision-making to promote fuzzy-based decision-making for IoT (FBDM-IoT) and monitor results consistently. The theory indicates approaches from two different viewpoints, both technical and customer-based, at the decision-making process. The second phase of the system integrates the use of a high-quality feature with the order preference strategy with optimal solution to evaluate the fuzzy-based decision problem. This paper developed an FBDM framework for interfacing decision-making and consumer values in selecting logistical suppliers to support logistic partners and investors. Besides, stakeholders have identified a decision support mechanism that can assist suppliers in ambiguous circumstances based on fuzzy linguistic variables. The proposed FBDM shows that the supply chain business model also aids in reaching goals for sustainability with reduced risk and cost.
Keywords: Fuzzy based decision making, Sustainability, Logistics, Supply chain management, business models, IoT.

1 INTRODUCTION

The Internet of Things (IoT) technology is being more commonly used in manufacturing and circulation as communications and information science advances rapidly. The invention of the aggregation, operations and transaction of business capital by the internet technologies of the subjects has significantly supported the productivity of development and circulation. It triggers the transition in human society's mode of production and consumption, which is a matter for all nations worldwide. Authors used the SWOT method to study the ties between China's industrial Chain of Things internet and found that the Chinese chain of industry chain Things has strong growth prospects, a comprehensive marketplace, a stable base, and other benefits.

Again, the study on supply chain firms has been an essential subject for many academics under the rapid evolution of the IoT. The authors of [2] and others have developed metrics of integration between the business and the upstream and downstream. They have examined the importance of integrating the supply chain in supporting corporate financial success and have disclosed the supplier development process that affects corporate behaviour and effectiveness. The thesis extends the organizational philosophy of success and gives an analytical framework for firms to develop market plans and national policy formulation. The growth of the IoT has provided a significant number of network information from supply channel companies.

The authors have developed computational equations in [3] to solve resource allotment optimization in supply chain companies where restriction in demand fees is irrespective of production schedule and association of the cut-off of order fees with lead time. In developing the fuzzy set hypothesis, more and more scientists use diverse fuzzy numbers to demonstrate the complexity and flexibility in knowledge in making choices. This article applies six-point fluctuating numbers to address the ambiguity of supply chain business management, constructs a fluid decision-taking statistical model and employs the cloud infrastructure to compute the response.

The remainder of this paper is organized as follows. Section 2 describes the associated research on supply chain management and IoT. In Section 3, fuzzy-based decision-making for IoT (FBDM-IoT) has been described. Section 4 provides results and discussion. Section 5 provides the conclusion and an overview which describes possible future studies.

2 RELATED WORKS

Client requirements can be met by various strategies relevant to vendors, producers, distributors, distribution, and consumers controlled by stock, credit, information, and technologic flows in the competitive, turbulent, and uncertain market [4,5]. Company companies should use experience and understanding ecosystem and asset utilization to develop strategic bases and approaches. This also helps to consider supply chains' behaviour and create evaluations to assist policymakers in designing potential solutions for a particular organizational challenge. The agility of the supply chain has been examined to cover the primary factors. Flexibility is the capacity to adapt rapidly and quickly to demand and sustainable consumers. In contrast, sustainable agility is the agility of the supply chain if it promotes relationships between systems and resources at all levels of the organization [6].

Because of concurrent advances in agile processes, production and supply chain management [7], the concept of supply chain flexibility was implemented. It was initially described in terms of agile company [8], goods and workforce [9], skills [10], automated teaming [11] and sustainable development [12]. Early advocates of agility described it as a unique internal mechanism capable of responding quickly to evolving needs in the market place [13]. The company's internal capabilities incorporate complex and straightforward technology, personnel, skilled and highly driven leadership and information systems. Simultaneously, versatility also means a high level of commitment across design requirements or product lines to meet consumer demand almost real-time [14].

Adaptability is then described as an organization's capacity, both in volume and variety, to adapt quickly to changes in demand [15], all of which relate to consumer response and the volatility of the market and unique capacities needed [11]. The researchers [13,16] subsequently defined an effective supply chain as a capability of demand awareness, responsive and rapid responses, and coordinated transactions. They proposed that reliability, viability, efficiency, creativeness and assertiveness, success rate, cost and strength can be assessed both with tough and gentle parameters. Subsequently, in the face of dynamic demand, risk management and the continuous delivery of services, researchers [17–19] redefined agility that enables organizations to rapidly and financially develop goods and services to satisfy the diverse needs of customers, focusing on reducing waste and customer dissatisfaction with speed and flexibility in the supply chain.

The proposals further proposed flexibility efficiency metrics as product consistency, innovative products, and organizational innovations. Thus, an efficient supply chain is concerned with the transition, complexity and randomness of the market climate. A competitive, effective supply chain also requires different skills to differentiate. These include four major components [20]: sensitivity that is capable of identifying and responding to changes rapidly, constructively or promptly, but can also be taken from them; competencies that enable organizational objectives to be efficiently and effectively achieved; flexibility that allows multiple procedures to be implemented and different instalments to be implemented; and endurance that is the ability to do an operation as fast as possible.

Modelling the sustainable agile supply chain is an effective way to improve knowledge of the supply chain behaviour. Such modelling can help policymakers find a strategic approach to a particular business challenge. Researchers [21] have dealt with a series of methods to assess agility in the supply chain. However, these measures are qualitatively defined by language words that can be criticized for the size restrictions used to obtain the capacity of the supply chain.

Organizations recognize that mobility is crucial to survival and productivity across their supply chain. When integrating agility in a supply chain, endurance, calculation, resilience, and barriers [22] are analyzed, and, in essence, agility indexing shows the company's strategic agility in a dynamic market environment [23]. Most scholars have proposed frameworks and methods [24–26] to determine the theoretical supply chain agility and the related success metrics that have contributed to supply chain management. Around the same time, some scholars have concentrated on the effective use of analytical and empirical case studies [9,21] and the validity and the applicability of the methods of endurance evaluation [29,30] effectiveness of specific hypothetical appraisal approaches developed.

3 FBDM-IOT SYSTEM

Resources to all related parts of the supply chain, such as organic product development, renewable resources and energy conservation, finished product warranty, after-sales operation, employee ethnicity, reuse/recycling design, outbound logistics, will render supply chain (SC) management renewable. Practically, these objects are customer-configured. Both these things of the supply chain must be consulted by clients/stakeholders and agreed with them.

3.1 Framework for Integrating Fuzzy Logic And IoT For Suatainable SC

FBDM aims to promote circular supply chains, as seen in Fig.1. An exposed supply chain extracts environmental assets and wants to get rid of goods, packaging materials, and waste from various stages of the supply chain. The undesirable objects are frequently stored in fields. The closed-loop supply chain increases ecological sustainability by returning a supplier's demand for products and packaging materials. The scope of the cost retrieval in the closed-loop supply chain is also narrower since activities of the manufacturer (supply chain producer) are limited and secondary supply chains are not included, and the introduction of additional sectors are involved.

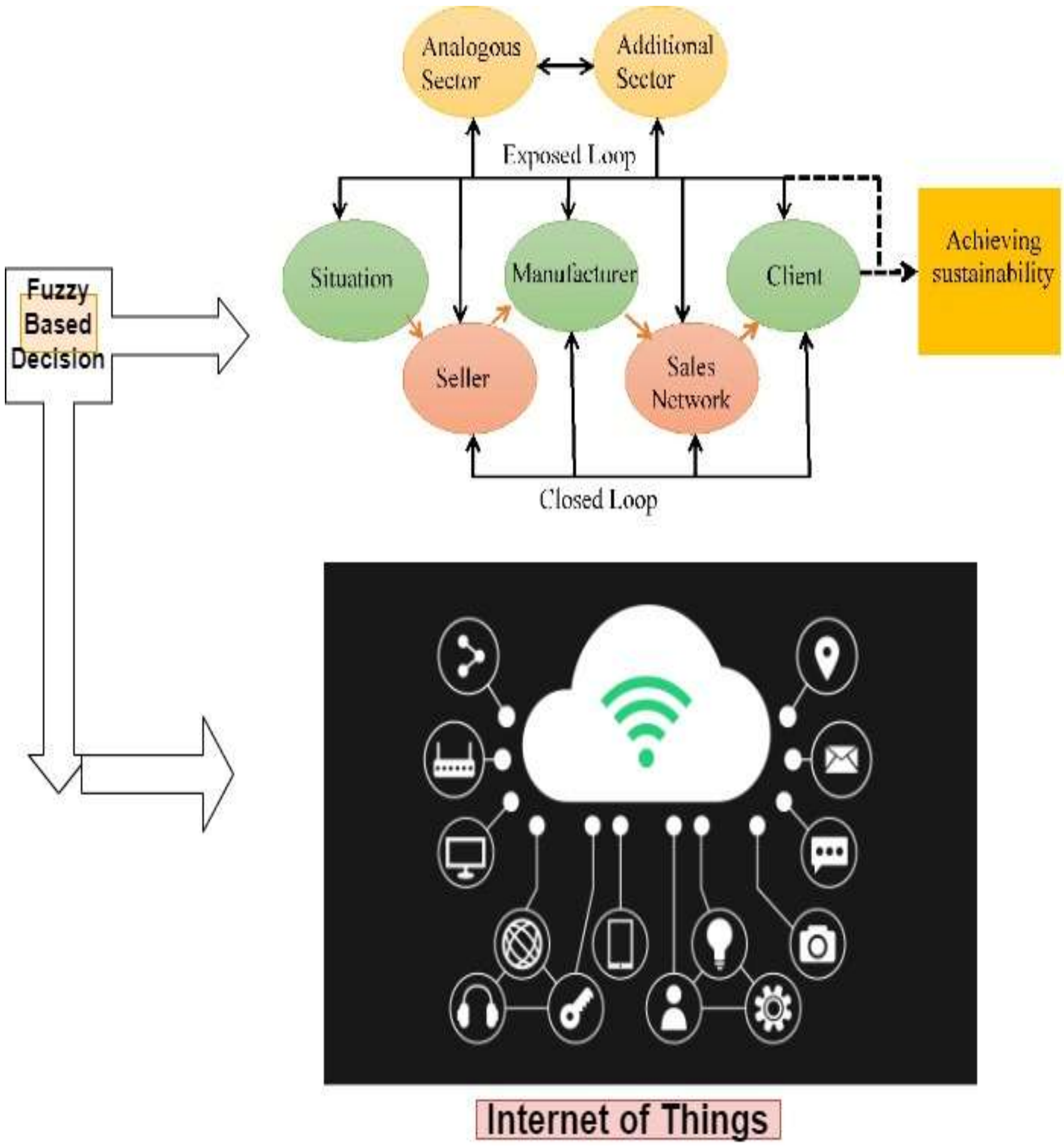

Figure 1 Framework of various models of supply chain

A closed supply chain also produces a considerable amount of waste, because reuse/recycling of all discarded items in the same supply chain is hardly feasible. By partnering with analogous sectors of industrial organizations or with different industrial sectors, an SC may also be used to extract profit out of waste. Ideally, SC would achieve nil waste, as it has been built to preserve and recycle land continuously in terms of the situation in which it is implemented.

By restoring the market for commodity and packaging materials, the closed-loop supply chain improves environmental protection. The extent of capital expenditure for the closed-loop SC is often smaller. There is selective and supplementary SC not included operations in the initial retailer (supply chain manufacturer) and secondary channel participants. The number of tasks is specified in the suggested FBDM model. Weights of the decision parameters subsequently were calculated using fuzzy decision-making processes (e.g., weights of technical supply chain requirements). Cloud systems provide conditions in the IoT network for broad accessibility and easy resource availability in the supply chain. Companies can combine product services to address consumer demands with a cloud platform in response to demand. Within the IoT system, the collaboration and improvement of Pareto's supply chain is studied to analyze market dynamics of allocated resources, discover economic activities, financial transactions, and decision-making.

3.2 Proposed Fuzzy Based Decision Making Approach

Agricultural production systems risk and uncertain conditions are designed to provide advancing expertise in sustainable agriculture decision making to understand the significant impacts of each phase of farming practices. The conceptual framework "stepping up and implementation are relatively low and ambiguous agricultural production systems of knowledge-based ICT solutions". This involves implementing a pilot study of high importance, which will incorporate real-life agricultural needs, alternate land management scenarios, promote creativity, and affect end-users and consumers in the development of agricultural production processes, procedures, logistics and supply chain management systems.

The following steps are involved in the fuzzy decision-making process:

Step 1: Identify Client Specifications (CS) and Technological Requirements (TR) related to the success of supply chain logistics suppliers.

Step 2: Understand the value of the consumer requirement by using fluctuating triangular and fluid weighted mean linguistics parameters, along with the association between CS and TR. A fluid collection consists of a member function that maps elements within an interval of [0, 1] to membership levels. The feature has a certain degree of membership when the allocated amount is beyond the interval (it belongs partially to the fuzzy set). The layout of the triangular fuzzy number used in this article is seen in Fig. 2.

Step 3 – Fuzzy weight measurement for technological needs for the supply chain. For the final selection procedure, a normalization rule is used to include normalized weights of the principal decision parameters. The method suggested takes the FBDM framework, the consistency matric, into technological considerations to transform customers and external variables. FBDM

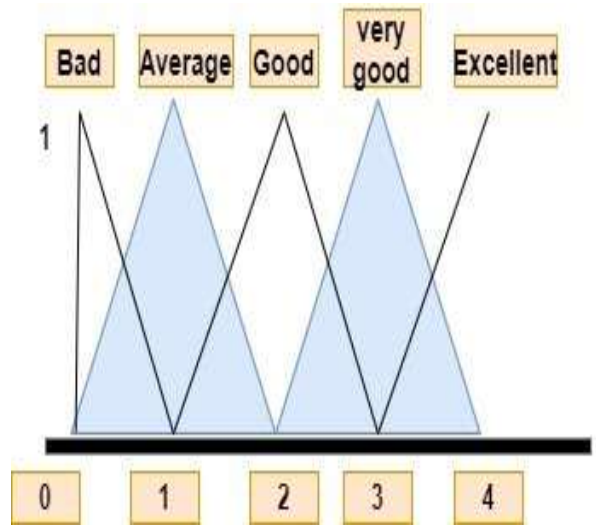

Figure 2 Framework for fuzzy membership function used in the proposed FBDM-IoT for SC

model was developed for connecting consumer demands with product design measures in a community decision-making environment. Stage 1 selects decision-makers and defines options, assessment requirements, considerations and the qualities of the client/stakeholder. At this point, a logistical provider's appraisal criteria are entirely decided and examined for stakeholders and consumers. The technological specifications should be stated as the means of satisfying customers.

Step 4 - A survey is conducted to assess the level of satisfaction and relevance of consumer requirements of consumers and end-users in the second stage. Fuzzy linguistic principles shall determine the degree of significance of consumer positions and technological specifications. These linguistic values are subsequently translated to fugitive triangular numbers for use in calculation stages. This transformation framework enables decision-makers to address the complexity and disagreement conditions of the decision-making process with linguistic variables in fuzzy numbers. To promote the involvement of policymakers, stakeholders have created a collection of five language labels. Choice-makers have a role to play in selecting language variables to make a decent quality and correct prediction. Semantic words like "extremely bad," "poor," "neutrally", and "good" are used to demonstrate consumer loyalty levels and professional supply chain requirements.

It has been invited three specialists, one from the field of agriculture, one from the supply-chain and purchase chain and one Professor of marketing, to finalize the checklist and decide. They were encouraged to go to the online process to complete the questionnaire by assigning a user and profile. If the research is complete, the facilitator may immediately observe the aggregated opinion and estimates and satisfy them. Stakeholders were told that specialists are fully independent, and the logistics suppliers' assessment process is completely unbiased.

Step 5 - Average triangular fuzzy numbers from q fuzzy numbers are essential since the community of decision-makers participates. Due to its relevance, samples of q individual participants, depending on their knowledge, assess the consumer specifications.

3.3 Analysis of FBDM-IoT

The analysis of the proposed FBDM has been carried with different factors for exposed model (EM) and closed sustainable mode (CM).

3.3.1 Risk Analysis

FBDM poses significant obstacles in a formative assessment of a critical market plan that calls for more substantial uncertainty and, therefore, investment risk. This paper defines business threat (L) as the probability before the investment and funding peril. S indicates the quantity of capital at risk. It has been given that

$$L_{FBDM} \succ L_{EM} \Leftrightarrow S_{CM}(W - Q_{CM}) \succ S_{EM}(I - Q_{EM}) \quad (1)$$

In favour of disparities, it can be shown that $Q_{FBDM} \prec Q_{CM} \prec Q_{EM}$. Compared to CM and EM, FBDM analysis is more difficult in reducing complexity for a good business strategy.

3.3.2 Cost Analysis

From a risk management viewpoint, it is difficult for FBDM, as critical industry prototypes have become complete with time. It is challenging to prepare for a long time for the hypothesis than to evaluate the postulates for a longer time to ascertain it in the long run. This is because costs/revenues are determined by the core assumptions and can change over time. Everything is the standard of the business compared to competitors and manufacturers at a certain pace of restoration. Take the cost-effectiveness of a transformation in the manufacture of batteries under the FBDM system in particular. Even though it can be constructed with a certain flexibility, its implementation independence is never defined in a single-way EM value chain. Although an FBDM offers more benefits, including lower production costs and reduced ecological consequences, it ensures that it is a significant task to pro-actively evaluate the business model's assumptions (lower P). This is given by

$$Q_{FBDM} < Q_{EM} \Leftrightarrow (I - Q_{CM}) > (I - Q_{EM}) \quad (2)$$

The fixed cost (G) plus variable costs (C) compounded by the verification period is the total amount of money expended before accepting an optimal business model. The validity period (μ) can be calculated using sales made or by continuous transactions. This is summarized in the following equation:

$$S_{FBDM} = G + C \times \mu \quad (3)$$

It could be handled as a specific EM scenario before delivery to the manufacturer during the first phase of an FBDM. Unless more expenditures are needed for recirculation, at this time, the amount of money spent (t=I) for FBDM and EM is the same. A new step to be taken to validate the FBDM before any recirculation determines the economic feasibility of the FBDM. To be clear, μ is better for FBDM than for CM and EM. Operational costs for a CM are usually much smaller during a second period since lowered product prices are the primary commercial rationale of a CM. The volume of the assets at threat can be defined as

$$\Delta S = C \times \Delta\mu \quad (4)$$

where $\Delta\mu$ is the new method used to validate the FBDM is described as a daily procedure. As L_{FBDM} comprises the first phase (SEM) plus the extra phase (ΔS), the total capital expenditure for validating the business model is greater than for CM and EM. Thus,

$$S_{FBDM} = S_{EM} + \Delta S \Leftrightarrow S_{CM} > S_{EM} \quad (5)$$

While the reliability of the CM performance by using cost and revenue theory is more complicated than EM, the FBDM aims to achieve optimum productivity by increasing collaboration and reducing uncertainty.

4 RESULTS AND DISCUSSION

This paper includes the implementation in SC of a decision support model that shows how a third-party vendor can be chosen from the list of potential suppliers as a partner. Twenty-five survey questions have been collected from logistic providers for the decision-making process, and analysis has been carried out based on the questionnaire obtained. The following industrial SC models have been selected for study:

- Exposed business Model (EM)
- Sustainable closed-loop model (CM)
- Proposed FBDM

Three parameters were analyzed: Risked Capital magnitude (S), (ii) costs (G&C), and (iii) Time validation (μ).

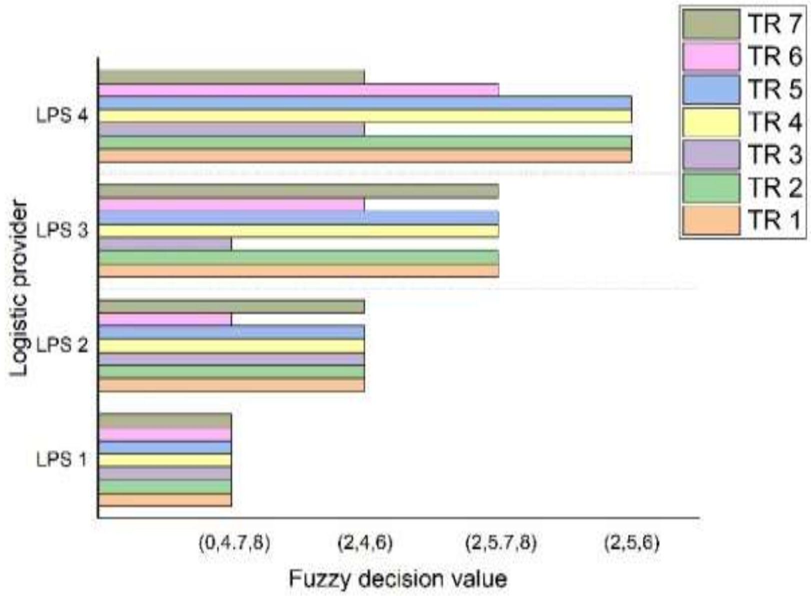

Figure 3 Fuzzy decision values against LPS for various TR in the proposed FBDM-IoT.

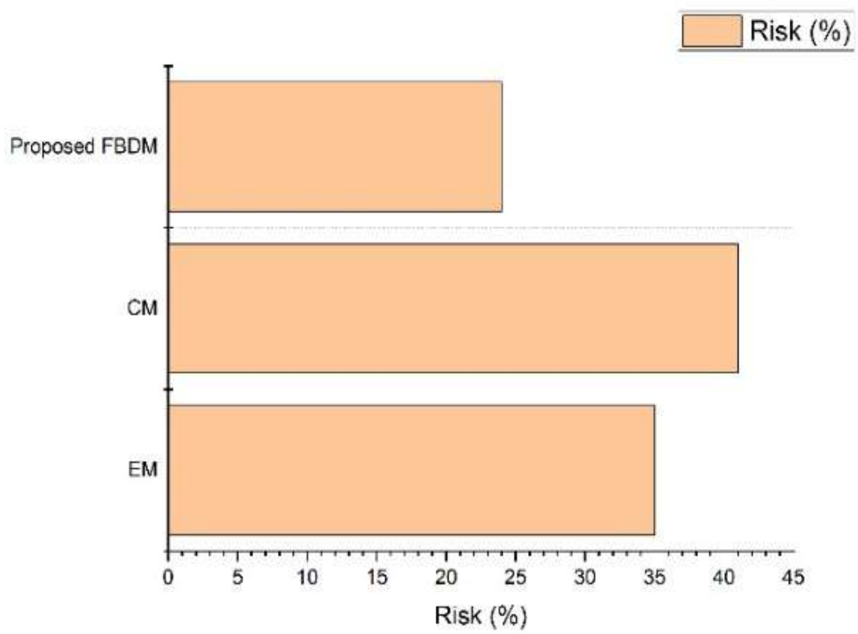

Figure 4 Risk in percentage for industrial IoT based SC models.

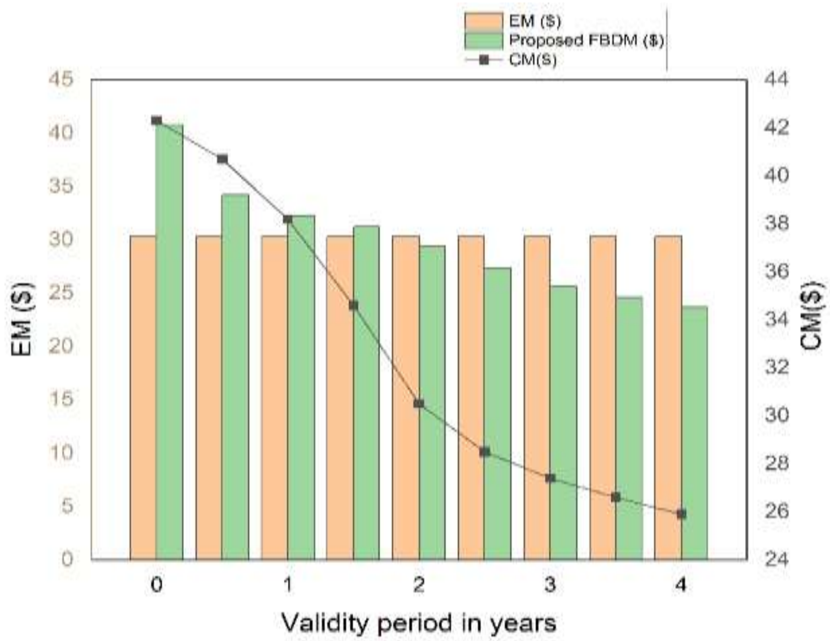

Figure 5 Total cost (G & C) against validity period (µ) for various industrial SC models

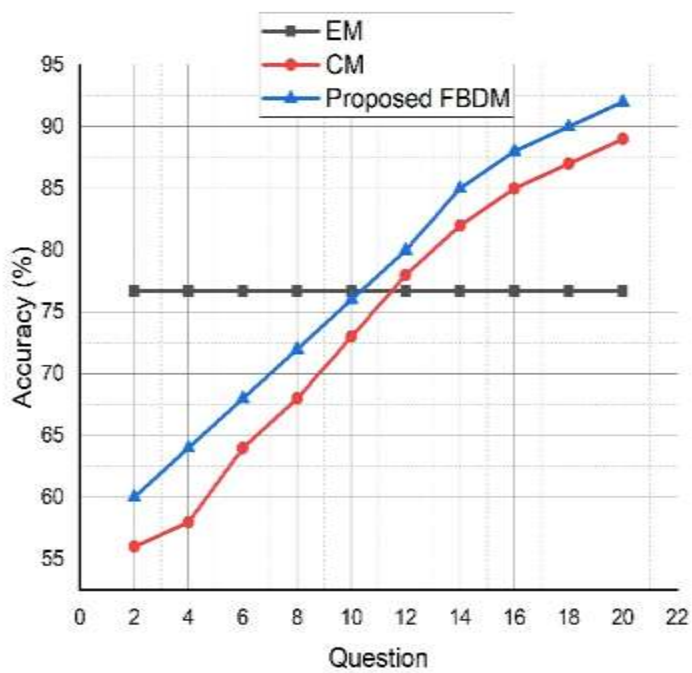

Figure 6 Accuracy in percentage against different survey questions for industrial IoT based SC models

Fig. 3 depicts the fuzzy decision values against LPS for various TR in the proposed FBDM framework for IoT applications. The decision-makers (DM) are asked to complete the survey or online forms of the operating system to rank substitutes. Stakeholders must make expert decisions and evaluate options using fuzzy linguistic values for each parameter. The complete details are collected and is shown in Fig. 3. For example, in assessing logistics providers (LPS), the decision-maker has considered "normal" and "good" quality values and supply requirements.

Fig. 4 depicts the risk in percentage for industrial IoT based SC models. The pragmatic assessment of industrial business model goals creates more volatility, and the capital challenge of CM presents a severe difficulty. Fig.4 shows the number of risks for the different business models involved in the percentage. It can be concluded that CM poses a high 41% risk because of the unpredictable reuse of capital. Due to the association and frankness between DM and LPS, the proposed FBDM reduces the risk to 24% compared to CM. Because of its exposed loop configuration, EM offers modest risk percentages.

Fig. 5 shows the total cost (G & C) against the validity period (μ) for various industrial SC models. The net costs are the amounts of fixed (G) and adaptable (C) costs. According to the number of contracts or the approved budget for consistent LPS, the validation time(μ) shall be calculated. The cost analysis varies according to the number of times during the validation period the commodity is successfully obtained, as seen in Fig. 5. The study has shown that it can be viewed as a specific EM event before the producer is given any products in the first year of the planned FBDM. There is a further step to validate the FBDM before any recirculation agrees on the cost-effectiveness of the FBDM. The FBDM risk is lasting longer than the EM and CM risk. As the validity time rises, costs of EM are higher than FBDM and CM.

Fig. 6 shows the accuracy in percentage against different survey questions for industrial IoT based SC models. The number of query sets for LBM does not impact accuracy, as coordination is not required or recycling is not required. Therefore, EM has a consistent precision ratio of 76%. The accuracy ratio increases as the number of questions increase with all other business models. Increasing the questions posed during the application process increases the consistency and precision of business models. The proposed FBDM has maximum accuracy of 93 per cent with 20 queries. CM has reduced efficiency than FBDM.

5 CONCLUSION

The paper provides a decision support mechanism to choose logistics suppliers dependent on the application of consistency functions and the technology for order choice, analogous to the optimal approach for the farm supply chain. The paper offers a forum for community decision-making to promote fuzzy-based decision-making for IoT (FBDM-IoT) and consistently monitor results. Risk, cost, validation time, reliability and accuracy based analyzes have been performed. The proposed FBDM system minimized risks and costs over traditional CM because of cooperation and efficient decision-making. FBDM was much higher than other current market models in skill and accuracy. The proposed FBDM demonstrates that circular economy and supply chain help achieve sustainable development.

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