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A SUSTAINABLE QUEUING SUPPLY CHAIN MODEL FOR GREENING ITEMS UNDER FUZZY ENVIRONMENT

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ABSTRACT

Supply chain operations go well when demand is stable, but when demand fluctuates, the chain's behavior becomes unbalanced and its participants may face risks to their financial well-being. Demand rate fluctuations are referred to as having an imprecise nature. Because burning petrol and diesel releases numerous pollutants that harm the environment, it is to blame for carbon emissions. Nowadays, a popular term related to production inventory optimization for the greening effect and other policies is carbon emissions tax. Present paper deals with the application of queuing in supply chain management where demand is imprecise in nature and has been taken as a triangular fuzzy number under carbon emissions. In the final, we have minimized the total fuzzy inventory cost with the applications of queuing theory for the supply chain management under carbon emissions. Numerical examples have been verified for the model, and sensitivity analysis of inventory parameters has been taken for good utilizations in various industrial scenarios.

1. INTRODUCTION AND LITERATURE REVIEW

The concept of a supply chain can be traced back to early human history, when people engaged in trade and exchange of goods and services. In ancient civilizations, the supply chain was simple and primarily consisted of local trade between communities. As civilizations developed, the supply chain became more complex, and trade networks expanded to cover greater distances. For example, in the Roman Empire, a well-developed transportation network allowed for the efficient movement of goods and resources throughout the empire. The Silk Road, a network of trade routes connecting the East and the West, was another early example of a complex supply chain system. It allowed merchants to transport goods such as silk, spices, and precious metals over long distances, connecting various civilizations and promoting economic growth and trade. Overall, the development of the supply chain has been driven by the need for efficient and effective distribution of goods and resources, and has been shaped by advances in transportation, communication, and technology throughout human history. When it comes to managing a supply chain that is sustainable

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and ecologically friendly, supply chain models are essential (Beloor et al., 2023). These models assist businesses in creating and improving their supply chains to lessen their impact on the environment, increase sustainability, and satisfy consumer and governmental demands for environmentally friendly products. Models of the supply chain take into account shifting consumer demands for green products. Organizations can increase market share and reputation by matching production to consumer demand for greener products. In order to proactively manage environmental risks and improve resilience, organizations can use green supply chain models to detect environmental hazards and vulnerabilities in the supply chain. These models can be used by organizations to set carbon emission reduction goals and monitor their success. Processes must be optimized to reduce product-related carbon emissions. Organizations evaluated the environmental impact of their products at every stage of the product life cycle thanks to supply chain models. Analyzing the environmental impact of the manufacturing, delivery, use, and disposal of goods also entails looking at how much energy, water, and garbage are used. The production and distribution of goods can be coordinated with an organization's sustainability objectives using supply chain models. Businesses can decide how to cut back on resource use and carbon emissions by assessing their environmental goals. Models of the supply chain are used to identify the most environmentally friendly modes, routes, and packaging materials. This limits greenhouse gas emissions and lessens the environmental effects of transportation. These models help in making supplier and material sourcing decisions that support sustainability goals. Utilizing recycled or renewable materials and ensuring responsible procurement are a few examples of how to do this.

In present, all countries and their peoples focused seriously to use greening concepts by using most of the products made under greening strategies due to environmental issues, like pollution, energy sources and limited resources. These products are outcomes of the concept Green Supply Chain Management (GSCM) (Souhli & En-nadi, 2023). Most of the organizations' approaches for various strategies, so that we have an eco-friendly environment by reducing pollutions and wastes and take other necessary actions towards all its related things. Green Supply Chain Management (GSCM), also known as Sustainable Supply Chain Management, is a business strategy that focuses on integrating environmental and sustainability principles into the supply chain processes (Li, 2023). It seeks to minimize the environmental impact of the entire supply chain while still meeting customer demands and achieving operational goals. GSCM involves a combination of eco-friendly practices, ethical considerations, and economic efficiency. Reduced operational expenses, an improved corporate image and reputation, adherence to rules, access to new markets and customers, and a smaller environmental imprint are all advantages of implementing GSCM. Customers are calling for more and more ecologically friendly goods and businesses that show a commitment to sustainability. As a result, in today's environmentally concerned world, adopting a green supply chain management strategy is not just a moral decision, but also gives firms a competitive edge.

The goal of GSCM is to reduce waste at each step of the supply chain (de Freitas et al., 2019). Reduced packaging waste, fuel-efficient transportation routes, and the implementation of recycling and trash reduction initiatives are all part of this. Companies can create items that have a lower environmental impact, a longer lifespan, and easier recycling. This may entail producing items that are more energy-efficient, utilizing less resources, or engineering them to be easily disassembled for recycling. Reverse logistics is the efficient management of product returns and recycling at the end of their useful lives to minimize waste and lessen the impact on the environment. In GSCM, working with suppliers is essential. To implement sustainable practices and make sure that ethical and environmental standards are upheld across the supply chain, businesses frequently collaborate closely with their suppliers

Researchers also doing their best in finding in the reduction of energy consumption and other greening items., Some researcher also applying the queuing theory concepts and transportation and inventory modelling techniques in the optimization process. Queuing and Inventory modelling in the supply chain management system is a best choice among researchers for their work in this field and hence in GSCM these modelling is also frequently used during optimized modelling and research in the same.

In order to increase the effectiveness and environmental impact of supply chain operations, a sustainable queuing supply chain model is a framework that combines the concepts of sustainability and queuing theory. This strategy strives to minimize waste, reduce energy use, and lower greenhouse gas emissions while ensuring that customer service standards are maintained. It recognizes the growing relevance of sustainability in business practices. Overall, a sustainable queuing supply chain model integrates sustainability objectives with the concepts of queueing theory to produce a supply chain that is effective, ecologically friendly, and customer-focused. In a company environment that values sustainability more and more, such a model can result in cost savings, decreased environmental impact, increased customer satisfaction, and a competitive edge.

Mohtashami et al. (2020) working with a green closed loop supply chain design by using the queuing system for the reduction of environmental impact as well as energy consumption. Amemba et al. (2013) explored that how firms can implement elements of green supply chain in their processes, authors findings support the necessity for companies to continuously incorporate green supply chain components in order to achieve sustainability in supply chain system. According to the study's findings, a business system need to increase the ratio of green supply chain practices and its employment they also find some new and effective outcomes in his work and surely they will be beneficial for all.

A multivariate version of the classical crisp logic that has several benefits, the main one being that it has more flexible decision boundaries. As a result, it is better able to adapt to different application domains and more accurately reflect their unique characteristics. The fuzzy environment are also assumed in the present model and the basic concepts for the same taken from Alsaedi et al. (2023). Authors investigates how learning and carbon emissions affect a comprehensive green supply chain model for defective goods in uncertain environments and times of shortage. Regarding the order amount and shortfalls, authors optimized the integrated total fuzzy profit and illustrated the vendor and buyer strategies using flowcharts, Authors treat the demand rate as a triangular fuzzy number and validated the study with the help of a numerical example.

In the proposed plan, queuing applications are used for more demand and more supply of a green product, where demand is considered imprecise in nature. Carbon emissions affect all living and non-living things in various forms. For example, in any queuing system of real-world situation, if any polluted gas emitted in that area, then due to the gaseous effect, some customers balking from queues and affecting the server and the system. Carbon emissions have a profound impact on supply chain systems. Organizations that proactively address these issues by reducing their carbon footprint, optimizing their operations, and aligning with regulatory standards can both reduce risks and seize opportunities for cost savings and competitive advantage in an increasingly environmentally conscious business environment Ahmad et al. (2023). A demonstrative figure showing carbonized environment is shown in Figure 1 which is taken from internet sources.

Firstly, Simon (1952) worked on a controlling production–inventory model with a new conceptual approach with the using of queuing theory for a single product. In this direction the are some authors who worked with the help of queuing theory like as Silver (1981), Parlar (1997) and Ha (1997). Parlor (1981) developed a queuing theory inventory-based model with the help of markov chain process for some useful applications for the industries. In the field queuing theory, the author prepared a new platform for researchers as well as industrial application. An M/M/1/S queuing control model for production controlling problem and its interrelated other problems are formulated by Ha (1997), and concluded some fruitful results.

Figure 1. Illustrative Green product figure from internet sources

A green closed loop supply chain design has suggested by Mohtashami et al. (2020) using the queuing application system for minimization of environmental impact and energy consumption. By figuring out loading, unloading, and manufacturing rates, which have an impact on waiting and transportation time, the model will lessen the environmental effects and energy consumption of transportation fleets. An exact solution to a numerical case using the NLP model in tiny size is also discussed by authors. To solve the complex problem, a meta-heuristics technique is also used and objective function and decision variables of the model are examined using the sensitivity analysis. Liu et al. (2020) presented a two-phase queuing theory-optimization model approach, The coordinated location-inventory problem in a stochastic supply chain system with facilities that are prone to arbitrary supply disruptions are studied. Uncertainties are seen to be a constraint on demand and replenishment lead times and in the concerned supply chain, a two-phase strategy based on queuing theory and optimization model methodologies is developed to address the location-inventory problem. The first stage addresses the uncertainty issues and obtains certain system performance metrics by using the queuing theory. Later, the optimization model incorporates the obtained results. The second phase of the optimization process involves an integrated determination of the strategic and tactical choices made throughout the supply chain.

Rasmi et al. (2021) developed a class-dependent inventory access in a multi-server heterogeneous queuing-inventory System, authors take into account a queuing inventory system with K categories of heterogeneous consumers arriving in marked Markovian order, various levels of inventory are admitted to exhaust for clients of each class because each class of customers has various service requirements and different priority are allocated for each class. Each class receives a single service node, with exponential services offering class-dependent service rates. All client classes receive service from a single source of inventory that is refilled in accordance with the (s,S) policy and has an exponentially distributed lead time. By using the matrix-analytic technique, stability conditions and steady state probability are determined and finally very useful and wonderful outcomes were produced. Aghsami et al. (2021) also developed a model related with a single retailer-single supplier issue with some imperfect quality and destructive kind testing acceptance nature of sampling in an integrated Markovian Queueing-Inventory Model. In the model when the inventory level reaches the economic reorder point, the retailer places an order. And the merchant uses a destructive acceptance sampling approach since the arriving items are imperfect and the lead time is projected to be exponential. The size of the sample affects the inspection rate. Authors display the response system's stationary demand number distribution. The retailer's inventory level and order status are then combined to derive the joint stationary distribution. By reducing the projected total cost after several performance metrics some fantastic and optimized outcomes produced. Recently Mohan et al. (2023) presented a comparative analysis to obtain optimal ordering quantity of the risk neutral and risk averse newsvendor problem. Sindhuja et al. (2021) derived economic ordering quantity model for constantly degrading items with quadratic demand rate which is further extended by Mohan et al. (2022) and constant deterioration was replaced by Pareto distributed deterioration.

Ozkar (2022) modeled a two-commodity queueing-inventory system that distributes service times according to phases. In author considered a two-commodity queueing-inventory system with phase-type service times and exponential lead periods. There are two distinct categories of clients: type-1 and type-2, service times follow a phase-type distribution, the demands from each type of consumer occur individually according to a Poisson process with varying rates. Customers of type- 1 are given non-preemptive preference over those of type-2. for type-1 consumers, we assume a finite waiting area, whereas there is no cap on the waiting area for type-2 customers. The matrix-geometric method is used to analyses the queueing-inventory model in steady-state by the authors. Wang (2023), also studied a location-inventory problems with (S-1, S) policy and retrial demands using an optimization approach, In order to derive performance metrics for (S-1, S) inventory problems with M/M/c replenishment under a retrial demand scenario, author adopted an easy and effective computing approach, for comparison the demonstrate of certain characteristics of the investigated situation under backordered needs. Both a capacity design problem and a location-inventory design challenge are addressed using the methodology. The approach combined with direct search and genetic algorithms (GA) for optimization on both issues and compared it to matrix geometric method (MGM)-based evaluation and other optimization techniques, such as enumeration and FICO Xpress Mosel and finally some most fruitful results are evaluated.

Seyedhoseini et al. (2015) applied the results of queuing theory in inventory modelling systems and developed a model by proving some lemma. In order to create a thorough substitution inventory model, two substitute products with ignorable lead times were taken into account in this work, and the impacts of simultaneous ordering were investigated by authors. In this study, client demands for both items have been treated as stochastic parameters, and a mathematical model has been created using queuing theory and model was created using the C++ programming language, Effectiveness of the model was discussed by analyzing a real-world example. The proposed plan uses the proofs and other key terms of Seyedhoseini et al. (2015) to complete our study.

A short outlook of the proposed work plan in the form of a flow chart is given in the following figure (figure 2).

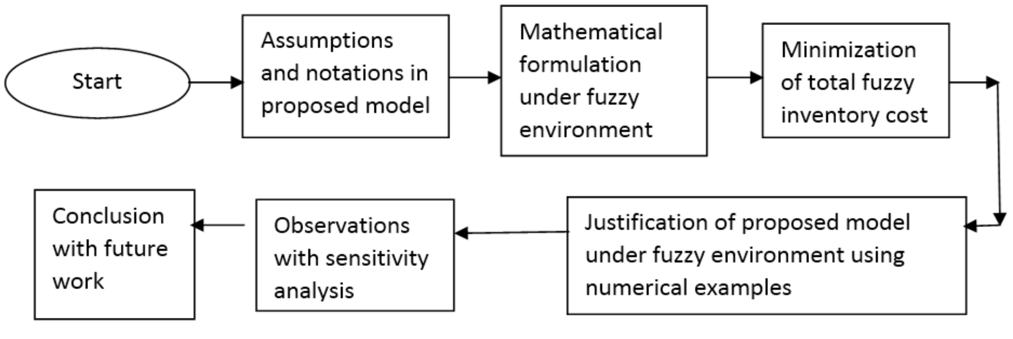

Figure 2. Flow chart of the proposed work plan

2. ASSUMPTIONS AND NOTATIONS

2.1 Assumptions

1) An inventory with bi-substitute has been taken.
2) Followed a bi-level Markov process.
3) Different holding cost for item-1 and item-2.
4) Production cost is also different for item-1 and item-2.
5) During production, carbon units emit from item-1 and item-2.
6) Neglecting Lead time and Shortages. Etc.
7) Average demand rate for item-1 and item-2 have been taken as a triangular fuzzy number.
8) It is also considered that centroid method is more beneficial for this model and optimized total fuzzy cost.

2.2 Assumptions

1) $\mathrm{H}_1, \mathrm{H}_2$: Holding cost for item-1 and item-2.
2) $\mathrm{D}_1, \mathrm{D}_2$: Demand rate for item-1, item-2.
3) O_1 , O_2: Ordering cost for item-1, item-2.
4) O_0 : Fixed instantaneous ordering cost.
5) O': Variable ordering cost..
6) r_1, r_2: Replacement cost for item-1, item-2
7) $S_{i,j}$: Steady-state probabilities of state (i, j).
8) q_1, q_2 : Order quantity for item-1, item-2.
9) d1, d2 Average demand rate for item-1, item-2.
10) $\widetilde{d_1}$, $\widetilde{d}2$ Fuzzy demand rate for item-1, item-2.
11) T_C : Total inventory cost
12) T_x : Imposed unit tax for emissions during production
13) e_c: Carbon emissions for electricity.
14) TC_1, TC_2 : Total fuzzy cost for item-1and item-2.
15) Φ : Flow for the various states.

SELECTED CONTRIBUTIONS: We have discussed some author's contributions in the Table 1, as given below.

Table 1. Research gap and their contributions

Authors	Production inventory	Inventory	Demand with different pattern	Replenishment policy	Queuing concepts and models	Carbon emissions effect	Fuzzy theory
Schwarz et al. (2006)	-	✓	-	-	✓	-	-
Bhaskar and Lallement(2010)	-	✓	-	-	✓	-	-
Mahapatra (2012)	✓	✓	✓	-	-	-	-
Rashid et al. (2015)	-	✓	✓	-	✓	-	-
Jayaswal et al. (2021)	-	✓	-	-	-	✓	✓
Zhang et al. (2022)	-	✓	-	-	✓	-	-
Alamri et al. (2022)	-	✓	-	-	-	✓	-
Pandey and Sharma (2022)	-	✓	-	-	-	✓	-
Present Paper	✓	✓	✓	✓	✓	✓	✓

3. MODEL FORMULATION

For modelling and analyzing the behavior of waiting systems, state transition diagrams are a helpful tool in queuing theory. They depict the various states that a system could be in as well as the changes that can occur between these states. State transition diagrams are frequently used in queuing theory to describe and analyse the dynamics of a queuing system, encompassing components such as servers, consumers, and queues.

In the proposed work plan, an inventory with bi-substitute products has been taken (see section 2.1). The state transition diagram of the proposed model is shown in figure 3, in which there are three groups, namely X,Y and Z, where the groups X and Z indicate the state having only type -one of the inventories. It will be reduced if demand for every kind of item enters the system, and group Y is for showing both items.

Solution methods has been adopted the methodology of Seyedhoseini et al. (2015) and our main findings in the total fuzzy costs for both the items:

Lemma 1: In any network, when the arrival of flow goes via any uni-state like in group Y and flows either in right or top, the arrival flow to node (i, j) and would be the total of flows that comes via (q_1,q_2). If Φ_ij^k denotes arrival flow which comes via path k, and Φ_ij^ represents interval flow for the state (i, j), and there are total n paths between (q_1,q_2) and (i, j), so we have:

$$\Phi_{ij} = \sum_{k=1}^{n} \Phi_{ij}^{k}$$

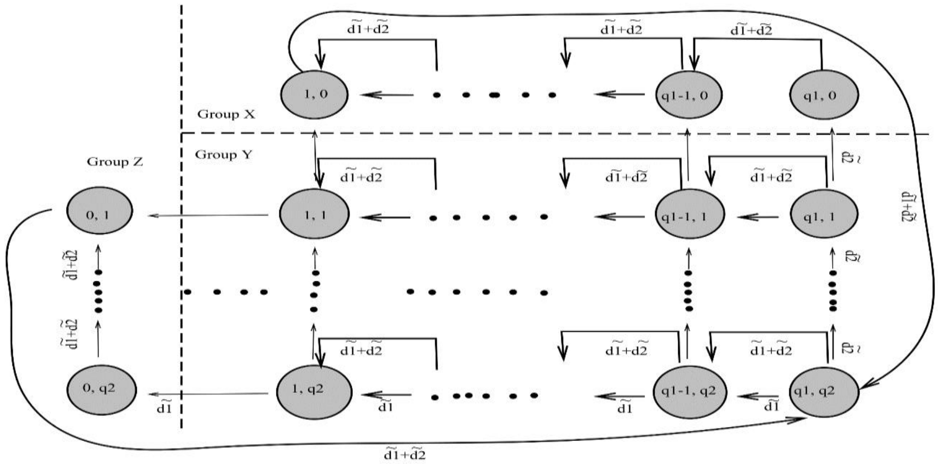

Figure 3. Transition diagram of the model

Lemma 2: In a queuing network having lateral output rate with value θ and vertical with D, the $S_{i,j}$ can be calculated by the following equation.

$$\Phi_{ij} = \left(\left(\frac{D_1^{q_1-i}D_2^{q_2-j}}{(D_1+D_2)^{q_1+q_2-i-j}}\right)\binom{q_1+q_2-i-j}{q_2-j}\right)\ \Phi_{q_1,q_2}$$

Lemma 3: For group P, the steady-state probabilities can be found by-

$$S_{i,0} = \sum_{s=0}^{q_1-i} S_{q_1-s,1}\ \frac{D_1}{D_1+D_2}$$

$$= \sum_{s=0}^{q_1-i} \binom{q_1+q_2-i-1}{q_2-1}\ S_{q_1,q_2}\ \frac{D_1^{q_1-s}D_2^{q_2-1}}{(D_1+D_2)^{q_1+q_2-s-1}} \frac{D_1}{D_1+D_2}$$

Lemma 4: For item-1 and item-2, the amount of substitution is given by:

$$\sum_{j=1}^{q_2} S_{1,j}\, j\left(\frac{D_1}{D_1+D_2}\right)^2 \sum_{i=1}^{q_1} S_{i,1}\, i\left(\frac{D_2}{D_1+D_2}\right)^2$$

4. SOLVING METHODS

After simplification, the calculated total fuzzy cost for the item-1 under carbon emissions is:

$$TC_{1f} = O\left(\frac{\frac{d_3+d_4+d_5}{3}+\frac{d_6+d_7+d_8}{3}}{q_1}\right)+H_1I_1'+r_2\frac{d_6+d_7+d_8}{3} + T_xe_xE_c\ I_1'$$

Where $I_1' = \sqrt{\frac{2O_1(\frac{d_3+d_4+d_5}{3})}{h_1}}$ then we can write

$$TC_{1f} = O\left(\frac{\frac{d_3+d_4+d_5}{3}+\frac{d_6+d_7+d_8}{3}}{q_1}\right)+H_1I_1'+r_2\frac{d_6+d_7+d_8}{3} + T_xe_xE_c\ I_1'$$

$$= O\left(\frac{\frac{d_3+d_4+d_5}{3}+\frac{d_6+d_7+d_8}{3}}{q_1}\right)+H_1\sqrt{\frac{2O_1(\frac{d_3+d_4+d_5}{3})}{h_1}} + r_2\frac{d_6+d_7+d_8}{3} + T_xe_xE_c\sqrt{\frac{2O_1(\frac{d_3+d_4+d_5}{3})}{h_1}}$$

And the calculated total fuzzy cost for the item-2 under carbon emissions is:

$$TC_2 = O\left(\frac{d_1'+d_2'}{q_1}\right)+H_2I_2'+d_1'r_1+T_xe_xE_c\ I_2'$$

Where $I_2' = \sqrt{\frac{2O_1(\frac{d_6+d_7+d_8}{3})}{h_2}}$ then we can write

$$TC_2 = O_L\left(\frac{\frac{d_3+d_4+d_5}{3}+\frac{d_6+d_7+d_8}{3}}{q_1}\right) + H_2\sqrt{\frac{2O_1(\frac{d_6+d_7+d_8}{3})}{h_2}} + \frac{d_3+d_4+d_5}{3} r_1 + T_xe_xE_c\sqrt{\frac{2O_1(\frac{d_6+d_7+d_8}{3})}{h_2}}$$

5. NUMERICAL EXAMPLE FOR VALIDATING THE MODEL

The inventory parameters for item-1 and item-2 have been taken from the renowned citation Seyedhoseini et al. (2015), Jayaswal et al. (2021), and Alamri et al. (2022).

Numerical Example with fuzzy environment under carbon emissions

$r_1 = \$\ 20, r_2 = \$\ 20, D_1 = 5\ unit/year\ ,\ D_2 = 10\ unit/year\ , d_1(95, 100, 105),\ d_2(195, 200, 205),\ H_1 = \$\ 25/unit/year\ ,\ H_2 = \$\ 6/unit/year\ ,\ O' = \$\ 30\ /order\ , E_c = 0.5 \times 10^{-3}$ ton,CO_2/Kwh,$e_c =$ 1.44 Kwh/unit/year, $T_x = \$\ 75$ / ton CO_2.

In this case, the maximum order quantity q_1 is 35 unit and its total inventory cost (TC_{1f_c}) for item-1is $\$\ 2803$ and the maximum order quantity q_2 is 45 unit, and its total inventory cost (TC_{2fc}) for item-2 is $\$\ 5877$.

6. SENSITIVITY ANALYSIS

Sensitivity analysis plays a crucial part in inventory management by assisting organizations in understanding how adjustments to various criteria and presumptions may affect choices, costs, and performance in relation to inventory. This analysis offers insightful information about the stability and adaptability of an inventory management model. In other words, sensitivity analysis in inventory management offers a structured method for figuring out the effects of changing variables and presumptions on decisions involving inventories, assisting organizations in making wise decisions, streamlining their inventory procedures, and improving overall supply chain effectiveness.

Performance metrics are used in sensitivity analysis to evaluate how changes to important parameters or presumptions impact a model's output or the outcome of a decision-making procedure. These metrics shed light on the model or strategy's robustness and dependability by quantifying the effects of changes in input variables. The specific context and analysis's goals will determine the performance measures to be used.

The main focus of the suggested work is a sensitivity analysis in which we discuss how the input parameter of this model affects the amount of orders and the overall cost of inventory in a supply chain system. The more useful element for determining the order quantity and total inventory cost is the holding cost for item-1 and item-2. Variable effect of the holding cost for item 1 and item 2 has been given in table 1 and table 2 which is given below.

7. OBSERVATIONS

Observations of the proposed model are managerial insight which explain for the manager of the industry to maintain the supply of the product as well as feedback of the supply chain from the buyer, seller and customer side. It can be easily seen that the behavior of the holding cost for item-1 and item-2 has been shown in the Table 1 and Table 2.

The Table 2 and Table 3 are reflecting the impact of holding cost 〖(H〗 _1) for item-1 and 〖(H〗 _2) for item-2. The implications of holding cost fluctuation on order quantity and overall inventory cost have been shown. The supply chain participants should be aware when they alter the value holding cost since the holding cost is closely related to the cost of the inventory system. This observation can be used to inform ordering policies. Decision-makers should be more mindful of the chosen items when the system is inherently imprecise.

Table 2. Impact of holding cost $(\boldsymbol{H}_1)$ on the total fuzzy cost for item-1

$\boldsymbol{H_1}$(\$ $/\boldsymbol{unit/year}$)	$\boldsymbol{q_1}$ **units**	$\mathbf{T_c}$**(\$)**
10	65	2619
15	55	2728
20	45	2756
25	35	2803

Table 3. Impact of holding cost $(\boldsymbol{H}_1)$ on the total fuzzy cost for item-1

$\boldsymbol{H_2}$(\$ $/\boldsymbol{unit/year}$)	$\boldsymbol{q_2}$ **units**	$\mathbf{T_c}$**(\$)**
6	75	5713
7	62	5748
8	57	5819
9	45	5877

From the above discussion, we now conclude our observations.

8. CONCLUSIONS AND FUTURE WORK

In this paper, we have worked with a sustainable queuing supply chain model for greening items under fuzzy environment for two items namely item-1 and item-2 and we got some beneficial results which have already been discussed in observation. From the observations and sensitivity analysis of the inventory parameters when demand rate of item-1 and item-2 is in imprecise in nature then holding cost for item-1 and item-2 is more changeable parameter corresponding to the initial vale to final value. During the supply chain of item-1 and item-2 decision maker should be aware about the cost of item-1 and item-2. The carbon and the fuzzy concepts gave the positive effect on the order quantity and total inventory cost during the supply chain. The carbon emission can control by using of the carbon emission cost as well as different types of government policies. The Fuzziness can be nullifying by using of triangular fuzzy number. The effect of fuzzy environment and carbon emission cost concerning with this model affect the total fuzzy inventory cost. The authors would like to improve this paper with a different approach like trade credit policy with various application of queuing theory under fuzzy2 environment etc.

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