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Modelling retail inventory pricing policies under service level and promotional efforts during COVID-19

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ABSTRACT
Most supply chain and production systems faced multiple manufacturing and delivery challenges during COVID-19 and transformed their supply chain for improved customer service. These challenges are mostly related to stocking and managing the inventory flow throughout the supply chain (from manufacturer to end consumer). Due to the COVID-19 travel and movement restrictions, inventory reorganisation is necessary for fulfilling consumer demand with adequate service facilities. The safety and serviceability of inventory consumption is the primary concern of many retail grocery stores and consumers. Maintaining the supply of groceries items during and post COVID-19 time without disruption is a real operational and policy challenge. Therefore, this research tries to solve an inventory pricing mechanism and retailer’s profit under the optimal service level and retailers’ promotional efforts. The proposed optimisation model is validated in the grocery retail sector. The grocery retail market situation is modelled when the demand for the grocery product (which may be essential items) and selling price depending on the investment in item promotional effort and consumer serviceability. The retail grocery store’s investment in the product promotional efforts, such as awareness of the item availability and no-contact delivery which, may attract consumers. Therefore, the proposed inventory consumption is modelled with an optimisation problem to maximise the store profit with the optimal investment in promotional activities and service facilities to the consumers and maintain an optimal replenishment cycle. The optimisation model is tested with three different cases (no investment in promotional efforts, no investment in service facility, and investment in both) of investment to maximise the retailer’s profit and stock availability. The optimality results depicted that investment in promotional efforts and service facility gives higher profit to the retailer. The proposed optimisation model’s policy implications would help grocery retail store managers to develop operational strategies for maximising profit with the optimal service level and promotional efforts.

1. Introduction

Managing inventory flow and meeting timely customer requirements is a critical global supply chain operational challenge. Due to the outbreak of the COVID-19 pandemic, many nations announced various movement restrictions such as stay-at-home and market visiting hours. The global COVID-19 pandemic also heavily impacted the supply chain and production system of the various essential commodities along with consumption patterns (Mahajan and Tomar, 2021; Nagurney, 2021). During COVID-19, many food/grocery stores developed their supply chain channels to meet consumer needs and safety requirements (Shen et al., 2022). The COVID-19 impact on the food and retail supply chain has been broadly discussed (Galanakis, 2020; Perdana et al., 2020). Perdana et al. (2020) proposed an optimisation decision support system to handle the impact of COVID-19 on regional food hubs under uncertainty for meeting consumer needs. Kumar et al. (2020) highlighted the role of revamping production and operations strategy during and post COVID-19 time. Ivanov (2020) studied that the operations and systems of many organisations have been relentlessly disrupted as the global outbreak affects both supply and demand. Wang et al. (2020) present various short-term and long-term issues of the grocery retail industry post-COVID-19 time. The consumers’ buying behaviour would significantly affect their consumption pattern, how to manage inventories of staples, when and where to buy and sell stocks, etc. (Alaimo et al., 2020; Mahajan and Tomar, 2021). Due to the various travel restrictions, many hyper local delivery systems significantly promote home delivery during
the pandemic (Dumitras et al., 2021; Güney and Sangiin, 2021). The home delivery service of the essential items plays a vital role in society as they deliver the product door to door with all safety measures.

The delivery of the consumer’s orders is highly dependent on the stock available to the retail store and the transport linkage between the store and the consumer (Al-Amin Khan et al., 2020; Zhou et al., 2018). Due to the high demand for the home delivery process during the pandemic, a significant investment in developing adequate transport infrastructure is required to meet the consumer requirement (Thilmany et al., 2021). The consumer’s shopping pattern would also impact the stocking pattern of the retailer. Omar et al. (2021) identified that consumer buying behaviours are influenced by uncertainty, perception, and anxiety during COVID-19. There is no doubt that consumer’s virus fear and uncertainty change the buying psychology for grocery items (Duan and Zha, 2020). Many countries such as the USA, India, China, UK, and Australia have experienced panic buying, leading to a massive stockout at the retailer’s stores (Omar et al., 2021). The pandemic-supported inventory system is transversal to several clusters to support the smooth flow of the items, and various researchers recommend a new direction for supply chain interruptions, risks, the unexpected demand (Butt, 2021; Cirić et al., 2020; Ivanov and Dolgui, 2020; Sarkis et al., 2020). Due to the uncertainty and panic buying behaviour, the grocery supply chain has short- and long-term issues (Shen et al., 2022; Wang et al., 2020). The short-term issues may be related to a) interruption in the global supply chain leading to stock items and price increase; b) a limited grocery choice due to the risk of using imported fresh products; c) Inflated grocery prices across the country to imitate increased stores’ operational costs (Wang et al., 2020). The long-term impacts are related to online grocery buying as treat and opportunity, safety concerns, and growing reliance on online grocery shopping (Bayram and Unal, 2020). Many of the developing nation’s grocery retailers face multiple issues maintaining the requisite inventory stock and meeting consumer demand during COVID-19 (Burgos and Ivanov, 2021; Shen et al., 2022; Suryawanshi et al., 2021). The grocery retailer was looking for some managerial solution to maintain the requisite service level with optimal investment in various promotional efforts. Therefore, this research is trying to support the retailers’ adequate inventory policies and optimal profit. The following section presents vital research questions, objectives, and novelty.

1.1. Research questions, objectives, and novelty to support the retailer

The present paper discusses a production inventory model during the scenario of pandemic COVID-19. The COVID-19 lockdown restrictions in the country cause a significant challenge in the product availability in the market and their delivery service to the end consumer. The various promotional efforts (viz., print media, TV advertisement, social media etc.) are necessary to cater to the end consumers’ needs. The grocery retailers are trying to meet customers’ demands with utmost safety measures to reduce the chances of infection. Advertising of a product plays a vital role in inventory management to create brand awareness and to appraise the brand available for the customers in different markets. In the advertisement, producers/retailers generally provide information about their products and services, especially introducing new products or modifying products from the older ones (Al-Amin Khan et al., 2020; Bhattacharya, 2009). With adequate information, customers are aware of the product and its use. So, the demand for any product directly depends on the advertisement’s efforts (Ren et al., 2020). In this connection, producers/Suppliers want to publish the advertisement, among other ways, with the help of modern media or popular people to attract more and more people to purchase the products. In this study, advertisement efforts are considered a function of the product’s induced demand. The inventory system modelling received considerable attention in the past three decades (Berman and Sapna, 2001; Chen et al., 2011). Berman and Sapna (2001) studied various inventory control problems with service facilities considering a single type of inventory and derived the optimal order quantity with optimized total cost. Al Hamadi et al. (2015) developed an optimisation control mechanism for impatient customers to maintain optimal service levels. Omar et al. (2021); Shen et al. (2022) shed light on service facility development and the requirement for managing inventory in the COVID-19 pandemic. Therefore, this is needed to develop policies for grocery retailers to meet the consumer’s needs during a pandemic. The key research questions are identified from past studies mentioned in the bracket.

- How would grocery retailers make an advertisement and service facility investment during and post-pandemic (Al-Amin Khan et al., 2020; Shen et al., 2022)?
- What is the impact of adequate business advertisement and service facility investment strategies on consumer demand during and after a pandemic (Baveja et al., 2020; Omar et al., 2021; Laato et al., 2020)?
- How would service and advertisement investment strategies affect the inventory selling price and stocking policy (Mahajan and Tomar, 2021)?

The proposed research is trying to help grocery retailers develop adequate decision strategies by following research objectives.

- To develop an optimisation model for a retailer to optimise investment decisions for investing in advertisement and adequate service levels for consumers.
- To propose the different investment strategies (policies) for improving the consumer service level, availability of stock, and total profit margin.

The present study aims to identify the operational challenges faced by the retailer during the COVID-19 outbreak to optimise the profit margin. To do that, retailers invest funds in service facilities and promotional efforts to accelerate consumer demand. Therefore, demand depends on the investment in service and promotional efforts. Here, the unit selling price is considered a function of investment in service and promotional effort. The main intention of the paper is to maximise the total profit per cycle by optimising the investment in service and promotional efforts. Table 1 highlights the novelty of the presented research are threefold. First, the proposed optimisation model is an early attempt to highlight the economic well-being of the retailers with respect to the promotional and service efforts. Second, most studies consider the consumer’s buying behaviour but fail to include the retailer’s investment strategy for meeting consumer demand. Third, in India’s context, this study would help the grocery retailers adequately plan for inventory management to maximise their profit with optimal service and safety concerns. Table 1 delineated the novelty of the present paper because most of the past studies discuss consumer perspectives rather than retailers’ perspectives. Therefore, the current research helps retailers decide on optimal investment strategies.

The above research objectives are modelled with a joint optimisation model for bridging the supply-demand mismatch. A case numerical example is carried out to investigate the impact of a range of parameters on the total profit of the grocery retailer. The given model contributes to the existing literature by considering a more realistic model incorporating the decision parameters to accelerate the demand and selling price during COVID-19.

The remaining of the paper is arranged in the following order. Section 2 presents the literature review along with the novelty of the research. Section 3 presents the assumption and model formulation. The applicability of the proposed model is discussed in section 4. The data validation and result analysis are presented in section 5, followed by the conclusion and scope for future research in section 6.
3

Table 1  
Grosery supply chain studies during COVID-19.

| Author (s)         | Food (grocery) supply chain challenge (s) | Approach of decision-making | Country          | Consumer/retailer perspective |
|--------------------|------------------------------------------|-----------------------------|------------------|------------------------------|
| Perdana et al. (2020) | Scenarios for handling the impact of COVID-19 based on food supply network through regional food hubs under uncertainty | Multi-objective location routing problem | Not specific | Consumer |
| Cirić et al. (2020)   | Consumer behavior in online shopping of organic food during the COVID-19 pandemic | Questionnaire survey | Serbia | Consumer |
| Alaimo et al. (2020) | How COVID-19 is changing the online food buying behavior | Questionnaire survey | Italy | Consumer |
| Dickins and Schalz (2020) | Grocery buying behavior in a risky and uncertain environment | State-based model | UK | Consumer |
| Hao et al. (2020)     | Chinese grocery stockpile behavior | Bivariate probit model | China | Consumer |
| Chenardies et al. (2021) | Food consumption behavior during COVID-19 with grocery delivery service | Questionnaire survey | USA | Consumer |
| Schmitt et al. (2021) | Consumption and food waste pattern | Questionnaire survey | Brazil | Consumer |
| Abdolazimi et al. (2021) | Inventory control problem | Bender decomposition and Lagrange relaxation optimization model | Italy | Retailer |
| Present model      | Grocery buying behavior with the service level and advertisement cost | Optimization model | India | Retailer |

2. Literature review

Verma and Gustafsson (2020) discussed that impact of COVID-19 on business and management research is quite high presents short, medium, and long terms policies requirement for handling various supply chain and inventory issues. The inventory planning and management is important segment of any supply chain operations. The relationship of production-distribution process is analyzed with different inventory models for maximising upstream supply chain profit and reduce the entire supply chain cost (Cárdenas-Barrón, 2009; Mahata, 2015; Mahata et al., 2019; Mukherjee and Mahata, 2018). The inventory production process are entirely different in disruptive situation and also the consumption may increase or decrease during disruption (De and Mahata, 2019; Dolgui et al., 2020; Hishamuddin et al., 2013; Kamal, 2017). The COVID-19 is also considered as most disruptive pandemic during 21st century that impacted and required various inventory level policies (Dolgui et al., 2020). Ivanov and Dolgui (2021) presents a detailed literature on disruptive event propagation and various supply chain challenges due a sudden disruption. They also recommended the various management theories and method of recovery from a pandemic situation. Particularly, inventory planning for maintaining low level of stock is not a wise move to manage the consumer demand, therefore a need a redefining the inventory management research. Alaimo et al. (2020) developed a consumer preference framework for buying grocery food items in Italy. The findings of the paper are recommending that the role of advertisement and awareness about the online food delivery increases the customer footfall. The role of online platform for increasing the awareness and safety measures are discussed in (Cirić et al., 2020). In this way, customer demand pattern and effective pricing model based on the technological interventions are significantly improve supply chain mechanism which has vital implications for the powerful business’ strategic, critical and operational objectives. This administration must ensure the stable availability of different products demanded by various customers, coordinate the sale, etc., to satisfy the target market at a normal cost. The primary serious problem is to make awareness among the local people about the availability and home delivery facility that they can meet their demand (Wang et al., 2016). De and Mahata (2020) proposed a three-level supply chain distribution process with consideration of imperfect quality and random supply chain disruption. They presented a optimized total cost model for entire supply chain under fuzzy environment, whereas the modelling of perishability issues with optimal lot-sizing policies are discussed in (Mahata and De, 2017). Pal et al. (2014) discussed how the demand is influenced by advertising media and the salesman’s effort. Nowadays, many online platforms are there for grocery, daily utility, electronics, etc are very focused on their marketing strategies, e.g. how they advertise, grab the attention of customers, promote, offer, etc. The efforts of the advertising media and sales team encourage the customers to buy more (Alaimo et al., 2020; Chenardies et al., 2021; Hao et al., 2020).

Moreover, social media or media usage also increased their impact during this pandemic time, and they updated their features to connect more people at a single time. The consumers are also expected the same service facility level in online market place. Pérez Vergara et al. (2021) work has been discussed various preservation strategies for service level during the emergence of COVID-19.

Delasay et al. (2022) discused the consumer shopping behavior during the COVID-19 including the less frequent in-store shopping and bulk-shopping tendency. They also found that store occupancy limitation reduces the service capacity, consumer shopping behavior, and consequently, reduce the store profit. Finally, the grocery retailers may turn toward finding some alternative solution to handle the consumers during COVID-19 time (Shumsky et al., 2021). Abdolazimi et al. (2021) proposed a new inventory model based on ABC analysis which is recommended for managers to simultaneously optimizes the revenue, investment in inventory and customer satisfaction along with planning for inventory cost. Janssen et al. (2021) modelled the inventory consumption pattern during the COVID-19 during lockdown period in Denmark, Germany, and Slovenia. Researchers concluded that across these countries consumption of ready to cook grocery is high compared to the drinks and dairy products. Also, in many countries like China and India consumers also start stockpiling the grocery inventory in the event of first phase of the lockdown (Hao et al., 2020). Although the inventory stockpiling behavior in emergency situation have been identified in past but during COVID-19 time very less studies are conducted (Horii and Iwamoto, 2014). Sarkis et al. (2020) have specified a few ways for production managers to endure the times of coronavirus spread and need to plan for inventory stocking and delivery. Rajak et al. (2021) highlighted the impact of COVID-19 on various supply chain processes and presented a hybrid decision model based on quality function deployment and best-worst method to priorities the supply chain critical success factor for disruption caused by COVID-19. The government decided supply chain adaptations, and inventory planning during and post COVID-19 impacts are discussed by (Nikolopoulos et al., 2021). The consumer shopping risk for the grocery items during the COVID-19 time is required attention to support the food security and safety from the virus (Dickins and Schalz, 2020). They concluded that panic buying of the food items as a method of buffering risk and predicting about food insecurity. With the review of above key studies, we found that inclusion of service facility and promotional efforts to lead the robust business model for the grocery retailers during the COVID-19 time. The novelty of
the present work is presented in Table 1.

3. Problem description

During COVID-19 pandemic most of the countries restricted the travel and movement, therefore consumers start buying and piling up the necessary items inventory due to the fear of prolonged lockdown and other restrictions (Girić et al., 2020; Kasas and Nayga, 2021). The grocery retailers was also in tough situation to manage the consumer demand and delivery of the items with significant level of service and safety condition (Baveja et al., 2020; Sarkis et al., 2020). Therefore, authors of this paper are motivated with the real-life inventory consumption and availability problem in grocery retailer-buyer relationship. The objective of this paper is to develop optimal strategies for maximising retailers profit with optimal service and promotion efforts. The consumer service facility in inventory research is not a new idea but earlier researcher used service facility in context of perishable inventory and queueing theory (Amirthakodi et al., 2015; Wei and Huhn and Hoberg, 2021). Wei and Huhn and Hoberg (2021) developed a smart replenishment system for managing inventory at end consumers. The optimal control of service parameters with ordering policies for perishable inventory is formulated by (Al Hamadi et al., 2015). The special sales offers would also attracts the consumers (Taleizadeh et al., 2013). Secondly, the impact of advertisement on consumers buying behavior is discussed by (Al-Amin Khan et al., 2020). They developed the two-inventory model where the frequency of the advertisement is considered. Another important factor investment in advertisement is also not new. Many researcher establishes that investment in advertisement has a better impact on the demand as well as total profit. This paper also establishes that investment will also affect the selling price of the items during this pandemic. Let us develop the consumer demand function as; 

$$D(A_d) = a - cI(A_d) + bA_d + qS(I)$$

where $I$ is the investment in maintaining home delivery service and $q$ is a parameter such that $0 < q < 1$ and the service facility $S(I) = \gamma I$ where $I$ is the investment in maintaining home delivery service and $\gamma$ is a parameter such that $0 < \gamma < 1$. Also, $s(I, A_d) = s_0 + \delta d + \rho A_d$ where $s_0$ is the product’s base price and $\delta$ are the coefficient of service and promotional effort investment, respectively. The only service investment is not sufficient to induce consumer demand sufficiently, but customer satisfaction also plays an important role in affecting consumer demand. Fig. 1 highlights the impact of investment on service performance $S(I)$.

This paper provides an insight into how one can optimise the profit with the help of certain investments appropriately during this pandemic. The overall grocery supply chain system is discussed in Fig. 3. The cycle begins at time zero with no inventory and rises till $t_1$ at a rate $P$ and simultaneously reduces due to demand. Ultimately, the inventory exhausts at time $T$. Fig. 2 depicts the inventory cycle pattern.

Fig. 1. Graph of the Investment and their effect on $S(I)$.

Fig. 2. Graphical depiction of the inventory scenario.

3.1. Research design

The proposed research is based on the optimisation modelling and validation of the optimisation model with the case study. The supply chain and inventory model helped decision-makers when it was validated with some case analysis (Abdolazimi et al., 2021). The validation of the optimisation model with a case gives a clear recommendation for decision-making (Fallahpour et al., 2017; Liu et al., 2019; Vachon and Klassen, 2006). The first step of this research is to include the various decision variables and parameters for deciding the cost and profit model from the retailer’s perspective. The novelty of the proposed decision model is carefully checked with the past relevant publications with reputable databases such as Elsevier, Springer, Taylor & Francis, Emerald, and Sage. The keywords used for search are ‘retail inventory’, ‘inventory pricing’, ‘service level’, ‘COVID-19’, ‘pandemic’, ‘inventory advertisement’, and ‘inventory promotion/offer’. After the initial search, the authors considered only peer-reviewed top journals for identifying the research gap (given in Table 1) for analysing the different promotional policies with optimal service levels for the retailers. The mathematical model’s objective is to maximise the total profit of the retailer under the COVID-19 (any pandemic) situation. The decision variables for the constructed model were the investment in service facility and advertisement with the total cycle time. The mathematical model is validated with the relevant parameters under a generalised reduced gradient (GRG) Solver. The GRG solver helps to optimise the gradient of objective function when the partial derivatives equal zero (Lasson et al., 1974). Based on the GRG solver output, this paper presents the managerial insights to optimise the retail inventory operations.

3.2. Model assumptions and notations

The grocery market has uniqueness in terms of the shopping occurrence, time, period, and expenses based on customer socio-demographic uniqueness (Shen et al., 2022; Suryawanshi et al., 2021). The noteworthy differences indicate that customers generally changed their in-store grocery shopping activities to decrease the frequency of shopping trips, increase their shopping hours, compact the duration of in-store stay, etc (Shen et al., 2022). As per a survey study by (Wang et al., 2020) claimed, many online grocery purchases occurred through a national grocery shopping platforms, such as Amazon Fresh (24%) and Instacart (7.55%). These behavioural changes require attention from the retail food industry, adding more strategic investment tactics to capture consumer confidence in the service facility (Shen et al., 2022). The investment strategies would influence the demand, leading to higher profit because of higher order. The impact of these investments on selling price is the most practical scenario that needs to be considered. The proposed model considers essential goods like food items, grocery items, medicines etc., for modelling purposes. The following
assumptions are kept in mind while modelling the optimisation model.

- The proposed model assumes that the demand rate is directly proportional to the selling price and the effectiveness of the investment in promotional effort and service facility.
- One important aspect to note is that investment in a service facility does not affect the demand directly; instead, the service facility influences it.
- The model assumes negligible lead time with no shortages to maintain a steady supply of goods to the consumers in the current COVID-19 crisis.
- To contain the virus transmission, the retailers have switched to home delivery service of goods, following government guidelines and adopting the necessary safety measures (like sanitisation before the next delivery, regular medical check-ups of the working staff, etc.).
- An investment in the promotional effort media is also required to make consumers aware of their service and safety initiatives.
- The unit selling price of the items are directly proportional to the investment in service facility and promotional effort.

The proposed decision model considers decision variables and constant parameters notation to represent the model. The graphical framework of the proposed decision model is presented in Fig. 3.

The proposed optimisation model considers the following assumptions, decision variables, and parameters.

Decision Variables
- Ad: Advertisment cost per unit time
- T: Total cycle time
- I: Amount of service investment

Parameters
- K: Cost of ordering (per order)
- D(A_d, s): Consumer demand rate
- S(I): Service performance
- t_1: Production time
- h: Holding cost per unit per cycle time
- Cp: Purchase cost per unit
- b: Demand sensitivity parameter related to the promotional effort investment

(continued on next column)

Fig. 3. Graphical depiction of the impact of various factors on the customers' demand.

4. Mathematical model formulation

The inventory differential equation at time t in [0,T] is

\[
dI_1(t) = P - D(A_d, s(I, A_d), s(I)), 0 \leq t \leq t_1
\]

(1)

\[
dI_2(t) = - D(A_d, s(I, A_d), s(I)), t_1 \leq t \leq T
\]

(2)

Using condition \( I_1(t_1) = I_2(t_1) \) with Eqs. (1) and (2) by substituting the boundary conditions

\[
t_1 = \frac{T}{P}D(A_d, s(I, A_d), s(I))
\]

(3)

4.1. Total average inventory is

\[
AI = \int_0^{t_1} I_1(t)dt + \int_{t_1}^T I_2(t)dt
\]

\[
= (P - D(A_d, s(I, A_d), s(I))) \left[ t_1 \right] + D(A_d, s(I, A_d), s(I)) \left[ \frac{T^2}{2} - Tt_1 + \frac{t_1^2}{2} \right]
\]

(4)

Now, the total profit of the inventory system is given as, Total profit = sales revenue - production cost - setup cost - holding cost -
Holding cost \( HC = \frac{h}{T} \left( (P - D(A_d, s(I, A_d), S(I))) \frac{T^2}{2} + D(A_d, s(I, A_d), S(I)) \left( T^2_1 \frac{I}{T} + \frac{c_i}{2} \right) \right) \) (8)

### 4.1. Test of model optimality

The main objective of the present study is to minimise the model’s total cost by jointly optimising the investment in service cost \( I \), cycle time \( T \) and investment in promotional effort \( A_d \). Therefore, to establish the optimality of \( I \), \( T \) and \( A_d \) it is necessary to test the necessary and sufficient conditions.

\[
\frac{\partial TP}{\partial I} = 0, \quad \frac{\partial TP}{\partial T} = 0 \quad \text{and} \quad \frac{\partial TP}{\partial A_d} = 0
\] (14)

Since the expression for total profit is

\[
TP = \left( (s_i + \delta f + \rho A_d) \times (a - c_s - c\delta - cpA_d + bA_d^\alpha + q\gamma \ln I) \right)
\]

\[
\frac{h}{T} \left( (P - a - cs_n + csI + cpA_d - bA_d^\alpha - q\gamma \ln I) \right) \frac{T^2}{2} + \frac{c_i}{2} \right) - \left( l_0 + \frac{I}{(a - c_s - c\delta - cpA_d + bA_d^\alpha + q\gamma \ln I)} \right) \frac{1}{T} \frac{K}{T}
\] (15)

Hence the total profit per unit time of the system is (TP)

\[
= s(I, A_d)D(A_d, s(I, A_d), S(I)) - \frac{h}{T} \left( (P - (D(A_d, s(I, A_d), S(I)))) \frac{T^2}{2} + D(A_d, s(I, A_d), S(I)) \left( T^2_1 \frac{I}{T} + \frac{c_i}{2} \right) \right) - \left( l_0 + \frac{I}{D(A_d, s(I, A_d), S(I))} \right) \frac{1}{T} \frac{K}{T}
\] (12)
\[
\frac{\partial TP}{\partial t} = \left( (s_t + \delta I + \rho A_t) + \left( \frac{q_T}{T} + c_T \right) \right) + \delta (a - c s_t - c \delta I - c p A_t + b A_t^0 + q_T + q_T \ln I) - \frac{1}{T(a - c s_t - c \delta I - c p A_t + b A_t^0 + q_T + q_T \ln I)}
\]

By solving Equations 16–18 the optimal values of \( I \), \( T \), and \( A_d \) can be calculated. And after substituting those optimum values in Equation (15) the overall profit of the system can be calculated. Further, the Hessian matrix is needed for the sufficient condition of optimality w.r.t. \( I \), \( T \), and \( A_d \) is given below

\[
H = \begin{bmatrix}
\frac{\partial^2 TP}{\partial t^2} & \frac{\partial^2 TP}{\partial t \partial A_d} & \frac{\partial^2 TP}{\partial A_d^2} \\
\frac{\partial^2 TP}{\partial t \partial A_d} & \frac{\partial^2 TP}{\partial A_d^2} \\
\frac{\partial^2 TP}{\partial A_d^2} & \frac{\partial^2 TP}{\partial A_d^2} \\
\end{bmatrix}
\]

and conditions are \( \frac{\partial^2 TP}{\partial t^2} \) and \( \frac{\partial^2 TP}{\partial t \partial A_d} \) and \( \frac{\partial^2 TP}{\partial A_d^2} \)

Second-order derivatives proof are given in Appendix A. Due to the complexity of the second-order derivatives, it is challenging to establish sufficiency criteria mathematically, and thus the graphical method is used to establish the concavity (cite some reference).

5. Numerical experiment and discussion

The effectiveness and efficiency of the proposed optimisation model are evaluated by numerical experiments and deploy the findings of the present model for better decision making. Pu and Piplani (2004) suggested that the optimisation model should be validated and tested with a
numerical experiment for making more realistic decisions. Goyal et al. (2016) developed a numerical investigation for testing the effectiveness of RFID in sales floor inventory. We also validated the proposed mathematical model for maximising the grocery retailers’ profit under different promotional scenarios and service levels.

The optimisation model is validated with a numerical case and analysed under multiple scenarios with the data set of existing literature with some additional parameters and their practical values. The optimisation model is solved with the help of a GRG solver. Mathematically, this solver solution guaranties that Karush-Kuhn-Tucker (KKT) conditions for local optimality have been satisfied (Lasdon et al., 1974). The optimum solution is obtained when the partial derivatives equal zero. The optimal solution plots are presented in Figs. 4–6.

Based on the optimisation model presented in Section 4, the optimal service facility investment, cycle time, advertisement efforts, and total profit is given in Table 2.

The proposed decision variables are modelled with three different scenarios and presented casewise.

**Case 1. Retailer’s zero investment in the service facility**

In this case, retailers do not invest any amount in developing the service facility. In this case store demand is only based on the advertisement, and the selling price also depends upon the investment in the advertisement. This general scenario has no better significance than a pandemic scenario. Comparisons of this case with the proposed model are given in Table 3.

**Case 2. Retailer’s zero investment in promotional efforts**

**Table 2**

| Decision variable                      | Optimal values |
|--------------------------------------|----------------|
| Service facilities investment (I)     | $733.90        |
| Cycle time (T)                        | 9.24 weeks     |
| Investment in promotional effort (A_d)| $293.309       |
| Total Profit (TP)                     | $18144.91      |

**Fig. 5.2.** Graphical sensitivity of decision variables w.r.t. $a$.

**Fig. 5.3.** Graphical sensitivity of decision variables w.r.t. $b$.

**Fig. 5.4.** Graphical sensitivity of decision variables w.r.t. $β$.

**Fig. 5.5.** Graphical sensitivity of decision variables w.r.t. $γ$.

**Fig. 6.** Graph of total profit versus investment in service and promotional effort.

The optimisation model is validated with a numerical case and analysed under multiple scenarios with the data set of existing literature with some additional parameters and their practical values. The optimisation model is solved with the help of a GRG solver. Mathematically, this solver solution guaranties that Karush-Kuhn-Tucker (KKT) conditions for local optimality have been satisfied (Lasdon et al., 1974). The optimum solution is obtained when the partial derivatives equal zero. The optimal solution plots are presented in Figs. 4–6.

The parametric values are given as follows: please cite from where you have taken these value

$$K = 800/\text{order}, a = 100, b = 40, s_0 = 200, h = 0.5/\text{unit/time}, \delta = 0.1, \gamma = 0.3, \alpha = 0.02, \beta = 0.03, p_0 = 120, \rho = 0.3, I_0 = 50, q = 15$$
In this case, retailers didn’t invest in promotional efforts. This is the case representing the scenario with service facilities but no promotions. During the pandemic, people avoided moving outside, so investing in a service facility with any promotion was quite irrelevant. Investment in a service facility is only beneficial when people are visiting the physical store. To make them aware of this facility, investment in promotional efforts is the backbone for retailers to convert their investment into higher demand, which ultimately turns into much higher profit. Table 3 presents a better idea of how the promotional efforts investment is crucial for these pandemic scenarios.

Case 3. No investment in service facility and promotional efforts

This scenario considers the investment in promotional efforts and service facilities are zero. This is the case which represents the model without service facility and promotional efforts. This model is not suitable for the pandemic situation because that needs adequate service and safety measures. Comparative details are given in Table 3.

All these three cases are summarised in Table 3. It directed to a retailer on how profit margin can be maximised under different investment strategies. Fig. 4, represent the difference in total profit as well as cycle time in all four case.

### Table 3
Optimal results of different cases.

| Optimal values | No service investment (Case 1) | No product promotion investment (Case 2) | No investment in any case (Case 3) |
|----------------|-------------------------------|----------------------------------------|----------------------------------|
| Total Profit (TP) | $14522.65                    | $9699.21                               | $6459.11                        |
| Service investment | Zero                         | $547.070                                | Zero                             |
| Investment in promotional effort (Ad) | $275.284                    | Zero                                   | Zero                             |
| Cycle Time (T) | 8.49 weeks                    | 8.27 weeks                              | 8.84 weeks                       |
| Demand | 87.17 units                   | 58.09 units                             | 40 units                         |
| Order Quantity | 740.20 units                  | 480.40 units                            | 353.55 units                     |

6. Model sensitivity analysis

The sensitivity analysis is used to check the model reliability and robustness of the mathematical model (Govindan et al., 2020; Li et al., 2018). Therefore, we have done the model robustness test with the varying values of the decision variables and parameters in presented model in Eqs. (1)–(13). In the numerical analysis section, the comparison of the traditional model and the proposed model provides an explicit analysis of the impact of different assumptions of this model in the current COVID-19 pandemic situation. Table 4 highlights the corresponding value change, and a graphical interpretation is given in Fig. 4.

Graphical representation for sensitivity table concerning various parameters.

The optimality of the decision variables are presented in Figs. 6–8.

### Table 4
Impact of various decision parameters on optimal investment policy.

| a   | T    | I    | A_d | Demand | Q    | Total profit |
|-----|------|------|-----|--------|------|--------------|
| 80  | 8.45 | 643.04 | 278.84 | 85.628 | 723.654 | 14447.756 |
| 90  | 8.76 | 685.68 | 285.909 | 95.789 | 840.003 | 16293.800 |
| 100 | 9.24 | 733.908 | 293.309 | 105.951 | 978.914 | 18144.917 |
| 110 | 9.89 | 788.974 | 301.08 | 116.118 | 1149.020 | 20001.251 |
| 120 | 10.79 | 852.507 | 309.271 | 126.289 | 1363.617 | 21863.045 |
| q  | 8.64 | 221.584 | 280.214 | 92.268 | 797.494 | 15903.026 |
| 10  | 8.89 | 464.288 | 286.376 | 98.817 | 878.655 | 16966.782 |
| 15  | 9.24 | 733.908 | 293.309 | 105.951 | 978.914 | 18144.917 |
| 20  | 9.70 | 1036.688 | 306.988 | 113.509 | 1101.769 | 19407.074 |
| 25  | 10.32 | 1380.264 | 309.464 | 121.403 | 1253.880 | 20740.488 |
| γ  | 8.750 | 339.927 | 283.192 | 95.446 | 835.766 | 16417.250 |
| 0.10 | 8.960 | 528.943 | 288.040 | 100.550 | 901.849 | 17252.285 |
| 0.20 | 9.240 | 733.908 | 293.309 | 105.951 | 978.914 | 18144.917 |
| 0.25 | 9.860 | 957.495 | 298.996 | 111.586 | 1098.630 | 20084.512 |
| 0.30 | 10.34 | 1202.828 | 305.121 | 117.418 | 1173.613 | 20664.351 |
| b  | 0.01 | 9.06 | 705.712 | 84.658 | 100.364 | 899.605 | 13811.997 |
| 0.02 | 9.08 | 718.365 | 81.428 | 102.929 | 934.816 | 17681.403 |
| 0.03 | 9.24 | 733.907 | 293.309 | 105.951 | 978.914 | 18144.917 |
| 0.04 | 9.44 | 752.616 | 424.26 | 109.439 | 1068.630 | 20084.512 |
| 0.05 | 9.70 | 775.094 | 578.778 | 113.427 | 1100.318 | 19292.389 |

Fig. 7. Graph of total profit versus cycle time and investment in promotional effort.

Fig. 8. Graphical representation of total profit versus investment in service and cycle time.
The present paper proposes a benchmark study related to the problem imposed by the pandemic and provides a solution to overcome the challenges faced by the retail business. The objective is an inventory optimisation problem to maximise the store’s profit with the optimum investment in promotional activities and service to the customers to maintain an optimum replenishment cycle. The indirect decision variables for the constructed inventory problem were the item’s selling price, which is dependent upon the investment in promotional efforts and service facility provided to the customers.

7. Managerial implications of model

The proposed decision model helps grocery retail stores managers to develop adequate policies for improving their overall profit considering the items promotional efforts and customer service level. The following operational and managerial implications can be drawn from the research.

When the scaling factor of demand a increases, investment in the service facility and total profit increase, whereas investment in the promotional effort decreases. The consumer demand uplifted the order size, which significantly affects the customer service cost. The store managers try to invest in promotional cost for increasing the demand that subsequently contributed in high profit margin. This scenario is a good sign for a retailer to optimise their cost and maximise the total profit. Since order quantity is increases significantly, it is advisable to retail stores to maintain high inventory level with marginal increase in advertisement cost.

If there is an increase in service facility q, it must increase the service cost notably, which also influences the demand positively. There is a negligible increase in investment in the promotional effort with marginal increase in demand with better service facility. The total profit goes up for the retailer as demand increases due to better service facilities, and also it will accelerate the cycle time. This is excellent recommendation of this research that investment in service facility would be beneficial only if it will enhance the impact of better service performance.

With an increase in the service parameter T, service facility will increase, subsequently influence the demand and leads to higher profit. It is known that better service facility always impact the demand positively. It is always advisable the investment in service facility would be beneficial only if it will enhance the better service performance. Retailers are recommended that they should hold inventory for a longer time to get maximum benefit of better service facility.

An increase in demand sensitivity parameter b related to promotional effort cost gives a boost to demand. Higher demand can be pulled by investing more in the promotional effort. Moreover, the service level increases to satisfy the surge in demand, but at the same time, the total profit of the system is increased significantly. To get optimal profit, the retailer increase the selling price. Retailer should always put emphasis to making impactful investment in advertisement or promotional effort to get maximum profit. The developed model emphasis on the additional investment in advertisement, which is again a crucial step towards effective investment in service facility.

An increase p leads to an increase in the effectiveness of the investment in promotional effort cost. More effective promotional effort results in higher profit, bigger inventory lot size and at the same time the total profit increases. It gives a clear insight to increase the selling price because the unit selling price also depends on the promotional effort’s investment. Also, with increasing the effectiveness, the total profit of the system increases. In such a case, it is suggested that the retailer may look lesser investment in advertisement.

The proposed model presents a decision support tool for retailer to decide and optimally invest in the promotional activities and better service facility design.

8. Conclusion

The entire globe was experiencing the various disruption such as transportation, supply chain, sourcing, delivery, and availability of the essential items during COVID-19 pandemic. The trend of online buying is also increases during COVID-19 time and that causes the various new dimensions for the physical retail stores. The consumer buying behavior is significantly changed for online and offline stores. Therefore, this paper developed an efficient optimal model for retailers to invest in promotional efforts while maintaining the adequate consumer service level. The proposed optimisation model is validated with a case of retail industry parameters. The main key findings of the proposed model are fourfold as follows. First, an extra investment in promotional efforts with improved service facility attract more customers that helps to increase retailer’s total profit. Therefore, retailers are recommended to invest in promotional efforts with optimal level of the promotion to increase the profit margin. Second, the product demand pattern, selling price, and their impact on promotional efforts and service facility are modelled for maximising the total profit of the retailers. The above findings help retailers to maximise the utilization of the stocking space and meeting exact requirement of the customers. Third, The realistic situation is modelled by considering product demand, selling price, and investment in promotional effort and service. The product selling price is depends on extra investment in promotional and service activities. Fourth, retailers’ total profit is maximised by optimising service level and promotional effort investment. The second important finding is related to the impact of investment on unit selling price is a more practical scenario that is addressed well in this model. The proposed model is also tested for the optimality of the analysis to present the model reliability and robustness. The above key findings would help to the retailer to plan optimal policies for inventory as well as meet the customer service level.

The proposed decision support model considering the fixed production rate system over considered period. The proposed model can be extended with variable production capacity or production strategies (make to order basis) for realizing the impact of the demand, advertisement cost under pandemic situation. Further, the demand can be considered as stock-dependent, promotional effort-dependent, or stochastic. The proposed model validation is done on the basis of the parametric values taken from the past researches, which can be extended with new data set from emerging economies context. Also, the uncertainty of the data availability can be considered with the suitable fuzzy inference modelling to develop a robust optimisation model considering the product nature viz. perishability. The presented model in this paper does not consider the perishability issues of the inventory. Also, the effect of the presence of imperfect items, Type-I or Type-2 error, deteriorating items, trade credit, and inflation on economic policies can be considered. Similarly, the future researchers can consider the nature of holding cost (time or quality based) with the current model to propose the joint optimisation model for buyer-retailer context.

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CRediT authorship contribution statement

Priyamvada: Research idea and initial draft preparation; modelling, data, Formal analysis, Methodology, Software. Aalok Kumar: Draft revision; manuscript handling, draft writing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
Appendix A

\[ \frac{\partial T}{\partial P} = \left( \frac{2(2Q^2 - c\delta)}{(a-cs_0-cd - cpA_d + bA_d + qr \ln l)} \right)^2 + \frac{qP(2Q^2 - c\delta)^2}{(a-cs_0-cd - cpA_d + bA_d + qr \ln l)} \]

\[ \frac{1}{T} - 2\delta \left( c\delta - \frac{qP}{T} - qr(d + s_0 + pA_d) \right) \left( \frac{T}{2} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

(A.1)

\[ \frac{\partial TP}{\partial A_d} = \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

\[ \frac{1}{T} - 2\delta \left( c\delta - \frac{qP}{T} - qr(d + s_0 + pA_d) \right) \left( \frac{T}{2} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

(A.2)

\[ \frac{\partial TP}{\partial A_d} = \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

\[ \frac{1}{T} - 2\delta \left( c\delta - \frac{qP}{T} - qr(d + s_0 + pA_d) \right) \left( \frac{T}{2} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

(A.3)

\[ \frac{\partial TP}{\partial T} = \frac{hI}{T} \left( c\delta - qr \right) - \frac{h(T-t_1)}{T} \left( c\delta - qr \right) + \frac{h(T-t)}{T} \left( c\delta - qr \right) - \frac{h(T-t)}{T} \left( c\delta - qr \right)

\[ + \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

(A.4)

\[ \frac{\partial TP}{\partial dA_d} = \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

\[ + \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

(A.5)

\[ \frac{\partial TP}{\partial dA_d} = \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

\[ + \left( \frac{2}{T} - T_1 + \frac{t_1}{2} \right) \frac{bA_d}{T^2} + \frac{tbq}{T^2} \frac{t_1}{2} \]

(A.6)

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