A viability study using conceptual models for last mile drone logistics operations in populated urban cities of India

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Abstract
Emerging Unmanned Aerial Vehicle (UAV) technologies have been under spotlight worldwide due to a promising spectrum of applications. Despite interesting use-cases receiving worldwide media attention, drones are expected to have their most significant impact on supply chain and logistics systems in highly populated urban cities once the regulations for commercial purposes are lifted. This article proposes two models of drone-delivery technology that can serve as a potential replacement in the Indian truck-delivery system. First, a drone–truck hybrid delivery model is proposed with trucks carrying multiple drones. Second, a stand-alone drone-delivery model is proposed with separate charging infrastructural facilities at specific points. The two proposed models’ findings present the advantages of significantly reducing carbon emissions, delivery costs, and time compared to truck-based delivery. The hybrid drone–truck model eliminates the need for separate charging facilities saving initial infrastructural costs. In contrast, the stand-alone drone model utilizes the current warehouse location facilities with charging stations on specific points for ease of adoption. This research presents initial viability suggesting that the drone technology can solve the current operational challenges in India’s urban cities. Furthermore, vital factors are discussed to enable stakeholders to select a model for drone logistics systems planning and experimentation.

1 | INTRODUCTION
The advent of modern-day Unmanned Aerial Vehicle (UAV; drone) technology has opened doors for many applications. These drones find their most common applications such as aerial photography, agriculture purposes, construction, e-commerce, surveillance and security, rescue, and relief operations. The demand for drone services (segmenting industries like infrastructure, agriculture, oil and gas, etc.) is projected at $4.4 billion in 2019, reaching $63.6 billion by 2025, at a Cumulative Annual Growth Rate of 55.9% from 2019 to 2025 [1]. With Amazon being the first to announce package deliveries via drones in 2013, a lot of research are in progress in this sector recently to implement drones in the last-mile logistics operations. During the forecast period (2019–2014), the drone logistics and transportation market are expected to register a Cumulative Annual Growth Rate of over 20% [2]. The rising demand for e-commerce and the growing use of drones for faster delivery of products in commercial applications are among the key factors driving the development of the need for drone logistics and transports. Countries like Germany, the United States, United Kingdom, Poland, China, Switzerland, and so forth are investing in this technology to transform such research projects into real-world supply chain applications [3].

Drone Delivery Canada, one of the leading drone-delivery firms, has signed an agreement with Moose Cree First Nation for $2.5 million to deploy its drone-delivery network to support Moose Factory and Moosonee communities [4]. In the United States, United Parcel Service (UPS) has started using drones for delivering medical samples, built by Matternet [5]. In Australia, a world-first drone-delivery business has been approved to take to the skies. Their aviation authority Casa approved Alphabet’s Project Wing, which delivers food, drinks, and medication after examining all the necessary factors like the safety of the drones, drone pilot training, maintenance, traffic management system, and operational plans [6]. Ghana

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also launched the world's largest vaccine drone-delivery network with Zipline, with each of its four distribution centres having up to 500 flights per day [7].

Drones are essential across all parts of Asia as a viable means of leapfrogging over infrastructural deficiencies [8]. The implementation of drone logistics in highly populated India could provide a significant boost in the future for the current supply chains in the booming e-commerce industry. One of the biggest challenges is the distribution cost in last-mile logistics, which costs about 53% of the total for e-commerce supply chains [9]. With the constant fluctuations in fuel prices, transport costs also pose one of the biggest problems. The logistics’ share of CO2 emissions is about 7% of India’s total CO2 emissions, which poses negative impacts on human health and the environment [10]. The congestion costs in India’s major cities are also projected to be INR 1.47 lakh crore annually [11].

This study attempts to introduce a last-mile drone logistics system in the supply chain operations of India to replace the current Stand-Alone Truck Delivery (SATD) system for parcel deliveries. Two case illustrations Truck-Drone Hybrid Delivery (TDHD) and Stand-Alone Drone-Delivery (SADD) system for implementing drones in last-mile logistics are presented to overcome the ongoing operational and congestion challenges. The TDHD system illustrated utilizes drones in collaboration with trucks in a real scenario. Hence, it provides a solution to avoid risks of driver shortages and reduce the number of delivery trucks. The SADD system illustrated utilizes drones with charging station points that are hypothetically placed on a conceptual basis across a populated urban region in collaboration with the current warehouse facilities for delivery purposes. This article also presents a discussion highlighting critical factors that emphasize which system (SATD, TDHT, SADD) may provide the best implementation criteria of success for using drone technology in the last-mile operations of highly populated developing economies.

The study addresses the following research questions (RQs):

- **RQ1**: What are the applications of drones in populated urban cities of developing countries?
- **RQ2**: In what ways can drones be used with delivery trucks to reduce delivery cost/time and carbon emissions?
- **RQ3**: In what ways can the existing warehouse and distribution facilities use drones for delivery purposes?

To address the above arguments, a conceptual framework is presented for the parcel-delivery logistics system using drones. Two models are proposed in the framework to demonstrate the application of collaborating drones with the existing trucking system as well as replacing it with a drone-only delivery system. This article also attempts to demonstrate real case scenarios for using drone technology in fulfilling multiple demand points of a particular area.

The study addresses the following research objectives (ROs):

- **RO1**: To understand the applications of drones in urban populated cities of developing economies like India.
- **RO2**: To propose a framework of the TDHD system with the consideration of delivery cost/time and carbon footprints.
- **RO3**: To propose a framework of the SADD system with the current warehouse and distribution facilities.

In Section 2, a literature survey is presented that provides a brief into the major obstacles in the current supply chain industry and past research on the potential use of drone logistics. In Section 3, a conceptual framework is proposed to overcome the significant obstacles of current logistics operational challenges in last-mile using drone technology. In Section 4, two case illustrations are presented to provide an insight into how drones can be implemented in the last-mile operations. In Section 5, the impact of drone technology on the current scenario is highlighted. It provides several managerial implications for the next steps in implementing drones in real case scenarios of supply chain operations in developing economies. In Section 6, the study is concluded with its application of the concept presented and future scope.

## 2 LITERATURE SURVEY

In this section, a study of the previous research on using of drones in the logistics field is executed. For better understanding, this survey is divided into four parts: (i) drone logistics system, (ii) drone logistics system, (ii) drones with trucking logistics system, (iii) stand-alone drone logistics system, and (iv) research gaps.

### 2.1 Drone logistics system

There are numerous problems which consider making deliveries using UAVs only. Amazon and DHL are already experimenting with the use of emerging drone technology in their delivery system where the drones directly deliver packages from their warehouses to the customers. Prior research demonstrates how drone technology can be leveraged for operations of delivery purposes. Chong et al. [12] and Chowdhury et al. [13] proposed a model based on disaster management and relief operation using drones. UAV logistics infrastructure by Shavaran et al. [14] and Hong et al. [15], healthcare by Kim et al. [16], civil applications by Otto et al. [17], forest management by Banu et al. [18], and sustainable farming by Tripicchio et al. [19] and Puri et al. [20] are all applications of using drones for several logistics-based operations.

### 2.2 Drones with the trucking logistics system

Murray and Chu [21] had identified the idea of combining a drone with a conventional parcel delivery truck. This article aimed to solve the problems of optimal drone routing and scheduling using drone technology and proposed a MILP
model to optimize the drone-delivery system's operational elements by considering routing constraints and seeking to minimize the latest time for truck or UAV return to the depot. Since then, numerous studies have explored variations of the single-truck drone problem, sometimes referred to as the Travelling Salesman Problem with a drone (TSP-D). Agatz et al. [22] address the planning problems for collaborating drone services with trucks. The proposed model is based on local search and dynamic programming for the TSP-D that can solve instances of up to 12 nodes to find the optimal truck and drone distribution best assignment. The article concluded that the combination of truck and drone results in considerable time savings between 30% and 38% on average.

Chang and Lee [23] considered a system in which the truck deploys multiple drones from launch sites along the truck's route in the case of single-truck multi-UAV problems. The proposed model further reduces the routing problems by identifying shift weights that transfer cluster centres and taking into account travel and flight time factors that affect overall delivery time. The model is more effective at decreasing the delivery time and operating costs of drones. Boone et al. [24] presented modifications to solve the Multiple Travelling Salesman Problem (MTSP) for the UAV Swarm Route Planning and showed that the results could lead to delivery time reductions. Sacramento et al. [25] discussed the advantages of including the drone-delivery option with the delivery of exclusive trucks. The proposed model solved the problem of vehicle routing with drones to minimize the operating cost of fuel, considering capacity and time constraints. The model shows the savings in the range of 20%–30% or even more when compared to the truck-only approach.

To reduce completion time for delivering packages and returning all vehicles to depot control, Poikonen et al. [26] researched the VRPD model (drone routing problem for vehicles). The author discusses drones allowing the truck to coordinate activities and leverage crow fly distances and improved carrying capacity. The proposed model optimizes the schedule of drones launched from the truck when servicing a given set of customers and differentiates on the degree of freedom concerning where a drone returns to the truck. The model successfully solves instances with up to 100 customers in just a few minutes of computational time. Wang et al. [27] address a bi-objective TSP-D to attain a compromise between operational cost and completion time. The proposed algorithm includes redesigning crowding-distance computation procedures and local search components to discuss the features of the problem. The article concludes with a trade study providing managerial insights for decision-makers to compromise solutions.

### 2.3 Stand-alone drone logistics system

There has also been significant research focusing on stand-alone drone system integration with the logistics industry. Besides, many applications of drones-only implementation in smaller package delivery like medicines, food packets, mails, and so forth are being considered as a step for such initiation of drone-delivery services. For instance, Vlahovic et al. [28] examined the impact of employing delivery drones as an alternative approach for pharmaceutical products in delivering them from a mainland warehouse to off-coast subsidiary. Drone delivery implemented in short-range deliveries could reduce the burden of workforce shortage that some countries may face in their logistics industry. Hua and Zhang [29] proposed one such simple case scenario for implementing drone logistics services with artificial intelligence technology in last-mile operations and replacing the dispatchers to increase efficiency. The stand-alone drone-delivery models rely solely upon the drone charging capacity itself to perform their services. Hence, several problems like flight path and distribution planning, routing schemes, and charging system design need to be addressed for an efficient model of delivering parcels on a large scale. For such persistent drone logistics operations, Song et al. [30] contributed by proposing a scheduling model and addressing the problem of optimally selecting resources (UAVs, service stations, and their locations) to share multiple service stations to replenish their battery power. Kim and Morrison [31] addressed the problem of optimally selecting resources (UAVs, service stations, and their locations) and scheduling in the persistent context. Dorling et al. [32] developed an energy consumption model to solve the vehicle routing problem that minimized delivery time and cost by considering the reusing of drones and optimizing battery. Coelho et al. [33] addressed the UAV complex fleet routing with vehicle autonomy and the need for charging them during their routes. Kim and Moon [34] proposed a model that proves to be beneficial for customers located far away from the distribution centre. The model describes a truck to deliver parcels from the far-away located warehouse to the drone stations. These drone stations near the demand points will have the packages delivered by drones once the station is initiated by the trucks arriving.

Raj and Sah [35] considered better infrastructure as a critical success factor for the adoption of drones to find veriports and service centres in prime locations for drone supporting infrastructure. To highlight the improvement of Unmanned Aircraft Vehicles in civil use, Troudi et al. [36] proposed a Post-Production Logistics Support Analysis to cover the exploitation phase of a drone-delivery operator. Irmanesh and Raad [37] proposed a novel method to data communications by providing a data delivery service along with the drone parcel delivery service. The proposed model generates data along their flight path and makes use of recharging stations in case the energy levels go out. Swanson [38] addressed the issue of comparing drone-delivery service with surface vehicles and highlights several considerations to be taken to examine both the services.

Shavarani et al. [14] developed a model that facilitates a distance-constrained single-flow hierarchical facility location to find the best spatial distribution of the facilities in two levels of launch and also recharge stations for a drone-delivery system. Bartoli et al. [39] proposed a model to introduce a warehouse in the drone-delivery service area to reduce the distance of the main distribution centre with the serving locations. Hong et al.
[15] proposed a new location model for an optimally siting recharging station to support the commercial stand-alone drone-delivery service in an area with obstacles.

2.4 | Research gaps

From the literature presented above, it is noted that researchers and authors attempted to use drone technology for commercial purposes in various operations of the supply chain industry.

However, much of the work takes in a lot of assumptions that may need more attention before the actual implementation phase of drones could happen. For instance, the charging stations are located based on the demand points without considering where the stations should be located and how such infrastructure could be built. Also, several patents and research work are being carried on where the charging stations could be located. Currently, charging towers, charging portals on building terraces, or even on lamp posts are under constant observations as a solution in the future. However, these solutions still have to be analysed with a lot of attention for their success. There is a clear research gap on how the drone-delivery services that require special attention mainly on the charging aspects be accommodated in developing economies either with the existing trucking system or the current warehouse and distribution facilities. There is also a lack of literature on developing a practical model for locating charging station points in a city map for drone-delivery services that is feasible for the logistics companies to invest. Also, based on previous research studies, a little work is done on managerial implications for whether such drone-delivery implementation with a high cost of investment is feasible, especially for developing economies.

3 | PROPOSED FRAMEWORK

The drone technology faces many challenges before being implemented in the logistics sector. The governmental restrictions where the drone pilots maintain the direct visual line of sight while flying and the fact that drones cannot be flown more than above 400 feet vertically, is a challenge. The other problems include the battery and capacity constraints, limited range, and lack of drone infrastructural facilities for charging or launching purposes. The recent improvement in drone technology and the grant of a drone-delivery licence by the Civil Aviation Administration of China motivates for a future Indian governmental consideration of drones for logistic applications. Hence, two cases are considered for utilizing drone technology in the logistics sector. The first is the hybrid drone–truck delivery system, where the drones are mainly the primary operators for package delivery while the trucks act as moving charging stations where the drones charge on the truck rooftops. The drone supported delivery coverage is maximized with this concept where charging time is utilized while the trucks are on routes, wherein case they are stuck in traffic and congested roads that allow the drones to be fully charged during that time. The second case is a different concept of a stand-alone drone-delivery system supported by separate charging station facilities established at particular location points to maximize the drone-delivery coverage. Multiple drones could be considered for continuous delivery and save the delivery time.

Figure 1 represents the conceptual framework of this article, which consists of three critical layers. The parcel logistics delivery system is based on truck-based delivery and drone delivery. The first layer is the constraints layer, where the main limitations of both the delivery system are noted. The second layer is the solution layer, where the solution for introducing the drone-delivery system in urban areas is proposed. For TDHD, a concept of drones charged on the truck rooftop while on the delivery route is introduced. For the SADD model, an establishment of a network of charging station points is proposed. The models introduced reduce delivery cost, carbon emissions, and delivery time. The last layer is the application layer for two concepts that utilize the drone-delivery services and their impact on the conventional truck delivery system.

4 | CASE ILLUSTRATION

4.1 | Truck-drone hybrid delivery system with on-route charging

Figure 2 represents a particular area for hybrid truck–drone delivery. The electric truck leaves from the warehouse carrying the products that need to be delivered, and the drones are on the rooftop in a charging mode. There will be one electric truck but multiple drones on the roof of the truck for a particular region (and multiple trucks in general). Electric trucks will have solar panels, and thus, trucks will act as a charging station and carry products that need to deliver. The product needs to be delivered within a minimum (5 h) to maximum (24 h) meeting consumer demand and will lead to consumer satisfaction and reduce delivery time with no CO₂ emissions. Proceeding to the Company ‘y’ App, the consumer must then type the Region name. Accordingly, the software will indicate the warehouse name according to the Region or Pin Code. By searching in the particular warehouse product list, the consumer can place an order for any product according to the weight factor. The maximum weight a drone can carry is 25 kg, and if the product is not available, the website will show when the product will be available in a particular warehouse. The consumer will receive the message when it is available on the registered mobile number.

After placing an order, the consumer will get a confirmation when their order leaves from the warehouse. It is assumed that an electric truck has a limit of carrying a minimum of six to a maximum of eight drones at a time for delivery purposes. Once the drone leaves, the consumer can see their delivery through the map navigation system like Uber and Ola, and this will be the in-built feature of the App. The consumer will receive a message to come out of their home just 5 min before the product gets delivered. Each consumer will be given a card,
and on that, a unique QR code will be there. Once the lidar sensors of the drone sense the QR code, the information will go to the handler of the electric truck. Once the access is given, the product will be delivered to the consumer. For more safety reasons that the product is taken from the particular consumer, fingerprint or face scanning may also occur, and if the fingerprint or face scanning matches the product, it will be delivered. If two or three deliveries are in the same area, but 50–100 m apart, drones can carry products depending on their capacity. No separate drone will fly if delivery is 50–100 m apart, and the products will be kept in a descending manner.

Figure 3 demonstrates the drones flying off to the assigned location where the product needs to be delivered. The drones can again fly and come back if the delivery is there in a particular region. This scenario describes how drones will operate from the roof of the electric truck in all different areas of a specific region according to the delivery. Once the drones come back, they will be charged again. The products on high demand and often ordered (according to the particular region) will be kept in the truck as storage so that the consumers can receive the delivery very fast and the truck need not go to the warehouse again. If the drone from Region 1 is nearby to the Region 2 and away from the electric truck of Region 1, then the drone will fly to the Region 2 to save the return travelling time and be useful for another delivery. There will be additional landing in each of the electric trucks so that the drones from other regions can land on it for charging purposes and prepare for another delivery.

Figure 4 describes the two regions, namely Region 1 and Region 2. In Region 1, the electric truck A is far from the drone and very much near Region 2. It is assumed that the drone has already delivered the product. In the next region, the electric truck B is very near to the drone so the drone will
fly to Region 2 instead of Region 1. Such flying operation saves the return time and also the charging capacity of drones. It will also reduce delivery costs and carbon emissions. On the other hand, another drone could be made available for the delivery so that it leads to on-time delivery and consumer satisfaction.

4.2 Stand-alone drone-delivery system with recharging station locations

For drone-delivery systems, there is a massive constraint of battery and range limitations. Also, the added battery weight reduces its payload carrying capacity. Hence, there is a need for recharging stations between the warehouses and customer location points for facilitating drone charging. There is a research gap or lack of literature on how to accommodate charging station points in a city map for the delivery process. Also, the design of recharging stations is currently. Figure 5 represents a charging tower for several drones on different levels. All the shown drones in the station are charging. In contrast, the other drones are either out for delivery and flying towards their respective customer demand points or approaching the charging tower for refuelling purposes.

4.2.1 Locating charging stations points

For densely populated cities with heavy traffic and congestion on roads, drone-delivery services can come as a very economical and eco-friendly system that can significantly reduce delivery time and carbon emissions. For the drone-delivery system, there must be a charging station point within a range of drones’ maximum range. According to Murray and Chu [21], the flight range for a commercial drone is nearly 10 miles. Considering that payload can significantly reduce the drone’s range, it is assumed that the maximum range is 5 miles. Hence, the charging stations should be within this range. Consider an urban location; there are numerous significant roundabouts or traffic circles of roads every 500 m. Hence, there can be a charging station at the docking station set up at major traffic circles within the maximum range. Selecting points based on maximum coverage for all the demand delivery points can also reduce time significantly when multiple drones are accommodated on the docking stations.

Figure 6 is a diagrammatical representation where multiple pin codes of Mumbai are considered and split into different zones for drone-based delivery areas for special one-day delivery services that can be complete the task within a maximum of 1–2 h. Also, the warehouse facilities and distribution services are considered as it is for ease of adaptability. The docking stations located on the circle point can contain multiple drones and serve at least ten demand deliveries from the same spot. It is assumed that a drone completes one delivery point at a time. Hence, an equal number of drones as demand deliveries will be released from the warehouse.

Figure 7 demonstrates another possibility of an innovative technique to utilize the recharging time. While a drone is charging, the parcel can be transferred to another charged drone that is kept as substitutes in the charging tower, and that would deliver the customer without any time lag. This idea can form a non-stop chain of delivery service without any interruption of charging limitations.

Delivery for unequal weighted packages: for this concept, three delivery points are considered far away from the warehouse, and the drones would need to charge once before delivery. The drones have single packages with different weights, and hence, they arrive at the charging station with different drained battery capacity. Thus, the drone with minimum battery discharge would quickly fly away for delivery. However, the maximum discharged drone would move its package to the stand-by drone for distribution to maintain quick delivery.

Figure 8a shows only the top layer where the drones A, B, and C have just arrived for charging and drones D and E are stand by drones to facilitate non-stop delivery. Figure 8b shows a sample drone charging station tower where the upper layer drones have just arrived for charging. The lower layer is stand-by drones that serve as drones for non-stop delivery, and the top drone is ready for continuing the delivery.
4.2.2 | Parcel-delivery for 10 location points

In this case, it is assumed that the station can accommodate ten drones to complete ten demand locations. The maximum capacity can be addressed according to the growing demands.

Figure 9 shows a warehouse that has 10 demand points to fulfil using 10 drones. There are two charging stations nearby for charging drones. The demand points near to the warehouse are accomplished without any charging, whereas the other demand points would need first need charging before the deliveries are completed. Ten different demand locations need to be satisfied using stand-alone drone deliveries. Two charging stations are near the warehouse within the maximum range. Hence, there could be 10 drones serving the delivery purpose, and the charging stations could contain some substitute drones for a continuous chain of the delivery system. Considering demand points 1, 2, 3, 4 to be within 5 miles and close to the warehouse, the drones can easily supply the parcels and either return to the warehouse or travel to the charging station according to load demands. Drone deliveries for other points would have to travel to stations 1 and 2 for charging and then deliver the parcels. It is assumed that stand-by drones are already charged and present in the stations to carry the parcels from arriving drones by transferring them to the docking station. The QR
codes on the parcel scanned by the drone with RFID technology ensure correct delivery. Hence, this process would result in quick delivery for demand and develop a non-stop delivery system. The drones can then quickly return to their warehouses without any additional charging due to no payload constraint during the return journey.

5 | DISCUSSION

This section presents the possible results and implications for managers to implement drones in their supply chain and logistics firms. For both the cases as described earlier, many implications need to be discussed as done in this section before the managers can decide whether to move ahead with the idea of modern ideas for drone delivery in their existing systems. The extent of the impact that the drones may produce in various aspects needs to be evaluated. Three significant factors of delivery time, costs, and carbon footprints are discussed for comparison for SATD, SADD, and TDHD systems. It depends majorly on the manager's point of view on which factor to put their most emphasis depending on their firm's work and criteria of the business. A comparison of all three systems is considered using 100 parcel delivery operations.

5.1 | Delivery time

The SATD system can take a day to deliver at all the packages, whereas for an SADD can hardly bear the least time for about 2–3 h depending on the charging station features and how quickly it can charge and move. The TDHD can also provide a lower delivery time as it utilizes the time of truck getting stuck in traffic where most of the drones either charge during that time or are out for delivery. In this aspect, the SADD is the clear option when delivering small packages as they can significantly reduce the delivery time with the available backup-charged drones for instant delivery. However, for combinations of large packages, the TDHD system is preferable as the truck can cover those delivery points while the drones deliver the small packages.

5.2 | Delivery cost

The SATD system includes the costs of fuel of truck that fluctuates over time, driver's salaries and labour costs, and maintenance costs of the vehicles which add up to around 28%–40% of the total delivery costs for a company. The SADD initially requires a substantial investment for setting up the charging stations and the number of drones needed for each delivery. However, a strategic plan for setting up a network of station points regarding customers' data and their history of delivery requests can aid in a long-term benefit. The TDHD can also provide a lower delivery cost with fewer stations to visit for a truck and resulting in cost savings. In this aspect, the managers may have to compare the costs depending on their reach of a network according to their history and size of the company. The SADD may be beneficial for a large company with a vast number of deliveries that prove economical in the long-term. However, for companies with the limited reach of customers, the TDHD proves to be beneficial for cost-effective plans.
5.3 | Carbon footprints

The SATD system includes vans, trucks, motorbikes, and so forth to deliver packages that add not only to traffic but also for the pollution in urban areas. The SADD system almost nullifies the carbon footprint aspect except for the electric power required for drones' charging. The TDHD may also have an almost similar effect as SADD when using electric trucks and vans instead of combustion vehicles for green package delivery. In this aspect, the managers must decide whether to go for a green initiative in their parcel delivery services and choose accordingly.

A significant problem of parcel-delivery in the logistics sector is the shortage of drivers and staff labour required to handle the last-mile operations. This aspect of labour staff is almost nullified in terms of the SADD system, where the only labour that is needed is for the maintenance and air traffic control purposes. For TDHD system, the staff labour requirement also decreases significantly as the number of vans and trucks reduces when drones cover up for most of the package deliveries. Additionally, important periods in the parcel-delivery scenario are the season of festivals where mass demands of packages are expected, incurring massive delays in shipments. For such situations, the SADD could be useful when only the number of drones has to be increased for the high number of demand points. For large parcels, an option for vans with drones could prove beneficial to overcome the problem of limited payload capacity of drones. Also, there are massive road blockages in urban areas of India, whether it be for construction purposes, sewage repair, and so forth. In this case, the SADD proves beneficial as the they travel only by air. Also, the point worth noting for the TDHD system is that trucks may be beneficial for the managers when they need moving charging stations where trucks can still be in places where drones could land, charge and fly back to their demand points for delivery. Initially, drones cannot fly in bad weather situations like rain, intensive heat, or even strong winds that can lead to crashing or losing a drone. In this case, SATD proves very useful and efficient in delivering the products to the consumer on time. But in case of good weather, the TDHD system is very beneficial to the manager.

Furthermore, reverse-logistics is an essential part of the logistics process in recent years. There may come many cases when a customer does not need his parcel at a certain point of time or wants to return the package. In such situations, the reverse-logistics system has to be well planned for fulfilling these critical cases. For this, the TDHD system may be the best option as it involves a manual input where the driver can still reach the location point and take the parcel back or hold off for some time until the customer demands their package. In the case of SADD, if a customer requires to return the package at the time of shipment itself, the drone might have to suffer the return trip of flight with payload and may not complete it. Hence, the SADD system may have to endure such challenges in the case of reverse-logistics.

6 | CONCLUSION

This article developed and modified two models for drone technology implementation in the logistics sector by providing instances of real case scenarios to either eliminate the existing truck-delivery or develop a hybrid truck–drone delivery. It is noted that for densely populated cities, there would be overcrowded areas of infrastructure that could pose problems for drone flights. Hence, to avoid those circumstances it is suggested to place the charging towers within a 2-mile range between them as per the big data gathered from the customer past demands of an area for any location. In addition to these discussed hype-cycle effects, drones are easy to disinfect after each delivery as touchless delivery is crucial for the Indian supply chain and logistics systems in a post-COVID-19 situation.

6.1 | Implications of study

This article aimed to provide the practicing managers the next step for drone-delivery system implementation in the supply chain and logistics management of highly populated urban cities. Many cases considering different demand conditions are discussed to give the practicing managers an insight into how the two proposed systems can be performed effectively in overcoming the ongoing critical challenges faced in last-mile logistics operations. The practitioners of the supply chain industry can utilize the hybrid truck–drone model demonstrated using real case scenarios for delivery in congested areas to deliver small packages using drones as well as delivery men associated with that truck to deliver the heavy parcels, thus reducing the overall delivery time. The drone-only model provides an idea for the companies to adapt their current established logistics facilities with a drone technology upgrade. The infrastructural constraint of building separate charging or docking stations could possess a huge barrier in economic terms because of the high initial cost of investments for a logistics company. However, it still provides an enormous advantage for the practitioners in long-term planning for a sustainable environment that eliminates the truck requirement, achieves eco-friendly parcel delivery, and significantly reduces the associated operational costs.

6.2 | Limitations and future scope

Despite the current technological advancements in the drone industry for the past decade, there is a lot of scope for future research. The actual plan of implementation for collaborating drones with the current logistics companies is not discussed in this article. A survey may be conducted to get insights into how the companies would feel comfortable taking such a big step that includes huge initial investments and safety concerns. This article also does not provide the necessary computational simulations for the demonstrated real case scenarios that may bring new perspectives and critical factors to be discussed
before the actual implementation phase. This article also does not discuss the feasibility and profitability aspects when companies adopt for drone-delivery services. Performing qualitative and economic analysis of drone logistics considering all the costs related to drone-delivery services, including several drones, charging station set up cost, and forecasting costs according to enormous potential demands, could be an extension. Companies could use big data from their delivery detailed data sets collected throughout the years and project it for future deliveries to satisfy future demands and build the charging towers according to those needs. The actual design of charging stations to accommodate numerous drones and technology for continuous delivery and quick charging could also be a concern.

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How to cite this article: Gabani PR, Gala UB, Narwane VS, Raut RD, Govindarajan UH, Narkhede BE. A viability study using conceptual models for last mile drone logistics operations in populated urban cities of India. IET Collab. Intell. Manuf. 2021;1–11. https://doi.org/10.1049/cim2.12006