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Implementing Delivery Drones in Logistics Business Process: Case of Pharmaceutical Industry

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***Abstract*—**In this paper, we will present a research about feasibility of implementing unmanned aerial vehicles, also known as 'drones', in logistics. Research is based on available information about current incentives and experiments in application of delivery drones in commercial use. Overview of current pilot projects and literature, as well as an overview of detected challenges, will be compiled and presented. Based on these findings, we will present a conceptual model of business process that implements delivery drones in business to business logistic operations. Business scenario is based on a pharmaceutical supply chain. Simulation modeling will be used to create models for running experiments and collecting performance data. Comparative study of the presented conceptual model will be given. The work will outline the main advantages and disadvantages of implementing unmanned aerial vehicles in delivery services as a supplementary distribution channel along the supply chain.

***Keywords*—**Business process, delivery drones, logistics, simulation modelling, unmanned aerial vehicles.

I. Introduction

In recent years, there has been growing interest in introducing unmanned aerial vehicles i.e. flying drones in the delivery of packaged goods. Number of companies have initiated pilot projects of commercial applications that are intended to be offered as delivery options to their customers in the following years. Some of these include DHL, UPS, Deutsche Post, etc., but also e-commerce companies such as Amazon.com or AliExpress. There are also projects that aim at using this technology to better connect organization's inner logistic between various subsidiaries. There are good indications that drones have substantial economic potential in delivering goods, but there is a lack of comparative studies on this subject.

The main goal of this paper is to provide insight into economic feasibility of this type of logistics organization in relation to current trends in business organization – business process perspective. There is valuable information regarding the technical feasibility of delivery drones with issue that still needs to be solved. There is less information available about economics aspects in terms of costs, investment, accuracy, service value and business process automation, possible economic opportunities and possible restrictions of business models and business environment. In this paper, we will try to address at least some of these issues.

Structure of the rest of this paper is as follows: In Section II a background of implementing business process perspectives in logistics is given. Short background on the development and applications of unmanned aerial vehicles in business processes and their potential for the future is also discusses. In Section III goals of this research are presented as well as methodologies used. Discrete-event simulation is explained and the developed models are presented. These models are used for simulation experiments that are also presented along with their results. Section IV presents additional qualitative and quantitative analysis based on the obtained results from simulation experiments. Here main findings on the technical and economic feasibility are presented as well as the future potential of implementing logistic delivery processes based on unmanned aerial vehicles. Finally, in Section V conclusions of work are given with remarks on future work.

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II. Background

A. Business Process Perspective and Logistics

Many weaknesses of the functional organization of business operations have been addressed by new approaches to business organization. Lack of coordination and transparency over functional units in traditional organizations were the source of many business inefficiencies [3]. Shifting focus from functional units to process view has proven to be an important catalyst of efficient re-organization of business operations over the past two and half decades [7], [9]. Business process orientation is based on the idea of considering organizations in terms of customer-focused and value-creating sets of activities - business processes which provide better understanding of business [2]. As managing a business means managing its processes [6] so does managing any part of these activities that may be concerned with specific issues related to product or service.

Logistics is one such specific area that pertains to most of the core business processes. Logistic can be defined as fundamental principles of movement of material and information in the function of satisfying customer demands [1]. Customer satisfaction is therefore the common denominator for business process orientation and business logistic or even more specifically retail logistic in final stages of supply chains. Well documented business processes carry high potential effective implementation of various technological innovation increasing overall business process efficiency [14]. Many companies have already reached sufficient level of business process maturity to be able to implement innovative approaches in logistics business process such as unmanned aerial vehicles in the delivery of their products and services. To better understand the issues and challenges of this technology we will take a closer look at this type of innovative technology and its background.

B. Innovative Technologies and Unmanned Aerial Vehicles in Logistics

In order to retain or increase their market share businesses are constantly trying to redefine themselves achieving ever higher level of efficiency. Technology and technological advancement have always been primary source of reaching higher level of competitiveness. First applications of new technologies are usually groundbreaking and innovative even though they may not always prove to be successful. These solutions can generally be either a product innovation or business innovation [15]. Product innovation focuses on achieving better business process efficiency in terms of operations optimization, improved control and management as well as increased customer value of the offering. Business innovation change business models and approach to customers [12].

From the logistics point of view implementing new type of transporting products to final stages of supply chain or end-customers presents all the characteristics of a product innovation as it directly increases customer satisfaction while embracing and upgrading current business model.

Unmanned aerial vehicles (or UAVs) are vehicles that can complete continuous flight without onboard pilot. They have been first used in military purposes with the first civil use on the turn from 1970s to 1980s. Further sophistication of various types of UAVs started attracting more commercial interest. Smaller dimensions, less weight, better accuracy and controllability as well as better resilience to elements are just some of the properties that promoted their commercial applicability. According to Bernauw [16] the potential of innovative drone services can be divided into two groups of applications: (1) applications for civilian public authority such as border security, firefighting, disaster relief, ground traffic surveillance, pollution control, monitoring wildlife, just to name a few; (2) applications for civilian commercial exploitation such as aerial photography, aerial mapping, remote sensing, camera platform for motion picture shooting, journalism, live event filming, surveillance, wireless communication relay station, transportation, and many other [16].

UAVs for logistics may be applied for specific delivery tasks that imply urgency, physical inaccessibility or various types of perils humans may be subjected to if delivering goods by other means.

There are currently various experimental implementations of delivery drones for both academic research and commercial applications. For further information refer to [14].

III. Methodology

We have created a business process scenario to test the feasibility of implementing UAVs in logistics. Scenario is based on current literature and exact administrative information, legislation and economic values currently applied in Croatia.

We will employ experimentation using simulation modeling to collect performance data. Later, the data will be used to perform comparative analysis and draw conclusions.

In the rest of this section, we will first present main features of the scenario and define research goals. After that, two models will be created: (1) Delivery business process model using pickup van and (2) Delivery business process model based on a concept that replaces delivery van with delivery drone. Next simulation experiments will be documented with an overview of main results.

A. Research Goals

Goal of this research is to examine the effects of employing an alternative approach to organizing the internal logistics of pharmaceutical product delivery using drones.

There is a number of specific situations and application areas that may benefit from this approach. Due to strict and inadequate regulations, currently, possible scenarios are focused on the internal operations logistics and subsidiary deliveries. Most appropriate situations include deliveries to hard-to-reach places with challenging geography. Critical and high priority deliveries of specific goods are also justifiable examples of employing this type of technology.

For the purpose of comparing currently common transportation methods and delivery drones, a scenario is developed. Scenario includes all of the circumstances that may justify the implementation of delivery drones. Firstly, delivery product group are medications that require special conditions and fast delivery. The delivery is based on a route between mainland Split to Supetar located on the island Brac in Adriatic archipelago. There is no road connection available. Instead, Supetar is reachable by road and ferry ride.

Finally, delivery is organized by a pharmaceutical company that needs to deliver the required items from their mainland warehouse to off-coast subsidiary.

In order to analyze this scenario and test the hypothesis of this research, a conceptual model of the business process in logistics is created. Then, the business process is modeled using simulation modeling software in order to analyses the efficiency of the proposed model through experiments.

B. Simulation Modeling

Simulation modeling is a collective name for a group of quantitative methods and techniques but also programming tools used to create virtual representations of stochastic systems. These representations can be used for experimentation and testing of changes without affecting the real systems [10]. Some of major simulation techniques include Petri nets, discrete-event simulation, system dynamics and agent based simulation [13], [5].

As the focus of this work is on the organization of a particular business process, the most appropriate simulation technique is discrete-event simulation. Logistic process is defined in terms of activities and stages of delivery, which corresponds to discontinuous advancement of virtual time typical for discrete-event simulations. Each activity has well defined starting point, length and ending point that changes the state of objects and generate events. For objects to participate in activities they need to queue and wait for an available resource that may restrict the initiation of an activity. This is why models primarily consist of a series of interlaced queues and activities. Discrete-event simulation models are therefore appropriate for functional verification and performance evaluation of real world systems.

There are several visual programming tools available for simulation that are based on discrete-event simulations such as commercial tools like AllLogic, Arena, Simio, Simul8 but also open source solutions such as JaamSim. In addition to tools designed for general simulation models, there are tools that are aimed for modeling more specific application areas. HERMES is an example of a tool specifically designed for the development of simulation models of vaccine supply chains [4].

Simulation models in the remainder of this paper are developed using an academic version of Simul8 software [11] developed by SIMUL8 Corporation.

C. Developed Simulation Models

For the purpose of this research, two models were developed: (a) Simulation model of the pharmaceutical delivery process using a delivery van and (b) Same delivery process using a delivery drone. This business process is initiated by the arrival of orders for pharmaceutical supplies from subsidiary pharmacies to the main warehouse. Received orders are processed sequentially during working hours. This processing is performed by the administrative staff (as shown in both models). Orders are directed to the warehouse picking and package zone where warehouse worker loads packages onto available vehicles. In the first model, delivery vans are used. Each van requires a driver who also acts as a delivery person.

Transportation of goods using vans is heavily dependent on the ferry schedule. Time required to reach the destination consists of the travel to arrive to the ferry port in Split (15 minutes), ferry embarkement and disembarkement (20 minutes), ferry ride (50 minutes) and arrival to the subsidiary in Supetar (15 minutes) grossing at approximately 100 minutes.

Next is the unloading of goods in the subsidiary and finally the return of the empty delivery van back to the mainland. Complete process takes about 200 minutes and is constrained by the ferry schedule so that a limited number of travels can be performed during working hours.

In Fig. 1, we can see a model that uses delivery van. Processing times used in the model are estimated, while traveling times are calculated using available data on travel times and ferry schedule. Model also calculates the delivery cost of each processed delivery.

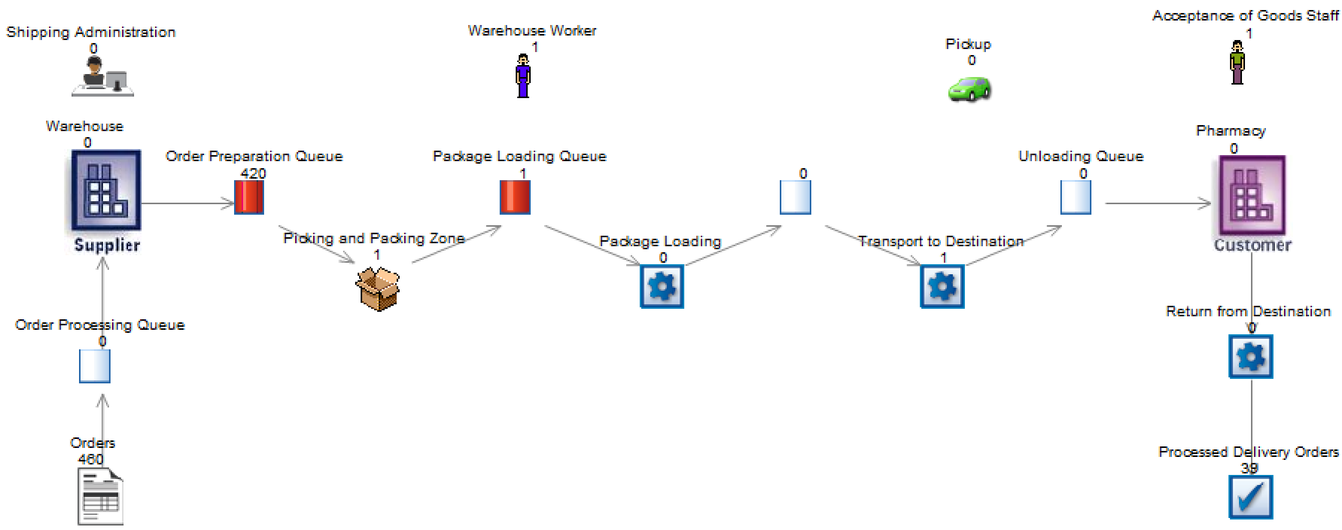

Fig. 1 Simulation model of the pharmaceutical delivery process using a delivery van

In Fig. 2 we can see a model that replaces the delivery van with the delivery drone. In this case, a particular drone model was used in order to estimate travel times and costs. We used Mikrokopter OktoXL. This change also determines other changes in the model. First of all, there is no need for additional worker who serves as a driver and delivery person for each delivery van. Also, subsidiary does not require additional time for the reception of delivered goods as the drone uses denoted landing and docking station, where it drops-off the package and recharges its energy before returning to mainland. In this scenario, the aerial distance between the mainland and destination is 18 km, so the estimated travel time is shortened to only 27 minutes, while being independent on road congestion or ferry schedule. Time required for the drop-off the package is estimated to 5 minutes and the recharge time to 20 minutes. Apart from electricity required for the operation of the delivery drone there are no additional costs in this scenario. Complete process of delivery using aerial drone is shortened to approximately 80 minutes. Cost of delivery and return of the drone is estimated to be more that 90% less than the total cost of delivery by delivery van as it will be explained in the following section.

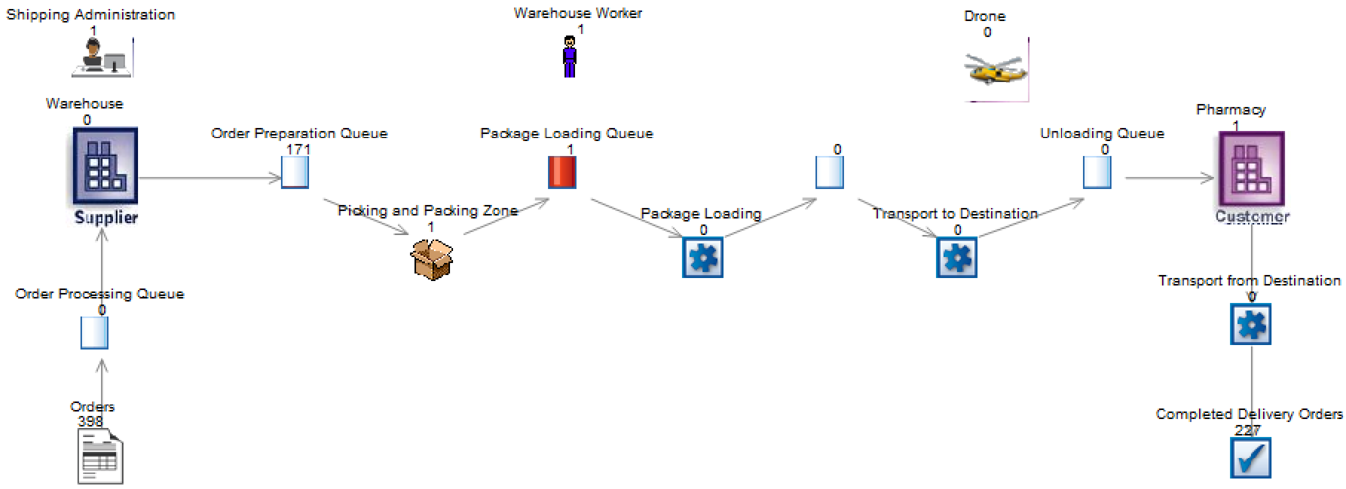

Fig. 2 Simulation model of a pharmaceutical delivery process using a delivery drone.

D. Simulation Experiments with Results

Models were used to run a series of simulation experiments to obtain the data on the process performance in both scenarios. The data were then used for a comparative analysis.

Comparability of results from various experiment runs is achieved by adjusting the simulation clock with same settings for each model and each experiment trail. Each trial uses 80-minute warm-up period to generate staring orders and initial queues within the system. Virtual clock is arranged on working day basis where the working period begins at 8:00 a.m. until 4:00 p.m. Data collection period is set for one month per simulation run for all simulation models.

For the given time frame, 398 orders entered the system. In the simulation experiment using delivery van model, 358 were being processed by the end of the trial. Only 40 orders were successfully completed. In this scenario, a pickup van is required to complete the package loading activity. This activity was identified as the main bottleneck of the process. It is clear that additional vehicles are required to satisfy the demand. For this research, only one pickup was used to compare its efficiency with the efficiency of one delivery drone.

For the same scenario simulation experiment using delivery drone model was performed. This time around, number of completed orders was 225. The package loading activity is no longer as restrictive bottleneck of the process as now there are 173 orders in model queues at the end of the trial run. Delivery drone was able to complete more orders. There are several reasons for this. Main reason is the fact that the drone movement is not tied to the ferry schedule as is the case of the delivery van. Ferry rides operate back and forth only four times during working hours of the day. The model showed that dependency of deliver van on ferry rides significantly restricts the efficiency of the delivery van. Even if delivery van transported 4 packages at the same time it would still be outperformed by the delivery drone.

IV. Discussion

In order to determine technical feasibility, a comparative analysis was conducted using obtained data. Economic feasibility was determined using twofold analysis. Quantitative feasibility was determined using cost estimation and cost benefit analysis while qualitative analysis measured potentials of the proposed concept through SWOT analysis.

The estimations of quantitative indicators are based on currently available costs retrieved from local market and therefore in local currency i.e. Croatian Kunas (expressed in Euros for improved readability). There are also some cost estimates that are taken from current literature as indicated later in the text.

Financial flows were also included within the developed simulation models. Financial costs and revenues were estimated for all relevant activities and key resources that incur costs or generate revenue. This information was additionally entered into models before experimental trials were initiated.

Most important activities that contain variable costs are the ‘travelling to destination’ and ‘traveling from destination’. Delivery van and delivery drone were the resources that incur significant initial costs, while the total number of completed orders provided information about generated revenue.

Traveling path for delivery van is different than the traveling path for the delivery drone. As we can see from the description of models in Section III, traveling path for the delivery van includes a ferry ride and is constricted by the ferry schedule. According to official pricing list cost of ferry ride in one direction is 42 euro (in local currency).

Traveling path of the delivery drone does not depend on any other transportation service, while it heavily depends on the weather conditions. The distance travelled is approximately a straight line 18 km long. According to [8], cost of delivering 2 kg package on a distance of 10 km is 0,10 USD. We estimate that the cost of 18 km travel with slightly heavier package would be below 0,17 EUR.

Each completed order for the delivery of pharmaceutical products generated revenue with average value of 200,00 Euro (in local currency). Based on this information, comparative analysis and SWOT analysis were performed.

A. Comparative Analysis

Simul8 provides simulation results in terms of time spent on performing activities of the model and using resources, as well as the number of processing and processed orders. Additionally, if financial data is available it can also simulate income statements for the analyzed process. As we have showed earlier in discussion, costs and revenues were estimated for bot simulation models and supplied before the experiment trials. These generated simulated income statements with data provided in Fig. 3. The initial cost of investing in one of these two possible delivery options represents the cost of the vehicle. In case of pickup van, the acquisition cost is 12.999,00 euros while the cost of purchasing a delivery drone is lower at 6.499,00 euros. Total cost of delivery with pickup van in the first month is 16.359,00 euros while the total cost of delivery using delivery drone in the first month is 6.571,00 euros. In the same time frame, delivery van was able to deliver 40 orders while delivery drone delivered 225 orders, yielding revenue of 8000,00 euros and 45000,00 euros respectively. Finally, at the end of the first month delivery van was operating with the loss of 8.359 euros with tendency to reach positive financial result during third month of operation. Delivery drone was able to generate considerable profit of 38.429,00 euros during same time period. Even if delivery van transported four instead of one package per each delivery trip it would only generate 32.000,00 euros in revenue resulting in profit as high as 15.641,00 euros which is more than half the profit generated by the delivery drone.

Income statements	***van delivery***	***drone delivery***
Costs	***16.359,00***	***6.571,00***
Transport to destination	1.680,00	36,00
Vehicle (Pickup van / Drone)	12.999,00	6.499,00
Return from destination	1.680,00	36,00
Revenue	***8.000,00***	***45.000,00***
Processes deliver orders	8.000,00	45.000,00
Profit	**-8.359,00**	**38.429,00**

Fig. 3 Comparison of simulated income statements for delivering pharmaceutical products using delivery van vs. delivery drone

B. SWOT Analysis

As we have shown in simulation experiment results and the analysis of income statements, delivery of pharmaceutical products using delivery drone outperformed more traditional types of transport. In order to understand the constrictions and the reach of possible implementation of this type of logistic model a SWOT analysis was conducted. The resulting SWOT matrix is shown in Fig. 4.

As we can see in the SWOT matrix given in Fig. 4, major strengths of using delivery drones for delivering pharmaceutical products primarily pertain to economic and operational efficiency. Most prominent increase of economic efficiency is the extremely low delivery cost per item delivered. Electricity-powered delivery drones require less maintenance than fuel-based vehicles since rechargeable batteries can be reused over longer periods of time before they need to be replaced. Electricity may be more expensive energy source than fuel, but due to shorter traveling paths and lower consumption, overall cost of the emergent is lower. Even the initial cost of acquiring delivery drone is lower than an average pickup van, and the prices show downward trend in the following years. On the organizational side of providing delivery service, drones can be used to automate some of the operative tasks such as scheduling, recharging, but also unloading packaged items (with the use of automated docking stations). Timeliness of the delivery service would increase, eliminating delays and providing new services to final users. All of these properties would introduce higher level of flexibility of scheduling deliveries as changes can be dynamically introduced as the orders with various levels of priorities accumulate during working hours.

Strengths	***Weaknesses***
Lower delivery cost Lower maintenance cost Increased delivery efficiency	High restrictions of size and weight of delivery items Dependability on weather conditions
Improved service responsiveness	Initial investment cost
Scheduling flexibility	Final legal regulation will apply additional restrictions to service availability
Opportunities	***Threats***
Allows for additional automation of delivery processes	Inadequate and insufficient legislation restricts (1) controlling and managing drones (2) flying zones
Allows for innovation in new delivery service options	Security issues in terms of securing (1) delivery items and (2) physical security of drones
Delivery service availability in geographically challenging areas	

Fig. 4 SWOT analysis of delivering pharmaceutical products using delivery drone

The positive effects of described strengths are subject to restrictions derived from physical properties of delivery drones. Some of the most restrictive ones are the maximum size of delivery packages in terms of limited dimensions and shapes, but also the weight that usually cannot exceed 5 kg. This is one of the most important weaknesses of the proposed delivery model. If weather conditions become unfavorable the delivery can be deterred. Since the capacity of delivery drone is not as high as the delivery vehicles, multiple drones should be used in place of one delivery pickup van, which may prove to present too high initial investment for businesses to implement this type of delivery.

Currently inadequate legal regulation and standardization of operating UAVs will become better defined in time, but it is quite certain that it will apply additional restrictions affecting the range and availability of deliver services using drones. Not only these restrictions will become weaknesses of the delivery drone services, they currently represent a threat for all the businesses trying to implement this type of deliver to their logistic business operations. There are various restrictions in terms of controlling the drone travel to the point that some areas require full line of sight fly paths, manual operation of the drone without automated controls and restrictive height of the flying paths. Administration and registration of flights with the appointed authorities also decrease efficiency of managing drones increasing the operating costs and reducing the availability of flying zones.

Permanent threats that will be significant even after better legal regulation becomes available and even standardized will be various security aspects. Security issues may vary: (1) securing the products delivered, especially pharmaceutical products due to their chemical compositions, but also possible high value and other circumstances; (2) ensuring the physical security of drones themselves from the elements, but also users, by passers or even malevolent individuals. Security issues may be worth the financial costs required for their resolution if the opportunities outweigh the threats.

Opportunities that delivery drones create may initiate radical changes in the reorganization of logistic business processes with high emphasis on automation and innovation (both back office innovations and front office innovation). Specific regions that are hard to reach may receive better and more complete coverage using delivery drones opening a new market niche.

V. Conclusions

In this paper we presented a concept of implementing UAVs in logistic business process in the area of pharmaceutical products. Current pilot models of delivery drone services mainly deal with technical issues of the service itself with lack of information about economic and organizational issues.

Main goal of this paper was to explore some of the economic implications of using delivery drones in existing logistic business processes. For this purpose, a scenario involving delivery of pharmaceutical products was developed.

We have applied discrete-event simulation and developed two simulation models each based on the same scenario involving delivery of pharmaceutical product to a hardly accessible destination. Experiments with this models provided valuable information to conduct comparative study of the results.

We concluded that implementing delivery drones is in line with business process perspective of organizations and as such they offer potential for additional automation of business processes as well as further improvements in efficiency of business operations (in terms of costs, maintenance, service responsiveness and flexibility). In order to take full advantage of this approach legislation still need to find best solutions that will not overly restrict the options and means of implementing delivery drones in product delivery, especially in specific situations of urgency and hard accessibility.

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