# THE USE OF DRONES TO HANDLE INTERNAL LOGISTIC FLOWS IN THE COMPANY FROM THE CHEMICAL SECTOR

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https://doi.org/10.37904/clc.2022.4572

**Abstract**

In logistics processes, we are currently observing trends related to reducing people's work in favor of the implementation of automated systems. It is influenced by the changes in the organization's environment and enterprises. The most frequently used autonomous systems supporting logistic operations include ground vehicles (e.g., AGV). However, many researchers emphasize that unmanned aerial systems will be the critical technology for factories operating following the Industry 4.0 concept. Companies from high-risk sectors are interested in automating routine logistics operations. In their case, the effect of implementing autonomous vehicles is to increase the efficiency and effectiveness of the process and reduce the occurrence of human errors, which are the source of adverse events. The article aims to present a project to implement an unmanned aerial system to handle internal manipulation operations between a warehouse and a laboratory at a manufacturer in the chemical sector. The research was conducted following the assumptions of the Business Process Management lifecycle. However, due to the level of advancement in the implementation of the presented project, the article will show the results of the first three stages of the research procedure: (1) Process discovery, (2) Process analysis, (3) Process redesign. Based on the analyzes, the main threats related to the implementation of the new solution were identified, as well as the potential benefits.

**Keywords:** Drones, unmanned aerial system (UAS), internal transport, safety, logistic service

## 1. INTRODUCTION

In logistics processes, we are currently observing trends related to reducing people's work in favor of the implementation of automated systems. It is influenced by the changes that occur in the organization's environment and enterprises. The most important of them include: (1) the growing importance and development of the Industry 4.0 concept and the related Logistics 4.0; (2) demographic changes causing high levels of turnover, high labor costs, and difficulties in recruiting employees; (3) continuous improvement of processes by eliminating the leading risk factor, which is human error. The implementation of automated solutions, including autonomous vehicles, also brings certain economic benefits [1]: (1) the capability to function on a 24/7 basis; (2) the minimization of labor cost; (3) the low maintenance cost; (4) the enhanced accuracy in daily activities; (5) the improved safety at industrial facilities. For this reason, automation usually concerns routine or dangerous operations for humans.

The most frequently used autonomous systems supporting logistic operations include ground vehicles (e.g., AGV). However, many researchers emphasize that the critical technology for factories operating following the Industry 4.0 concept will be unmanned aerial systems [2]. Kostrzewski et al. [3] indicate in their research that by 2025 the use of unmanned aerial vehicles in logistics processes will be one of the leading development trends not only in Logistics 4.0 systems. Today, the scope of logistic applications for UAS includes [4]: internal logistics of the company, identification of products in a warehouse, supervision over the company's infrastructure, and last-mile deliveries in highly urbanized areas. Research conducted by Wawrla et al. [5]

indicates the wide use of drones, primarily in cargo warehouse handling. This is also confirmed by numerous business reports and descriptions of implementations, which usually relate to supporting warehouse processes [6,7]. **Figure 1** shows the most popular areas of application of drones in warehouse operations.

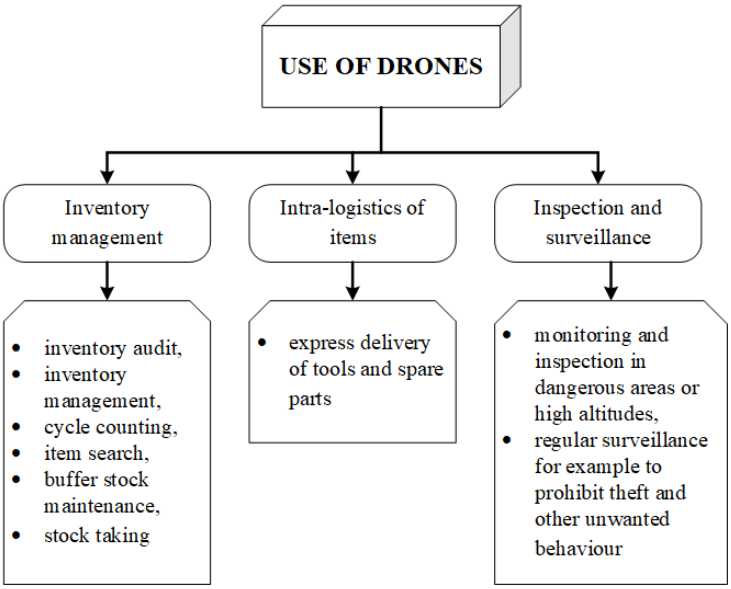


**Figure 1** The use of drones in warehouse operations [5]

The use of drones in logistics operations is also an issue that has been of particular interest to researchers in recent years. This is due to the fact that the implementation of these systems in logistics processes still generates numerous challenges and drawbacks as [8]: (1) technological challenges; (2) operational challenges; (3) organizational challenges; (4) legislative challenges; (5) societal and mental challenges. Among the publications on the implementation of UAS in logistics processes, noteworthy [9,10]. Also, the authors of this article have been conducting research on the analysis and assessment of risks related to implementing drones in warehouse service processes for two years. Our research so far concerned mainly the use of drones in the inventory audit process, and the obtained results were presented, among others, in [11,12].

Increased interest in the use of autonomous systems can be observed in sectors with a higher risk of operation. In these sectors, taking care of the safety of processes, systems, and employees is the main factor driving the organization's continuous improvement. One of such sectors is the chemical industry. The chemical sector is considered one of the essential branches of the economy. Due to its specificity, this industry cultivates the concept of a safety culture in the organization. It looks for solutions to eliminate human errors, the negative consequences of which may affect the company's operations and the environment. For this reason, enterprises from this sector are interested in implementing autonomous solutions that will reduce personnel participation in routine and hazardous operations related to the flow of hazardous substances. One of such processes is the transport of material samples for laboratory tests. Therefore, the article aims to present a project to implement an unmanned aerial system to handle internal manipulation operations between a warehouse and a laboratory at a manufacturer in the chemical sector. In addition to introductions, the article's structure includes section 2, which presents the methodology of the research. In section 3, the authors contributed and described the results obtained. The most important conclusion is presented in section 4.

## 2. METHODOLOGY

The research was conducted following the assumptions of the Business Process Management lifecycle, which includes five stages of the procedure [13]: (1) Process discovery; (2) Process analysis; (3) Process redesign; (4) Process implementation; (5) Process monitoring and controlling. Due to the level of advancement in

implementing the presented project, the article will deliver the results of the first three stages of the research procedure. The characteristics of the methodology, along with the research tools used and the results, are presented in **Figure 2**.

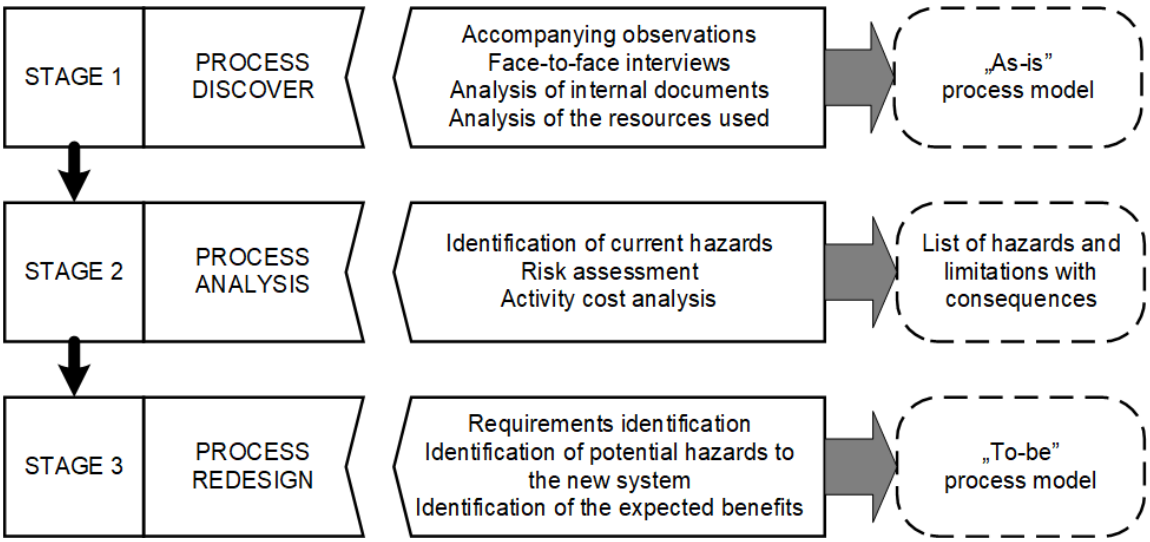


**Figure 2** Research methodology stages

**Stage 1:** The first stage of the research focused primarily on identifying and characterizing operations in the analyzed process. To create a process map and competence maps, the company's documentation was investigated, particularly the applicable procedures and scopes of duties of persons involved in the process. The source data was supplemented with the results of accompanying observations and unstructured direct interviews with process participants and managerial staff, which described (supplement the descriptions) the course of the process in the standard version and emergencies. The level of employee involvement and the technical and information infrastructure used was determined based on a resource analysis. The "as-is" process model was obtained as a result of the research work.

**Stage 2:** The "as-is" process model provided the basis for detailed process analysis. Due to the specific nature of the enterprise, the assessment was focused both on the criteria of effectiveness and efficiency of the process implementation, as well as on safety aspects. For this reason, the analyses included identifying threats and assessing the risk of adverse events occurring in the currently performed operations. The following tools were used for the analysis: cause and effect analysis, brainstorming, what-if analysis, and 5 x Why. A cost analysis was also carried out following the assumptions of the Activity Based Costing concept. The result of the analyzes was a list of the existing hazards and limitations of the current process, together with an assessment of their consequences.

**Stage 3:** The response to the results of Phase 2 was preparing a proposal for a new sample transport system using an unmanned aerial system that would eliminate the worker delivering samples between the warehouse and the laboratory from the process. The introduction of an autonomous system improves the efficiency and effectiveness of the current process and reduces the occurrence of identified adverse events. However, its implementation generates new adverse events with different characteristics. Their identification is required already at the stage of designing a new process. Therefore, in stage 3, identifying potential hazards related to the use of UAS in the transport of samples was carried out. The output of step 3 is the "to-be" process model.

## 3. RESULTS

The research was conducted in a manufacturing company in the chemical sector. The enterprise carries out its processes in several units located in one construction complex. The undertaken research procedures made

it possible to identify and evaluate the current course of transporting samples between the warehouse and the research laboratory. An illustrative diagram of this process is presented in **Figure 3**.

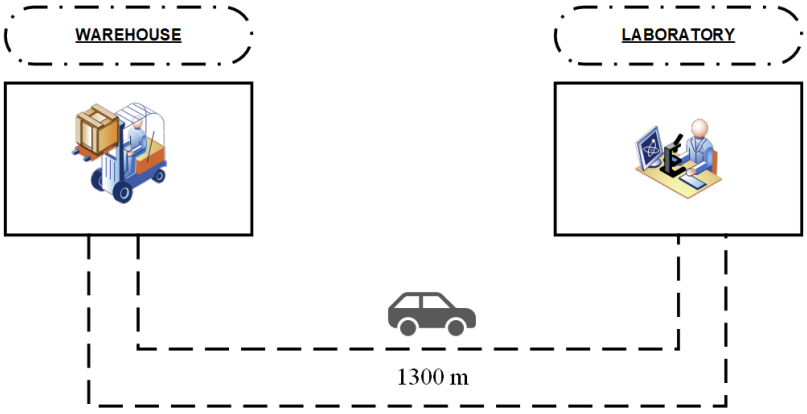


**Figure 3** The traditional process of transporting samples of hazardous substances

A dedicated warehouse employee handles the current process of transporting samples between the warehouse and the laboratory. This person is obliged to take a suitcase containing four samples with hazardous substances once an hour (8 deliveries a day) and deliver them to the laboratory. The distance between the warehouse and the laboratory is about 1000m, but due to the road layout, the employee must travel 1300m. A passenger car is used for transport, driven by an employee responsible for transportation. An employee takes samples from a warehouse on the 2nd floor and goes downstairs to the car. Then he transports the pieces to the laboratory, which is located on the 3rd floor of the second building. There is no elevator in both buildings - the employee travels with a suitcase on a staircase that is accessible to other people. The average transport time is a minimum of 10 - 15 minutes. The conducted analysis of the costs of activities was focused primarily on the costs of the resources involved in the process, including the costs of the employee and the cost of moving the load with the use of a car. Based on the obtained results, the logistics director assessed that the current process method is ineffective. At the same time, due to the type of transported cargo, there is a risk of negative consequences for the health of the worker involved in the process and the environment.

After analyzing the current state of affairs, the company recognized the legitimacy of automating this process. Among the arguments in favor of the automation of this process, the following were distinguished: (1) considering the process of moving samples as routine activities, (2) the possibility of human error, the consequence of which will be the loss of cargo or the risk of loss of health to employees; (3) release of existing resources (employee + car) for more complex operations; (4) shortening the process implementation time and response time to the existing transport need.

For the company's needs, a design of a new system for transporting samples with hazardous substances was developed. The new process diagram is presented in **Figure 4**, and the requirements for the designed system are presented in **Table 1**.

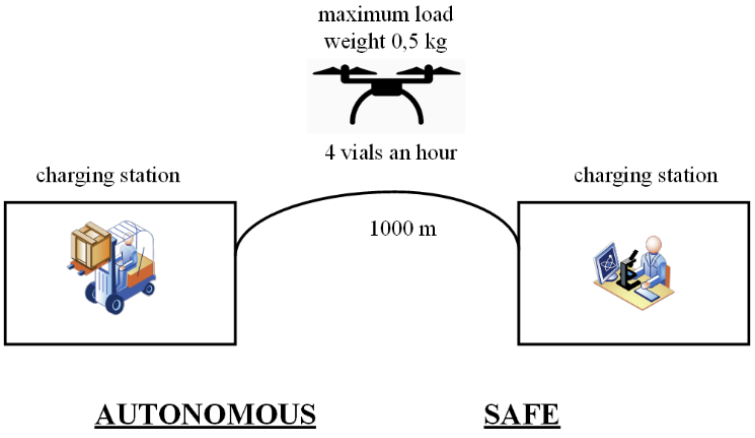


**Figure 4** The autonomous process of transporting samples of hazardous substances

**Table 1** Requirements for transportation of samples

| Requirement | Specification |
|---|---|
| Autonomy level | The flight is 100 % autonomous |
| Distance | Flight of the drone for a distance of up to 1000 meters |
| Freight | 4 vials containing hazardous substances |
| Frequency | 8 times a day (on average, one transport per hour) |
| Battery charging | Charging stations at shipping and pickup locations |
| Safety | The flight is carried out in conditions that are safe for employees and the environment |

For the developed solution, an analysis of the risk related to the autonomous implementation of the sample transport process was carried out. The critical hazards in the new system include: (1) the presence of objects at the height of the drone flight that should be taken into account when planning a mission (e.g., trees); (2) possible collision of the drone with other flying objects (birds, insects); (3) loss of communication with the aircraft while on a mission. A significant limitation of the implemented solution is the permissible load weight not exceeding 5 kg. It results mainly from the parameters of the load capacity of the drone used and the requirement of an autonomous flight in an open space (exposure to atmospheric factors). However, the use of a drone reduces the time of transport service to 4 minutes (2 minutes of flight + 1 minute for take-off + 1 minute for landing). This means that the flight frequency can be increased if there is a need to transport more samples.

## 4. CONCLUSION

The article presents a proposal to automate the process of transporting samples between the warehouse and the laboratory in a selected company from the chemical sector. Due to the contact of employees moving the cargo with a hazardous substance (risk of losing health and negative impact on the environment) and the high costs of the current implementation of this process, the company decided to implement drones in the sample transport process. Thanks to the implemented unmanned aerial system, the company will increase the efficiency and effectiveness of the current cargo handling process. However, it should be remembered that the introduction of an autonomous solution, on the one hand, will reduce the risk of human errors. Still, on the other hand, it is exposed to other adverse events related to the functioning of such a system. For this reason, in addition to the analysis of future benefits, it is also necessary to analyze possible hazards already at the stage of designing the proposed solution. In the risk assessment process, at this stage, it is crucial to test the proposed solution, analyses prepared by experts should complement the results of which. The initially developed solution is usually universal - it does not consider specific adverse events resulting from the environment of the missions being carried out and the specificity of the transported cargo. Thanks to the risk assessment results, the project can be customized, thanks to which the impact of the existing hazards will be minimized.

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