Exploring potential applications of drones in the petrochemical industry

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Abstract

The purpose of this paper is to investigate the potentials of using drone technology in petrochemical industry. Evidences from different industries reveal that industrial applications of drones are growing fast. Many petrochemical plants have started to use drones for visual inspections, and it seems that drones might become a source of technological innovation in the petrochemical industry. We conduct a multiple case study in the petrochemical industry. We collect and synthesize the opinions of 18 managers from three petrochemical companies. We describe potential use cases of drones in this industry and discuss perceived benefits and challenges.

Keywords: Drone technology, Petrochemical industry, Process innovation

Introduction

The purpose of this paper is to investigate the potentials of using drone technology in the petrochemical industry. Drones have been used in the agriculture industry for many years to increase the precision of mapping crops, fertilizers and pesticides (Mazur et al., 2016). Many other industries are evaluating or have started to use drones in their operations (Maghazei and Netland, 2017). For instance, solar power plants are evaluating applications of drones to monitor production levels and quality assurance through rapid identification of malfunctioning cells or panels; logistics companies are testing the possibilities of last mile deliveries by using drones (Wells and Stevens, 2016); and mining companies are using drones to monitor movements and stock management (Lee and Choi, 2016). It seems we are at the beginning of a mass-adoption of drones for various tasks in many industries. Notwithstanding industrial growth, there is little research about the use of drones in manufacturing operations.

Petrochemical industry is among those that shows high potentials for using drones. For instance, Royal Dutch Shell in a report entitled “Eye in the Sky” explains the use of drones for hazardous and time-consuming jobs, such as inspection of flaring stack which has increased safety of their operations. Another example is the case of gas leakages where drones can be used to monitor harmful gases as well as detecting the sources of gas leakage (Li et al., 2017). Drones also allow for gaining a quicker overview of incidents with less costly processes (e.g. no need for scaffolding). Drones can increase flexibility of petrochemical industry in inspection processes as well as increasing rate of inspections (Kridsada et al., 2016). Improving inspection operations in the petrochemical industry can bring huge cost savings where any failure of a critical equipment can turn into a plant-wide shutdown with enormous cost penalty.

Although there are many perceived benefits, industrial applications of drones in petrochemical industries also have several challenges. For instance, indoor applications of drones need to deal with localization of drones in a confined space, and collision issues (Floreano and Wood, 2015). Moreover, many areas in the petrochemical industry are considered to be hazardous with high safety measures which impose many constraints on applications of drones with new procedures that do not necessarily comply with pre-defined routines and existing standards. Specific characteristics of the petrochemical industry such as physical complexity of production processes with multiple components, safety protocols, and high standards imply that using drones is likely to be more challenging compared to the other manufacturing operations.

Potential applications of drone technology in petrochemical industry indicate that some of the existing operational and organizational processes might undergo many changes. In the past, the use of new technologies in the maintenance operations of petrochemical plants, such as non-destructive tests, thermography, and vibration measurement, has already allowed for non-intrusive inspections (Tsang, 2002). Integration of the drone technology into the inspection operations is likely to change some processes associated with, for instance, maintenance planning, information flow and systems, safety procedures, and training programs.

Drones can potentially become a source of technological innovation for the petrochemical industry. The degree of innovativeness of the drone technology for the petrochemical industry depends on what specific applications they can potentially deliver. Specifically, the current progress of drone technology allows for incremental changes in some processes (both primary and support activities) in petrochemical plants that might lead to efficiency improvement. In order to gain efficiency improvements from such a technological innovation, there is a need to explore what applications petrochemical plants can implement with drones. Therefore, we address the following research questions:

RQ1: What are the potential drone applications in the petrochemical industry?

RQ2: What are the potential benefits and challenges of using drones in the petrochemical industry?

Theoretical background

Innovation management scholars have studied the intentions of companies to foster technological innovation. Utterback and Abernathy (1975) explain the relationship between innovation and competitive strategy (e.g. market and growth), as well as innovation and production process characteristics (e.g. process equipment, work force, work and information flow). These intentions have roots in what companies aim to get from a specific technological innovation – exploiting existing competences, or exploring new capabilities (Teece et al., 1997). Therefore, companies need to define whether they aim to improve existing products, processes, or capabilities, or to establish new ones (Ghemawat and Ricart Costa, 1993).

Companies innovate in two ways, i.e. product innovation and process innovation. Product innovation is effectiveness-driven stimulated by market needs, and might lead to product quality improvement, new product development, etc. (Lager, 2002, Bergfors and Larsson, 2009). Process innovation is efficiency-driven stimulated by internal production objectives, and might lead to production costs reduction, production performance improvement, etc. (Lager, 2002, Bergfors and Larsson, 2009, Von Krogh et al., 2018).

This distinction between product and process innovation allows us to better understand the drivers of technological innovation, as well as the objectives they primarily address.

Given the distinction between the product and process innovation, specific characteristics of some industries might influence the management of technological innovation. For instance, process industries call for specific tools and methods for R&D and innovation management compared to other manufacturing industries (Utterbach, 1994, Lager et al., 2013). Lager et al. (2013) summarizes some of the studies that elaborate on specific characteristics of innovation management in the process industry. For instance, Frishammar et al. (2013) explain the experimental nature of technological innovation; Schmidt (2013) outlines the challenges of an efficient patent strategy; Storm et al. (2013) underline the importance of R&D-Manufacturing collaboration in order to achieve more cost-efficient production processes in the process industry.

Petrochemical plants are classified as process industry with often engineering-intensive, high cost and capital systems with multiple components (Hobday, 1998, Lager et al., 2013). Bauer and Leker (2013) outline that in the chemical industry as well as the other process industries; both exploration and exploitation exist for the product and process innovation. Exploration is associated with activities such as “search, experimentation, and discovery” and exploitation is concerned with activities such as “refinement, implementation, and efficiency” (March, 1991). Sinclair et al. (2000) explain that the goal of process innovation in the chemical industry mainly is to increase efficiency or cost reduction.

Use of drones in the petrochemical industry shows high relevance to the process innovation category of technological innovation that aims to improve processes as well as increasing efficiency, i.e. exploitative process innovation. Barnett and Clark (1996) identify four key areas of technological change in the process industry in which two areas aim to improve production equipment, and to improve levels of process control. Aylen (2013) proposes a taxonomy of ‘stretch’ that explains how incumbent plants can improve their processes and increase efficiency of their plants. He elaborates on improving maintenance operations as an underlying attribute of the ‘stretch’ mechanism, that is likely to increase the efficiency and reliability of production processes (Bauer and Leker, 2013).

Maintenance operations in process industries are very important and often account for large expenses (Levitt, 2004, Arts et al., 1998, Tan and Kramer, 1997). The chemical industry and its growth has established new areas in maintenance activities such as labor protection (Luxhoj et al., 1997). New technologies also allowed for developing new tools and techniques in maintenance operations, such as automated data collection systems, computer tools, and video technologies (Luxhoj et al., 1997). Similarly, development of the information and communication technologies (ICT), together with digital technologies (e.g. mobile devices, and wireless technology) created new possibilities to improve maintenance operations through remote sensing, and condition monitoring (Muller et al., 2008). These technologies support maintenance decision making, improve communication processes, reduce costs of downtime, and increase efficiency of maintenance operations (Muller et al., 2008).

Following the use of new technologies in the petrochemical industry, Li (2016) offers new perspectives for smart petrochemical factories which is mainly characterized by application of growing technologies – such as micro-electromechanical technology, big data, industrial Internet of Things, embedded technology, sensor technology, and intelligent robots – aiming at higher efficiency, safety, and sustainable development. We question whether drone technology can also improve operational processes and deliver similar benefits in the petrochemical industry like the other technological innovations.

Drones – defined as *flying robots* that can be equipped with different payloads (e.g. technologies such as sensors) – offer new areas of applications for petrochemical plants for exploitative process innovation.

Methodology

Our research explores applications of drone technology in the petrochemical industry. We apply a multiple case study (Voss et al., 2002). Our cases are three petrochemical plants located in the Middle East that are evaluating the future use of drones in their operations. The plants are anonymized as "Plant A" and "Plant B" and "Plant C".

We conducted 18 interviews with different managers and experts within the plants (see Table 1). Our interview guide included three main parts; the first part aimed at gaining a general understanding of the characteristics of the plant; the second part aimed at exploring potential applications of drones as well as benefits and challenges; and the third part was concerned with evaluation of a potential experiment project to use drones for the most promising use case. We also had site visits in two plants, and particularly in one of the plants, we visited the areas for the potential applications of drones.

Table 1- Interview details

Company name	Role of interviewee	Duration (min)
Plant A	Operations manager	45
	Head of Inspection Department	30
	Inspection expert	30
	Inspection expert	30
	HSE Manager	30
	Head of Maintenance Planning	45
	Complex Manager	30
Plant B	Inspection expert	20
	Inspection expert	30
	Inspection expert	30
	Inspection expert	20
	HSE Manager	30
	Complex Manager	20
	Head of Production Planning	20
Plant C	Complex manager	20
	R&D manager	30
	Head of engineering	30
	Operations manager	20

We tape-recorded our interviews and took notes during the interviews as well as site visits, and coded them with three categories of codes. The first category was concerned with specific applications of drones. The second and the third categories were defined based on the benefits and challenges associated with specific applications of drones. Following, we aggregated the specific applications (e.g. visual inspection of pipelines) into the main areas of applications (e.g. inspection) that allowed us to summarize all the potential applications for each area as well as benefits and challenges.

Findings

Based on our interviews and site visits, we classify the applications of drones in the petrochemical industry into four main clusters, and we identify concrete applications for each cluster (see Table 2).

Table 2 – Potential applications of using drones in the petrochemical industry

Area of application	Specific potential applications
Inspection	Visual inspection of pipelines, pipe-supports, gas flare, welding, silos, tanks, furnaces, stacks
	Thermal inspection of the tip of gas flare, and pipelines
	Internal thickness and corrosion inspection of drums and boilers
	Paint inspection of equipment
Health Safety, and Environment (HSE) support	Gas detection
	Noise monitoring for detection of leakages
	Helping patrol systems
	Supporting search and rescue teams
	Monitoring employees for hazardous activities
	Aerial imaging of the plant during natural disasters
	Imaging and video recording of manoeuvres
	Sampling plants to check the level of contamination
Maintenance	Delivering light spare parts such as gaskets during overhaul maintenance
	Monitoring maintenance teams
Warehouse	Counting
	Supporting firefighting systems of warehouses

We summarize the potential benefits and challenges of each area of application (see Table 3). The main benefits of using drones for inspection operations are increasing safety and rate of inspections, reducing cost and time of activities, and improving the reliability of production operations of plants. Main challenges are concerned with the drone technology and its operations such as safety and explosion proof, flight endurance, payload limitations, and redundant systems in case of failures, as well precision and reliability of collected data.

Drones have many potentials to support health, safety, and environment (HSE) activities in the petrochemical industry. For instance, drones can be an important tool in emergencies where workers cannot easily get access. Such capability of drones will increase safety, precision, and response time in search and rescue operations, as well as enabling plants to prevent incidents by regularly monitoring hazardous gases and noises. Moreover, drones can be used in manoeuvres to monitor and record videos of search and rescue teams in order to spot weaknesses and improving activities. In the future, advancement of the drone technology will allow for autonomous operations such as sampling plants to check the level of contamination in order to improve conformity assessment of environmental standards. The main challenges of using drones to support HSE department can be privacy, and security issues, as well as compliance with regulations and standards.

Drones can also be used in maintenance operations, mainly in overhauls. For instance they can deliver light spare parts and tools where workflow processes are rather disorganized. However, implementation of such application still needs further enhancement in the drone technology, particularly in the payload. The use of the drone technology in warehouse operations has been experimented by many other firms, and it shows that it has potentials to increase safety as well as improving data collection.

Table 3 – Potential benefits and challenges of using drones in the petrochemical industry

Area of application	**Benefits**	**Challenges**
Inspection	1. Improving data collection: better overview and access to hard to reach areas 2. Cost reduction: elimination of scaffolding, associated setups and labor costs 3. Increasing safety of workers 4. Increasing rate of inspection at regular intervals 5. Reducing the risk of plant shut downs due to unexpected incidents	1. Explosion proof 2. Safety issues in case of drone failure 3. Reliability of collected data 3. Payload limitation to carry different sensors and devices 4. Flight endurance 5. Collision with workers and equipment 6. Experienced pilots
Health Safety, and Environment (HSE) support	1. Increasing safety of workers 2. Improving emergency management during prevention, preparedness, response, and recovery 3. Better documentation of manoeuvres to improve performance of search and rescue teams as well as employees 4. Improving conformity assessment of environmental standards (self-declaration)	1. Security issues and permissions 2. Privacy issues 3. Regulations and standards
Maintenance	1. Quick delivery of spare parts 2. Reducing downtime 3. Increasing productivity of maintenance teams	1. Payload limitation 2. Collision issues 3. Privacy issues
Warehouse	1. Quicker data collection 2. Increasing safety	1. Power supply for autonomous flights 2. Reliability of collected data

Discussion

The explorative nature of our study allowed our interviewees to conceptualize potential use cases in their plants. However, there are several technological limitations of drones, which reduces its applicability in a real-life context. We classify the potential use cases into *Very Likely*, *Likely*, and *Unlikely* applications based on the time of adoption by the petrochemical industry that partly mirrors current capabilities of drone technology (see Figure 1).

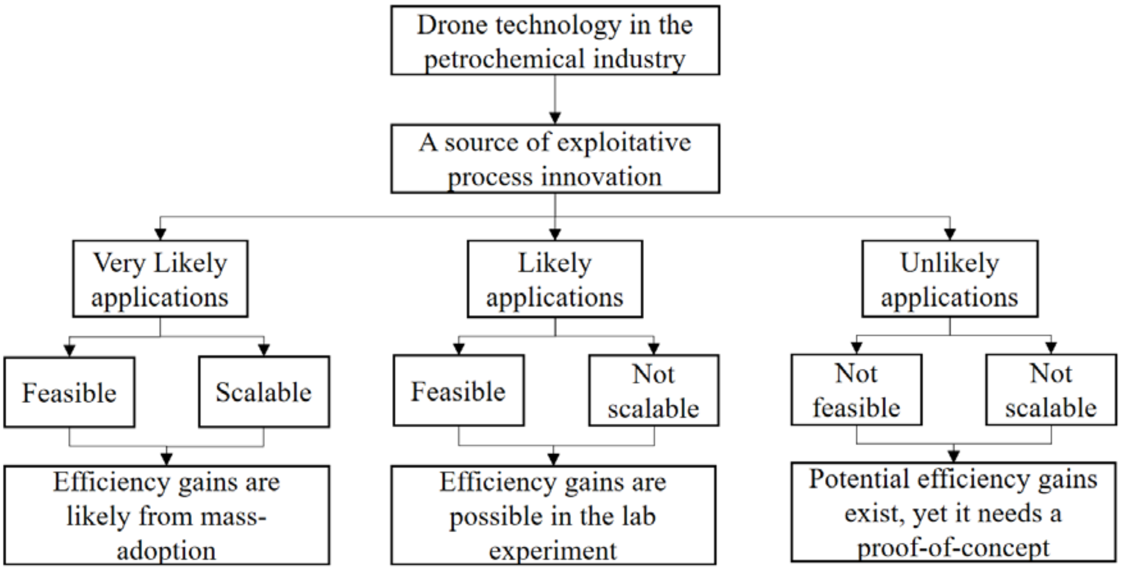

Figure 1- Classifications of the applications of drones in the petrochemical industry

We define *Very Likely* applications as uses cases that are currently both feasible and scalable and efficiency gains are clear. Visual and thermal inspections are among the most promising applications that are operational with current off-the-shelf drones, and petrochemical plants present viable contexts for such application (e.g. numerous equipment distributed in large areas). Using drones for visual and thermal inspections improve inspection and maintenance processes in several ways such as quicker access to hard to reach equipment as well as reducing costs. Large areas of petrochemical plants unlock potentials for such applications without addressing explosion proof concerns since many equipment such as silos, gas flare, and many pipelines are beyond restricted hazardous areas.

We characterize *Likely* applications as use cases that are currently feasible but efficiency gains from scaling them up requires further investigation. Moreover, they are not fully operational with current off-the-shelf drones. Examples are specific kinds of inspections such as thickness measurement, gas detection, supporting search and rescue teams, and counting items in warehouses in which they are experimented in labs, yet, replacing it with current operations at large scales need more investigation (e.g. cost-benefit assessment, integration with existing operations, and compatibility with information systems). One of the main problems for the large-scale adoption of such use cases is concerns about the precision of operations as well as the accuracy of the collected data. For instance, in order to collect accurate ultrasonic thickness measurement, drones should have remarkable stability. Another main problem with such use cases is the customization of drones, and the integration of payloads into drone systems that is concerned with battery issues, flight endurance, and reliability.

We define *Unlikely* applications as use cases that are not entirely feasible and scalable but represent some improvement areas that drone technology can address in the future. Current advancement of drones does not virtually allow for even testing some of these uses cases, yet they suggest a promising direction for the growth of drones in the petrochemical industry. For instance, physical advancement of drones allow for carrying tools and spare-parts in the maintenance operations, especially in the overhauls. Increasing the capabilities of drones in machine learning and artificial intelligence enhance autonomous operations of drones for instance in sampling plants for contamination, supporting patrol systems, firefighting systems, and search and rescue team in HSE departments. Moreover, the progress of this category is also associated with the progress of other technologies that drones will be equipped with, such as sensors.

We believe that all the three categories of potential applications of drones for petrochemical industry lead to incremental changes in the form of exploitative process innovation. Incremental changes are preliminary associated with “one or a few segments of a production process”, even though they might influence the whole system when they evolve (Robertson et al., 2012). Our findings reveal that applications of drones in the petrochemical industry would not lead to substantial changes in the production process of the plants, rather offer improvements in the activities of particular segment they are applied, such as maintenance, inspection, or HSE.

Ettlie et al. (1984) believe that incremental process innovation mostly takes place in large and complex organizations. Incentives to develop incremental process innovation increase when the industry matures and firms get bigger (Adner and Levinthal, 2001). In the work of Bauer and Leker (2013) on the chemical industry, they explain that substantial changes in the production process need higher investment, hence investment for the incremental changes better payoff. Pavitt (1984) describes chemical plants as relatively large firms with “little incentives to look for innovative opportunities beyond their principal sector”. We interpret this characteristic of the petrochemical industry with our classification of drone application; the more investment the drone application needs, the less likely petrochemical plants implement it.

Notwithstanding incremental changes of the drone technology and its influence on one or a few segments of production process, successful implementation of such technological innovation needs linkages to entire production system, complementary assets and utilities, and users (Teece, 1996). Such integration of drone technology into the production process of petrochemical plants is more important when they collect data at regular intervals and autonomously; and when the data has to be integrated into existing information systems such as computerized maintenance management system (CMMS), and warehouse management system (WMS). Another determinant of the integration of drones into petrochemical plants is the compliance with the standards and routines, particularly in inspection operations, and supporting HSE activities. Petrochemical plants have hazardous areas with classified zones (e.g. zone 0, zone 1, zone 2) based on the likelihood of an explosive atmosphere being present (Tommasini, 2013) which represents the challenges of integrating drones into such plants. We argue that the more complicated the integration of drone operations into the existing production processes and standards is, the less likely the implementation of it will be.

Conclusion

Application of drones are growing in different industries, yet the literature in operations management on the use of drones is at a very early stage. In this paper, we discuss how and in which areas drone technology can be used to carry out tasks related to *inspection*, *HSE*, *maintenance*, and *warehouse operations* in the petrochemical industry, and we identify benefits and challenges. We argue that drones can be a source of exploitative process innovation in the petrochemical industry that might lead to incremental changes into some of the production processes. We classify the identified applications of drones in the petrochemical industry into three categories of very likely, likely, and unlikely.

One of the main limitations of this study is the low number of the case companies for such an explorative research. Another limitation of our study is the lack of case companies where they have implemented or even experimented use of drones in their settings. Such case companies allow for a deeper understanding of the benefits and the challenges of the use cases in a real-life context. Another area of improvement can be the integration of other similar plants, such as oil platforms and refineries in order to enrich the findings, and to generalize them into a broader class of process industries.

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