Delivery drones from a technology assessment perspective

Overview report

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Delivery drones from a technology assessment perspective

Overview report

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Zusammenfassung

War das Thema Drohnen vor Jahren noch vom Militär dominiert, ist es längst im zivilen Bereich und im Alltag angekommen. Hunderttausende Spielzeugdrohnen sind weltweit im Einsatz und wir haben uns an atemberaubende Filmaufnahmen aus bisher ungeahnten Perspektiven gewöhnt. Immer öfter begegnen uns auch Überwachungsdrohnen, viele haben schon einen Videoclip eines „Drohnen-Balletts" gesehen oder beobachtet, wie sich eine Touristin mit einem „fliegenden Selfie-Stick" filmt. In vielen Bereichen werden Pilotversuche durchgeführt, um den Nutzen von Drohnen zu testen, etwa in der Landwirtschaft, im humanitären und medizinischen Bereich, bei der Überprüfung von Anlagen, im Vermessungswesen und nicht zuletzt in der Forschung, um nur ein paar Beispiele zu nennen. Schließlich lassen die großen Online-Händler, einige Postunternehmen und zahlreiche Startups weltweit vor unserem geistigen Auge eine Welt entstehen, in der Lieferungen des täglichen Bedarfs durch die Lüfte erfolgen werden.

drohnenbasierter Lieferverkehr ist voraussetzungsvoll, es stellt sich eine Reihe von Fragen, die noch nicht beantwortet sind

Insbesondere die Vision eines drohnenbasierten Lieferverkehrs ist freilich nicht voraussetzungslos. Viele regulative und technische Hürden werden noch genommen werden müssen, um sie Wirklichkeit werden zu lassen. Aufgrund der großen Eingriffstiefe dieser Technologieentwicklung – immerhin würde sich der uns umgebende Luftraum, der bislang nur von Vögeln und gelegentlichen Hubschraubern benutzt wird, gravierend ändern – stellen sich freilich eine Reihe von typischen Fragen der Technikfolgenabschätzung (TA): Bestehen Sicherheitsbedenken? Gibt es Umweltrisiken? Kann die Technologie für kriminelle oder terroristische Zwecke missbraucht werden? Besteht ein gesellschaftliches Konfliktpotenzial angesichts unterschiedlicher Interessen? Reicht die aktuelle Regulierung aus oder müssen neue Regeln geschaffen werden?

Überblicksstudie gibt erste Antworten

Diese Überblicksstudie stellt das Thema in groben Zügen dar und gibt erste Antworten auf die genannten Fragen. Sie basiert im Wesentlichen auf einer ausführlichen Internet- und Literaturrecherche, einigen ExpertInnen-Interviews sowie auf analytischen Überlegungen.

Die wesentlichen Ergebnisse lassen sich so zusammenfassen:

zahlreiche Anwendungen

- Es gibt zahlreiche Anwendungsgebiete für zivile Drohnen: vom Einsatz in Katastrophengebieten, in der Landwirtschaft und in der Forschung über die Filmindustrie, den Tourismussektor und den Journalismus bis zur privaten Überwachung, Unterstützung von Wartungsarbeiten und der Kartographie.

Hoffnungsgebiet für die Logistik

- Ein von bereits vielen Akteuren als vielversprechend erkanntes Gebiet ist die Logistik, konkret der Transport von kleineren Gütern zu den EndkundInnen.

einige technische Herausforderungen sind noch zu meistern

- Damit Lieferungen „durch die Luft“ ökonomisch machbar sind, müssen die Drohnen autonom fliegen können, also ohne Piloten am Boden. Dafür müssen noch eine Reihe technischer Herausforderungen gemeistert werden. Diese reichen von Gewichts-, Reichweiten- und Wetterproblemen bis zur Perfektion der Sensor- und Ausweichtechnologien. Prinzipiell dürfte davon ausgegangen werden können, dass es nur eine Frage der Zeit ist, bis diese Probleme gelöst sind. Darüber hinaus muss auch die nötige Infrastruktur am Boden bereitgestellt werden, etwa Landeplätze.

ein Markt entsteht

- Der Markt für Drohnenlieferungen entwickelt sich weltweit. Es gibt bereits viele Pilotanwendungen, insbesondere in Afrika und Asien, aber auch in Europa. Die bislang transportierten Güter reichen von Fast Food bis zu Medikamenten und Blutproben.

Österreich

- In Österreich gibt es eine Reihe von Drohnen-Herstellern und einige Forschungseinrichtungen, die sich mit Drohnen aus unterschiedlichen Perspektiven beschäftigen. Amazon testet hierzulande Drohnen und auch die Österreichische Post hat in Graz einen groß angelegten Pilotversuch durchgeführt.

fehlende Regulierung

- Die rechtlichen Voraussetzungen für autonom fliegende Drohnen sind in Europa und Österreich noch nicht geschaffen. Es gibt jedoch weltweit zahlreiche Gesetzesinitiativen.

zwei Szenarien

- Der Bericht unterscheidet bei der Untersuchung der potenziellen Folgen zwei Szenarien: (1) Lieferungen aller möglichen Güter des täglichen Bedarfs (von der Pizza bis zur Kleidung) und (2) Spezialllieferungen zu schwer zugänglichen Orten oder bei besonderer Dringlichkeit, etwa im medizinischen Bereich. Der Bericht kommt zum Schluss dass folgende Aspekte im Detail untersucht werden sollten:

TA-Aspekte:

Umwelt

- Drohnenlieferungen können Wildtiere stören (Vorbeiflug, Lärm); abstürzende Pakete oder Drohnen können die Umwelt verschmutzen; eine Lebenszyklusanalyse und eine Untersuchung des Energieverbrauchs müssten durchgeführt werden.

Gesundheit

- Abstürzende Drohnen können Verletzungen verursachen; bestimmte Ladungen könnten dabei auch Verseuchungen hervorrufen.

Arbeitsmarkt

- Der Markt für Arbeitskräfte, der im Zuge des Online-Shoppings massiv gewachsen ist, könnte wieder schrumpfen, abhängig von den konkreten Liefermodi und -szenarien. Insbesondere Jobs für gering ausgebildete Menschen könnten wegfallen.

Resilienz

- Eine massive Umstellung des Systems auf Drohnenlieferungen „auf der letzten Meile“ müsste berücksichtigen, dass Drohnen nicht immer fliegen können, also ein redundantes Liefersystem benötigt würde.

Ethik

- Bekannt aus der Diskussion zu autonomen Kfz stellen sich auch bei autonomen Drohnen ähnliche ethische Fragen, da vorab programmierte Algorithmen im Fall von Unfallsituationen ethische Entscheidungen treffen müssen. Weiters stellt sich etwa die Frage, ob dieser

Service für alle offen sein muss.

- Online-Shopping hat bereits das Verhalten und die Erwartungen der KonsumentInnen massiv verändert, noch raschere Lieferung durch die Luft wird das weiter verändern. *Verhalten von KonsumentInnen*
- Insbesondere in Szenario 1, in dem es zu praktisch allgegenwärtigen Drohnen in der Luft, auch im urbanen Gebiet, kommen würde, ist Lärmbelästigung zu erwarten, da zwar die einzelne Drohne leise, aber Schwärme laut wären. *Lärm*
- Es steht zu erwarten, dass Teile der Bevölkerung mit der massiven Nutzung des bodennahen Luftraums auch aus ästhetischen Gründen Probleme haben. *Ästhetik*
- Um autonom fliegen zu können, wären Drohnen mit einer Vielzahl von Sensoren und Kameras ausgerüstet, die eine große Menge von potenziell sensiblen Daten erzeugen. Diese können gespeichert und missbraucht werden. *Privatsphäre*
- Drohnen können auf einfache Weise für verschiedene illegale Zwecke missbraucht werden, vom Schmuggel bis zu terroristischen Absichten. Missbrauch ist schwierig unter Kontrolle zu bringen. *Missbrauch*
- Der Bericht gibt vor dem Hintergrund der o.g. möglichen Folgen eines Einsatzes von Drohnen im Lieferservice einen Überblick über potenzielle Regulierungserfordernisse. Insbesondere müsste das Luftverkehrsrecht „drohnen-fit“ gemacht werden; der Bereich KonsumentInnen- und Privatsphärenschutz untersucht werden; eventuell das Steuer- bzw. Abgabenrecht angepasst werden; sowie wirksame Mechanismen zur Rechtsdurchsetzung gefunden werden. *mannigfache Regulierungserfordernisse*

Im Abschlusskapitel wird argumentiert, dass aufgrund der vielen offenen Fragen und der Konfliktträchtigkeit dringend eine umfassende, auf Österreich fokussierende TA-Studie mit partizipativen Elementen durchgeführt werden sollte. *vertiefende TA-Studie mit BürgerInnen-Beteiligung für Österreich dringend notwendig*

1 Introduction

drones recently became ubiquitous, many fields of application are being tested

While ‘drones’ have been predominantly used by the military until quite recently, they arrived meanwhile in the civilian domain and in everyday life. Hundreds of thousands of toy drones or quadrocopters are around worldwide and we all got used to breath-taking shoots from so far unimagined perspectives. Increasingly we encounter surveillance drones, many of us have already watched a video clip of a “drones’ ballet dance” or observed how a tourist films herself with a “flying selfie stick”. In many other areas pilot tests are carried out to test the usefulness of drones, for instance in agriculture, in the humanitarian and medial sector, for inspection of facilities, in the field of mapping and surveying, and last but not least in research, just to mention a few examples. Furthermore the large online retailers, a few post enterprises and numerous start-ups worldwide lead us finally to imagine a world, in which everyday commodities will be delivered by drones through the air.

drones-based delivery is not without presuppositions

In particular the vision of drone-based delivery is not without presuppositions. To realise it, many technical and regulatory obstacles have to be overcome. Given the considerable depth of engagement – considering that the airspace around us, which was so far used by birds and occasional helicopters only, would change profoundly – a number of typical technology assessment (TA) questions are on the table: Are there safety concerns? Are there environmental risks? Could criminals or terrorists misuse the technology? Are we in the face of a societal conflict given the divergent interests involved? Does the current regulatory framework suffice, or do we need new rules?

This overview study presents this topic along general lines and gives first answers to the above questions. It is mainly based on an extensive internet and literature search, a few expert interviews and on analysis. Given the many open questions and the potential of conflict, we propose that an encompassing TA study with participatory elements focussing on Austria should be carried out urgently.

an encompassing TA study is urgently needed

1.1 Definitions and common abbreviations in the field

a 'drone' is an unmanned aircraft vehicle

A 'drone' is defined an unmanned aircraft vehicle or system[1]. This definition has two main parts: we talk about a flying object which has no pilot on board. Drones can be based on different technologies, some resemble more airplanes and have wings, others are more like helicopters with a rotor system. The latter, unlike helicopters, however, have more rotors, at least three, usually four and more. For instance a 'quadrocopter' or 'quadcopter' has four rotors and a 'hexacopter' has six rotors. Whatever the number of rotors, they are alternatively called 'multicopter' or just 'copter'.

a 'copter' is a drone with rotors

civilian drones

[as opposed to military drones]

Within this report, we focus on 'civilian drones', that is, unmanned aerial vehicles for civilian purposes only. We distinguish them clearly from drones that are used by the military or for military purposes. In particular, armed drones are not dealt with here. Use of drones by the police, e.g. for surveillance, strictly speaking is no civilian use either.

consumer vs. enterprise drones

Among the civilian drones, some distinguish between consumer drones, also known as personal drones, and enterprise drones[2], also known as commercial drones. While the first category refers to drones that are sold for hobby purposes and recreational use, the latter are used by enterprises to offer services by drones.[3]

autonomous drones

As mentioned earlier, drones have no human pilot on board. They could either be piloted remotely by an operator on the ground or they may be more or less flying autonomously. Although a remotely controlled flying object may give the impression of being autonomous, we define an object as 'autonomous' only if it is flying automatically on the basis of its program, meaning that it can operate and reach its target without human supervision, control, or intervention.

levels of autonomy

The concept of autonomous driving is well developed in the context of cars (and even ships: Krieger-Lamina/Nentwich 2016). We may apply and adapt the so-called 'levels of autonomy' used by the car industry to flying vehicles. In Table 1 below shows on the left side the five levels of autonomy with regards to autonomous vehicles. Based on this logic, on the right side we show how these levels of autonomy translate to drones and other autonomous aerial vehicles.

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[1] This definition of the European Aviation Safety Agency, easa.europa.eu/easa-and-you/civil-drones-rpas. is also shared by the Federal Aviation Administration of the United States, faa.gov/uas/. All URLs in this report have been last checked on 5.3.2018.

[2] Business Insider, 08.09.2017, businessinsider.de/commercial-uav-market-analysis-2017-8?r=US&IR=T.

[3] gartner.com/newsroom/id/3602317.

Table 1: Levels of autonomy or smartness

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*	Drone Smartness-Level
***Human driver* monitors the driving environment**							
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	A. Remote-controlled flight from ground with the pilot controlling with direct visibility
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	B. Remote-controlled, cameras on drone steam video to operator
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	C. Remote-control by autopilot with GPS stabilization
***Automated driving system* ("system") monitors the driving environment**							
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	D. Automatic: programmed route with self-reliant landing
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	E. Autonomous: programmed to target, self-reliant route-planning, self-sufficient in averting obstacles
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**	

Source: SAE International (2014)[4], adapted by Krieger-Lamina/Nentwich (2016), partly translated by authors

For additional reference, see the following short list of typical abbreviations used in the context of drones:

BVLOS	Beyond Visual Line of Sight
FPV	First Person View
MAV	Micro Aerial Vehicle
OPV	Optionally Piloted Vehicle
RPAS	Remotely-Piloted Aircraft Systems
SAA	Sense and Avoid Technology
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight
VLOS	Visual Line of Sight

[4] motorauthority.com/image/100593055_sae-levels-of-autonomy.

1.2 Structure of this report

Apart from this introductory chapter 1 this report has seven more chapters. In chapter 2 we give an overview of the areas of application of drones in the civilian domain, focusing on delivery drones in the second part. chapter 3 describes the technical status quo of the technology and the current challenges. In chapter 4 we give a preliminary overview on the emerging market of drone deliveries. chapter 5 gives a short introduction on the current legal rules applicable to (delivery) drones. Chapter 6 is the core chapter of this report. It distinguishes between a more far-reaching and a much more restricted scenario of drone delivery and then systematises the potential main effects, from safety and environmental issues to various kinds of societal impacts and potentials for conflict. On the basis of the results of the previous chapter, chapter 7 summarises the potential need for regulation. Finally, the concluding chapter 8 contains our reasons for advocating an encompassing and participatory technology assessment study, because the timing is perfect for anticipatory governance.

chapter 6 is this study`s core, focusing on potential impacts of widespread drone delivery

2 Application areas for civilian drones

2.1 General overview

While in the media and in everyday experience we encounter mainly toy drones and those employed by the film industry, there are many more areas of application for this novel technology. Its main characteristics – being relatively cheap, lightweight, fast, versatile, relatively quiet and so on – open up many potential fields of action in which drones may solve problems or replace the incumbent socio-technical arrangements, because they are more efficient or would improve the quality of a service. And indeed, there are already many pilot projects and sometimes regular operations in the field. See Table 2 for an overview, followed by a more detailed explanation and sources to each of the areas.

Table 2: Application areas for civilian drones

Disaster and emergency response/civil defence	Private surveillance
Environmental protection	Science
Surveying and mapping	Agriculture
Film Industry	Facility management and maintenance
Journalism	Delivery of goods
Hobby/toy	Law enforcement
Tourism	Illegal applications

current fields of usage of drones:

In the following we give an overview of the current fields of usage of drones:

emergency response

Disaster and emergency response as well as civil defence purposes can include in particular situation survey, location survey, civil protection through monitoring, search-operations. Drones can further be used as flying ad-hoc Internet access providers (especially in remote locations), and they can support rescue helicopters in their operations (as a 'second eye', see Bergtora Sandvik/Lohne 2014).[5] In the insurance business drones can be used for quick data collection, e.g. after a flood, for location survey, and for mapping.[6]

insurance business

environmental protection

mapping and surveying

In the field of environmental protection drones can be used for data collection, location survey, and mapping.[7] In general, mapping and surveying is a prime field of application, for instance for recording footage, where drones produce special maps (not only high resolution pictures, but also infrared and other wave-lengths, laser images etc.).[8]

film industry

journalism

The film industry uses drones to achieve spectacular shots from new perspectives; in addition footage is also often used for marketing and other commercial purposes.[9] In journalism current applications include observing sport events and being able to take footage from locations that are difficult to reach (closer to the target location, or approaching locations that are closed for humans)[10].

arts

Drones are also used for the purposes of arts. This can manifest itself in many forms, such as 'dance' performances (e.g. 'drone ballet'[11]), perfor-

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5 European Commission, 21.11.2016, ec.europa.eu/echo/field-blogs/stories/how-drones-can-help-humanitarian-crises_en.

6 Air-World, 20.06.2017, air-worldwide.com/Blog/5-Ways-Drones-Are-Transforming-the-Insurance-Industry/; The Balance, 03.02.2017, the-balance.com/how-drones-change-insurance-industry-4125242.

7 Environmental Law Institute, February 2017, epic.org/news/Drones-and-Environmental-Monitoring-ELI.pdf; SenseFly sensefly.com/industry/environmental-protection/; Remote Aerial Surveys remote-aerialsurveys.co.uk/environmental-monitoring.

8 New Atlas, 10.05.2017, newatlas.com/intel-drones-falcon-8-bridge-inspection/49452/; DJI, 11.10.2016, newatlas.com/intel-drones-falcon-8-bridge-inspection/49452/.

9 Production Hub, 02.10.2017, productionhub.com/blog/post/drones-and-their-impact-in-the-film-industry; SkySeeVideo, 16.08.2017, skyseevideo.com/drones-changing-film-industry/; Boston Globe, 23.06.2017, bostonglobe.com/business/2017/06/23/drones-rising-valuable-tool-commercial-film-industry/mbvWUH4Ydc5rkdHrMqxgjN/story.html.

10 There are a few websites dedicated to this topic: Professional Society of Drone Journalism, dronejournalism.org; and Drone Journalism Lab, dronejournalismlab.org. Furthermore, several articles discuss the topic: Cisco, 03.07.2017, newsroom.cisco.com/feature-content?articleId=1851973; Simulyze, 27.03.2017, simulyze.com/blog/drones-and-journalism-how-drones-have-changed-news-gathering.

11 FuturZone,19.12.2015, futurezone.at/digital-life/drohnen-verhuellen-nackte-taenzer/170.384.779/slideshow.

mances of drone swarms on the sky.[12]

recreational activity, toy

Obviously drones can be used for recreational purposes. This includes model-building, air races, private filming, using drones as a flying selfie-stick, and generally as entertainment for children, as well as adults.[13]

tourism

Apart from the just mentioned use of drones by the tourists instead of photo cameras, they can be used for marketing purposes, providing footage from new perspectives to advertise a particular place or event.[14]

private surveillance

Drones can be used by private persons as well as commercial enterprises as burglar alarms or supplements to CCTV on private estates; they can as well be tools for private investigators.[15] Although this is not a civilian application in the narrow sense also the police may use drones for surveillance, in particular during events (e.g. protest marches, sports events, cultural open-air events), or, potentially, for the pursuit of suspects, etc.[16]

illegal applications

Drones can also be used for illegal purposes, for instance for smuggling (e.g. of weapons into prison buildings, of drugs across a border, of illegal documents or money)[17], and for criminal (e.g. shooting) or terrorist attacks (for e.g. transporting of bombs); finally, espionage may be a wide field of application.

science

Within the domain of science drones can serve in particular as data collection devices, for instance in hard-to-reach areas like caves, the wilderness, or at archaeological sites; surveying and monitoring of wildlife and measuring environmental parameters (quality of air, level of pollution) may be easier and more efficient; finally special cameras (night light, infrared) can be used for observation.[18]

maintenance and facility management

The monitoring and inspection of various sites and large infrastructure nets, like pipes systems, rooftops, cables, rail tracks, ski-lift pillars etc. can also be done by special drones.[19]

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[12] Tech Radar 10.02.2018, techradar.com/news/intels-drones-broke-a-world-record-at-the-winter-olympics-opening-ceremony.

[13] Dronethusiast, dronethusiast.com/drone-videos-that-blow-your-mind/; TechCrunch, 08.01.2018, techcrunch.com/2018/01/08/watch-intels-drones-play-the-piano-and-dance-in-the-air/.

[14] Global Drone Solutions gdronesolutions.com/use-drones-tourism-marketing/; Skytango, 13.04.2016, skytango.com/how-drones-are-changing-tourism-marketing/.

[15] Tech Crunch, 22.08.2016, techcrunch.com/2016/08/22/drone-startup-aptonomy-has-created-robotic-flying-security-guards/.

[16] For a science-fiction account of police drones see (Hillenbrand 2014).

[17] FutureZone, 05.02.2015, futurezone.at/digital-life/us-start-up-plant-marihuana-lieferung-per-drohne/145.301.373.

[18] Columbia University, 16.06.2017, blogs.ei.columbia.edu/2017/06/16/how-drones-are-advancing-scientific-research/; Nature, 12.06.2013, nature.com/news/drones-in-science-fly-and-bring-me-data-1.13161.

[19] Control Solutions, 25.04.2017, controlyourbuilding.com/blog/entry/drones-in-facilities-management-saving-lives-time-and-money; ORF-Salzburg, salzburg.orf.at/m/news/stories/2737193/.

agriculture

Farming and agriculture is a field where drones may support the digitisation and precision farming efforts are currently under way. For instance particular parameters of the fields may be surveyed (such as humidity, temperature, pest attacks etc.); the application of fertilizers could be optimised and drones can be used for protecting young animals sleeping in the grass in front of a harvester. Drones can also be used as scarecrows.[20]

logistics

Delivery of goods can entail the transportation of small goods, meals, everyday supply goods, pharmaceutical products, medical samples, spare parts etc. This will be the main focus of this report. Passenger transport entails aspirations to use drone technology to transport people, i.e. in small electrical copters with several rotors for short distance flights.[21]

2.2 Drones for delivery in focus

In this report, the focus is on one specific application of drones, namely the delivery of goods. Either due to popular trends or economic considerations the idea of delivering items (small parcels, food, medicine and others) by drones is an idea that several enterprises from various fields have taken up and continue to engage with (e.g. Bruckner 2017).

a new market is unfolding

Following initiatives of small enterprises[22], large corporations as diverse as Amazon, Google (Project Wing), DHL or Mercedes-Benz and many others started to invest a lot of resources in testing delivery by drones and lobbying for making this service a reality. Many start-ups are launching delivery services by drones all around the word, testing the market and the legislative frameworks with this novel approach. Furthermore national companies such as national postal service providers have expressed interest in this novel idea, including the Austria Post.[23]

many open questions

Concerning the entire phenomenon, many questions arise: would delivery services by drones be successful on the market only for special items (e.g. in the medical sector), or would it expand to the delivery of all kinds of goods. Will this be a special service, serving only a small fraction of the population, or will this practice replace all existing delivery practices? Will fast delivery by drones be a premium-service for special occasions, or will society demand acceleration (e.g. delivery within one hour) for all deliver-

[20] Microaerial Projects, microaerialprojects.com/services/agricultural-environmental-monitoring/.

[21] A successful test was just recently carried out, see TechCrunch, 05.02.2018, techcrunch.com/2018/02/05/watch-ehangs-passenger-drone-take-flight/.

[22] Like pizza delivery by drones in New Zealand by the company Dominos, see CNBC, 16.11.2016, cnbc.com/2016/11/16/dominos-has-delivered-the-worlds-first-ever-pizza-by-drone-to-a-new-zealand-couple.html.

[23] Post AG has also engaged itself in a pilot project with drones, mapping up and testing the feasibility and economic dimensions of the idea. For further information on this see chapter 4.2.

ies? Finally, would even long-distance delivery be a field for drones?

These and many other questions will be opened up and discussed through the rest of the report. First, we start by examining the technical aspects of these questions.

3 Technical challenges

Civilian drones as multicopters are relatively recent. It is only a few years that they appeared on the market and increased in numbers. No wonder that the technology is still in development and the technicians face a number of challenges with a view to construct viable, secure and well-functioning systems. In this chapter we address a few of the main issues to be solved on the path to widespread use of delivery drones.

drones are technically not yet fully ripe for delivery services

3.1 Autonomous flying

Launching delivery services by drones seems only reasonable when they can be operated in an autonomous mode – except for very special scenarios (e.g. occasional fast delivery to remote areas). Otherwise the main reasons for launching such a service (such as cost reduction, automatization, speed) would be compromised if pilots are needed for each drone. However, to operate a drone autonomously is challenging in technical terms.–

The main challenge regarding the operation of autonomous delivery drones is the development of a robust *sense & avoid technology* (AAE/3AF 2015, p. 40ff). This term refers to a drone's capability to take-off, fly and land at the intended location and in the intended manner without colliding on the way. In order to do so the device has to have a continuously functioning and accurate geo-location device; clear vision through cameras (or radar) and well-developed algorithms to execute accurate landing. Beyond these, delivery drones would need to have the technical readiness to overcome challenges that weather, physical obstacles on the way (tall buildings, electric poles, cables, flying birds, other drones, and not least humans) and internal malfunctions could cause.

sense & avoid technology to be perfected

It is yet unclear which sense & avoid technologies (or which combination) would be the most reliable and cost-efficient. In particular, the development and testing of GPS, radar, infrared and other technologies are still ongoing. Up to today the threat of drones crashing (with another object or with each other) is a challenge, which the technicians have so far not solved satisfactorily.

reliable geo-location is essential

Furthermore, delivery drones would need to be able to respect the designated no-fly zones (see section 7.1 on geo-fencing), i.e. the need to have up-to-date access to the respective databases or air signals. Finally they need the ability to communicate and coordinate autonomously and constantly with the other air traffic and with air control.

respecting no-fly zones

communication skills

3.2 Further technical challenges

Apart from enabling secure autonomous flights, there is a wide range of further technical challenges for a drone-based delivery system to function properly.

atmospheric conditions

A prime concern is the weather. Most pilot projects to date have been carried out in 'ideal' weather conditions which raise the question: How would drones perform when there are typical, non-ideal conditions? Wind, precipitation (rain, snow), humidity, strong UVA radiation, fog, zones of low air pressure etc. are still difficult external circumstances for delivery drones[24]. Technical readiness of delivery drones need to reach a level so that they are able to cope with all possible micro-climate conditions of the territory they fly through. These questions would become especially relevant when we imagine launching a wide-scale delivery service that offers 'instant' delivery.[25] In addition, low temperatures would decrease battery performance significantly and hence reach (see below).

securing parcel on drones

Beyond weather, an additional technical challenge is how to efficiently secure parcels on drones. The scenario of losing packages involves a number of additional concerns, in particular questions of responsibility and insurance, as well as the consequences of delivering hazardous materials or if precious or vital parcels are lost (e.g. with a badly needed blood sample).

cargo weight restrictions

Regarding further aspects of delivery, the question of 'weight' represents another challenging factor. To date, there has been a number of pilot tests carried out with parcels ranging between 0.5-3.5 kg.[26] If the weight of the good exceeds this range, the wide-scale nature of a possible service would be in question (or different delivery drones would need to be employed that may affect the cost of the service – which is "advertised" to a more economic option compared to regular delivery services).[27]

decisive factor battery capacity

As the typical delivery drone has an electric engine, the battery capacity directly contributes to the overall weight of the aircraft and hence to the distance the drone is able to fly in one go. Reach is a decisive factor when we speak about both feasibility and cost-efficiency. While energy efficiency and battery capacity is certainly a field of rapid improvement, the current drone models diverge a lot in their capabilities based on the type of engine and battery and performance in speed and distance. A pilot project for example which was carried out in collaboration with the Austrian Post, tested drones with packages that weighted maximum 3.5 kg and which flew with up to 60 km/h to a 10 km distance.

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[24] UPS tests show delivery drones still need work', techcrunch.com/2017/02/21/ups-tests-show-delivery-drones-still-need-work/.

[25] futurezone.at/science/tu-graz-testet-drohnen-als-paketzusteller/274.382.090.

[26] futurezone.at/science/tu-graz-testet-drohnen-als-paketzusteller/274.382.090.

[27] See e.g. RedStage, 01.04.2017, redstagfulfillment.com/drone-delivery-is-about-to-revolutionize-the-supply-chain-industry/.

re-mating with the delivery van

Another relevant technical challenge is the act of re-mating with the delivery van. This part of the delivery sequence is reportedly one of the most challenging aspects when gross delivery is carried out with an accompanying van or truck.[28]

spoofing and hijacking

Lastly, there is a group of technical challenges that would result from vandalism and other human-generated actions against delivery drones: Spoofing is an act of manipulating the course or behaviour of drones by sending false GPS signals to them. By this, hijacking or crashes can be achieved. To date, technology to prevent such actions or to evade them is still underdeveloped, anti-jamming technology, shielding against radiation etc. seems to be in its infancy. But when such a service becomes widespread, its importance is going to increase and become outstandingly relevant.

3.3 Necessary infrastructure

In order to have delivery by drones as an everyday reality, several infrastructural elements need to be worked out and established.

landing spots

If delivery by drones would be permitted in urban settings, the first question to be addressed is where they would land. Initiatives aspiring for drone delivery in urban settings have approached the matter in various ways:

- In sub-urban areas, delivery to the backyard, balcony, terrace or doorway are imagined as viable options; in more urban areas they are not available, therefore
- WinPort (a German company) is currently developing landing ports that can be attached to windows;[29]
- Connect Robotics (a Portuguese company)[30] builds designated landing points for delivery drones, at which parcels could be collected;
- Matternet (a Silicon Valley start-up)[31] has approached the matter in a similar manner, diverging only in that aspect that it builds stations on private grounds (such as hospitals).[32]
- There are pilot tests in the United Arab Emirates[33] and on the grounds

[28] Blick, 27.09.2017, blick.ch/news/wirtschaft/neuer-service-von-mercedes-und-coop-heute-weltweit-erster-test-in-zuerich-die-drohne-liefert-das-paeckli-zum-auto-id7385534.html.

[29] win-port.de.

[30] connect-robotics.com.

[31] mttr.net.

[32] The Verge, 20.09.2017, theverge.com/2017/9/20/16325084/matternet-autonomous-drone-network-switzerland.

[33] By Costa Coffee, arabianbusiness.com/industries/technology/379426-costa-coffee-tests-drone-delivery-service-in-dubai.

of a universities (Virginia Tech, US[34]) aiming to deliver goods right into the hands of recipients.

Figure 1: Delivery drone brings coffee on the beach

Source: Arabian Business 2017[35]

delivery modes and needs on the ground

There are different delivery modes: The drone

- lands and deposits the parcel,
- stays in the air and lowers the parcel with a rope, or
- drops the parcel with a small parachute attached.

There are trials with all three methods, and the manner of choice will be dependent on the actual circumstances of the target location.[36,37,38] Depending on the delivery method, a different infrastructure on the ground may be needed, e.g. a basket in which the dropped parcel would fall or specifically marked and possibly sheltered areas for drone delivery. Here regulatory measures are to be expected (see below chapter 7).

parcel design

Additionally, there is another aspect regarding infrastructure that needs to be considered: the specific design of the parcels that the drones would be carrying. Obviously the current cardboard boxes would not be suitable for all weather conditions and some goods would need special protection that

[34] time.com/4493291/google-tests-drone-deliveries-virginia-tech/.

[35] arabianbusiness.com/industries/technology/379426-costa-coffee-tests-drone-delivery-service-in-dubai.

[36] theverge.com/2017/9/20/16325084/matternet-autonomous-drone-network-switzerland.

[37] technologyreview.com/s/602356/burrito-delivering-drones-seriously/.

[38] theverge.com/2016/4/5/11367274/zipline-drone-delivery-rwanda-medicine-blood.

goes beyond the usual packaging fillings as there is always the danger of dropping them from the air. Furthermore it may be necessary to develop more streamlined parcels as opposed to the usual, rectangular shapes. Another question would be whether in the future there would be a need for standardized parcels (shape and size), similar to the EURO pallets, in order to allow for general delivery services as opposed to company-specific services.

Our interim conclusion is therefore that several technical aspects and standards of drones still need further development before it would be safe enough to launch commercial delivery services.

4 A market for drone deliveries in the making

Despite the fact that technological readiness of delivery drones is not yet fully developed, it can be observed that initiatives continuously pop-up aspiring to put delivery services by drones onto the market (Lee et al. 2016; AAE/3AF 2015, p. 30ff).

4.1 Worldwide development

niche markets: special goods

local delivery of pizzas and drinks

general parcel delivery

In the landscape of services by delivery drones various approaches can be observed. Some business models are built on the idea of transporting special goods, aiming to serve a niche market, some target a wider audience. The former specialise on the delivery of medicine, blood samples, organs and business-specific small parcels. The latter business models usually target local delivery, frequently fast-food (e.g. pizza, burrito), various drinks (coffee, beer) or the delivery of small non-perishable goods (such as books, small electronics, etc.). Other business models would aim to expand, perhaps even revolutionize the whole market of delivery of small-scale packages that are now delivered by delivery vans. Note that often these services are closely linked to the parallel implementation of other digital tools, in particular online ordering.

drone manufacturers

Within this landscape of drone manufacturers there are a couple of large enterprises whose activities already stand out in pursuing further applications for drones.[39] The biggest producers are in China and the USA (see Table 3). The figures are impressive: In 2016 about 2.2 million drones have been manufactured and sold for recreational and commercial use.[40] That shows an estimated 60 % growth in production numbers, and 35 % growth in sales compared to 2015.[40] Revenues for toy drones and commercial drones were 1.7 billion USD and 2.8 billion USD in 2016, respectively.[40] Revenues for personal drones and commercial drones are estimated to rise to 11.2 billion USD by 2020.[40]

[39] See also droneii.com/drone-market-environment-map-2018 for a large database of the drone market.

[40] Gartner, 09.02.2017, gartner.com/newsroom/id/3602317.

Table 3: Largest producers of drones worldwide

Enterprise	Headquarter	Specialisation	Website
DJI	China	producing a wide range of commercial and recreational drones[41]	dji.com
Zero Zero Robotics	China	embedded Artificial Intelligence-powered camera in drones	gethover.com
3D Robotics	USA	autonomous drones with GPS point planning, so-called "smart drones"	3dr.com
Yuneec	China	manufacturing of commercial and recreational drones, software development[42]	us.yuneec.com
Parrot SA	France	recreational and commercial UAVs especially quadrocopters	parrot.com

the main actors in the field of logistics

Amazon, *Google*, and *DHL* are the largest companies worldwide that are on the frontline of testing the employment of drones for various services. However, not these big companies are the most important players of this developing industry. Rather there are dozens of start-ups at various locations worldwide that aspire to develop this market and which already run delivery services using drones. Indeed, the majority of the most widely known initiatives by drones have been carried out by small start-ups (e.g. *Zipline International, Matternet*). Note that only a few of these companies are located in Sillicon Valley, but the hotspot of delivery services by drones seems to be Africa (and Asia) – however some of those operators have their headquarters in first-world countries (see sub-section 4.1.1 below for specific examples).

[41] DJI also covers approximately 70% of the market, see Business Insider, 09.08.2017, businessinsider.de/commercial-uav-market-analysis-2017-8?r=US&IR=T.

[42] Yuneec together with DJI have been referred to as the 'Samsung and Apple of the drone industry', see Business Insider, 09.08.2017, businessinsider.de/commercial-uav-market-analysis-2017-8?r=US&IR=T.

Table 4: Big players and start-ups in the delivery sector

Enterprise	Headquarter	Specialization	Website
Zipline International	USA	blood samples and medical supplies	flyzipline.com
Matternet	USA	emergency goods and medical supplies	mttr.net
Amazon	USA	small parcels	amazon.com
Google/ Project Wing	USA	small parcels	x.company/projects/wing/
DHL	Germany	small parcels	dhl.com
Flirtey	New Zealand	pizza	flytrex.com
Flytrex	Israel	fast food	flytrex.com
Mercedes-Benz	Switzerland	coffee and sandwiches	mercedes-benz.com
Win-Port	Germany	small goods	win-port.de
JD.com	China	small goods	jd.com
AEON	Japan	small goods	aeon.info
Connect Robotics	Portugal	small goods	connect-robotics.com
Alibaba	China	small/middle-weight goods	alibaba.com
Asda	USA	small parcels	asda.com
Rakuten	Japan	small goods	rakuten.com
Starship Technologies	Estonia & UK	small goods	starship.xyz

public-sector companies

In addition, it is noticeable that several public sector entities also perceive the idea of delivery by drones as a potential opportunity. Numerous national post enterprises entered partnerships with start-ups specialized in delivery services by drones and launched pilot projects, most notably those of Switzerland, France, Finland, the United Kingdom, Ukraine, South Korea, Australia and also Austria.

delivery drones are a hot topic

Media coverage of delivery drones is especially high. Many articles follow and report on the development of this technology, giving account of initiatives, estimations, calculations and perceptions regarding the future, cost-efficiency, technical-readiness and social aspects of delivery drones.[43] Occasionally one gets the impression of a hype or technology push agenda. The social-media presence of delivery drones is outstanding. It is obvious that the theme is a hot topic from the point of view of various spheres and sectors from investment firms to public institutions.

[43] Television, radio, news portals, magazines and websites of investment firms, business magazines, tech magazines, social media (Twitter and Facebook), and other field-specialized websites (Drone World Expo; AUVSI International; Drone Life).

associations, conferences, expos

Furthermore, there are several events and organizations that specialize on unmanned aerial vehicles and commercial services by drones: for instance the Drone World Expo, AUVSI Unmanned and AUVSI Exponential by the Association for Unmanned Vehicle Systems International.[44]

4.1.1 Selected pilot tests with delivery drones internationally

The sphere in which delivery drones have first proven their usefulness and efficiency was the sphere of healthcare in developing countries. The companies that launched pioneering services were Matternet and Zipline International.

emergency good delivery in developing countries

Matternet has been the first to carry out pilot projects in Haiti, Lesotho and the Dominican Republic in 2014, transferring emergency goods and medical supplies to areas that are difficult to access. In 2015 they carried out further pilot projects in Papua New Guinea and Bhutan.[45] *Zipline* International is known to be the organization that started the first and still operational commercial delivery service in Rwanda in 2016, delivering blood samples and medical supplies. Further on, just recently in August, 2017 they acquired a contract with the Tanzanian government to launch permanent services in Tanzania as well.

food delivery

The value of services by delivery drones have been first recognized in such locations where sufficient infrastructure was lacking, or streets were in a bad condition, but there are other pilot projects that saw business potential from a different angle. A number of pilot projects were carried out for testing drones for food delivery. One noteworthy example was the pilot delivery of pizza in New Zealand in November 2016 by a drone start-up named *Flirtey* together with *Domino's Pizza Enterprise Limited*.[46] Another interesting example is *Flytrex* (an Israeli company), which tested delivery of fast food in Rejkjavík, Iceland. Since August 2017 the service went beyond the experimental phase – so it is the first permanent food delivery service by drones. Others are following, such as *Mercedes-Benz*, which launched in September 2017 a pilot project in collaboration with *Matternet* and the Swiss company *Siroop* to deliver coffee in Zürich. By now this pilot has been completed and the latest articles say that this service will be launched in Zürich on a continuous basis, making it the world's first delivery service by drones in an *urban* setting.[47]

[44] auvsi.org.

[45] fortune.com/2015/05/01/matternet-drone-delivery/.

[46] dominos.com.au/inside-dominos/media/november-2016-pizza-by-drone-a-reality-with-world-first-customer-deliveries-in-new-zealand.

[47] cleantechnica.com/2017/09/25/matternet-launching-first-permanent-autonomous-drone-delivery-network-switzerland/.

Other than the mentioned examples there are several more reports about food delivery services in various locations all around the word (India, Korea, Japan, etc.), but so far, due to various regulations and regulatory processes (see section 5.2) the launch of these services is in limbo.

4.2 The status quo in Austria

In Austria there are a number of companies and start-ups that engage themselves with drones. Some of them are manufacturers, others offer various commercial services by drones, and a few do both.

quite a few Austrian drone manufacturers

Austria has a number of manufacturers of drones, although only some for commercial activities. *Schiebel* produces drones and other unmanned vehicles for both commercial and military purposes. *Stromkind* is a company that develops aerial, 'land', and 'aquatic' drones to fulfil environmental protection, disaster response, and risk mitigation functions. It might be worthy to note that just recently, this company won the Pioneer's Challenge Award for 2017.[48] *Austrodrones* and *Diamond Aircraft* are also special purpose drone manufacturers. *Dynamic Perspective* is a manufacturer of various unmanned aerial vehicles (UAVs), high precision cameras and sensor stabilization systems, which are specifically developed for the film industry. *Airborne Robotic* is not a manufacturer, but provides services for video and photography. *Riegl* is a company that has over 40 years of experience in developing and applying laser measurements systems, and which also employs drones and various other unmanned vehicles while doing so.

Other entities that engage themselves with drones are various universities and research institutes such as the Technical University Graz, Technical University Wien, AEC Linz, and the Alpen-Adria-University of Klagenfurt.

The Technical University of Graz has a division that engages itself with drones within its Institute of Computer Graphics and Vision. The division is called "Dronespace" which is a Micro Aerial Vehicle (MAV) Flying Environment, where testing of drones is carried out with a motion tracking system called Optitrack[49]. With this technology, researchers are aiming to better understand and control the movement of drones and improve its sense & avoid technology.

The Technical University of Vienna is engaged with the technology of combining autonomous flights with Smartphones. Within the project SmartCopter[50], researchers within the laboratory of Virtual and Augmented Reality[51] are testing an on-board core processing unit on the basis of

[48] pioneers.io/blog/post/stromkind-wins-pioneers-challenge-pioneers17.

[49] optitrack.com.

[50] ims.tuwien.ac.at/projects/smartcopter.

[51] ims.tuwien.ac.at/research/virtual-and-augmented-reality.

smartphones to allow for autonomous localization, mapping, exploration and navigation in an unknown environment, without requiring additional ground hardware for UAVs.[52] This could allow to reach an additional level within the development of delivery services by drones if on a mass scale.

Table 5: Austrian drone manufacturers and service providers

Enterprise	Headquarter	Specialisation	Website
Schiebel	Vienna	development of larger UAVs and mine detection systems - also for the military	schiebel.net
Stromkind	Vienna	development of UAVs for environmental protection, disaster response, risk mitigation	stromkind.at
Austrodrones	Alberschwende	drone manufacturing and flight services	austrodrones.com
Dynamic Perspective	Vienna	development of UAVs and high precision cameras, sensor stabilization systems	dynamicperspective.com
Airborne Robotics	Klagenfurt	drone manufacturer especially for the film industry	airborne-robotics.com
Riegl	Horn	development of laser measurement systems that are employed by using drones	riegl.co.at
Drone Rescue	Graz	development of parachutes for drones	dronerescue.at
Team BlackSheep	St. Anton a. A.	manufacturing quadcopters	team-blacksheep.com

The Ars Electronica Center (AEC) in Linz engaged itself in a project that aimed at making a spectacle with 100 autonomous drones to demonstrate what can be achieved by the power of technology and programming. This performance was created in 2016 in collaboration with Intel and made a world record at this time.[53]

In the Alpen-Adria-University Klagenfurt, within the scope of project SO-SIE[54], researchers have specialized in advancing system intelligence connected to drone technology, where they are working to develop a method for dimensioning a drone-based delivery service that would be used by start-ups and companies that plan on deploying a drone delivery service. [55] The research group is funded by the Carinthian Economic Development

[52] ims.tuwien.ac.at/projects/smartcopter.

[53] Since then, Intel surpassed previous world record at the opening of the 2018 Winter Olympics in South Korea, techradar.com/news/intels-drones-broke-a-world-record-at-the-winter-olympics-opening-ceremony.

[54] aau.at/en/blog/packages-delivered-by-air-drones-as-delivery-service/.

[55] nes.aau.at/?p=7093.

Fund and works closely in collaboration with Lakeside Labs GmbH[56].

To date, there is only one known company in Austria that carried out a delivery pilot project by drones, and that is the Austrian Post (Post AG)[57]. Please see next section for details.

See also a recent bachelor thesis, to be defended at the Vienna University of Economics and Business Administration (Lustig 2018), which approaches the subject from a transport logistics perspective.

4.2.1 Pilot projects in Austria with delivery drones

Amazon testing area

Austria seems to be an interesting territory concerning the development and testing of delivery drones, perhaps because of the varied landscape. For instance, it is one of the few sites worldwide where Amazon's delivery drones are being developed and tested[58], and there are a number of Austrian start-ups which engage themselves with the development of delivery drones for emergency response (e.g. *Stromkind*); finally, just recently the Austrian Post conducted a pilot project, testing alternative delivery methods by drones.

In collaboration with Technical University Graz, Austria gives home to the development of Amazon drones' sense & avoid technology. The research centre is situated in the outskirts of Graz where the work is led by leading experts from various technical universities and research institutes.

[56] Lakeside Labs is an entity that claims to be a 'hub for science and innovation in self-organizing networked systems' in Klagenfurt, lakeside-labs.com.

[57] tugraz.at/tu-graz/services/news-stories/tu-graz-news/einzelansicht/article/post-ag-und-tu-graz-erproben-autonome-transportlogistik-auf-der-letzten-meile/.

[58] theverge.com/2016/5/10/11642686/amazon-prime-air-lab-drone-delivery-microsoft-experts-austria; techcrunch.com/2016/05/10/amazon-prime-air-opens-austrian-outpost-with-focus-on-sense-and-avoid-tech/.

pilot project of the Austrian Post

In another notable pilot project with drones the Austrian Post was recently experimenting with alternative delivery methods. In September 2017 a pilot project called 'HEIDI' was completed. The test comprised 1000 test flights with drones that were carrying up to 3.5 kg packages to a distance of 10 km and flying with up to 60 km/h to a rural setting in the Alps in Styria. Besides the drones, a special utility vehicle called 'ELI' was also tested. In this setting, the drones were completing the deliveries, flying off of a special delivery van and repeatedly returning to it while the van is in motion. The pilot project was reported to be successful, functioning well from a technical point of view in 99% of the cases.[59] The team announced its plans to test delivery by drones very soon within an urban setting as well (in the centre of Graz).[60]

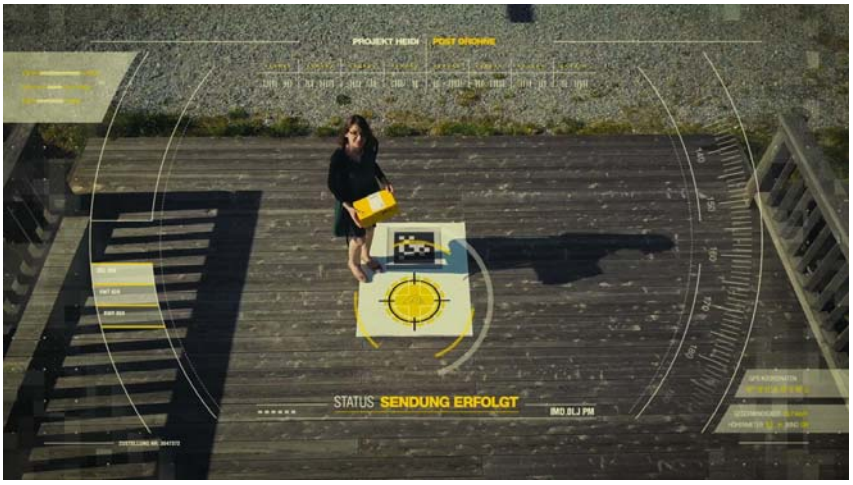

Figure 2: Customer receiving a parcel by a drone from the Austrian Post
Source: futurezone.at [61]

provisioning an alpine hut

In summer 2017 another experiment with a delivery drone took place: Initiated by the Naturfreunde Österreichs, a hiking NGO owning a number of shelters in the mountains, a (remote-controlled) drone delivered food to a hut in the alps in the Salzburg region. The drone could carry 100 kg, fly with 120 km/h and up to 1000 meters. The trial was successful; the main problem was the capacity of the batteries (only 20 min). The initiator argued that this may be the future for provisioning remote huts as an alternative to expensive and environmentally unfriendly helicopter flights.[62]

[59] futurezone.at/science/tu-graz-testet-drohnen-als-paketzusteller/274.382.090.

[60] Apart from drones the Austrian Post also experimented with unmanned vehicles as an alternative delivery method. Within this pilot, TU Graz, Post-AG und i-Tec Styria conducted a pilot project in downtown of Graz, testing a land unmanned vehicle, kurier.at/wirtschaft/steirischer-roboter-stellte-post-in-graz-zu/293.798.027.

[61] futurezone.at/science/tu-graz-testet-drohnen-als-paketzusteller/274.382.090.

[62] ORF Salzburg, 21.8.2017, salzburg.orf.at/news/stories/2861539/.

The local helicopter company seems not alerted, arguing that such drones would have to fly ten times more often than the helicopter; in addition a spokesperson raised safety concerns.[63]

Figure 3: A drone delivers food to an alpine hut

Source: ORF Salzburg[64]

These examples suggest that there is either a sense of need or business opportunity from a practical point of view (to experiment with delivery by drones), or a demand felt in the logistics industry, not only in Austria, but also by several other postal services elsewhere.[65]

[63] ORF Salzburg 22.8.2017, salzburg.orf.at/news/stories/2861765/.

[64] salzburg.orf.at/news/stories/2861539.

[65] techworld.com/picture-gallery/apps-wearables/best-uses-of-drones-in-business-3605145/.

5 Legal aspects of employing drones

5.1 Civilian drones in general

The legislative system surrounding drones is a remarkably complex matter on which various countries have various uptakes, approaches, and as a result different laws. While there are certain common elements, there is a large degree of variation, especially when we look at the situation worldwide, but even within the European Union.

Generally speaking, the regulation distinguishes between non-commercial (recreational) and commercial use.[66] Several criteria and conditions apply to each use and operation. The drones themselves have to be licensed by the European Aviation Safety Agency (EASA) if they weigh more than 150 kg, below that it is the national aviation agency, for instance Austro Control. If still lighter they may be regulated differently; in Austria, for instance, all drones lighter than 25 kg are licenced by Aeroclub (ÖAeC)[67], if the drones are not commercially used. The toy drones with less than 0.25 kg that fly no higher than 30 meters are usually not covered by the more strict rules. Beyond that the main distinction by the law is about whether or not the pilot is in eye contact with his/her drone. Without eye contact – which includes piloting with the help of a camera transmitting pictures taken from the drone ('first person view') – flights need to be individually allowed (for more details see Knyrim/Kern 2014). The current regulation, at least in Europe, does not cover autonomous unmanned aerial vehicles. In most legislative frameworks neither flying a drone with a camera[68] nor above a crowd of people is permitted unless with a special licence.

autonomous aerial vehicles are not covered by legislation in Europe and need therefore individual licences for each flight

Interestingly there are several legal concepts that are either not exactly defined or not defined at all, for instance airspace: above what height do we consider the space 'airspace', or up to what height is it a person's property? There are certain countries where it is not clearly defined whether the air over one's property is *their* property, therefore in many cases it is unclear whether one is entitled to claim rights for or against objects flying over their property or not.

This and various other parameters are not clear or exact, but would come afore in the case of the launch of wide-scale delivery services by drones.

[66] dronerules.eu/de/; for a short overview see also (ITA 2014).

[67] aeroclub.at.

[68] futurezone.at/digital-life/drohnen-fotografie-alle-fluege-muessen-genehmigt-werden/163.784.355.

5.2 Delivery drones in particular

current laws do not allow delivery drones

Obviously delivery drones do not belong to the category of lightweight flying objects (which their toy equivalents are) because they need to carry a load in addition to the equipment needed for autonomous flying (such as cameras and other sensors etc.). So delivery drones could only be employed under special conditions (e.g. license). For on-board cameras etc. one would need a special extra license given by the aeronautical authority. However, so far, autonomous drones do not exist in the law and are therefore currently not permitted for use in Austria. In addition, delivery drones would have to fly over people and urban areas, something which – under the current regime – can only be allowed by the authorities on a case-by-case basis, which is obviously not suitable for a business model for regular deliveries.

need for new rules

The legal framework would have to be adapted for delivery drones, for instance with an additional drone category with special rules. This means that there would be a need for regulation in order to enable mass deployment, especially when the delivery service by drones would be authorized in urban areas.

the cross-border and international dimension

Furthermore, more questions would arise when it comes to cross-border flights, similar to the big airplanes, for instance: Would one need also a license in the other country or does the home license suffice? Are there different rules in the other air territory? The European Union is currently developing a legal framework aiming at harmonizing the different national approaches.[69]

examples of legislative initiatives

Since the inception of the idea of delivery with drones, the United States was in the forefront of starting initiatives for the legislation of commercial drone activities for delivery services. At the same time, even recent as well as past initiatives were so far unsuccessful in reaching substantial progress. It would be interesting to know why a country which is usually at the forefront of enabling new technological ideas is in a legislative limbo. The question of speed and the question of success in making drone delivery services possible seem to depend on numerous factors that are deeply embedded in the particular country's socio-cultural and economic context and their legislative traditions. In a number of cases in Africa (Lesotho, Rwanda, Tanzania) and Central America (Haiti, Dominican Republic), it can be inferred that the legislation of delivery activities by drones were made possible in a faster way. It seems that for these countries it may have been the condition to receive aid and support by those organizations offering help in various humanitarian and emergency response

[69] See IDG News Service 20.06.2017, via cio.com/article/3202386/vertical-industries/eu-wants-to-ease-commercial-drone-use-with-future-flight-rules.html; in 2015 the EASA European Aviation Safety Agency, easa.europa.eu made proposals for drones 'with restricted risk', see easa.europa.eu/download/ANPA-translations/205933_EASA_Summary%20of%20the%20ANPA_DE.pdf.

situations.[70]

various legislative initiatives world-wide…

The vision of potential growth seems to drive legislative initiatives. In China, reasons of practicality enabled legislation in regions where it would otherwise be very difficult to manage logistics.[71] This was also the case in Iceland where, additionally, population density and their socio-cultural background favoured drone delivery as an ideal solution.[72] Various benefits and the potential of economic growth was probably also the reason driving legislative initiatives in Europe as well. In the summer of 2017 it has been reported that the European Commission aims to ease regulations on light-weight drones to enable logistics, inspection services and agricultural businesses.[73]

… including at the EU level

[70] See the following examples: Tanzania, flyzipline.com/uploads/Tanzania%20Announcement%20Press%20Release%20vFinal.pdf; money.cnn.com/2017/08/24/technology/east-africa-drones/index.html; Rwanda, qz.com/1003810/the-worlds-first-commercial-drone-delivery-operates-from-a-hill-in-rwanda/.

[71] Economic Times 07.11.2017, economictimes.indiatimes.com/news/international/business/alibabas-drones-deliver-packages-to-islands/articleshow/61545583.cms.

[72] Bloomberg 23.08.2017, bloomberg.com/news/articles/2017-08-23/iceland-set-to-become-island-of-drone-deliveries.

[73] IDG News Service 20.06.2017, via cio.com/article/3202386/vertical-industries/eu-wants-to-ease-commercial-drone-use-with-future-flight-rules.html.

6 Overview on potential impacts of employing drones for deliveries

chapter overview

In this chapter, we give an overview about the possible impacts of the introduction of commercial delivery drones (AAE/3AF 2015; Rao et al. 2016; from a TA perspective see Čas 2015; ITA 2014; Nentwich 2015; Krieger-Lamina/Nentwich 2016; Nentwich 2017; Moe 2013; POST 2014). In this overview study, only a preliminary analysis can be made, which should be explored in a follow-up study. The topics addressed here are: environmental risks (6.1), health risks (6.2), societal impacts and potential areas of conflict (6.3) and protection against misuse (6.4). Section 6.3 in particular is addressing the following aspects: the job-market, resilience of delivery systems, ethics, consumer behaviour, noise pollution, aesthetic derogation of airspace, protection of private sphere, and commercial use of the public good ground-level airspace.

Throughout this chapter we use two scenarios[74] in which we preliminarily test and assess the potential consequences of drone deliveries:

scenario 1: widespread delivery of all kinds of small goods

The basic scenario no. 1 (the so-called 'pizza scenario') on which we focus our examination on is the widespread delivery of all kinds of small goods (parcels) by drones, instead of (or in combination with) delivery vans and trucks. Within this scenario, drones would be fulfilling the function of the so-called "last mile delivery": this means that various logistics providers would use the urban (and rural) airspace on a regular basis to deliver goods by drones to the consumer.

scenario 2: delivery of special goods only (niches)

The alternative scenario no. 2 (the so-called 'emergency scenario') is less far-reaching: the delivery service by drones would only be a niche market, in which special goods, e.g. in the medical field, would be routinely transported between hospitals, pharmacies, and practitioners, or for other emergency purposes. Another potential niche market could be the regular supply of goods to remote areas, where no roads lead or there is no other connection in specific seasons.

Obviously most of the impacts discussed below are much aggravated in the case of scenario no. 1 as it is about ubiquitous and massive drone flights, whereas in scenario no. 2 flights will take place less frequently, perhaps only occasionally. We flag out those risks that are negligible if only scenario no. 2 would be implemented.

[74] Note that these ‚scenarios' are not scenarios in a strict technical sense, i.e. not created using the scenario technique, but rather ad-hoc 'narratives' describing in general terms possible futures.

6.1 Environmental aspects

threat to wildlife

As drones would move in the environment (both natural and man-made) they pose potential risks for it. The first concern is the drones' effect on wildlife, and birds especially. When drones intrude into the habitat of animals, there would be a double risk: either the animals may be harmed, or they could be a threat to the effective operation of drones. Concerning the latter, such scenario has already been documented in Austria when eagles mistook drones for food.[75] Regarding the former, there are concerns that due to the possibility of collision, the safety of birds could be at higher risk (see the related discussion with regard to windmills). Note that it is not only wildlife that could be affected. Depending on the territory the drones would be allowed to fly through, they could have an impact on various range of domesticated animals (pets and farm animals) as well.

noise

Even without collisions, the noise and frequent presence of these devices in the habitats of animals may be a stress for them, similar to nearby roads. To date, the effect of noise produced by drones onto wildlife has not been studied yet, but there are serious concerns that should be taken into consideration. Several factors play a role: the height drones would be required to fly, the territories they would be allowed to fly over, and the places where they would be allowed to land.

debris

A further possible environmental risk is debris. Either as a result of collision or in the case of forgotten or abandoned goods, the question of waste poses another series of challenges. The matter or responsibility and actual response comes afore: who would be responsible for cleaning up debris, and who would bear the cost of damage or compensation? This issue reminds us of wild dumps, for which it is difficult to assign responsibilities.

energy consumption

A further environmental aspect to be considered from a technology assessment perspective is energy consumption. Drones need electricity and although each individual flight would not consume much, the overall picture of a generalised drone delivery system may be different, in particular if compared with current deliveries with cars carrying many parcels at once. In a recent research article the authors conclude that for parcels up to 0.5 kg the energy balance is in favour of the drones (Stolaroff et al. 2018). However, the overall assessment may be different if the whole infrastructure is put in perspective (Redaktion 2018). Overall, a serious eco-balance (life-cycle assessment) is warranted, including among other factors the life cycle of the batteries needed.

eco-balance needed

[75] The Independent, 13.11.2015, independent.co.uk/video/News/two-eagles-mistake-a-drone-for-food-in-austria-a6733351.html.

6.2 Health and safety

injuries because of collisions

There are two kinds of health risks resulting from accidents. First, malfunctions of the navigation system, in particular in bad atmospheric conditions, may lead to accidents. In particular in urban areas with a dense population collisions of drones with humans are possible and injuries are quite likely, as the rotors are sharp and a loaded drone weighs a few kilograms. As long as delivery drone systems are not in place and also depending on the scenario implemented, it is difficult to estimate the likelihood of accidents for now.

contamination with dangerous loads

Another potential health risk stems from the load. In the event of a crash of a drone carrying a dangerous good various unpleasant scenarios are imaginable. The definition what counts as dangerous would have to be refined; for instance one may ask whether blood samples of ill people, medical probes, or vaccines would be included, as they could potentially contaminate the environment or threaten people directly. Possibly the transport of dangerous goods could be banned altogether.

6.3 Societal aspects and potential areas of conflict

With regard to societal aspects and conflict potential, the first wave of critique has already appeared in various forms on different platforms, and the first signs of resistance have already been articulated. For instance, in the US you can buy anti-drone guns to shoot them down if they trespass your private territory.[76] In the following, we give an overview of the most relevant areas in which concerns have been raised.

6.3.1 Labour market

the labour market for delivery services increased considerable with the diffusion of online shopping …

A first area of concern is potential effects of this technology on the jobmarket (OECD 2015). The transport and logistics sector is personnel-intensive, as drivers who deliver the parcels in person are needed on the last mile. With the advent of 24/7 online shops, the market segment of delivery to the homes of the customers increased considerably[77], and so did the labour market for packet assemblers and for drivers of delivery vans.

… and may shrink again

In the event of widespread employment of drones for the last mile, the latter part of the labour market would eventually shrink again.

[76] Wired, 27.07.2017, wired.com/story/watch-anti-drone-weapons-test/; The Drive, 21.06.2017, thedrive.com/aerial/11505/the-7-most-significant-anti-drone-weapons.

[77] Global online retail sales are growing and are estimated to reach 8.8% of total retail spending in 2018 as compared to 7.4% in 2016. In 2016 this meant 1.88 billion USD, which rose to 2.19 billion USD in 2017. By the end of 2018 this number is projected to be 2.48 billion USD. See invespcro.com/blog/global-online-retail-spending-statistics-and-trends/.

effects depending on delivery modes and scenarios

These effects very much depend on the concrete scenario and the delivery modes put in place. Obviously the labour market for drivers in the pharmaceutical sector is much smaller than the field of consumer goods. In case the drones would start from automated intermediate storage facilities, van drivers would be out of business in the longer run (except for the large and/or heavy parcels). In case the drones would start from the delivery vans, there is still a need for drivers – unless those vans eventually become autonomous themselves – but much less than hitherto, because using the drones for the last mile is supposedly much more time efficient: not only are drones faster than a human walking up the stairs, there could also be more drones starting from one van in parallel, which would lead to faster turnovers of the delivery vans with still only one driver.

economic estimations are split, but labour market in the transport sector is certainly under threat

We couldn't find any specific study about the last-mile delivery, but there are several studies that examined the process of digitalization and automatization in various job markets in different countries (EPTA 2016; Frey/Osborne 2013; Čas et al. 2017). The economists are split about the exact figures, but for some sectors they predict huge job losses, and the transport sector in general (taxi drivers, lorry drivers etc.) is a case in point. Further research is needed.

the societal importance of jobs for unskilled labour

It is important to acknowledge that mundane tasks, which can be carried out by unskilled workers, serve as a social safety-net for those individuals who lack formation and specific training, but who need a job they can fulfil without further qualifications, at least for an interim period.[78] As the process of automatization would result in less need for human workers, the group of unskilled workers could suffer most.[79]

The threat of delivery by drones to the job market is also a recurrent topic in the media. The majority of the articles and debates are centred on economic aspects of automatizing delivery. In particular the threat to unskilled labour is being discussed frequently, as are distributional issues.[80]

6.3.2 Resilience/redundancy of the delivery system

When the launch of any infrastructural service is under consideration, it is advisable not only to look at the potential economic advantages (like to opening up of new markets), but also to examine how resilient the overall system would be.

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[78] Especially in the case of immigrants or in case of job losses and a need for fast employment to secure income.

[79] Forbes, 17.4.2017, forbes.com/sites/quora/2017/04/17/should-package-delivery-be-automated-with-drones-a-look-at-the-pros-and-cons/#3ccf82681bc9.

[80] Forbes, 17.4.2017, forbes.com/sites/quora/2017/04/17/should-package-delivery-be-automated-with-drones-a-look-at-the-pros-and-cons/#3ccf82681bc9; Goldman Sachs, 2016, goldmansachs.com/our-thinking/technology-driving-innovation/drones/; Reuters, 21.03.2017, reuters.com/article/us-usa-drones/u-s-commercial-drone-use-to-expand-tenfold-by-2021-government-agency-idUSKBN16S2NM.

dependency on drones that cannot fly at all times may be a source of risk

There are certain circumstances when drones cannot fly safely, for instance in case of strong wind or icy rain or thick fog (just like the big airplanes). This means that in a scenario in which the existing van-based infrastructure is replaced to a large extent with delivery drones, the drone-based system would not be able to deliver. We may assume that the delivery firms would not keep the van pool "just in case". The question then is, whether this is acceptable or would we need alternatives?

For our general scenario no. 1, a temporary delivery stop may be acceptable (but needs further analysis), but what about scenario no. 2 in which the medical sector counts on daily delivery service by drones? This vulnerability of an important part of our life-saving infrastructure has to be avoided. In this case, alternative delivery services need to be on call at all times.

6.3.3 Ethics

pre-programmed algorithms take ethical decisions

For the scenario of an impending and non-avoidable accident, what behaviour will be pre-programmed in the software of drones? Similar to algorithms that are discussed with regard to other autonomous vehicles, e.g. passenger cars, there are a number of decisions to be made, prior to events, which become operative in the time of split-seconds. For autonomous cars, these tricky issues have already seen extensive discussions among ethicists and technologists (Maurer et al. 2015), a respective discussion for drones is still missing (see, however, Luppicini/So 2016).

the ethical dilemma of autonomous cars revisited

In one often quoted scenario in which damage seems unavoidable, there would be at least three options what the car/the drone could do: i. hit two adults with a great possibility of heavily injuring them; ii. hit a child with a great possibility of heavy injuries; or iii. somehow manage to avoid crashing into the two formerly mentioned, but instead crashing down and destroying itself and its parcel which could have saved someone else's life (e.g. the parcel containing a human organ for transplant). It is an open and difficult ethical question what decision to take. All this has to be decided and programmed beforehand. Is it the programmer who decides in advance, is it the drone manufacturer, the delivery service enterprise, the sender or the recipient of the parcel, or rather the society at large and hence the legislator? How would we – whatever decision is taken – oversee the implementation of these decisions? We may easily assume that answering all these questions is not easy (Krieger-Lamina/Nentwich 2016). Note that for the drone to be able to take whatever decision, permanent surveillance and analysis of the environment is a precondition.

what counts as an emergency?

By the way, this ethical dilemma is also present in the case of a delivery service restricted to emergency parcels only (our scenario no. 2). If the fact that it is an emergency would be taken into consideration for that difficult appreciation, we still face the question, what counts as an emergency situation and what doesn't? We may assume that the delivery of living organs may safely be considered an emergency, what about other cases,

like the transfer of medical probes and blood samples?

In our scenario no. 2 we may even go one step further: Would delivery services by drones in urban settings be an exclusive right of medical entities? If so, what counts as a medical entity? Would we strictly regulate who is allowed to fly and who is not, and how would we react if these privileges would be misused? If there is strict control, time restrictions, flight corridors etc., then this kind of service would be a scarce commodity. Usually this would lead to higher prices. For instance, a certain patient's blood could be given priority because she or he paid extra fees just to have their results faster. This is a typical technology assessment reasoning that we could term 'drones' divide': in one scenario only the rich may afford it (but still use the common good airspace) and it may lead to an additional difference in the quality of healthcare that patients receive. The same set of questions may also be asked for other services.

'drones divide': a service not available for everyone?

6.3.4 Consumer behaviour

What consumers buy, how and when they buy, how they pay, what their expectations are, all this varies geographically and is changing constantly, not least because industry and commerce try to influence their behaviour, even creating previously unknown needs. Recently the advent of online shopping with 24/7 availability instead of fixed opening hours and with no need to leave home, neither for the search & order activity nor for the delivery, has the potential to enduringly change consumer behaviour (Lee et al. 2016). And so have drones.

drones have the potential to change consumer behaviour

Previously, mail-order firms, now web-shops delivered within a couple of days, and even expensive fast-track delivery usually takes a day to arrive. The promise of drone delivery is to reduce this to an hour or less. We may rightfully ask whether this would satisfy an already existing need or rather a new one is about to be created. Whatever the answer, it seems safe to predict that this development would speed up the whole consumer market and be an additional strain on location-based shops. Actually, even today we can observe a fierce competition between the latter and the online shops with their usually much broader portfolio, driving many non-virtual shops out of business (Bruckner 2017). This competition will certainly increase and may change the landscape of shopping outlets considerably. At the end, the consumer may be left with less local choices, but a vast online offer, perhaps with much less competitors on the market.

instant delivery as an induced consumer need

This new world of commerce – online and very prompt delivery (by drones) – could be assessed from both psychological and egal perspectives: this new environment would lead to almost instant gratification, and the promise of the 'fulfilment of all wishes' in a very short time. While on the one hand this is certainly welcomed by many, it may on the other hand fuel problems with binge buying, increasing levels of consumer debt, the danger of excessive indebtedness, and finally insolvency. From the point of view of consumer protection, legislating this is certainly an issue.

novel consumer protection issues

Note that the right to step back from an online purchase is psychologically speaking even more reduced (usually two weeks from the time of order) in case the delivery time is negligible; hence the opportunity to 'think twice' is diminished.

6.3.5 Noise pollution

It is not only the wildlife (see above 6.1) that is affected by noise pollution, so are also humans. Just like those who live nearby high-traffic roads or airports, those who would live directly under the delivery air-corridors where drones fly regularly could suffer the disadvantages of noise pollution as well. Note that at in our scenario no. 1 massive drone traffic would develop over time. While a single drone with eight electrical mini-engines is not very noisy (unless it is very near), many of them at the same time certainly would. Even if we assume that later generations of drones would be more silent, there is certainly a limit to further improvements because the airflow around the many rotors cannot be avoided – similarly to the noise produced by car tires which is, together with the airflow around the autobody, above a certain speed louder than that of the engine and, hence, even the most silent electrical engines cannot produce silent e-cars.

noise in densely populated areas may be a problem

Apart from highly used corridors, the expected delivery manoeuvers close to the customers, in particular in a densely populated urban area, are not negligible, at least not by those more noise-sensitive. Only the noise produced by the air traffic expected in scenario no. 2 would not be a of substantial concern.

So in scenario no. 1 we may assume that noise could be a problem which if unsolved may lead to resistance in the population. The question then is how the society would decide where drones would be allowed to fly to reduce the noise problem. No-fly zones may be part of the solution, as would be corridors high above street level and away from buildings, but can there be any solution for the last mile, i.e. the surroundings of the prospective landing spots close to the customers? These are open questions that cannot be answered without an informed public debate; we shall come back to this in the concluding chapter.

6.3.6 Aesthetic derogation of airspace

Similarly to powerlines, windmills and skyscrapers in the past, the aesthetic appearance of drones swarming the lower airspace can be expected to be questioned by parts of the population.

Figure 4: A sky full of delivery drones

Credit: RikoBest/Shutterstock.com

At first this sounds like a luxury problem and indeed our societies have accepted a lot of similar compromises in the past: there are less and less untouched natural landscapes, and in urban areas the utilization of the ground level for traffic and all sorts of public furniture and appliances is standard. Furthermore opinions about the aesthetic value of all kinds of buildings and infrastructure will always remain split. However, one may argue – and we assume it would be put on the table if discussed widely – that using massively the so far empty airspace could be considered a new and qualitatively different step in exploiting a common good.

commercial use of the common good 'ground-level airspace'

Note that at least in our scenario no. 1 drones would fly mainly for commercial purposes in the private interest, whereas the use of the ground level is a shared space for commercial, public and private activities. This raises the additional question whether, if allowed at all, would the commercial enterprises be required to pay for the use of the space? There are many examples from the past, not least from the traffic sector, such as road charges, motor vehicle taxes, and the famous Austrian 'Luftsteuer' (air tax)[81], which is due if one uses public ground for private purposes, e.g. with billboards extending into the air above sidewalks (see section 7.3).

6.3.7 Protection of the private sphere

drones potentially threaten privacy

In case packet delivery by drones would become a (legally) accepted service, this technology has the potential to affect and possibly conflict with the private sphere. Today even without large numbers of drones in the air, the issue is already tabled. In particular many toy drones are equipped with cameras (which is actually not allowed under most regimes unless you have a specific license), and so neighbours are alerted when drones fly over one's ground or approach one's balcony. There are numerous ar-

[81] Gebrauchsabgabengesetz ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=LrW&Gesetzesnummer=20000131.

ticles in the popular media addressing the issue[82] and several firms offer anti-drone devices for self-helped 'law enforcement' purposes.[83]

challenge: autonomous drones technically need a variety of sensors ...

Even though taking pictures, filming or audio surveillance is not among the main functions of delivery drones, these are however needed to sense where they are going (and constantly survey their environment) and therefore are necessarily equipped with technology that can 'see' to orient them (see section 3.1).[84] The data generated by these sensors during the flight could be immediately deleted. However, it may be the case that they would be legally required to keep a record of a flight, in case they need to prove that they were not the cause of damage or have obeyed all flying rules. Such a scenario seems likely as it parallels similar developments in other areas, in particular the black boxes of airplanes, in the near future also of cars, as well as the trip-recorders of trucks. This means that video material coupled with location data and time stamps would be generated and stored. All this data can be quite sensitive if people are on the videos or can be indirectly related to it. Also birds' eyes views from private properties may be sensitive, as are public buildings (e.g. the parliament building) or military facilities.

... and the resulting data may be required to be stored

We assume that the privacy issue should not be underestimated. In section 7.2 we shall therefore come back to this topic.

6.4 Protection against misuse

drones can be a target of criminals or used for a variety of illegal purposes

With all new technologies comes the potential of misuse. The dissemination of delivery by drones is expected to be no different (AAE/3AF 2015, p. 49f). Acts of misuse could be theft of the drones' loads, vandalism and so-called 'spoofing', i.e. electronic hijacking by overtaking control of the drone remotely or sending false GPS signals. Furthermore drones could be used by criminals to transport illegal goods, e.g. drugs, or to deliver something (e.g. weapons) to prison inmates.[85] Finally terrorists may load bombs onto drones or simply use drones to spy out potential targets (e.g.

[82] Consumer Reports, 10.02.2016, consumerreports.org/electronics/drone-privacy-is-anyone-in-charge/; The Next Web, 24.08.2017, thenextweb.com/tech/2017/08/24/amazon-patent-details-the-scary-future-of-drone-delivery/; Recode, 15.03.2017, recode.net/2017/3/15/14934050/federal-privacy-laws-spying-drones-senate-hearing.

[83] E.g. special rifles, 20min.ch/digital/news/story/Drohnen-Gewehr-holt-Gadgets-vom-Himmel-25911389?redirect=mobi&nocache=0.6997041974682361 and http://www.spiegel.de/netzwelt/gadgets/battelle-dronedefender-das-anti-drohnen-gewehr-a-1058093.html and spiegel.de/video/dronedefender-gewehr-beschiesst-drohnen-mit-radiowellen-video-1617446.html. Another option seems to be to train birds (falcons or eagles) to hunt drones, futurezone.at/digital-life/niederlaendische-polizei-trainiert-adler-fuer-drohnenjagd/178.424.561.

[84] This is also true for remote controlled drones, not only for autonomous ones, as the pilot needs the camera to be able to fly at distance.

[85] tagesspiegel.de/berlin/gefaengnis-in-berlin-moabit-drogen-per-drohne-in-den-knast/19931882.html.

nuclear plants[86]). These criminal purposes become easier to execute the denser the air traffic is, because the prospective high numbers of drones may be good to hide and go undiscovered. Also the drone itself could be the weapon if flown into a crowd of people or highway traffic.

knowledge about the rules for drones is generally low

Even non-criminals, just ordinary citizens often employ drones not correctly, e.g. when flying over crowds of people or with a camera attached; obviously, the general knowledge of the applicable legal rules is very low or it is imply indifference or neglect (Pfluger 2017).[87] To counteract, the Austrian authorities recently launched websites targeting the ordinary user with information about the applicable rules.[88]

how could authorities counteract misuse?

So we need to ask the question how authorities could prevent acts of misuse and criminal activities. To date, the legislation does not give the police the means to effectively counteract and penalize misuse. We shall come back in section 7.4 what options the legislator would have to improve the situation (e.g. electronic license plates).

[86] spiegel.de/wissenschaft/technik/drohnen-ueber-akw-frankreich-raetselt-ueber-terror-gefahr-a-1005559.html.

[87] See also welt.de/regionales/bayern/article147407964/Viele-Hobbypiloten-kennen-die-Vorschriften-nicht.html.

[88] See austrocontrol.at and bmvit.gv.at/verkehr/luftfahrt/drohnen/.

7 Potential need for regulation

Based on our preliminary analysis of possible societal impacts, we are now in a position to assess whether or not it would be necessary to regulate this emerging market for delivery of goods by drones.

legislation is lagging behind technology development and commercial aspirations

A general problem with new technologies and in particular with rapid developments such as in this case, regulation either lags behind and would need to constantly adapt to new technological options or it is a formal barrier to innovation, as is the case at the moment (remember that under the present legal framework autonomous drones cannot be licensed at all). Furthermore this particular field of activity, like all transport-related activities, has an international dimension as flying objects may easily transgress international borders and fly into territories with another legal regime.

international dimension

In this chapter we give a first overview of legal fields touched upon by delivery drones, in particular we look at open issues in air traffic laws (7.1), consumer and privacy protection (7.2), tax law (7.3), and measures for law enforcement (7.4).

7.1 Air traffic laws

As mentioned earlier (5.2), to date, autonomous drones are not permitted by the law in Austria and many other countries (see AAE/3AF 2015, p. 52ff, on the regulatory discussion). So if society and the legislator wish to allow for delivery drones operations – which remains an open question, see our conclusions in chapter 8 – the option of not only remotely controlled, but also autonomously flying drones need to be legislated in the first place. Together with this new option, both technical requirements for licensing delivery drones, the service enterprises, and specific air traffic rules would need to be worked out:

technical licensing of the drones

To begin with, the drones themselves would need to be licensed and undergo special test processes to check safety and performance, weight, accuracy of geo-positioning and sense & avoid systems, type of engine (electrical only or also combustion engines), etc. Special rules may apply to drones with special purposes, like transporting dangerous goods. A further aspect is, what data a black-box, if it will be mandatory, should include, how long this data would be stored etc.

licensing service providers

In addition, it is most likely that enterprises offering delivery services would be required to fulfil certain conditions and would have to acquire specific licenses. This may also encompass a data protection and privacy assessment. The licensing could be handled according to the current system, i.e. by the respective flight control authority and/or transport ministry.

no-fly zones, corridors, geo-fencing

In particular in scenario no. 1 the air space would become densely populated with massive and regular drone traffic. Similar to the traffic on the streets traffic rules are needed to avoid chaos. Air traffic rules would have to include speed limits, flight heights, minimum distance to other objects and in particular humans and animals, drone identification, emergency procedures, etc. In addition, it seems advisable to think about air corridors where drones would be allowed to fly and 'no-fly zones' where they are not. These no-fly zones would be flagged out in a dynamic database accessed by the drones during flight (or shortly before taking off) and would tie to the more and more frequently mentioned practice of geo-fencing. Special cases are temporary or locally established no-fly zones around helicopters or in an emergency area, but geo-fencing could be aimed to serve both security and privacy purposes. These rules would take into account the differences in the urban and rural environments.

ground-level air space surveillance body

It is an open question whether we would need, at least in scenario no. 1, a specific ground-level air space surveillance body (like air traffic control that exists for airplanes) or whether an automated or even decentralised system of mutual traffic control is conceivable. The latter would mean that a protocol needs to be established for drones coordinating among themselves in order avoid collisions. This may also include a functional hierarchy to allow for priority flights (e.g. a pizza delivering drone would give way to a drone that carries medical samples).

priority flights?

dangerous goods

Further regulatory decisions would need to be made regarding the delivery of dangerous goods, and for security reasons. Apart from specific technical safety requirements of the drone itself, it may or may not be allowed to fly dangerous goods at all or only under specific circumstances.

7.2 Consumer and privacy protection

withdrawal from contract

Although this is primarily an issue connected to online shopping in general, we observed earlier (6.3.4) that ubiquitous delivery by drones would speed up the fulfilment of consumer contracts. In this context the legislator may reconsider the right of withdrawal, that is, under what conditions and in what timeframe could a consumer cancel an order without further obligations.

insurance issues

Furthermore the rules of liability would possibly need amendment when it comes to the loss or damage of a good, either during the flight (for instance in case the customer ordered despite heavy rain) or during the delivery process (who is responsible for the correct functioning of the landing platform or window-attached basket?). Would insurance be obligatory, for the drone or for the delivered good, and who would have to pay the fees? (AAE/3AF 2015, p. 49)

privacy protection

Last but not least, as already discussed above in section 6.3.7, existing data and privacy protection would need to be adapted to the new technical possibilities (AAE/3AF 2015, p. 48), including black-box recordings.

7.3 Tax law

compensation for using a common good?

It is conceivable that states would consider drone flights a new object of taxation. The reasoning behind would probably be that drone operators use the common good near-ground airspace for non-public purposes – similar to car owners using the streets and people putting out an overhead billboard.

7.4 Law enforcement

preventing misuse is particularly challenging when it comes to drones

Law enforcement with regard to the current air traffic is complex but relatively easy with a great, but still limited number of licensed airplanes and helicopters, with a limited number of operators, and with any particular airborne airplane on one or more radar screens, and even stand-by interceptor planes to enforce national no-fly zones. In addition, almost everything that boards an aircraft has undergone a safety check. In our scenario no. 1, by contrast, this would be different in many respects: drones are very small; many, many more flying objects would be airborne at any given moment; radar would partly not detect drones flying near-ground and between buildings and in valleys; and there would be many more operators. In some respect overseeing drone traffic would be similar to car traffic on the ground with essentially no possibility of full surveillance.

As we have seen, however, the potential for drone misuse is non-negligible (see 6.4). So a future regime for delivery drones needs to take these challenges into account. Whatever the institutional solution would be (the traffic police or a special authority entrusted to supervise), these authorities would need to be given the respective resources to fulfil this demanding task.

remote identification system?

One possible option would be to establish a remote identification system. This would include compulsory registration of every drone and its permanent identification by a radio signal and would further allow the authorities – and perhaps also the private citizen[89] – to identify every drone in sight remotely. The authority may then have access to a database with the current details of each flight (provider, route, load), like with truck, cargo planes and container ships. Special devices could be developed (similar to radar guns in use to control car speeds) that would receive the identification data.

mandatory black box?

A further option, which would have an equally deterrent effect for potential misusers (not criminals or terrorists though), would be a mandatory black box on board of each drone (similar to those on airplanes), i.e. a specially protected and tamper-proof storage device that stores flight data for immediate (i.e. even during the flight with the help of the above mentioned

[89] The wish of private persons may be considered legitimate to know who is flying over one's garden or passes-by one's window for the third time in ten minutes.

special radar gun) or at least control after a specific flight.

permanent near-ground air traffic control?

Technically it may further on be possible to let drones be connected to the general or a specific mobile communications network during flight even permanently and let them send the data constantly for automated tracing and supervision of all rules. However, the problem of non-compliant drones would persist.

8 Conclusion: Debate now!

numerous open questions

As we have seen, there are a lot of open questions regarding the commercial use of drones. Questions concern the technical, legislative as well as societal aspects, safety, and environmental risks.

The answers to these salient questions will differ when we distinguish between possible implementation scenarios as outlined in the introduction to chapter 6. In the case of the "pizza scenario" (1) with ubiquitous delivery drones being part of our everyday reality the impacts on our societies are obviously more severe than in the restrictive "emergency scenario" (2) with deliveries only in special cases.

'pizza scenario' [no. 2] is highly controversial

While realising scenario 2 still needs quite some preparation, both technically and in legal terms, establishing such niche markets would be probably without wider opposition. By contrast, scenario 1 not only requires much more sophisticated infrastructure and rules, but also raises some potentially controversial questions.

in-depth and interdisciplinary TA research needed

From a technology assessment perspective these questions cannot be answered without in-depth interdisciplinary examination. The present overview study only provides a preliminary stock-taking of the issues involved; it is to be expected that some of the points raised in this short report are less controversial or turn out to be negligible, but there may even be more salient issues to find out.

a technology close to everyone's private life

Furthermore many of the issues detected are value-laden and the technology touches upon the private lives of a large number of individuals. To give a few examples: the relationship between economic interests and the protection of wildlife is not an obvious one; the question of the aesthetic consequences of mass-droning is difficult to answer in a top-down manner; noise is another issue where society constantly searches for compromises.

participatory TA is recommended

As the technologies are almost mature and many commercial entities wait in the wings, it would be high time to open up a debate now, and examine the possible chances and risks of such a service. Our recommendation is to conduct a participatory technology assessment study, that is, a combination of expert-, stakeholder- and citizen-oriented research. The study would try to give an answer to this question: "Which of the above scenarios (or any other that may come up) do we want as a society, and under what conditions?" Such a study would have four elements:

work packages of the TA process proposed

1. A detailed examination of the technical, regulatory and economic framework as well as the risk issues (this would be an enriched, extended and updated version of the present report);
2. An informed debate with stakeholders (drone manufacturers, delivery service providers, airspace authorities, police, NGOs from the fields of consumer protection and environmental protection, etc.);
3. An informed debate with citizens; lay participation would be particularly

rewarding in order to bring in everyday knowledge and values from non-experts;

4. A concluding, policy-oriented analytical part aiming at proposing policy options.

the issue is timely for anticipatory governance and public debate

On a final note, the authors of this report are convinced that the issue is timely for carrying out such an encompassing study now and for inducing a public debate about it. Today the technology is not yet fixed and the commercial actors have not yet invested heavily in their business models; in other words: today, anticipatory governance aiming at shaping the technological and economic path is still an efficient and effective option.

Bibliography

AAE/3AF, 2015, *Present and Future of Civilian Drones*, No. AAE Dossier #40/3AF Cahier #16, Paris: Air and Space Academy/French Aerospace Society <http://espas.eu/orbis/sites/default/files/generated/document/en/D40_Ebook_UK.pdf>.

Bergtora Sandvik, K. and Lohne, K., 2014, The Rise of the Humanitarian Drone: Giving Content to an Emerging Concept, *Millennium – Journal of International Studies 43(1)*, 145-164 <http://dronepriva-cyplease.wikispaces.com/file/view/Rise+of+Humanitarian+Drones.pdf>.

Bruckner, R., 2017, Ihr Packerln, so kommet doch all, *Der Standard*, 19.12., 18.

Čas, J., 2015, Drohnen – TA-Perspektiven, *UAV SIFO Workshop (Sicherheitsakademie des BM.I)*, 6.10., Wien.

Čas, J., Rose, G. and Schüttler, L. (Institut für Technikfolgen-Abschätzung), 2017, *Robotik in Österreich: Kurzbericht – Entwicklungsperspektiven und politische Herausforderungen*; Endbericht, commissioned by: BMVIT, No. ITA 2017-03, Wien: ITA <http://epub.oeaw.ac.at/ita/ita-projektberichte/2017-03.pdf>.

EPTA (European Parliamentary Technology Assessment), 2016, *The Future of Labour in the Digital Era. Ubiquitous Computing, Virtual Platforms, and Real-time Production*; Report, October, Wien: EPTA <http://epub.oeaw.ac.at/ita/ita-projektberichte/EPTA-2016-Digital-Labour.pdf>.

Frey, C. B. and Osborne, M. A., 2013, *The future of employment: How susceptible are jobs to computerisation?*, January: Oxford Martin Programme on the Impacts of Future Technology.

Hillenbrand, T., 2014, *Drohnenland: Kriminalroman*, Köln: Kiepenheuer & Witsch.

ITA, 2014, *Drohnen – fliegende Alleskönner? ITA-Dossier Nr. 6 (Jänner 2014; Autorin: Julia Haslinger)* (2014-01-30), Wien: Institut für Technikfolgen-Abschättzung <http://epub.oeaw.ac.at/ita/ita-dossiers/ita-dossier006.pdf>.

Knyrim, R. and Kern, C., 2014, Drohnen – Fliegen im rechtsfreien Raum?, in: Jahnel, D. (Ed.): *Jahrbuch Datenschutzrecht*, Graz: NWV, 207-215.

Krieger-Lamina, J. and Nentwich, M., 2016, Zivile Autonome Fahrzeuge zu Land, in der Luft und zu Wasser, *Smart New World – Was ist smart an smarten Technologien? (TA16)*, 30.5., Wien.

Lee, H. L., Chen, Y., Gillai, B. and Rammohan, S., 2016, *Technological disruption and innovation in last-mile delivery*; White Paper, June, Palo Alto: Standford Business.

Luppicini, R. and So, A., 2016, A technoethical review of commercial drone use in the context of goverance, ethics, and privacy, *Technology in Society 45*, 109-119.

Lustig, J., 2018, *Lieferungen per Drohnen (Arbeitstitel)*, Bachelorarbeit (unveröffentlicht), Dept. für Transportwirtschaft, Wirtschaftsuniversität Wien.

Maurer, M., Christian J., G., Lenz, B. and Winner, H., 2015, *Autonomes Fahren – Technische, rechtliche und gesellschaftliche Aspekte*, Wiesbaden: Springer Vieweg.

Moe, Å. R. (Norwegian Board of Technology), 2013, *Take-off for civilian drones*; Blog; Last update: 19.06.2013 [Accessed on: 02.03. 2018] <http://teknologiradet.no/english/take-off-for-civilan-drones>.

Nentwich, M., 2015, Zivile Drohnen aus TA-Perspektive, Statement am Podium, *Science-Talk "Invasion der Drohnen"*, 19.10., Wien.

Nentwich, M., 2017, Zivile (Liefer-)Drohnen aus Sicht der Technikfolgenabschätzung, *Österreichische Computer Gesellschaft: OCG Horizonte*, 28.11., Wien <http://epub.oeaw.ac.at/ita/ita-papers/Nentwich-OCG-28112017.pdf>.

OECD (Organization of Economic Co-operation and Development), 2015, *Employment Outlook*, Paris <http://dx.doi.org/10.1787/empl_outlook-2015-en>.

Pfluger, B., 2017, Hälfte der Drohnenbesitzer missachtet Gesetz, *Geldstandard*, Oktober 5, 17.

POST, 2014, *Civilian Drones*. POST Notes, No. 479 (October), London: Parliamentary Office of Science and Technology <http://researchbriefings.files.parliament.uk/documents/POST-PN-479/POST-PN-479.pdf>.

Rao, B., Goutham Gopi, A. and Maione, R., 2016, The societal impact of comercial drones, *Technology in Society 45*, 83-90.

Redaktion, 2018, Drohnen könnten Pakete energiesparender liefern, *Der Standard*, 14 Februar.

Stolaroff, J. K., Samaras, C., O'Neill, E. R., Lubers, A., Mitchell, A. S. and Ceperley, D., 2018, Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery, *Nature Communications 9(1)*, 409 <https://doi.org/10.1038/s41467-017-02411-5>.