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A Guide to Regulatory Practice

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Executive Summary

In order to efficiently design, test and evaluate UAV-based workflows for land tenure data acquisition activities, internal and external elements that determine and decree respective characteristics need to be considered. This report provides insights about the most important external element that impact upon UAV workflows: legal frameworks that regulate the use of UAVs. The project related research investigation aims to identify past, present and future developments in order to guide regulatory practices for UAV-based data acquisition land tenure data acquisition workflows. At this, the methodological approach uses a research synthesis on UAV regulations and includes a thorough literature review as well as comparative analysis of national and international UAV regulatory frameworks. In general, the results reveal that UAV regulations are subject to national legislation and focus upon three key issues: 1) targeting the regulated use of airspace by UAVs as they pose a serious danger for manned aircrafts; 2) setting operational limitations in order to assure appropriate flights; and 3) tackling administrative procedures of flight permissions. Since the early 2000's countries gradually established respective legal frameworks. Although all UAV regulations aim for one common goal – to minimize the risk for other airspace users and people and property on the ground – a distinct heterogeneity of national regulations is present. Nevertheless, national commonalities, international mandates and pioneering countries can be identified that further allow to predict possible future developments. The its4land case countries – Rwanda, Ethiopia, and Kenya – are each at different stages of regulation maturity, with the former being the most advanced in terms of established laws and regulations. However, at the time of writing, the latter two countries are in the process of promulgating new regulations that appear to mirror the emerging international norms. It is likely that, at least in the short term (e.g. 1 year), more clarity on the legal requirements enabling UAV flights in the three case countries will be apparent, however, most likely this will mean stricter controls on usage – and administrative support to enable implementation of the laws may lag.

Contents

1. Introduction

its4land is a European Commission Horizon 2020 project funded under its Industrial Leadership program, specifically the 'Leadership in enabling and industrial technologies – Information and Communication Technologies ICT (H2020-EU.2.1.1.)', under the call H2020-ICT-2015 – and the specific topic – 'International partnership building in low and middle income countries' ICT-39-2015.

its4land aims to deliver an innovative suite of land tenure recording tools that respond to sub Saharan Africa's immense challenge to rapidly and cheaply map millions of unrecognized land rights in the region. ICT innovation is intended to play a key role. Many existing ICT-based approaches to land tenure recording in the region have not been highly successful: disputes abound, investment is impeded, and the community's poorest lose out. its4land seeks to reinforce strategic collaboration between the EU and East Africa via a scalable and transferrable ICT solution. Established local, national, and international partnerships seek to drive the project results beyond research and design (R&D) into the commercial realm. its4land combines an innovation process with emerging geospatial technologies, including smart sketchmaps, UAVs, automated feature extraction, and geocloud services, to deliver land recording services that are end-user responsive, market driven, and fit-for-purpose. The transdisciplinary work also develops supportive models for governance, capacity development, and business capitalization. Gender sensitive analysis and design is also incorporated. Set in the East African development hotbeds of Rwanda, Kenya, and Ethiopia, its4land falls within TRL 5-7: 3 major phases host 8 work packages (excluding work package 9 on ethics) that enable contextualization, design, and eventual land sector transformation. In line with Living Labs thinking, localized pilots and demonstrations are embedded in the design process. The experienced consortium is multi-sectorial, multi-national, and multidisciplinary. It includes SMEs and researchers from 3 EU countries and 3 East African countries: the necessary complementary skills and expertise is delivered. Responses to the range of barriers are prepared: strong networks across East Africa are key in mitigation. The tailored project management plan ensures clear milestones and deliverables, and supports result dissemination and exploitation: specific work packages and roles focus on the latter.

This document constitutes D4.1 for Work Package 4 'Fly and Create'. The deliverable provides a guide to regulatory practice for the use of UAVs in the field of land tenure recording. It can be used as the basis for other documents including community awareness campaign material, government policy development, and scientific publications. To achieve the overarching aim, the document is structured as follows. First, an overview of UAVs and the potential application in land administration is provided. A specific UAV land tenure recording workflow is also articulated. Subsequently, how UAVs use is governed is examined from the perspective of past, present, and future approaches. A specific focus on the contexts of Ethiopia, Rwanda, and Kenya is also provided. Annexes provide lists of other useful resources along with an overview of the applied methodology and its limitations.

2. What are UAVs?

"UAVs are to be understood as uninhabited and reusable motorized aerial vehicles." van Blyenburgh, 1999

Unmanned aerial vehicles (UAVs) – also known as remotely piloted aircraft systems (RPAS) or just 'drones' – are remotely controlled and follow semi-autonomously or autonomously predefined flightpaths. The term unmanned aerial systems (UAS) can also be found throughout the literature and considers the whole system which includes the unmanned aircraft and the on-ground command-and-control station (Everaerts 2009). Within the last decade UAVs became a genuine gain for scientific as well as commercial applications. Since the price and the size of UAVs significantly dropped within the past 5-6 years (Barnes & Volkmann 2015), they stand out as an affordable acquisition tool for mapping and investigations at short time frames. A distinct analysis of Scopus literature search proves this trend through an increasing number of research publications within the field of UAV surveying and/or mapping (fig. 1). Here, subject areas include computer sciences and engineering as well as social sciences, earth and planetary sciences with

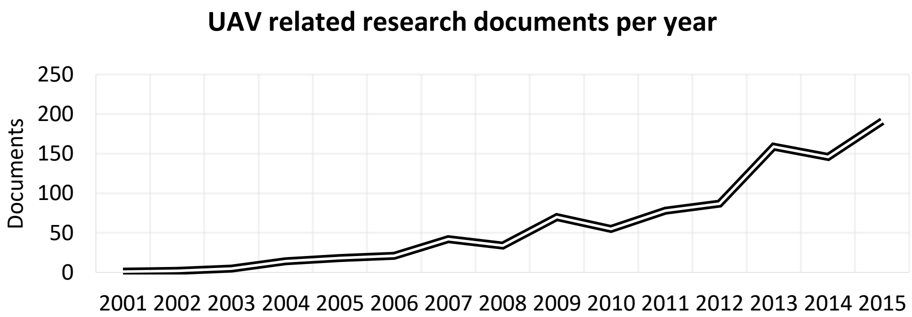

Figure 1: Publication analysis including articles, reviews, conference papers, conference reviews (923 results).

each more than 150 contributions to overall 923 publications. The range of distinct contents spreads through various applications such as high resolution surface reconstruction in geosciences (J. Everaerts 2008; Eltner et al. 2015; Anders et al. 2013; D'Oleire-Oltmanns et al. 2012; Stöcker et al. 2015), documentation of cultural heritages and archaeological sites (Remondino et al. 2011), agriculture and forest change detection (Zhang & Kovacs 2012; Honkavaara et al. 2012; Grenzdörffer et al. 2008) support of disaster management (Maza et al. 2011; Tatham 2009; Adams & Friedland 2011), surveying and mapping (Barry & Coakley n.d.; Tampubolon & Reinhardt 2014; Gevaert et al. 2015) or cadastral purposes (Barnes & Volkmann 2015; Mesas-Carrascosa et al. 2014; Mumbone et al. 2015). (Pajares 2015) gives a very detailed review of remote sensing applications based on UAVs. The subject of UAV in general and UAV data acquisition in particular refers to a wide variety of different platforms, instruments and sensors, data acquisition procedures, calibration and image processing methodologies. The classification of UAV platforms follows existing military descriptions that are based on endurance and altitude. According to these parameters, van Blyenburgh (1999) distinguished between High Altitude Long Endurance, Medium Altitude Long Endurance, Medium Range Endurance, Low Altitude Endurance, Short Range, Mini and Micro UAVs. Scientific applications mainly utilize mini and micro UAVs since they are optimized for easy flight operations and simple transportation. The typical weight is 1–10 kg. Due to the compromise of weight, the payload is limited, endurance range from 15 to 90 minutes and communication capabilities cover a radius of few km of the ground station (Watts et al. 2012).

Next to endurance and altitude, UAVs can be distinguished according to their propulsion system, either as fixed wing vehicles or as copters (fig. 2). Typical definitions for the latter one refer to the number of rotors, e.g. single-rotor, coaxial, quad-copter, octo-copter or multi-rotor UAV (Nex & Remondino 2014). Copter take-off and land vertically, so they need very little space whereas fixed wing vehicles need significant area for this procedure. Since fixed wing UAVs fly like conventional aircrafts they require a basic motion for their aerial mission. On the other hand, copters have the ability to 'stay' in the air which is very beneficial for inspections or surveillance applications. Both classes have their own strength and weaknesses; hence the selection of the UAV platform should ideally suit the purpose. In general, rotary blade UAVs are preferably used when high resolution missions for small areas are required. In contrast, fixed wing UAVs are more efficient for large areas because of less energy consumption, thus long flight times. At this, the bias of cruising speed and camera shutter speeds may limit the final ground sample distance. Nowadays, hybrid UAVs like the Songbird (Aerolution) are also available on the market. Those vehicles ideally combine advantages of each group; i.e. the long endurance of fixed wing and the take-off and landing capabilities of rotary wing UAVs which only need small areas and entail little risk that the payload will be damaged during landing.

Figure 2: Example UAV platforms - Phantom 3 (DJI), Ebee (SenseFly), Songbird (Aerolution)

In order to facilitate navigation, the UAV is equipped with different instruments and sensors, such as, Global Positioning Sensors (GPS), Inertial Measurements Units or Inertial Navigations Sensors (IMU/INS), altitude sensors, gyroscopes and accelerometer (Quinchia et al. 2013). Nowadays, also forward and nadir perspective cameras are used to support navigation and piloting (e.g. Exom, SenseFly). Since the remote sensing mission is the main reason for the UAV to fly, the aircraft carries instruments and sensors which collect and store data during the flight. Here, the variety of sensors is likewise extensive as the field of applications. Remote sensing instruments that are suitable for UAVs include passive image sensors (as well as active image sensors (Colomina and Molina, 2014). The limits of additional payload for small UAVs hinder the utilization of heavy imaging equipment. Thus, in most cases consumer-grade off-the–shelf cameras are employed for data acquisition within the visible spectrum (J. Everaerts 2008). Instruments covering near-infrared and thermal ranges (e.g. Sugiura et al., 2007) as well as multi- or hyperspectral sensors (Capolupo et al. 2015; Zhang & Kovacs 2012) could be also successfully applied for UAV data acquisition operations.

3. Can UAVs impact on land administration?

In order to provide land information, the legal and spatial interests of people in land need to be recorded. Cadastres provide parcel-based up-to-date information about rights, restrictions and responsibilities. The legal extent of cadastral information includes rights, ownership and areas: this textual information is often referred to as the land register. Meanwhile, the spatial description of size, shape, boundary and location of land parcels is depicted or digitized on cadastral maps. The process of collecting spatial data, i.e. boundaries of land parcels is defined as cadastral surveying. According to the data acquisition method, data acquisition techniques are commonly distinguished as direct and indirect techniques (fig.4). Direct techniques measure the physical location of boundary points directly on the ground. Indirect techniques on the other hand rely on remotely sensed observations. These observations are based on space- or air-borne images are seen as the medium which allow for imagery based boundary delineation and subsequent cadastral mapping.

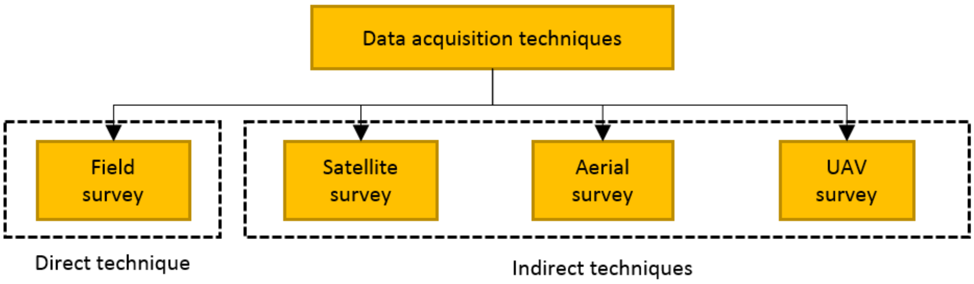

Figure 3: Data acquisition techniques for land administration, based on (Ali et al. 2012)

In general, direct field surveys need more time than indirect techniques, when medium to large areas are to be mapped. In terms of data delivery, UAVs (Meha et al. 2016) can be acquired within time frames of few hours to days, depending on spatial extent and post-processing. On the other hand, the order, acquisition, processing and dissemination of satellite imagery and aerial photographs needs considerably more time (Gianinetto et al. 2004), (Kelm et al. 2014) estimate up to 9-12 month for aerial surveys and (Zein 2016) estimates 4 month for satellite imagery. In terms of ground coverage satellites data remains unbeaten. The footprint of IKONOS images surrounds more than 10km², for instance. Satellite data is followed by aerial images at first and UAV images as second. Up to now, UAVs are seen as best suited for small areas rather than as a good option for mapping large areas like whole counties or states (Barnes & Volkmann 2015). The area which can be covered by field surveys within one mission is very limited. The factor of costs is highly dependent on the context. Traditional aerial surveys are expensive and become merely economically feasible for high value projects (Whitehead et al., 2014). However, (Williamson et al., 2010) mentioned that satellite mapping can be even more expensive than aerial photogrammetric mapping. For both techniques each new dataset causes recurring costs since satellite or aerial orthoimages need to be purchased frequently in order to keep the database up-to-date.

In contrast, UAVs and field work imply on-going labour costs but involve only on-off investments for the equipment. Regarding these costs, classical surveying techniques require more professionals than indirect methods where automatization and digital photogrammetry methods entail less number of manpower. The criterion of spatial resolution obviously correlates proportional to the remoteness of each technique. Commercial satellite imagery from earth observation satellites can reach 300 - 0.3 m, aerial images around 25-5 cm, UAV surveys up to 5-1 cm ground sampling distance (Toth & Jóźków 2016). Field measurements with tachometers can obtain sub-cm level of accuracy. The ground resolution directly impacts the interpretability of data products (see fig. 5).

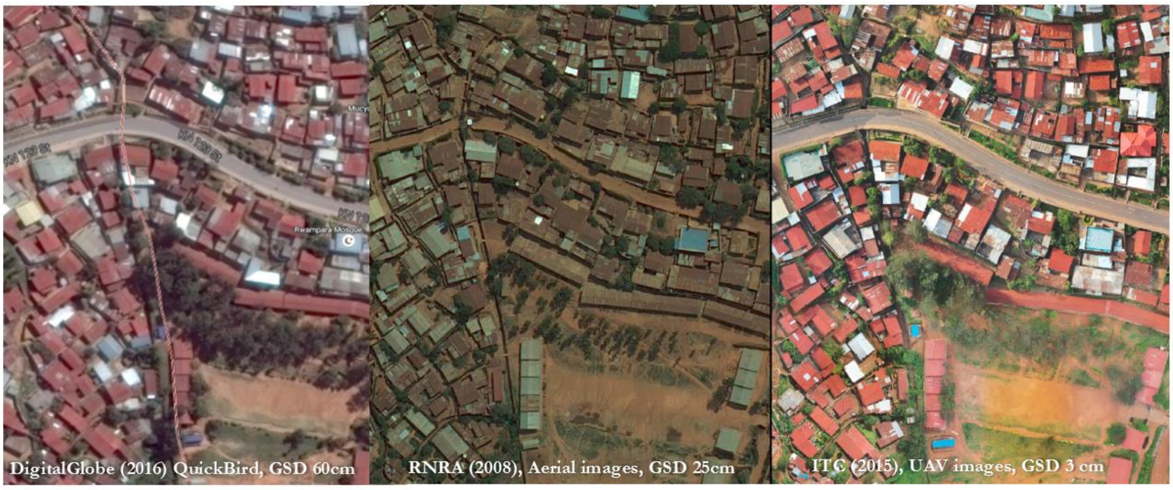

Figure 4: Comparison of satellite, aerial and UAV based orthophoto of an informal settlement in Kigali

Here, satellite images don't allow exact building extractions and shallow paths and footways can hardly be identified. Next to this, the radiometry of aerial images is not always ideal and automatic classification and feature extraction algorithms might be ambiguous due to the occurrence of mixed pixels that represent reflectance of different surfaces. Small features like bushes, fences or stones that represent boundaries might not be identifiable within these orthoimages. In contrast, the high ground resolution of UAV images allows clear visual interpretation and feature recognition (Gevaert et al. 2016).

The revisit time of satellite images varies highly, but can be almost daily as for the Pleiades, WorldView or RapidEye missions. Due to the short preparation phase and high flexibility, UAVs allow for arbitrary repetitions and thus can be tailored for respective purposes. In contrast, classical aerial surveys are mainly involved in on-off data acquisition processes since more repetitions are economically seen barely feasible for cadastral demands. At this, long periods of scheduling hinder flexible implementations of this technique (Whitehead et al., 2014). There is broad consensus in literature that indirect techniques are economically more effective than direct field surveys with professional equipment. More precisely, those methods need less time, less costs and less manpower to acquire spatial information for cadastral maps. Satellite and aerial surveys have their strengths clearly at area and time characteristics and weaknesses in costs and spatial resolution. In contrast, field surveys have their strength in spatial resolution and distinct weaknesses in terms of time and ground coverage. Due to their flexibility and low-cost application, UAVs show the best performance in terms of economic considerations (time and cost) and within maintenance processes for small areas.

Table 1 concludes the characteristics of each data acquisition technique. Relative rating is based on rough estimations of the author which are taken from scientific publications that are mentioned above.

Table 1: Comparison of land administration data acquisition methods. Relative rating is based on rough estimations which are taken from relevant publications

	Ground coverage	Costs	Timeliness	Spatial resolution	Maintenance processes
Satellite images	large areas	\$-\$\$	weeks	dm/m	++
Aerial images	large areas	\$\$\$	month	Dm	+
UAV images	small areas	\$	days	Cm	+++
Ground measurements	small areas	\$\$\$	months	(sub)cm	+

Besides those aspects, all indirect techniques provide inherently more land-related information than just cadastral boundaries. For instance, land use specifications and topographical features can also be derived in order to support environmental management purposes such as land conservation. Hence, indirect techniques can meet the requirements of multi-purpose cadastres much better than classical field surveys.

Next to technologically driven aspects and possibilities it should be considered at all stages that ‘boundaries’ as such are a very multifaceted term that requires multi-lens perspectives (Zevenbergen & Bennett 2015). Furthermore, when talking about surveying accuracy and precision, the concept of ‘idealisation precision’ should be taken into account (Baarda and Alberta 1960, cited in Bennett et al., 2012). The concept suggests that the final precision of a surveyed point depends on the precision of the survey tool itself but also on the precision of the identification of the boundary (Bennett et al. 2012) which is inherently determined by the nature of the boundary and thus can vary enormously. As indirect techniques solely acquire base data, a second phase of data collection in the field is needed in order to gather the required information about boundaries, land tenure, land use and land rights. To meet the challenges of new land administration practices (i.e. Fit-for-Purpose [FFP] land administration) participatory approaches to boundary determination receive more and more attention. At this, orthoimages are used as background information data base to demarcate visual boundaries of physical features by communicating to the citizen (Enemark 2014). Finally, as cadastral mapping deals with societal goods, the surveying practice needs to make sure to be aligned to the context of the country’s societal challenges and political interests (Bennett et al. 2012). Concluding, compared to field surveys, aerial and satellite surveys, the utilization of UAVs entails certain advantages: 1) cost-effectiveness makes UAVs an affordable data collection instrument for both top-down and bottom-up land tenure data acquisition; 2) flexibility addresses fit-for-purpose tailor-made data acquisition workflows; 3). high spatial resolution as well as high positional accuracies of final data products facilitate a reliable data base to guarantee a high level of idealization precision. Thus, UAVs have a great potential to be utilized as an innovative land tool for responsible land administration.

The information on cadastral data acquisition techniques showed, that UAVs are able to bridge the gap between field surveys and space- or airborne surveys and promises flexible, cheap, real-time and fast land tenure data acquisition – characteristics which are necessary to address current land administration challenges. Furthermore, the simple and easy-to-use approach of UAV operations allow various stakeholders such as individuals, communities or businesses to acquire mapping capacities (Barnes & Volkmann 2015), and can be seen as an affordable and promising instrument for bottom-up initiatives, particularly in countries with multiple tenure systems (e.g. Sub-Saharan Africa).

4. What are the steps of a UAV workflow?

A UAV workflow is built upon technical and non-technical aspects. As shown in figure 3, the general workflow for data acquisition includes four major phases: 1) planning and preparation, 2) field work, 3) data processing, and 4) quality assessment. In order to emphasize dependencies of parts of the workflow, external and internal elements are distinguished. Here, internal elements tackle variables and processes that are determined by the project. On the other hand, external elements are outside influences that impact the workflow. These can influence the execution of the project and can hardly be controlled.

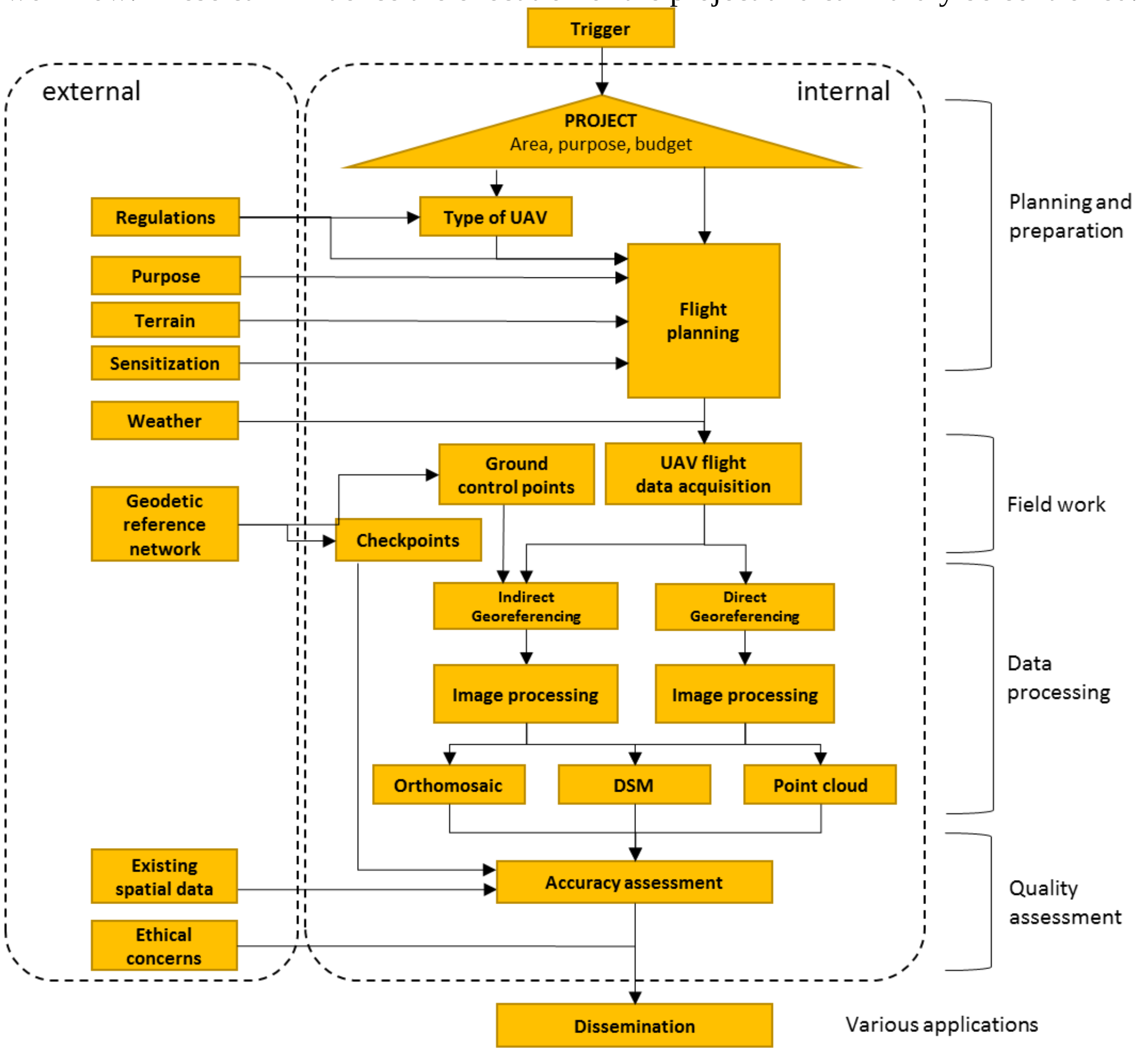

Figure 5: Overview of UAV-based data acquisition workflow, distinguished into internal and external elements

Triggered by a certain need or occurrence, a project for UAV-based data acquisition is admitted. In its first instance, the planning and preparation phase deals with the design of the project that defines the purpose and therefore the area of interest and the environment for the UAV mission. The desired coverage area, the goal and the budget mainly influence the selection of the UAV platform and the purpose determines the sensor that needs to be utilized. Here, regulations can also decree a limited take-off weight of the UAV. Based on the type of a UAV and the project, the flight planning can be carried out. At this, the regulatory framework can narrow the operating range or prohibit to fly above certain areas and thus can influence the flight planning from outside. Next to this, the sensitisation of the local community and the terrain can impact the final flight route. In general, field work considers the data collection outside the laboratory setting. Since field work is not strictly necessary for some remote sensing techniques, data collection in field campaigns is mandatory for UAV missions. In a typical UAV-based photogrammetric workflow (Nex & Remondino 2014) estimate one third of the whole time effort for data collection in the field. The author's report that time requirements are evenly spread between flight mission and ground control measurements. Other experiences suggest, that the time effort can also vary enormously according to the area and amount of ground control measurements. During the flight mission, some aspects involve special attention. Since flying in rough meteorological conditions (i.e. wind, rain, fog) is mostly not allowed under enacted UAV regulatory frameworks and furthermore not advisable because of data quality constraints (Heipke & Van Wegen 2013), the weather forecast should be taken into consideration before each UAV mission.

The flight operation itself commences with a security and battery check due to security issues. Afterwards the pilot launches the UAV manually, semi-automatically or even autonomously. Once the aircraft reached the planned altitude, it autonomously follows the predefined flightpath while driving from one waypoint to another. Sometimes even the landing procedure is without any interference by the pilot. Whilst the flight operation is more or less autonomously, ground truthing requires manual interventions. Therefore artificial target points are deployed throughout the area of interest and are surveyed with direct geodetic measurements, mostly differential GNSS devices. According to the method of georeferencing these targets can either be used as ground control points and/or checkpoints. Next to artificial targets, clearly visible and distinct natural points such as the centre of a manhole or road markings can be measured and used for ground truthing procedures. Once the UAV collected images and all ground targets are captured image processing follows. This stage aims for image triangulation in order to derive camera and image orientation, surface reconstruction, and finally seeks for the generation of dense point clouds, digital surface models and orthomosaics. The data processing can be followed by a quality assessment. For instance, checkpoints or existing spatial data such as topographic maps or existing orthoimages can be used to assess the positional accuracy. In due consideration of ethical constraints final data products are disseminated.

Legal frameworks that aim to regulate the use of UAVs are the very first and most important external element as they impact significantly on if, how, where, and when data can be captured – and the diffusion of the technology within a country context. Thus, the following sections provide insights to the past, present and future developments of UAV regulations with particular emphasis on its4land three target countries.

5. What are UAV regulations?

As UAVs are a new object in the airspace they constitute a potential risk to other airspace users as well as to third parties on the ground. Therefore, a growing number of countries are establishing regulations in order to minimize this risk. UAV regulations basically decree “Go”, “No go” or “How to go” statements and therefore either allow, prohibit or restrict flight operations. In general, the investigations reveal that UAV regulations are subject to national legislation and focus on three key issues: 1) targeting the regulated use of airspace by UAVs as they pose a serious danger for manned aircrafts; 2) setting operational limitations in order to assure appropriate flights; and 3) tackling administrative procedures of flight permissions, pilot licenses and data collection authorization in order to address public safety and privacy issues.

As shown in figure 6, the global overview of UAV regulations as per October 2016 reveals that nearly one third of all countries have respective regulatory documents in place. Approximately half of all countries do not provide any information regarding the use of UAVs for civil applications. However, this does not imply that flights are per se prohibited. Announcements for pending UAV regulations were found in 16 countries. On this, some countries (e.g. Kenya) already published draft versions and enacted regulatory documents are expected in 2017. In Cuba, Egypt and Uzbekistan UAVs are officially banned and the use of UAVs is prohibited. In 13 cases, the information of relevant precompiled lists could not be validated and no documents were found that prove the existence of particular regulations.

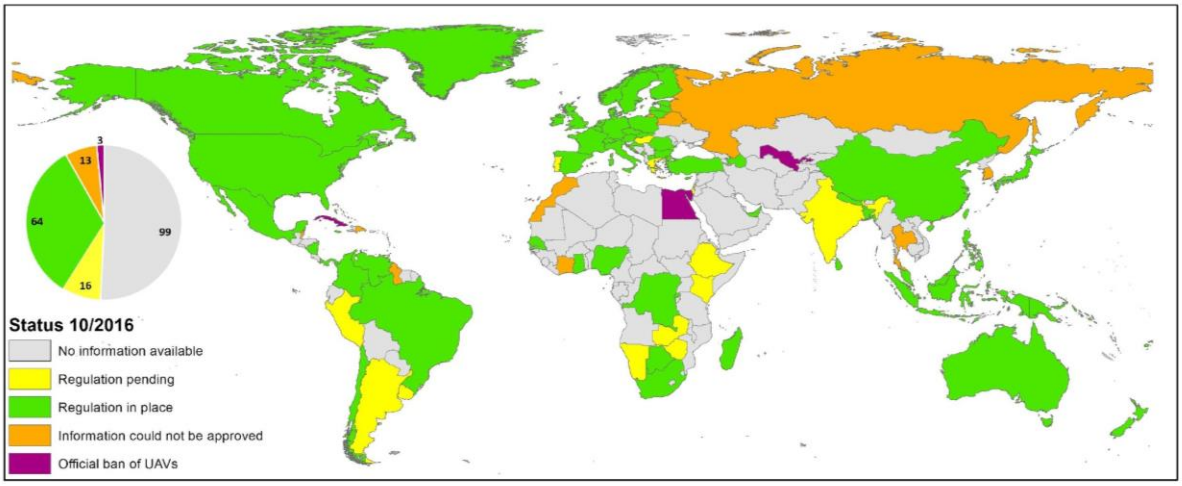

Figure 6: Global overview of current status of UAV regulations on a country level resolution (status: 10/2016)

6. How did we regulate UAVs in the past?

The history of UAV regulations dates back to manned aviation and the emergence of airplanes during the World War II. In 1944, the international community established the first globally acknowledged aviation principles - the Chicago Convention. Besides the main focus on requirements for safe and secure flights in manned aviation, one article addresses pilotless aircrafts and highlights the need for special authorization of UAV operations.

> *"No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization. Each contracting State undertakes to ensure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be controlled as to obviate danger to civil aircraft." – Article 8* (ICAO 1944)

Due to the early developments of UAVs in the form of manipulated model aircrafts (Eisenbeiß 2009), UAV operations were usually conducted under respective regulations for model aircrafts (Rango & Laliberte 2010). In the 2000's – after years of technological research and innovation – UAVs developed into a commercially workable system. Hence in 2006, the ICAO identified and declared the need for international harmonized terms and principles of the civil use of UAVs (ICAO 2015). At this time, five countries had already established and enacted UAV regulations (see figure 7 and 8). UK and Australia were the first nations that promulgated regulations in 2002 and the first operator certificates were issued in 2003. Several countries followed, however, even by 2012 the propagation of national UAV regulations remained very limited. From 2012 onwards, this trend changed and an increasing number of countries established national UAV regulations: between 2012 and 2015/2016 more than 80% of the 64 countries with national regulations enacted them.

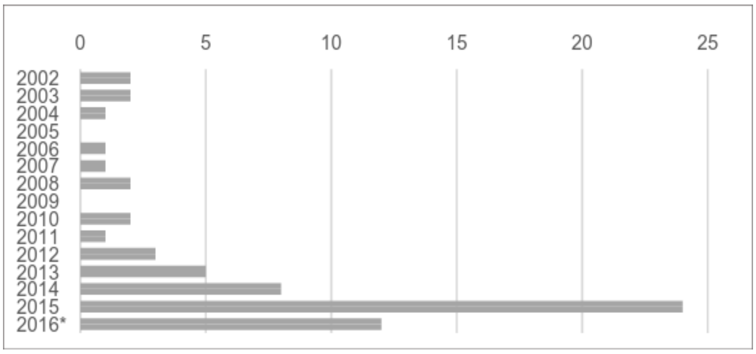

Figure 7: Temporal overview of first releases of UAV regulations on a country level resolution (status: 10/2016)

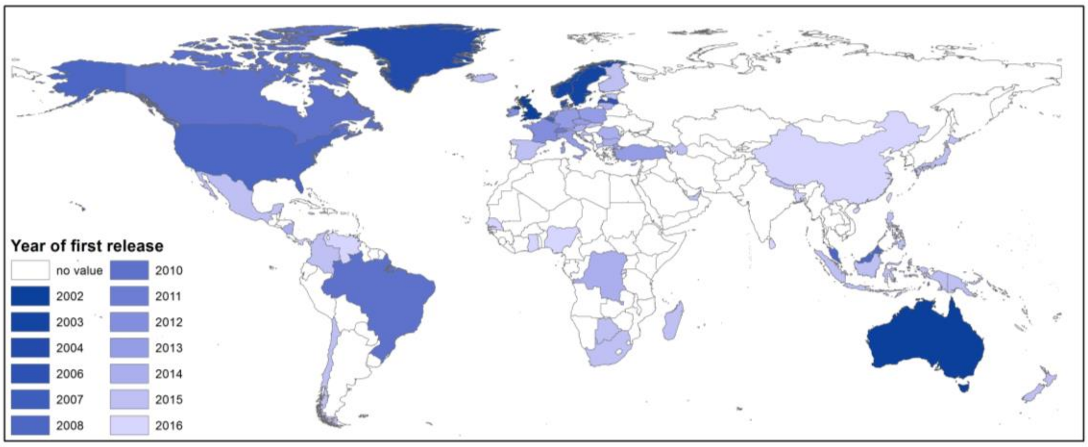

Figure 8: Global distribution of first releases of UAV regulations on a country level resolution (status: 10/2016)

Generally speaking, national UAV regulations were established in reaction to the growing UAV industry and the identified need to regulate the emerging technology for public safety. In several cases countries further promulgated regulations as a response to high-profile incidents, as witnessed in Japan. Here, UAVs were originally widely operated without a sophisticated regulatory framework, however, an incident where a UAV that carried radioactive soils and intentionally landed on the rooftop of the Prime Minister's office triggered the discussion and the subsequent revision and amendment of the Japanese Aviation Act 1.

Besides national efforts to introduce UAV regulations, international organizations took initiatives in parallel. In 2002, the Joint Aviation Authorities (JAA) and European Organization for the Safety of Air Navigation (EUROCONTROL) jointly established a UAV Task Force aimed at safely integrating UAVs into European Airspace through the setting out of a guiding concept for civil UAV regulations (JAA & EUROCONTROL 2004). As a successor of the JAA, the European Safety Aviation Authority (EASA) as a legal regulatory authority within the EU further pursued this mission from 2008 onwards. Various documents for the development of one European policy on UAVs were published. In 2012 the European Commission set up the European RPAS steering group (ERSG) – a gathering of organizations and experts in this field. ERSG received the mandate to create a roadmap for integration of civil UAVs into the European aviation system (European RPAS Steering Group 2013). The final report was published in 2013 and is briefly outlined below (4.2.1). Next to the regional context of Europe, global interest groups and professional organizations were established as well. In addition, a special UAV study group of ICAO, the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) was established in 2012 and comprises a group of experts from national and regional aviation authorities. JARUS aims to provide guidance material to support and facilitate the creation of national UAV regulations.

[1] http://www.japantimes.co.jp/news/2016/02/16/national/crime-legal/man-landed-drone-roof-japanese-prime-ministers-office-gets-suspended-sentence/#.WFEvqIrQf_w, 12.12.2016

7. How are we regulating UAVs now?

International context

The ICAO is an international actor that serves as a collaboration and communication platform for national civil aviation authorities. They are concerned with fundamental regulatory frameworks at a global scale and provide information material, Standard and Recommended Practices and Procedures for Air Navigation Services (ICAO 2011). In 2016, ICAO published an online toolkit that delivers general guidance for regulators and operators[2]. The same organization further issued recommendations to the safe integration of UAVs into controlled airspace. At this, UAVs are "(…) envisioned to be an equal partner in the civil aviation system [that are] able to interact with air traffic control and other aircraft on a real-time basis" (ICAO 2015). As this manual particularly focuses on a global harmonization of UAVs in air traffic controlled environments, lower priority is granted to visual line of sight (VLOS) operations (ICAO 2015).

JARUS is a group of 49 national authorities (12/2016) and experts that recommend operational, safety and technical regulations and particularly focus on UAVs that weigh less than 150 kg. This international actor aims for harmonized standards and specified guidance materials. Amongst others, current publications include detailed recommendations for light unmanned rotorcraft systems (JARUS 2013b), requirements for C2 command and control link (JARUS 2016) and recommendations for personnel licensing (JARUS 2015). Ongoing work concerns design objectives for detect and avoid systems and operational categorizations.

Besides global acting organizations, diverse stakeholders in the European Union are discussing developments and principles for future regulatory frameworks of UAVs. One important step taken in Riga 2015 was the publication of the Riga Declaration on Remotely Piloted Aircrafts (EASA 2015c). The declaration highlights five main principles that should guide the regulatory framework in Europe: 1) Drones need to be treated as new types of aircraft with proportionate rules based on the risk of each operation; 2) EU rules for the safe provision of drone services need to be developed now; 3) Technologies and standards need to be developed for the full integration of drones in the European airspace; 4) Public acceptance is key to the growth of drone services; 5) The operator of a drone is responsible for its use (EASA 2015c).

EASA further developed proposals for common rules for UAV operations (EASA 2015a; EASA 2016; EASA 2015b). The concept of the proposed regulatory framework is based on a proportional and operation-centric approach that focusses on the way and conditions of the operation rather than just on the characteristics of the UAV (i.e. weight) (EASA 2015b). Data protection and privacy are not yet included. These actions are accompanied and guided by the European Roadmap for the Integration of Civil Remotely - Piloted Aircraft Systems into the European Aviation System. Published in 2013, this document

[2] http://www4.icao.int/uastoolkit/Home/About 19.12.2016

identifies different levels of harmonization and integration and addresses these with an incremental approach. Furthermore, the roadmap includes three annexes with clear work plans for regulatory improvements, foreseeable research and development contributions and a study on the societal impacts of UAV applications (European RPAS Steering Group 2013).

Next to governmental efforts on national and international levels, UAViators - Humanitarian UAV Network refers to a worldwide initiative with more than 2500 members. Besides other tasks, the initiative develops clear standards for the responsible use of UAVs and provides up-to-date information on regulatory frameworks. Documents and databases are the result of collaborative action of active members. (UAViators 2015) was drafted in an open consultative process where UAViators members, UAV experts and global acting organizations were involved.

National context

A detailed comparative analysis between the regulations of different countries reveals a clear heterogeneity of national UAV regulations (see Annex iii for details). However, clusters and similarities between countries are evident. The following paragraphs provide a summary of each indicator and highlight generalities and particularities before certain country-specific context and constellations are shown.

Applicability

In general, UAV regulations only apply for certain scenarios of civil UAVs that are classified and limited by the weight of the UAV and/or the area, operational range or purpose of its utilization. As a matter of the objective of this research, all regulations are applicable for UAVs that are used for commercial purposes. Most of the countries define commercial flight operations as flights for purposes others than just for the flight itself. Here, a mounted camera can already indicate commercial use (e.g. Austria). However, 14 countries also include the regulations of UAVs for fun and recreational purposes whereof more than half of the countries do not distinguish any purpose and thus include both uses. Only four countries explicitly exclude UAVs that are considered as model aircrafts. This initial definition of the applicability is further reflected in different safety levels for respective uses. The same applies for another classification criteria: weight. All countries except of Japan, China, Rwanda and Nigeria have a classification scheme according to the weight and thus follow the basic concept of a risk-based approach – the higher the associated risk the stricter the flight conditions. Regarding weight limitations, only two countries – U.S. and Japan – introduced a minimum threshold, 250g and 200g respectively. All drones that are lighter as the threshold are not subject to the regulations. In contrast, almost all countries incorporate a maximum take-off mass (MTOW). At this, UAVs that are heavier than 150kg are usually not regulated by national Aviation Authorities but by international bodies like EASA in Europe. However, the MTOW is not consistent in all cases. Here, China and Chile are extreme cases that allow comparatively low MTOWs. Other predominant weight thresholds refer to 20/25kg and ≤ 10kg. The presence of weight classes allows for multi-layered regulations that are adopted to the associated risk and has implications for administrative procedures and the qualification of pilots.

Next to the classification according to the weight, Austria, France and Italy include the area of the intended flight as a second criterion and therefore create different scenarios that are compiled in a more complex risk-matrix (cf. Austria). France and South Africa also incorporate visibility as one classification criteria. At this, beyond visual line of sight flights are already considered as one flight scenario and thus involve particular regulations.

<u>Technical prerequisites</u>

Besides general recommendations for pre-flight checks of all technical functionalities only twelve out of 18 countries specifically mention technical prerequisites for UAV operations. Here, the Latin American representatives Chile and Colombia stand out for their very extensive and concrete requirements that encompass the material of the blades, the GNSS device, command and control requirements, the autopilot and recovery capabilities, just to name a few. In contrast, the remaining ten countries mainly demand special technical arrangements if the flight operation is classified as risky and thus either exceed a certain MTOW and/or is operated in populated areas. In six cases, main requirements concern the command and control system and special fail and safe instruments like safety parachutes that are able to safely terminate the flight in emergency situations such as malfunction or loss of command and control links (e.g. in France and Italy).

In addition to general requirements, collision avoidance capabilities were chosen as a separate indicator as it is currently widely discussed for the safe integration of UAVs into national airspace systems (Yu & Zhang 2015). In manned aircraft aviation the pilot observes whether other users of the airspace are on a collision path and adjusts the airplane and flight if necessary. As UAVs are operated without any pilot on board, the so called ‘see and avoid’ concept of manned aircrafts cannot be fulfilled anymore. Especially in cases where UAVs are operated beyond visual line-of-sight (BVLOS), substitutes like special technical instruments may become necessary in order to achieve an equivalent level of safety to the ‘see and avoid’ concept. From 18 UAV regulations which were compared, only seven cases particularly mention sense and avoid, see and avoid or detect and avoid requirements, respectively. However, these mandates are only applicable in particular operational conditions such as flights in controlled airspace (UK), BVLOS (France) or UAV operations above a certain MTOW (Canada). In all cases, respective requirements remain very general. Besides countries that already included collision avoidance strategies into their UAV regulations, several other cases refer to sense and avoid instruments which may help (Germany) or are mandatory (China, U.S.) in order to obtain exceptional flight permissions on a case-by-case decision. The U.S. further outline their reasoning for not incorporating any collision avoidance requirements into their regulations as the technology is still in its early stage and none of it has an airworthiness certification so far (Federal Aviation Administration 2016).

<u>Operational limitations</u>

Operational limitations are a major element of most UAV regulations and refer to restrictions of the UAV flight. Apart from Nigeria, all countries define distances to people and property and/or so-called no-fly zones which need to be taken into account. The most prominent example of a no-fly zone is the surrounding of aerodromes, airports and airstrips. As UAVs pose a serious risk for manned aircrafts, they are usually not allowed to fly in controlled airspace and thus in the proximity of places where manned aircrafts may land or take off[3]. Besides the prohibition to operate UAVs in controlled airspace, some countries define no-fly zones that are available on online map services (e.g. Japan, The Netherlands). Others refer to distances that demarcate a circular surrounding of airports (e.g. Australia, Rwanda) and are applicable if the airport/airstrip is not subject to means of air traffic control. Another important operational limitation states a safe distance to people, property and vessels that are not associated with the UAV flight itself. Here, ten countries specifically mention concrete lateral distances in the range of 30 m to 150 m to people. Five countries raise a general prohibition to fly in the vicinity of people and/or crowds of people. The remaining countries Nigeria, China and Malaysia do not discuss operational limitations related to people.

One hierarchal level higher than prohibitions to fly over people refers to flight regulations over congested areas such as towns, cities and roads. Here, eleven countries prohibit UAV flights over these areas – some even point to a minimum distance that need to be kept. However, terms like congested areas as well as crowds of people remain vague and expressions are rarely defined. In contrast, the extent of restricted areas is very sharp and includes UAV flights over jails, military areas, industrial buildings, nuclear power plants, hospitals, and/or governmental buildings, respectively. All cases except Malaysia and Nigeria incorporate this kind of prohibited areas into their UAV regulations. In addition to permanent restricted areas, emergency situations such as police or fire brigades operations might restrict UAV flights temporarily (e.g. Australia, Germany). More exceptional operational limitations refer to a maximum flight time of 60 min (Chile), a restricted distance of 9.2 km towards all international borders (Columbia), or a specified distance of 10 km to any other aircraft (China).

Besides flight restrictions due to location of the UAV operation, general limitations refer to a maximum height level and horizontal limitations in terms of visibility and range. Regarding the height level, all cases apart from China and Nigeria allow only low-altitude flights and define a maximum flying height within the range of minimum 90 m (Canada) to maximum 152 m (Columbia) above ground level. These particular heights can be explained by the fact that UAV regulations currently aim to separate manned aircrafts and UAVs – and thus allow UAV flights only below the minimum safe altitude for aircrafts[4]. Regarding the horizontal limitations of UAV flights, regulatory bodies usually distinguish between two ranges: VLOS and BVLOS (see fig. 5). All cases of the comparative analysis allow UAV flights in VLOS. In VLOS conditions, the pilot or any other person in charge must be able to maintain direct unaided visual contact to the UAV

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[3] Special authorization might be possible on a case-by-case decision

[4] Besides international recommendations by ICAO, the value for minimum safety altitude changes in different national contexts, e.g. the U.S. defines the in non-congested areas to 500 feet (152 m) AGL (Federal Aviation Regulations, Sec. 91.119)

(ICAO 2015). In addition to this definition, seven countries designate maximum lateral distances that range from minimum 100 m in France to maximum 750 m in Columbia. The required distance bounds a vague interpretation and strictly determines the term VLOS. Some cases further include extended visual line-of-sight (EVLOS) operations. Here, the pilot uses an additional observer or remote pilots to keep the visual contact to the UAV (cf. fig 9). The US, UK, Italy and South Africa particularly mention the possibility of EVLOS operations within their UAV regulations. Furthermore, twelve out of 18 countries basically allow BVLOS flights. However – apart from France and Nigeria – BVLOS flights, which are outside the general permission for the commercial utilization of UAVs, require either special flight conditions or exceptional approvals.

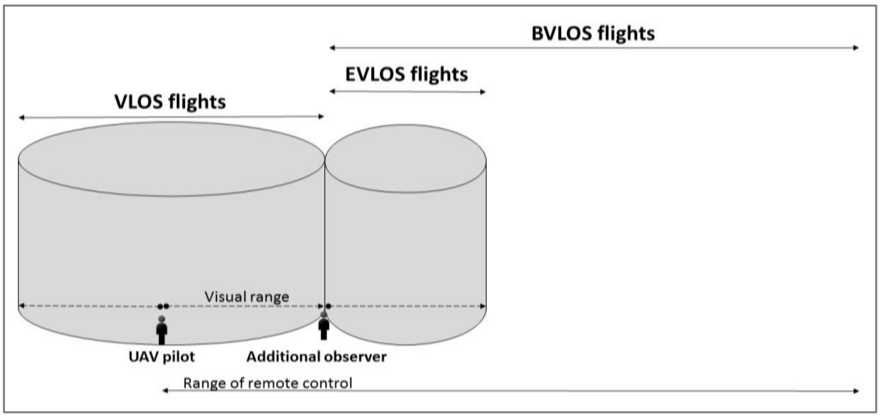

Figure 9: Schematic distinction between UAV flight ranges - VLOS, EVLOS and BVLOS, based on (South African Civil Aviation Authority 2016., p.15)

Administrative procedures

The indicator of administrative procedures distinguishes variables according to the application process including operational certification and the need for UAV registration. Here, a markedly heterogeneity can be observed. In general, the amount of effort to apply for flight permission depends on the complexity of the UAV operations. Due to the initial definition of different classifications and thus cluster of various UAV operation scenarios, nearly all application procedures are multi-layered and different strategies have to be followed in different contexts. In order to provide a comparable basis, the following results are based on best-case scenarios where the UAV flight meets all operational prerequisites and does not fall under special approval conditions – if not mentioned otherwise. Pursuant to this assumption, some countries do not envisage any application procedures for UAV operations below a certain MTOW – neither for the platform nor for the flights whereas others follow a single-case flight authorization approach that entails a new application for each flight operation. Australia, Italy and Canada do not require a formal flight application if the MTOW of 25 kg is not exceeded. Others demand applications if the flight is intended to happen in areas that do not conform to standard operational procedures (Japan, France, UK). Light UAVs in Austria and Germany are subject to a general permission which is granted for a specified timeframe. In six cases, UAV flights permissions encompass single-case application procedures.

In addition to official and formal flight permission procedures at respective national aviation authorities, notifications, preannouncements and flight approvals of local authorities are common praxis for the majority of cases that were analysed. Based on the regulatory texts, the approval and notification procedure follows three main purposes: 1) to acknowledge specific local operational restriction, 2) to impede conflicts of airspace users, and 3) to avoid concerns and interruptions from the public. Furthermore, declarations of compliance to applicable sections in the UAV regulations can also be mandatory before a flight is allowed to be commenced (e.g. Italy, UK). If the flight will be (partly) executed in controlled airspace, a notification to the air traffic control service is compulsory in all cases that are compared. Besides these formal requirements, most of the regulations further involve a notification to the local police and approvals of the land owner where the UAV is about to take-off and land (e.g. Germany). At this point, search and rescue operations by fire brigades or UAV operations of governmental institutions are usually exempt from formal application procedures.

Next to the application procedure, ten cases require a registration for any kind of commercial flight operation. Here, the registration either involves a registration number, markings, or an electronic ID plate as in Italy. The aviation authorities in Malaysia and Azerbaijan require a registration only if the weight of the UAV exceeds 20 kg. Six cases do not embrace a registration process. Insurance obligations are further considered within the majority of UAV regulations of this analysis. An insurance basically addresses the subject of a clear liability regime that is able to sufficiently compensate for any harm and/or damage caused by the flight operation. However, in six out of 18 UAV regulations an adequate insurance policy is not treated as a compulsory requirement for the commencement of commercial UAV flights.

Human resource requirements

Besides the UAV itself, many regulations include demands on the UAV operator. Here, practical training, theoretical knowledge tests, aeronautical tests, and medical assessments encompass the most common requirements. Just as with the application procedures, the level of required pilot skills usually depends on the complexity and the risk of the flight mission. So far, Japan does not mention any pilot needs and Azerbaijan, UK and Germany only request a basic confirmation of the competencies of the UAV operator. Besides this, the majority of the cases either demand a pilot certification or a license. The main difference between both is based on the amount of training that is attached to the issuance of the degree (cf. Italy). A certificate is usually granted by intermediaries like authorized training centres or UAV manufacturers and entails a basic practical and theoretical training of the pilot. In contrast, the procedure and requirements to obtain a UAV pilot license usually involve sophisticated aeronautical background knowledge and is issued by national aviation authorities. However, a sharp distinction between both pilot qualifications is not possible and some countries chose “middle ways” and refer either to certificates or licenses. In this comparison, Malaysia and Nigeria outline exceptional cases. Here, Malaysia requires two operators: a pilot and a commander. Both shall hold a valid pilot license. In Nigeria, the UAV pilot needs to be licensed to operate manned aircrafts in order to be authorized to execute UAV flights.

Implementation of ethical constraints

The issue of privacy and data protection in relation to the increasing use of UAVs underlines one currently widely discussed topic. A UAV equipped with a camera can easily capture and record images of people, houses or other objects and thus potentially violate privacy and data protection rights of citizens. Based on the outcomes of this comparative analysis, these issues are barely incorporated and reflected in current UAV regulations. Only twelve cases mention privacy and/or data protection. Here, the majority “only” advises to respect personal privacy. Furthermore, many cases state, that actions might be subject to other laws and that national and international applicable legislations need to be followed. However, only five countries directly refer to respective laws. Rwanda particularly incorporates the prohibition of surveillance activities without people’s consent into their UAV regulations.

Country context and pattern

The comparison of variables of all 18 cases reveals a heterogeneous picture. Even though all countries except of Azerbaijan, Chile, Nigeria and Rwanda are part of JARUS, no coherent concept or strategy for national UAV regulations can be identified. Particularly striking are Japan and Nigeria as more than half of the variables of the comparative analysis were not applicable. One would now suggest, that both cases are similar. However, the opposite is the case. Without tangible technical and human resource requirements UAV flights in Japan can easily be commenced within given operational and geographical restrictions. In Nigeria, no general operational limitations or technical requirements are stated. Nonetheless, each flight needs a special authorization and the pilot requires a manned aircraft license which involves a very elaborate procedure and impedes widespread usage of UAVs. In contrast, France, Italy and Austria acknowledge nearly all variables in their regulations. In all three cases, the regulations show a certain maturity as different scenarios and a complex risk-based classification is recognized. Technical and administrative requirements as well as operational restrictions are formulated according to the risk of the flight operation. This allows the realization of various flight settings in a riskless manner without generally impeding certain UAV operations. All other cases exclude the area of interest as one classification criteria and mostly refer to special approval procedures if one intents to fly in usually restricted areas – such as developed and inhabited areas. Regarding the temporal aspect of date of release or last update, all UAV regulations except those of Malaysia were either issued or updated within the last two years (2015 and 2016). All cases that show updates since the first release tend to involve lower administrative procedures and lower demands for pilot qualification for normal and risk-less UAV operations within respective limitations. During the online search and investigations of the authors, different levels of the provision of information about respective UAV regulations became prevalent. Except of Malaysia, all cases characterized by early releases before 2012 show active public relations activities, dissemination and awareness campaigns of respective regulatory frameworks including clear homepages that provide insightful infographics and online templates for notification forms. Besides this, a few countries like U.S. and the Netherlands already embrace different kinds of media and platforms to raise the consciousness of mandatory pre-flight requirements and operational limitation for UAV flights [5].

[5] The Netherlands: http://www.veiligvliegen.nl 12.12.2016
U.S. B4UFLY app: https://www.faa.gov/uas/where_to_fly/b4ufly/ 12.12.2016

8. UAV regulations in Rwanda, Kenya and Ethiopia

As shown in figure 6, only Rwanda has enacted UAV regulations at the time this report (deliverable) is written. In Ethiopia and Kenya, respective regulatory frameworks are yet to be built. The following subsections provide insights of processes and workflows that are needed to obtain legal flight permission in all target countries of its4land.

Rwanda

When it comes to UAVs, Rwanda can be seen as very progressive in comparison to other East African countries. Current UAV projects such as Zipline[6] – drone based delivery of medical supplies – tell a story of success. Furthermore, CHARIS UAS Ltd[7], a local Rwandan drone company that provide diversified services in UAV industries seems to create a robust foundation for UAV innovation growth in Rwanda.

In April 2016, the Ministerial Regulations N°01/MOS/Trans/016 relating to UAVs were officially gazetted (Rwanda Civil Aviation Authority 2016). Respective regulations are very prescriptive and contain subparts dealing with UAV registration and marking, privacy and safety, airworthiness certification, operating rules and pilot licensing. Before any commencement of activities, the UAV needs to be registered and marked with a unique identifier. The next step to receive a flight permission involves the application for an activity permit. Required documents include:

- Operational documents including an illustration of the whole operation process, safety measures, emergency procedures, risk assessment of the site, and procedures for reporting to RCAA.
- Declaration of compliance that the UAV will not cause interference with any other radio communication station
- Copy of the operating manual provided by the manufacturer
- Evidence of remote pilot training, licenses and past experiences
- Evidence of insurance coverage
- Pictures of the UAV and the payload
- Proof of payment of fees

However, in order to legitimately pursue a UAV flight, the institution or legal entity which will carry out the flight must also hold an operator permit that is valid for one year. According to the (Rwanda Civil Aviation Authority 2016), an operator permit is only granted "(…) if the applicant is able to ensure safe operation of unmanned aircraft, taking into account the applicant's organisational set-up, competency of the personnel especially those flying the unmanned aircraft, procedures to manage safety including the conduct of safety risk assessments, and the airworthiness of each of the aircraft."

[6] http://flyzipline.com/product/, accessed 02.02.2017
[7] http://www.charisuas.com , accessed 02.02.2017

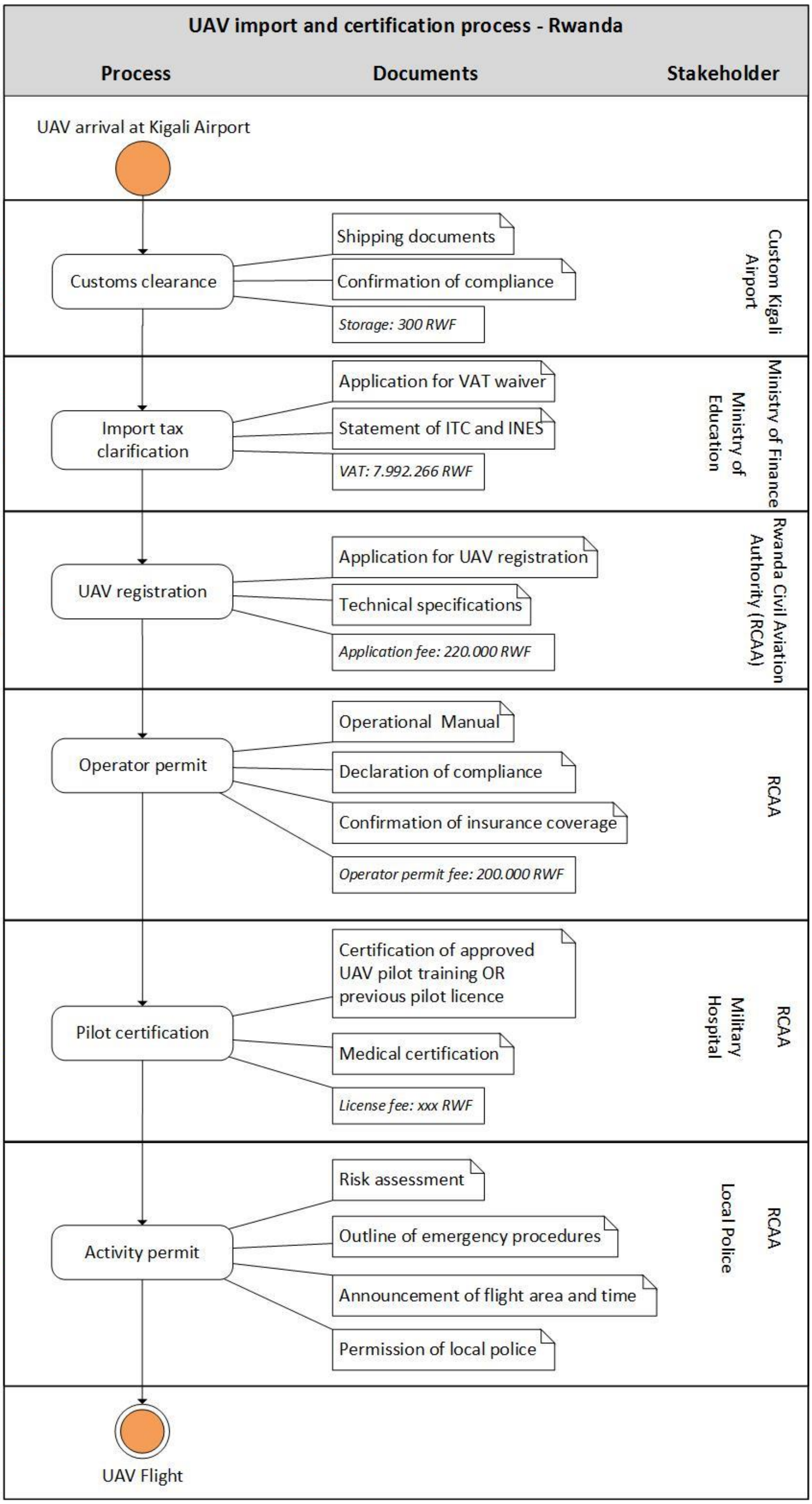

Figure 10: Activity diagram to obtain legal flight permission in Rwanda

The flowchart of figure 10 shows an overview of processes, necessary documents and stakeholders that are involved in the flight approval process. These requirements demand a high standard of UAV professionality and make it very difficult for new companies and institutions to obtain legal flight permissions. From the start of WP4, options and opportunities for legal UAV flights were investigated. Lessons learned tell that the way is not as straightforward as implied by the formal regulations. Vague statements by the authorities, non-adherence to deadlines and missing capacities for pilot licensing procedures – although a license is demanded – make it a hurdle race to receive a legal UAV flight permission. However, INES, ESRI Rwanda and ITC collaboratively push towards the commencement of first flights although some processes are still uncertain.

Kenya

In February 2017 – as the second country after Rwanda in the Eastern African region – the Security Council of Kenya approved the draft regulations for the use of UAVs (Kenya Civil Aviation Authority 2017). The final regulations are now waiting to be gazetted. In general, the draft of the Kenyan UAV regulations shows huge similarities to the Rwandan UAV regulations and the same tripartite scheme becomes evident: UAV registration certification, operational certification and pilot certification are needed to apply for a flight permit. However, an appreciable difference exists within the classification scheme. Here, the Kenyan ones also distinguish private use where the UAV is utilized for private activities excluding recreational and sports purposes (see Fig. 11).

	Cat A Recreational and Sports	Cat B Private	Cat C Commercial
Class 1 0 – 5kgs	1A	1B	1C
Class 2 5 – 25kgs	2A	2B	2C
Class 3 25kgs and above	3A	3B	3C

Figure 11: UAV classification according to purpose and weight

Depending on the classification of the intended flight operation, different requirements apply. Before institutions, entities or individuals plan their flight missions, they need to seek authorization from the Ministry of Defence. After receiving an approval from the Ministry of Defence, an application should be made to KCAA to register the drone, to become an authorized UAV pilot and to obtain an operational certificate. The following activity diagram outlines in Fig. 12 main steps to acquire a legal flight permission for light UAVs for commercial activities - the category that fits to our intended UAV operation (1C).

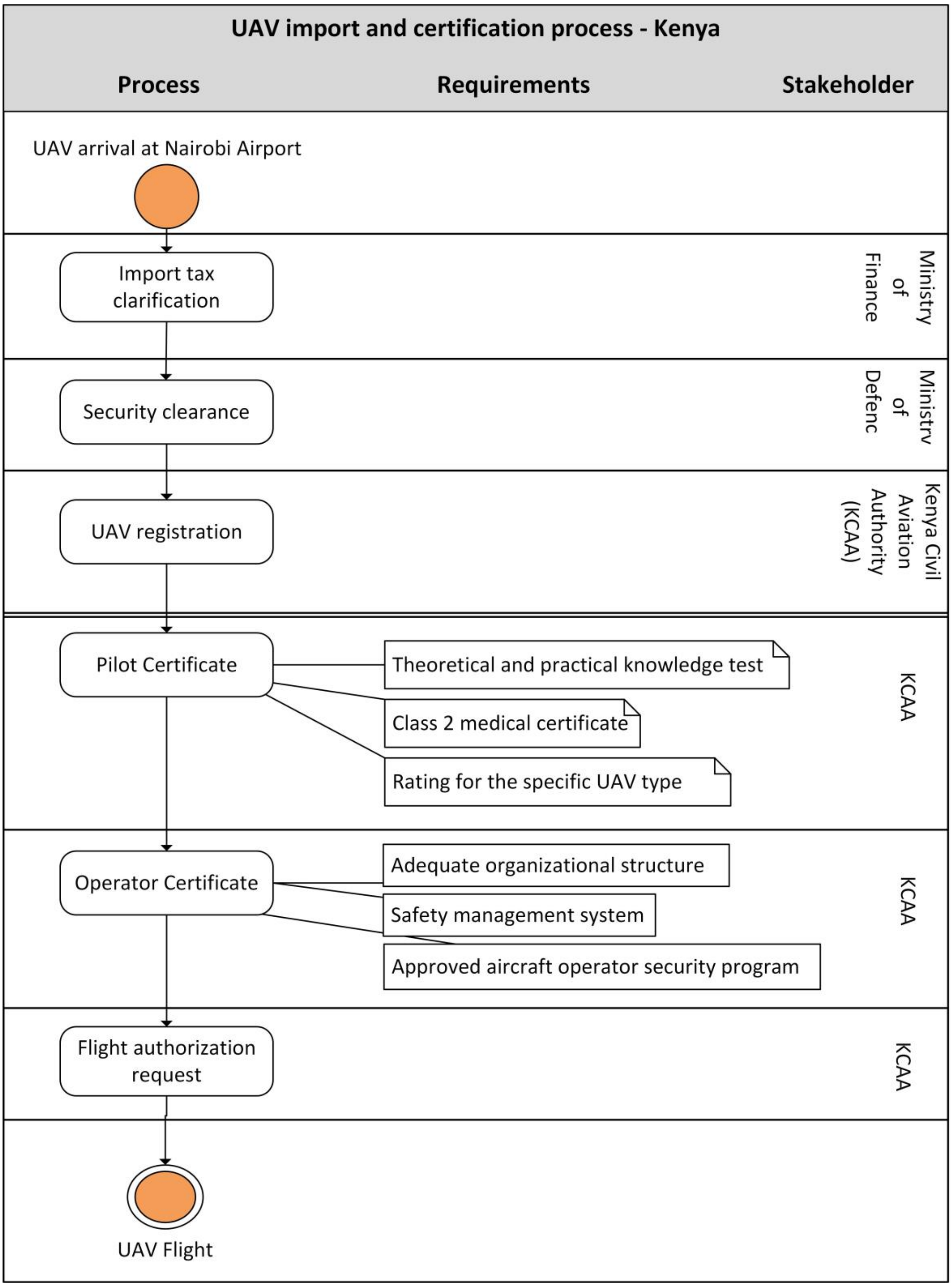

Figure 12: Activity diagram to obtain legal flight permission in Kenya. As the regulations are still not legally binding, requirements and documents that lead to the fulfilment for all steps could not be precisely outlined.

Once the UAV is registered and both pilot and operator are licensed, the delivery of flight permits is based on a single-case request. At this, the request for authorization for operation shall include the following:

a) Name and contact information of the operator;
b) RPAS characteristics (type of aircraft, maximum certificated take-off mass, number of engines, wing span);
c) Copy of certificate of registration;
d) Aircraft identification to be used in radiotelephony, if applicable;
e) Copy of the certificate of airworthiness;
f) Copy of the RPAS operator certificate;
g) Copy of the remote pilot(s) licence;
h) Copy of the aircraft radio station licence, if applicable;
i) Description of the intended operation (to include type of operation or purpose), flight rules, visual line-of-sight (VLOS) operation if applicable, date of intended flight(s), point of departure, destination, cruising speed(s), cruising level(s), route to be followed, duration/frequency of flight;
j) Take-off and landing requirements;
k) RPAS performance characteristics, including: (i) Operating speeds; (ii) Typical and maximum climb rates; (iii) Typical and maximum descent rates; (iv) Typical and maximum turn rates; (v) Other relevant performance data (e.g. limitations regarding wind, icing, precipitation); and (vi) Maximum aircraft endurance;
l) Communications, navigation and surveillance capabilities; (i) Aeronautical safety communications frequencies and equipment, including: (ii) ATC communications, including alternate means of communication; any (iii) Command and control links (C2) including performance parameters and designated operational coverage area; (iv) Communications between remote pilot and RPA observer, if applicable; (v) Navigation equipment; and (vi) Surveillance equipment (e.g. SSR transponder, ADS-B);
m) Detect and avoid capabilities;
n) Emergency procedures, including but not limited to: (i) Communications failure with ATC; (ii) C2 failure; and (iii) Remote pilot/RPA observer communications failure, if applicable; (iv) Number and location of remote pilot stations as well as handover procedures between remote pilot stations, if applicable (v) Document attesting noise certification, if applicable; (vi) Confirmation of compliance with the Civil Aviation (Security) Regulations; (vii) Payload information/description; and (viii) Proof of adequate insurance coverage.

Other than in Rwanda, KCAA may grant upon application a temporary permit to person(s) intending to operate RPAS not registered in Kenya. However, as the respective document is only approved but not gazetted, abovementioned requirements remain uncertain. Before the current draft becomes law, legal UAV flights are only possible with a special authorization from KCAA.

Ethiopia

Already in 2015, the Ethiopian Civil Aviation Authority (ECAA) reported the need to regulate the import and use of UAVs in Ethiopia[8]. Although no legal UAV regulations are yet in place, progress in content related work can be reported. Information from BDU correspondence reveal that the legal UAV framework is drafted and the final approval can be expected in spring 2017. The main stakeholders who contribute to the UAV regulations are the ECAA and the Ethiopian Information Network Security Agency (INSA).

Before the final UAV regulations will become law, it is recommended the stakeholders follow common rules such as stated in the following[9]:

- Do not fly your drone over people or crowds of people
- Respect other people's privacy when flying your drone
- Do not fly your drone near military installations, power plants, or any other area that could cause concern among local authorities
- Do not fly your drone near airports or in areas were aircraft are operating
- You must fly during daylight hours and only fly in good weather conditions

Besides these general recommendations, the UAV operator should seek a legal permit to fly its UAV. Here, INSA and ECAA are also concerned when it comes to current UAV flight permissions before the final UAV regulations are gazetted. Once, the flight permit is granted, further stakeholders such as the military, police and local administrations should be informed before the flight is commenced.

[8] http://allafrica.com/stories/201511160760.html, accessed 31.01.2017
[9] https://uavsystemsinternational.com/drone-laws-by-country/ethiopia-drone-laws/, accessed 31.01.2017

9. How will UAVs be regulated in the future?

The current state of UAV regulatory frameworks constitutes a major focus for different stakeholders in the domain (R.A. Clothier et al. 2011) and the heterogeneity of national UAV regulations shows different approaches to responding to the demands of interest groups. However, commonalities are present and recent changes in national UAV regulations allow to predict possible future developments and challenges. For example, civil UAV operations in both controlled and un-controlled airspace are largely restricted and this will continue to impede wider utilization, at least in the short term.

The key challenge appears to be to find an appropriate balance between the demands of different actors. That is, allowing for innovation on the one hand, but, at the same time ensuring recognition and support for fundamental human rights and civil liberties. Future development of civil UAV usage will ultimately involve multiple interest groups and various motivations (Rao et al. 2016; Clothier et al. 2008). Government institutions and regulatory bodies holding political mandates want to ensure civil liberties, public safety and security – but, also promote UAV innovation – and technology innovation more generally. Stakeholders in research strive for UAV technical advancement. Hardware and software manufacturers aim to sell products and are interested in lowering market barriers and opening up new application areas. End users have their own needs and market interests according to their application.

In both national and international contexts, a risk-based approach to regulate the use of UAVs appears to be the strategy of choice. An initial step towards risk-based assessments and requirements is acknowledged through weight classifications: it is already present in the majority of cases. However, the inclusion of other parameters such as area, purpose, and visibility provides an even more proportional approach. Following this, an all-embracing framework would ultimately allow the streamlining of regulatory efforts for all kinds of civil UAV operations and to disentangle complicated requirements for special exemptions and waivers. If the UAV flight can be considered as riskless (i.e. light weight, in inhabited areas and VLOS), or extremely low risk, no bureaucratic barriers should impede it. The more risky the flight operation the more requirements are applicable. This goes in-line with current national harmonization actions undertaken by EASA where riskless *open* and more risky *specific* categories are outlined (EASA 2016). France, Italy and Austria already follow a risk-based approach and in this regard can be considered as pioneering countries.

Grounded in this risk-based regulatory framework, detailed safety requirements for different scenarios can be built in (Reece A. Clothier et al. 2011). With regard to the growing UAV market, the activity levels and requests for the approval of flight permissions are likely to increase. In this context, aviation authorities should avoid treating every request as a stand-alone exercise: the administrative time and expense will overwhelm bureaucracies and undermine any policies towards technological innovation. Increased efficiency and capacities dealing with administrative processes of flight approvals and UAV platform registration are needed. In addition to this, general flight permissions for riskless UAV operations in un-controlled airspace, as in place in Australia and Canada, can be seen as pioneering. However, additional (in the best case online) notification forms - with details about the date, time and place of the intended UAV operation - are very important in order to allow safe and efficient management of respective airspace and to avoid mid-air UAV collisions. Overall, it is evident, that countries with a longer history of frequently updated UAV regulations show more maturity than countries that released regulations in 2015/16. At this, maturity can be referred to as efficient administrative processes, the presence of awareness campaigns and established procedures to register UAVs and train UAV pilots.

In addition to administrative procedures, accountability addresses another main aspect when it comes to UAVs and public safety. The responsibility of the pilot lasts the entire flight mission and thus involves being aware of and adhering to legal regulations from the very beginning. However, UAV regulations that can hardly be found in print, let alone on the homepages of aviation authorities, neither contribute to raising the awareness of pilots nor the public at large. This condition was found in some countries and information services and consulting initiatives were only present in a few cases. Based on a given political will to foster the use of civil UAVs, educational modules, easily accessible information services and awareness campaigns that simply explain prevailing legal norms need to be developed, promoted, and made easily accessible. Lessons learned, best practices but also consequences of misuse, can contribute to sensitize the public and to create trustworthiness. Besides accountability in general, backtracking of the platform and the pilot is necessary in order to hold the responsible person liable. This can only be achieved if the UAV platform carries unique identifiers such as a registration number or a special ID plate. Although platform registration schemes are in place in many cases, this requirement is likely to become mandatory for remaining countries as well (e.g. current developments in Germany[10]). Once the UAV and consequently also the pilot can be identified after an incident with damage to people and/or property, this implies that sufficient insurance cover is needed in order to guarantee the reimbursement of expenses incurred.

UAVs enable or directly involve the capture and potential processing of personal data and consequently trigger the application of legal frameworks for data protection. The challenge to appropriately address data protection and privacy issues is hardly being solved in either national or international UAV regulations. However, a broad (scientific) discourse is already initiated and this topic continues to gain in importance. Although adequate national and international laws and regulations are mostly in place and implicitly deal with these ethical concerns, two main problems remain: 1) gaps in relation otorespective laws and regulations with the use of UAVs (Marzocchi 2015), and 2) the lack of awareness of applicable data protection and privacy rules (Finn & Wright 2016; Marzocchi 2015). Thus, in order to reach full compliance with these fundamental rights, awareness-raising actions and communications between industry, users and the general public need to be stimulated. In addition to this, easily accessible information platforms and soft law measures such as guides, code of conducts and impact assessments on privacy are important tools to adequately address challenges on fundamental rights with regard to the utilization of UAVs. *Privacy by design* (Cavoukian 2012; Marzocchi 2015)

[10] UAV DACH information: https://www.uavdach.org/Home/uav_dach.htm, accessed 16.01.2017

might also be a future option and refers to design-specific technically embedded data protection requirements.

Much effort is being devoted by international organizations to formulate common standards such as prescriptive requirements for UAV operations (ICAO 2011), technical standards of UAVs (JARUS 2013b), and pilot licensing recommendations (JARUS 2015). Currently, implementation and links to national regulatory frameworks remain very limited. Examples can be given by the JARUS standards of light rotorcraft UAVs (JARUS 2013a) or the evolution of VLOS and BVLOS flights as stated in the European roadmap (European RPAS Steering Group 2013). According to the latter, VLOS operation over populated areas should have already reached the ultimate goal of a successful integration into non-segregated airspace. However, only a small number of countries envisage UAV operations in populated areas without exceptional permission. The same applies to BVLOS flights which are rarely mentioned in national UAV regulations, but should have reached a certain level of national/international integration (European RPAS Steering Group 2013). This is mainly attributed to technological reasons, as an equivalent level of see/sense and avoid capabilities is yet to be developed. However, the efforts of the EASA in the promotion of common EU rules for UAVs will most likely result in the first internationally harmonized UAV regulations in the next 5-10 years.

Apart from potentially foreseeable future developments of (inter)national UAV regulations and countries with pioneering roles, “history has shown us that some of the greatest obstacles facing the realisation of a new technology are not always technical in nature but are often related to its integration into society.” (Clothier et al. 2008, p.1). (Clothier et al. 2008) reviewed the developments of the regulations of early automobiles in the UK and presented insights about the risk management of new technologies in general. At this, resentments, conspicuous drawbacks, limited public knowledge about the technology and threatened industrial competitors paved the way for very precautionary formal regulations of automobiles in the UK (cf. “Red Flag Law” 1865 (Clothier et al. 2008)). For 30 years, this law blocked further technological developments in the UK, leaving other countries benefit from pioneering. Only in 1930, a comprehensive law including regulations on construction, weight, driver licensing, insurance obligations, and penalties were defined. Although some differences exist, (Clothier et al. 2008) show clear parallels to current UAV regulations which allows for the hypotheses about future regulatory developments in a broader context.

Existing – mainly prescriptive legal frameworks - are expected to change in the future. Pioneering countries will involve successors and thus national regulations will converge towards international harmonized standards. However, due to the on-going emergence of new UAV technology, slowly adapting formal UAV regulations are challenged to keep the link to current developments (Bennett Moses 2013). The main problems concern the constant need to address new harms, risks and negative impacts (Marchant et al. 2011). Therefore, alternative means of rulemaking may also play a critical role in order to adequately address the gaps left by formal regulations. Here, distinguishing between co-regulation, industry self-regulation and organisational self-regulation – which basically result from different influences of the state, industry associations, corporations and other stakeholders – is useful (Clarke & Bennett Moses 2014). In the context of a review, (Clarke & Bennett Moses 2014) found only a small number of initiatives in all three areas. However, with due regard to the growing UAV industry and resulting competition, it is expected that means of industrial co-regulations will gain in importance. It is likely that key players will play an important role in establishing international recognized industrial standards in order to increase entry barriers for new market competitors. Design standards for UAV components or standardized communication devices that prevent mid-air collisions are conceivable examples. Besides the influence of industrial manufacturers, professional users are expected to play another key role in regulating the use of UAVs. Their involvement will probably contribute to the decision whether UAVs are going to be a tool for everyone or for professionals. According to the market interests of professional UAV users, and furthermore also more conventional imagery suppliers, who extended their business with shares of UAV companies, their vote is likely to be for the benefit of already established UAV professionals.

In the context of law and technology, regulations target the management of risks and perceived harms (Bennett Moses 2013) in order to ensure public safety. The main harm of UAV operations are malfunction, mid-air collisions and consequent damages to people and/or property on the ground. Based on the lessons learned from other technologies and the current legal framework for UAV operations, the future development of UAV regulations could be based on three pillars:

1) **Technological and organizational advancements**: With due regard to the growing number of UAV operations, technological means of on-board communication devices can play a vital role for BVLOS and even beyond radio line-of-sight flights to avoid mid-air collisions. Nokia is one example who currently develops technology for UAV-based traffic management [11]. It is conceivable, that UAVs in non-segregated airspace are equipped with communication devices that allow for safe operations together with other airspace users – manned as well as unmanned vehicles. Central flight coordination services need to know where, when and which UAV is flying at each point in time in order to monitor and safely manage all operations. According to that, UAVs that are not equipped with special communication devices might be only allowed to fly in segregated airspace i.e. in UAV test centres or special zones for private users who seek to use UAVs for recreational purposes.

2) **Awareness and knowledge about UAV technology and respective regulations:** In order to integrate the widespread use of UAVs into society, public acceptability needs to be increased. Information about best practices can help to increase existing knowledge about UAV technology and to develop objective opinions about associated risks and benefits. “The information made available (…) will be influential in shaping public perceptions, and ultimately, acceptance of [UAV] technologies”(Clothier et al. 2015, p.1179). Existing resentments can be eliminated by educational processes, awareness campaigns and information services.

[11] http://www.space53.nl/2016/09/25/nokia-and-europes-first-drone-based-smart-city-traffic-management-test-facility-collaborate-to-ensure-safe-global-aerial-operations/, 27.01.2017

3) **Sophisticated, risk-based, accessible, and understandable (inter) national UAV regulations** as outlined before.

Overall, besides formal regulations, it is apparent that markets and information as tools to control behaviour will most likely gain on importance in order to influence and change current behavioural pattern. Nonetheless, without the basic requirement of political will, changes are unlikely to happen. Although UAV regulations are in place in one third of all countries, it has been shown that there are gaps and lack of capacity when it comes to enforcement and implementation. Although tangible evidence can only be taken from Rwanda, it is assumed that these characteristics apply to other countries, too.

10. Summary and Conclusions

This report provides insights about the most important external element that impacts on UAV-based data acquisition workflow: the legal frameworks that regulate the use of UAVs. In general, the investigation reveal that UAV regulations are subject to national legislation and focus on three key issues: 1) targeting the regulated use of airspace by UAVs as they pose a serious danger for manned aircrafts; 2) setting operational limitations in order to assure appropriate flights; and 3) tackling administrative procedures for obtaining flight permissions. Since the early 2000's countries gradually established respective legal frameworks with the result that by 10/2016, 64 countries verifiably enacted UAV regulations. Although all regulatory frameworks aim for one common goal – minimize the risk for other airspace users and people and property on the ground – a distinct heterogeneity of national UAV regulations is present. Each country sets its own limitations to UAV flights, and efforts towards international harmonization remain yet unsuccessful. However, besides others, possible future trends include risk-based, accessible, and understandable (inter) national UAV regulations.

Although Rwanda already gazetted UAV regulations in 2016, the implementation of the law remains very limited. This status can be attributed to non-transparent procedures and missing capacities to manage flight permission requests. Ethiopia and Kenya are expected to enact UAV regulations in 2017 and factual statements about the content are not yet possible. However, based on lessons learned from other African countries, regulations in Kenya and Ethiopia are predicted to involve highly prescriptive legal frameworks. Lessons from the context of law and technology reveal that an informed society builds one important foundation for the acceptance of new innovations. Thus, awareness and knowledge about UAV technology and respective regulations are claimed to be mandatory for future developments.

Annex i – References

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Annex ii – Research Methods and Limitations

The overall methodology encompasses a research synthesis of multiple data sources that are related to UAV governance, legislation, and regulatory frameworks. In general, a research synthesis uses existing facts and multiple sources to draw generalizations about the topic of research (Cooper & Hedges 2009) and thus fits the aim to provide a comprehensive overview of UAV regulations and their implications for flight operations. The first methodological pillar of the research synthesis is a comparative analysis of various documents that regulate UAV operations. This analysis embraces national regulatory frameworks, international principles and guidelines which are analysed in a comparative manner. Facilitated by indicators, a point-by-point comparison allows for quantitative as well as qualitative analysis. The indicators consider main aspects within UAV regulations and were derived in an iterative review process of current UAV regulations. The findings provide an overview of the characteristics of past and present UAV regulatory approaches and enable predictions for future trends. In addition, a review of scientific literature that focusses on the relationship between law, innovation, and technology constitutes the second pillar of the methods for this research synthesis. The literature is reviewed under the scope of legal considerations of UAV regulations and lessons learned from other “problems with ‘technology’ as a regulatory target” (Bennett Moses 2013, p.1). Outcomes will provide further inputs for the definition of possible future trends. The framework for this analysis is outlined in figure 11.

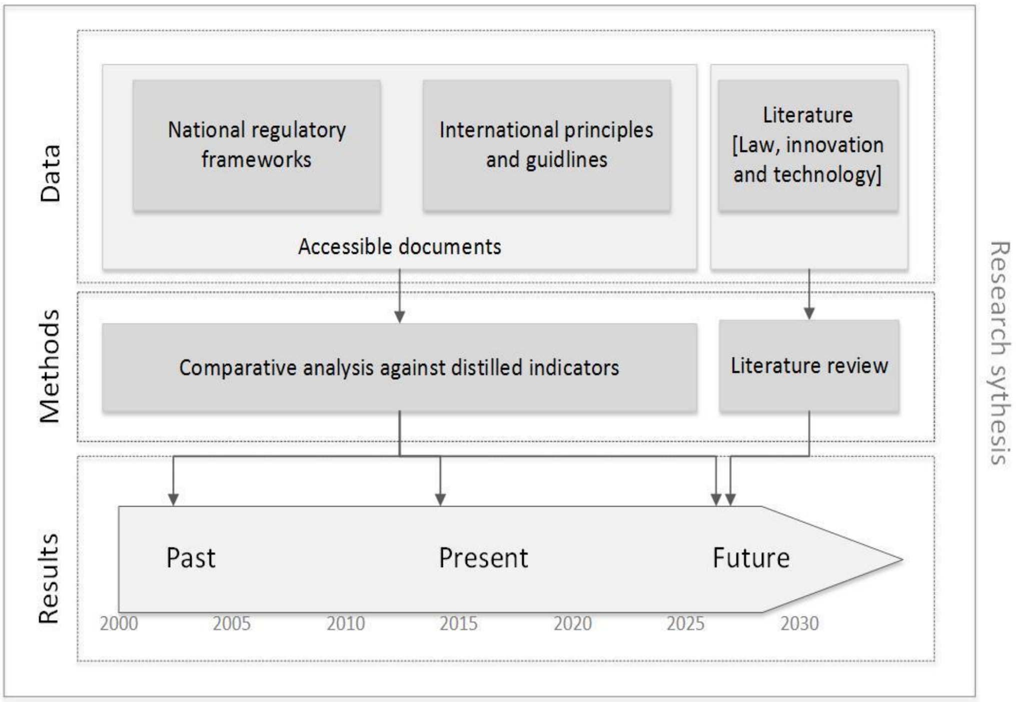

Figure 13: Schematic overview of research framework and process flows – including data, analysis and results.

In order to ensure an objective and reproducible data base the search strategy and selection criteria need to be explicitly outlined. The first step of the search strategy targets on national UAV regulations and comprises a comprehensive online-search. Due to local language constraints, an online-search of regulatory documents in a manner of country-by-country cases would not lead to a satisfactory result. Thus, internet presences of relevant international UAV organizations are reviewed for precompiled lists and overviews. Table 1 presents a list of known sources that provide links to national UAV regulations and outlines their content briefly[12].

Table 2: Overview of online accessible lists and overviews of UAV regulations (status 10/2016)

Internet presence	Content
http://www.eurocontrol.int/articles/national-UAV-regulations	EUROCONTROL: List 23 different national UAV regulations and provide links to respective documents
http://jarus-UAV.org/regulations	Joint Authorities for Regulation of Unmanned Systems (JARUS): List 24 different national UAV regulations and provide a comparison of 26 countries.
http://wiki.drones.fsd.ch/doku.php	Collaborative wiki: Global UAV Regulations Database
http://uvs-info.com/index.php/european-matters/regulation-monitor-europe/european-matters-regulation-monitor-europe-open-access	UVS International: Regulation monitor for UAV regulation in Europe (status: 17 March 2014), access to other documents is restricted and necessitates user registration
http://dronerules.eu/en/	Homepage is co-funded by the European Union: The organizers aim for an online interface for national regulatory profiles in EU member states and Norway and Switzerland (planned for January 2017)

Due to the rapid emergence and ongoing changes of UAV regulations, none of the collections provides a complete and coherent picture of the global situation. Respective links, documents and information are either outdated, incomplete or still in development and not yet released. Thus, this article used all links available from these platforms for a first global overview on UAV regulations. Based on this information, a sub-sampling of regulations for a deep and detailed comparative analysis was realised. Consequently, the representative sample of 18 regulations in total aims to cover all continents – and a diverse range of legal systems, economic development levels, and geographical environments. Besides, different times of first releases were acknowledged in order to indicate pioneers and followers. Documents with an international context include various principles, guidelines, codes of conduct and roadmaps. Oral communications and references from grey literature provided an additional valuable source of information.

A comparative analysis is a very general research method (Lijphart 1971): it compares two or more cases and thus puts a particular sample of cases into a relation. The rationale behind a comparative analysis in the context of UAV regulations is to aim for a narrative of developments, commonalities, and differences in various regulatory documents. In order to focus on the analysis and to achieve a point-by-point, rather than

[12] This online search was conducted in October 2016 and does not consider later releases.

a case-by-case comparison (UNC 2003), indicators and respective variables need to be determined. As shown in table 2, six different indicators were distilled: 1) *applicability* refers to the scope of respective regulations; 2) *technical prerequisites* acknowledge essential instruments that are demanded; 3) *operational limitations* cover restrictions for the flight itself; 4) *administrative procedures* include visits to the authorities and required documents/services; 5) *human resource requirements* cover demanded piloting skills; and 6) *implementation of ethical constraints* refers to inclusion or references to respective privacy and data protection regulations. Both qualitative as well as quantitative variables are part of the analysis and characteristics of each indicator are not restricted.

Table 3: Overview of indicators and variables of the comparative analysis

Indicator	Variable(s)
Applicability	Definition of UAV, type of classification, weight limits
Technical requirements	Required instruments, required level of sense and avoid mechanism
Operational limitations	Restricted areas, height limitation, range limitations / visibility
Administrative procedures	Application procedure and operational certificate, need for registration, need for insurance
Human resource requirements	Qualification of pilots
Implementation of ethical constraints	Indication of requirements for data protection, Indication of requirements for privacy

As a matter of the extent of this research investigation, the amount of indicators and variables was limited to the insights that could be gained by reviewing national regulatory frameworks that deal with UAVs. However, additional indicators such as political will, establishment of dedicated institutional units, rulemaking parties, and social acceptance could also be valuable sources of information but would demand other research methods that were not in the scope of this article. Although enacted UAV regulations are tangible documents, evidences of the solely do not allow insights “behind the scenes” such as political backgrounds, law enforcement, human capacities and processes. Thus, the status that UAV regulations are present does not necessarily mean, that UAVs can be used in a straight way forward.

Annex iii – Overview of Regulatory Approaches

Table 4: Comparative analysis of 18 national UAV regulations. Light grey cells indicate that the variable is covered by the UAV regulations, text outlines further details if applicable. Dark grey cells indicate that the variable is not applicable.

	Applicability				**Technical requirements**		**Operational limitations (distances)**								**Administrative procedures**			**Human resources**	**Ethical constraints**	
Country issued and/or last updated [reference]	MA	RPA	Classification (**w**eight, **p**urpose, **a**rea, **v**isibility)	Weight limits (**max**)	Special technical requirements	Collision avoidance capability	Airports / strip	People	Congested areas	Prohibited areas	Additional	Max height	VLOS / lateral distance	BVLOS	Application and operational certificate	Need for registration	Insurance	Qualification of pilots	Data protection	Privacy
Australia 07/2002 09/2016 (CASA 2016)			W, P	2/ 25/ **150** kg	N/A	N/A	5.5 km	30 m			emergency situation	120 m		need for special approval	> 2/25 kg	N/A	recommended	license > 2 kg	advice to respect personal privacy	
Austria 01/2014 08/2015 (austro control 2015)	>500 m from pilot		W, A	5/ 25/ **150** kg	depending on scenario	depending on scenario		not over crowds	N/A		N/A	150 m		need for special approval	general permission, single approval for risky operations			depending on flight area	license > 2 kg	
Azerbaijan 01/2015 (Republic of Azerbaijan State Civil Aviation Administration 2015)			W	20/ **150** kg	N/A	for BVLOS		50 m	150 m		N/A	122 m		in segregated airspace	for critical operations and/or > 20 kg	> 20 kg		pilot competency	N/A	N/A
Canada 2010 05/2015 (Transport Canada 2015)			W, P	2/ 25 kg	N/A	> 25kg	9 km	150 m			forest fires	90 m		N/A	> 25 kg	N/A	depending on weight	pilot competency	advice to respect personal privacy	
China 09/2016 (Civil Aviation Administration of China 2016)			N/A	**7** kg	N/A			N/A			10 km to other aircrafts	N/A		N/A	flight authorization and operational certificate	registration	N/A	certification	N/A	N/A
Chile 04/2015 (Direccion General De Aeronautica Chile n.d.)			W	**6 kg**	many special demands	N/A	2 km	30m	N/A		< 60 min	130 m	500 m	N/A	flight authorization		N/A	license	N/A	N/A

Colombia 07/2015 (AERONÁUTICA CIVIL DE COLOMBIA 2015)			W	**25 kg**	many special demands	N/A	5 km				intern. border	152 m	750 m	N/A	flight authorization			license	not allowed to violate the rights of privacy	
France 2012 12/2015 (DIRECTION GENERALE DE L'AVIATION CIVILE 2016)			W, A,V	2/ 8/ **150** kg	> 2kg	in populated areas and BVLOS		not over crowds	N/A		emergency situation	150 m	100 m / 200 m / EVLOS		for specific operation procedures	depending on flight scenario		depending on flight scenario	Commercial use: ask for permission to use data	advice to respect personal privacy
Germany 12/2013 07/2016 (Deutsche Flugsicherung 2016)	N/A		W	10/ **25** kg	> 10kg	May help to get BVLOS permission		not over crowds	N/A		emergency situation	100 m		need for special approval	general permission, single operational approval for >10-25 kg	N/A		pilot competency	emphasize that actions might be subject to other laws	
Italy 12/2013 12/2015 (L'Ente Nazionale per l'Aviazione Civile 2015)	N/A		W, A	2/ 25/ **150** kg	For critical flights	N/A	5 km	50 m	150 m		N/A	150 m	500 m / EVLOS	in segregated airspace	for critical operations and/or > 25 kg	plate and electronic ID		0-25kg certification, > 25kg license	refer to Italian Data Protection Code	N/A
Japan 12/2015 (Japan Ministry of Land Infrastructure Transport and Tourism 2015)	> 200 g		N/A	N/A	N/A	N/A	no fly zone	30 m			N/A	150 m		N/A	for restricted areas	N/A	N/A	N/A	N/A	N/A
Malaysia 02/2008 (Aeronautical Information Services Malaysia 2008)			W, P	20 kg	Request equivalent level of compliance with rules for manned aircraft			N/A	N/A	N/A	N/A	122 m		if ATC capable	flight authorization and airworthiness certification	> 20 kg		license for pilot and commander	UAV operation shall comply with civil requirements	
Netherlands 2012			W,P	1/4/25 /**150** kg	N/A	N/A	no fly zone	50 m			moving cars	120 m	100 m / 500 m	N/A	operational certificate			license	refer to related regulations	

07/2016 (ILT 2016)																				
Nigeria 12/2015 (Federal Republic of Nigeria 2015)			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	special authorization	N/A		no limitation	flight authorization	N/A	N/A	manned aircraft license	license	N/A
Rwanda 05/2016 (Rwanda Civil Aviation Authority 2016)	not for toy aircraft		N/A	**25** kg	N/A	N/A	10 km	50 m			N/A	100 m	300 m		flight authorization, operational certificate	registration marks		license	respect privacy of others, surveillance of people and property without their consent is prohibited	
South Africa 09/2015 (South African Civil Aviation Authority n.d.)	N/A		W, V	7/ 20 kg		N/A	10 km	50 m			N/A	122 m	EVLOS possible	need for special approval	air service license, letter of approval and operation certificate	registration marks		license	N/A	N/A
United Kingdom 25/2002 03/2015 (Civil Aviation Authority UK 2015)			W, P	7/ 20/ **150** kg		for special operations		50 m	150 m		N/A	122 m	500 m, EVLOS possible	need for special approval	various approval requirements for different flight operations	N/A	N/A	pilot competency	refer to Data Protection Act , CCTV Code of Practice	advice to respect personal privacy
United States 08/2008 06/2016 (U.S. Department of Transportation Federal Aviation Administration 2016)			W, P	0,25/ 25/ **150** kg	N/A	N/A	8 km		N/A		N/A	122 m	EVLOS possible	need for special approval	> 25 kg	registration number	depending on purpose	certificate	N/A	refer to related laws