Work Package 2: Technological Innovation for Sustainable Development

Deliverable T2.3.1: Project report

Drone Surveying for the Protection of Natural and Built Heritage Sites

Jessica Giannoumis

March 2021

SUSTAINABLE RESILIENT COASTS

Project Partners

Comhairle Contae Mhaigh Eo
Mayo County Council

Northern Periphery and Arctic Programme

This contributes to Future Earth Coasts, a Global Research Project of Future Earth

Executive Summary

The potential of drone technology to support local authorities to promote sustainable development of coastal regions has been appreciated but has thus far been underutilised. This report provides practical guidance to local authorities in the use of drone technology to digitally preserve, document, and monitor natural and built heritage sites to promote the sustainable development of regions at the coast. The report has been produced as part of the EU-funded Sustainable Resilient Coasts (COAST) project, a collaboration between partners from Iceland, Finland, Ireland, and Northern Ireland focusing on the future challenges and development of coastal areas in Europe's Northern Periphery and Arctic (NPA) region. The project seeks to deliver practical guidance for coastal local authorities to support resilience building and coastal sustainability. This document is therefore intended to enable local authorities with limited experience but a desire to understand and use drone technology for the digital preservation and documentation of natural and built heritage sites.

This report describes a six-step process that guides local authorities through the considerations that need to be taken before, during, and after conducting drone surveys. The key steps include 1. Flight purpose; 2. Study design; 3. Pre-flight fieldwork; 4. Conducting drone survey; 5. Processing of aerial data; 6. Quality assurance. Each step will be described and explained to ensure that drone surveys are conducted efficiently and safely. The flight purpose sets out the intent of the survey and will introduce Rathlin Island as a case study and different ways in which drone survey applications may be used to support the Rathlin community. Rathlin Island in Northern Ireland has many natural features and landscapes in addition to many built heritage sites and as such provides a unique case study. Due to current Covid-19 travel restrictions (March 2021), the testing of the presented methodology in this report has not yet commenced. More details on the case study and the piloting of this methodology will be presented at a later time. The flight purpose includes the access to drone survey output as an important consideration that has to be taken prior to the study design. The study design focuses on technical aspects of the drone, the drone classification and potentially necessary training, and the drone regulations and aviation authorities. The pre-flight fieldwork describes the planning and some practical considerations pre-flight fieldwork. The planning stage ensures that the next step, conducting the drone survey, is done safely and efficiently. Processing of aerial data provides some practical considerations regarding the data management and data sharing and some of the General Data Protection Regulations (GDPR) that have to be considered for the presentation of the output. Quality assurance ensures that drone survey operations have used the best practice guidelines for drone operations. The final chapter of this report provides local authorities with a quick drone operator's checklist for safe drone operations.

Acknowledgement

This report has in large parts been produced with the aid and help of Dr. Sarah Kandrot, Green Rebel Marine. Thank you to Dr. Fiona Cawkwell (UCC), Tryggvi Stefánsson (SVARMI), Teresa O'Hare (Causeway Coast & Glens Heritage Trust), Mikko Posio (Oulu University of Applied Sciences), and Brian Wilson (County Council Mayo) for the valuable feedback and input into this report.

Acronyms

EASA	European Union Aviation Safety Agency
FOV	Field of View
GCP	Ground Control Point
GNSS	Global Navigation System
GRC	Ground Risk Class
GSD	Ground Sampling Distance
ICAO	International Civil Aviation Organization
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LiDAR	Light detection and ranging
OM	Operations Manual
RGB	Red, green, blue (visible portion of the electromagnetic spectrum)
RTH	Return to Home
RTL	Return to Launch
SOP	Special Operating Permission
SORA	Specific Operations Risk Assessment
STS	Standard Scenario
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
VLOS	Visual Line of Sight

Contents

1. Introduction

Unmanned Aerial Vehicles (UAVs) such as drones can be used to contribute to promoting sustainable development in coastal regions. UAVs enable the cost-effective, relatively easy documentation and digital preservation of natural and built heritage sites in coastal regions. UAV or drone surveys also allow the exploration of difficult-to-reach and/or inaccessible sites with none to minimal impact and disturbance to the natural and built environment. Additionally, repeat surveys can easily be undertaken to monitor changes of the natural and built environment over time. Many of these coastal regions are threatened by the effects of climate change, sea-level rise, and coastal erosion. Hence, drone surveys of these regions could contribute to documenting and digitally preserving these heritage sites through photography, video recordings, surveying and modelling using various sensors like cameras, LiDAR, magnetometers, radars, and more. The use of drone surveys has become a preferred method for geoscientists due to drones' easy-to-use interface and the wealth of data that can be collected efficiently and effectively in a relatively short time (Jiménez López & Mulero-Pázmány, 2019; Joyce, Duce, Leahy, Leon, & Maier, 2019). However, the potential to support local authorities in monitoring remote areas and promoting sustainable development through the use of UAV or drone surveys for natural and built environments has not yet been fully realised (Manfreda et al., 2018).

This practical guide is designed for local authorities in coastal regions as a one-stop-shop providing information and key considerations for the use of drones for the digital preservation and documentation of sites of cultural and natural significance. Drone surveys can be useful for small survey areas and when mapping can be done using RGB cameras[1]. Drone surveys are one way to digitally preserve natural and built heritage sites. However, before diving deeper into the practicalities of drone surveys for digital preservation, local authorities consider the purpose of the survey and the most suitable and appropriate way of obtaining remote sensing data. Remote sensing is the process of collecting data without physically being in contact with the object (Simic Milas, Cracknell, & Warner, 2018). Depending on the purpose of the survey, using remote sensing data collected from satellites or plane surveys, or hiring expert drone operators to carry out the survey may be alternative options to consider. Expert drone operators can also advise on the most suitable sensors to obtain the data and create output from the data as high-end sensors will produce higher quality data.

In particular, this report outlines key considerations for the use of drone surveys to monitor the natural environment and to preserve built heritage in coastal regions. This practical guide loosely follows the Unmanned Aerial Systems (UAS)-based mapping according to Tmušić et al. (2020). The UAS-based mapping identified five key considerations which help structure the planning and operating of drone surveys. The five key areas are: 1. Flight purpose; 2. Study design; 3. Pre-flight fieldwork; 4. Conducting drone survey; 5. Processing of aerial data; 6. Quality assurance (figure 1). This report has built on the work Tmušić et al. (2020) and is structured on the modified methodology. This report is tailored to local authorities' needs and considerations when planning the digital preservation and documentation of sites of the natural and built environment.

[1] RGB (red, green, and blue) cameras are able to capture the same bands of light that the human eye can capture. Kandrot and Holloway (2020) detail the applications of drone technology for sustainable development of the coastal zone and provide an in-depth literature review of the available uses and abilities of state-of-the-art drone technology, available here: https://coast.interreg-npa.eu/subsites/coast/DT2.1.1_Applications_of_drone_technology_for_sustainable_development_of_the_coastal_zone.pdf

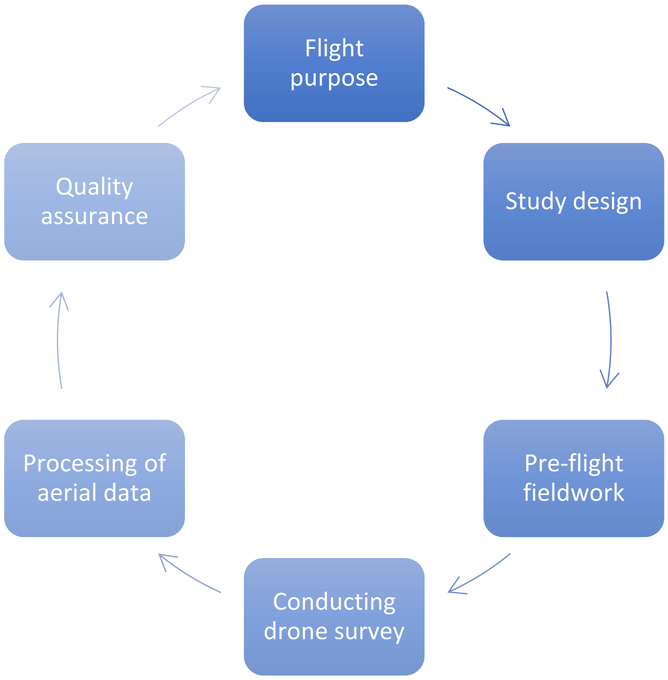

Figure 1: Activities involved in UAS-based mapping, adapted from Tmušić et al. (2020)

This document aims to provide local authorities practical guidance in how to digitally preserve the natural and built environment using drone technology. Rathlin Island in Northern Ireland has agreed to partner up with Causeway Coast & Glens Heritage Trust (CCGHT) and University College Cork (UCC) to implement and test the six-step methodology to use drone surveys to digitally preserve and monitor the natural and built heritage sites. Due to current Covid-19 travel restrictions (March 2021), the testing of the presented methodology in this report has not yet commenced. More details on the case study and the piloting of this methodology will be presented at a later time.

This report was produced as part of the Sustainable Resilient Coasts (COAST) project, a collaboration between the Agricultural University of Iceland, Oulu University of Applied Sciences, Mayo County Council, University College Cork, and the Causeway Coast and Glens Heritage Trust. This collaborative project focuses on the future challenges and sustainable development of coastal areas. Information from this repot will be integrated into our Sustainable Resilient Coasts Toolbox for local authorities, an online resource focusing on SMART Blue Growth[2].

For more information see: http://coast.interreg-npa.eu/

[2] SMART Blue Growth refers to the sustainable development of marine and maritime sectors based on the principles of Sustainability, Mitigation, Planning, Adaptation, Resilience, and Transition (SMART) (De Vet, Edwards, & Bocci, 2016).

2. Drone Operation at Natural & Built Heritage Sites

Drone surveying and operations can be used for many applications among others the preservation and documentation of natural and built heritage sites. To make the most out of the drone survey, it's useful to establish the flight purpose, this will ensure that the drone survey will be able to deliver the needed outputs. In this report, drone surveys may include 360° video, photogrammetry mapping, single images taken by drones, and LiDAR scanning[3]. Natural and built heritage sites require careful consideration and planning to ensure that the drone survey will not cause any damage or harm to the sites. Using drones or unmanned aerial vehicles (UAVs) at natural and built heritage sites enables drone operators to monitor changes over time, condition of the site, and an easy-to-use birds-eye view on the heritage sites. These data can in turn be used to appropriately manage the site (Liao, Mohammadi, & Wood, 2020).

2.1. Flight Purpose

In this report, we will focus on providing useful information on using drones at natural and built heritage sites and have therefore focused on the four different drone applications: 1. Monitoring the natural environment in coastal areas; 2. Preservation of built heritage in coastal areas; 3. Virtual tourism; and 4. Educational purposes. To demonstrate these different applications, Rathlin Island has been chosen as a case study which will follow the guidance given in this report to illustrate the different applications of drone usage to support the documentation and preservation of the natural and built environment. However, due to current Covid-19 travel restrictions (March 2021), the testing of the presented methodology in this report has not yet commenced. The following section introduces Rathlin Island briefly, more details on the case study will be presented at a later time.

2.1.1. Case Study Rathlin Island

Rathlin Island is uniquely positioned between Ireland and Scotland off the north east coast of the island of Ireland and is Northern Ireland's only inhabited offshore island. Rathlin's geological composition consists of Cretaceous Chalk on the southern part of the island and Lower Basalt on the rest of the island, which causes differences in landscape features on the island. Additionally, Rathlin has a rich and diverse cultural heritage. As such, Rathlin Island presents an excellent case study[4]. The Rathlin community has agreed to partner up with the CCGHT and UCC to pilot and test some of the methodology that is presented in this report. This report hence provides some practical guidance on how drone technology can be used to digitally preserve the natural and built heritage of Rathlin.

2.1.2. Monitoring the Natural Environment in Coastal Areas

Drone are easy-to-use tools to help monitor the natural environment, which is of particular interest in coastal areas where the environment changes quickly due to tides or in hard-to-reach areas such as cliffs. Coastal areas are under constant threat of destruction due to natural occurrences such as coastal erosion and sea-level rise and due to human-induced causes such as climate change and extreme weather events, waste and plastic pollution which may have long-term effects on the natural environment (Van Rijn, 2011). Drone surveys are cost effective solutions that enable the monitoring of the natural environment spanning over weeks, months, or even years. This in turn allows a comparative analysis of the site, which would help local authorities to make decisions on necessary

---

[3] Kandrot and Holloway (2020) detailed different types of survey data that can be collected through the use of unmanned aerial vehicles (UAVs), available here: https://coast.interreg-npa.eu/subsites/coast/DT2.1.1_Applications_of_drone_technology_for_sustainable_development_of_the_coastal_zone.pdf

[4] More information on Rathlin Island can be found here: http://www.rathlincommunity.org/

mitigation plans. One such example is the surveying of beach cusps[5] in Ireland, where Nuyts, Murphy, Li, and Hickey (2020) use drone technology to determine the changes in the cusps. Enabling the monitoring and video capturing of the coastal geomorphology revolutionises our understanding and our ability to monitor and manage the coastal area (French & Burningham, 2009).

2.1.3. Preservation of Built Heritage in Coastal Aeras

Drones can contribute to a cost-effective and efficient way of documenting and preserving the built environment and to use as ways to rebuild or restructure historically accurate buildings (Themistocleous, Ioannides, Agapiou, & Hadjimitsis, 2015). There is a growing need for the protection and preservation of historic architecture and buildings using innovative technologies to document and conserve built heritage (Banfi, 2016). Using drones to map historic sites can support the restoration of historic sites, which is particularly important in areas where there may be natural deterioration of the buildings, or the natural environment may have reclaimed buildings. drones can thereby increase the safety of the operation by identifying areas where precaution needs to be taken.

The drone surveys of sites with cultural and historic significance require careful planning and may, in some instances, also require permission from the landowner or the local authority prior to conducting the survey. Additional considerations also include the data protection of people and their property.

2.1.4. Virtual Tourism

Drones may provide additional income streams for communities living in remote areas through virtual tourism (Kandrot & Holloway, 2020). Virtual tourism is a way of experiencing a place digitally without a need to be physically present in the area (Kitonsa & Kruglikov, 2018). This enables a new and innovative way of exploring sites from a different perspective while also providing additional information on interesting features or historic encounters. This new way of exploring sites from the comfort of any digital device will only gain importance and has been particularly accelerated through the current coronavirus pandemic (Ilkhanizadeh, Golabi, Hesami, & Rjoub, 2020; Templin & Popielarczyk, 2020).

If the flight purpose is to create a virtual tourism campaign, it is advisable to consider aesthetics that highlight the features of the natural or built environment. Creating a 3D model ready for virtual reality can be challenging, in terms of obtaining data that can be used for virtual reality and processing the data. To process the data, access to different virtual reality processing programmes and platforms may be needed. It would be advisable to consider how the survey would be consumed, i.e. an immersive experience through the use of virtual reality goggles would require different considerations than virtual tourism campaigns designed as short videos to be viewed on mobile devices. It is also advisable to consider the *typical tourist* that would access the information. Additional considerations include language preferences, accessibility for people with hearing or visual disabilities, age appropriateness and whether the tourist travels by themselves or with a family, etc. Understanding the needs of the *typical tourist* could either take place through physical surveys while the tourists are at the site or through the use of machine learning and utilising points of interest through social media platform[6].

[5] Beach cusps are formations in the shoreline that appear in the swash zone where waves push sediment, i.e. sand or gravel, into moon-shaped formations along the coast (Pitman, Hart, & Katurji, 2019)

[6] Giglio, Bertacchini, Bilotta, and Pantano (2020) used georeferenced images to understand the behaviour and movements of *typical tourists* in Italian cities.

2.1.5. Educational Purposes

Drone surveys can also contribute to new ways of providing education and teaching materials for students of all ages (Palaigeorgiou, Malandrakis, & Tsolopani, 2017). The use of drones could enhance the learning experience for educational purposes by enabling students' unique access to the sites, for example through virtual field trips. The created output should match the age-appropriate syllabi and it is advisable to consider how the information will be accessed.

If the information is to be consumed in a classroom or at home before an excursion to the field, it would be advisable to create similar visual cues in the videos and on the site, to enhance and deepen the connection to the learning experience. If the information is to be consumed without a follow-on excursion to the field, it may be helpful to the student to create small quizzes that ensure that the learning outcome has been achieved. Much like with using drone surveys for virtual tourism, it is advisable to consider how the content will be consumed.

2.2. Access to Drone Survey Output

One key consideration is where and how the outputs of the drone surveys are going to be accessed. Some tourists, pupils, and students prefer access to the information on site, whereas others prefer access to the output off site. Different solutions to cater to the 'consumers' needs exist but need to be carefully planned before conducting the survey.

2.2.1. Access Information through Site-Specific Mobile Applications

Mobile Applications that can be downloaded on mobile devices before the tourist, pupil, or student visits the site are an easy way for local authorities or tourism boards to collect and present available information regarding the natural and built environment. Integrating the drone survey as an essential part of a mobile application could ensure an easy-to-use and immersive experience for the mobile user. The use of apps to access the output from the drone surveys also enables tracking of user behaviour. The application provider could then gain an understanding of the *typical tourist*, their needs, interest, feedback, etc. Please review national General Data Protection Regulations (GDPR) when considering the use of mobile applications.

2.2.2. Accessing Information through QR Codes

If the drone surveys are to be consumed while tourists, pupils, and students are physically at the site, installing easily accessible QR codes on existing infrastructures, for example on information boards, or in the tourism centre present cost-effective solutions. Once the user scans the QR code, information on a mobile device could be prompted. The use of QR codes could also be used as interactive guided multimedia tours[7].

The information available through the QR codes could be maintained by the tourism board or the community and could be periodically updated providing access to newly available resources. Utilising innovative solutions such as QR codes ensure a non-destructive way of providing tourists and students with information without altering the landscape dramatically. Please be advised, that using QR codes while on site requires internet access on the mobile device (figure 2).

[7] Fino, Martín-Gutiérrez, Fernández, and Davara (2013) conducted a study that show the use of QR codes and interactive tourist guides in a World Heritage city, guiding tourists on different paths providing information on heritage buildings through the city.

Figure 2: Example of a QR code used on IOS device (left) and Android device (right) (Tap2Assist, 2014)

3. Study Design

The flight purpose established the application and the purpose of the drone survey. The study design focuses on some of the technical elements that are determined by the make, model, and specifications of the drone and what kind of output the drone can create. As drone operator there are also some practical considerations regarding the drone classification and potentially necessary training for the drone operator, this will vary depending on the drone used and the flight purpose as well as national regulations which can change.

When using drones, it is important to understand how the drone is equipped, i.e. what specifications does the drone camera have, does the drone have a sensor – if so, which one. Knowing these specifications will ensure that the drone is technically able to create the desired output[8].

The study design will also help determine what (if any) kind of models will be created from the drone survey. Promotional drone videos demonstrating the natural and built environment may not require a very high resolution, because they do not require any modelling. Not every mapping and modelling activity requires software to process the data – more details on this can be found in section 6 – Processing of Aerial Data – of this report.

3.1. Creating 2D/3D Models from Drone Surveys

Drone surveys can create a variety of outputs, including 2D maps and/or 3D models, which can be used to map and document the natural and built environment. The application of the drone survey determines what kind of model can be created. 2D maps are two-dimensional, they capture imagery from directly above or from the side if the flight purpose is looking at walls or cliffs. 3D models are three-dimensional and capture the length, width, and height of features of the environment (Gevaert, Persello, Sliuzas, & Vosselman, 2016). The appropriate resolution to capture the drone imagery depends on the model that is chosen to portray the drone survey data. Cameras producing low resolution output can be used to create 3D models and 2D maps. Higher resolution cameras, which are more complex and may be more costly, will yield better 2D and 3D data.

Figure 3: 2D map of Rathlin Island East Lighthouse (Google, n.d.)

[8] Kandrot and Holloway (2020) detailed the applications of drone technology for sustainable development of the coastal zone and provide an in-depth literature review of the available uses and abilities of state-of-the-art drone technology, available here: https://coast.interreg-npa.eu/subsites/coast/DT2.1.1_Applications_of_drone_technology_for_sustainable_development_of_the_coastal_zone.pdf

Drone imagery can be processed to produce 3D point clouds using photogrammetric techniques. Point clouds are clusters of data points in space which represent a 3D shape or object that contain X, Y, and Z-coordinate locations and some other information, for example RGB colour value. The UAV camera captures an object from different angles and perspectives and uses sophisticated computer vision algorithms to detect each shape or object from different angles. By knowing the parameters of the camera, the algorithm can reconstruct a point cloud based on the matching pixels in all the images. Exact geo location of each image greatly helps in this modelling and provides a model with absolute Global Navigation Satellite System (GNSS) coordinates with accuracy in direct translation to the GNSS sensor linked to the images as well as accurate relative distances. GNSS is the general term used and consists of the Global Positioning System (GPS) used in the United States of America, Glonass used in Russia, Galileo used in the European Union, and BeiDou (China). Photogrammetry is therefore at its core a modelling technique but not a direct measurement. There are multiple parameters that can affect the accuracy.

3.1.1. Photogrammetry parameters

Parameters that greatly affect photogrammetry are lighting conditions (such as sunny or cloudy conditions, or nightfall), visibility, the relationship between flight speed and flight height, and the surface that is being mapped. Photogrammetry that relies on computer vision needs some heterogenous features in the ground, i.e. stable physical properties that make distinctions possible. A homogenous surface like snow, sand, water, tarmac, or rooftops can create errors or failures in photogrammetry models. At the same time, the mapped area needs to be constant and cannot move, i.e. drone survey data collected during windy conditions causing waves in the sea or in rivers or moving trees may be unusable.

One key photogrammetry parameter is the resolution which comprises of three metrics: the pixel resolution, the ground sampling distance (GSD), and the spatial resolution. Pixel resolutions refers to how many pixels compose one image and is generally expressed in the number of columns and rows or by the total numbers of pixels, e.g. 1920 x 1080 or 2.1 MP. The GSD is the measurement between the centres of two adjacent pixels, i.e. the closer the camera is to the object, the smaller the distance between the pixels, the higher the resolution of the image (Flyability, 2021). GSD is directly affected by the pixel count, the sensor size, the flight height and the focal length of the camera lens. Spatial resolution, as well as sensor size, camera quality, flight height, atmospheric conditions among other parameters, are affected by the GSD. Spatial resolution refers to the smallest details visible on the image and can account for blur, image noise, contrast, etc. (Flyability, 2021). The characteristics of the camera and its flying height will influence the resolution of the images (Kandrot & Holloway, 2020). Drone operators need to be aware of these photogrammetry parameters to ensure that the collected survey data is usable for the desired output. The flight purpose and application of the survey will determine many of the photogrammetry parameters.

3.1.2. Sensors

Depending on the specifications of the drone, it may be equipped with different types of sensors. The most commonly used are RGB cameras – this refers to the red-green-blue visible bands of the electromagnetic spectrum which are typically used in cameras; thermal infrared sensors which are able to capture thermal radiation from objects or surfaces; multispectral sensors and hyperspectral sensors which are able to capture radiation across a range of wavelengths reflected from a surface or object; and Light Detection and Ranging (LiDAR) sensors which are also able to collect point clouds or direct elevation measurements (Kandrot & Holloway, 2020).

The flight purpose will determine the required resolution and the necessary sensors to capture the imagery. If the purpose of the drone flight is to capture images from a birds-eye view for promotional videos, then RGB cameras may be sufficient to deliver that output. For environmental monitoring of coastal areas where the output should provide an in-depth image of the site, sensors that are able to capture a higher spectral and spatial resolution may be necessary.

3.2. Drone Classification and Training

The classification of drone operations does not distinguish between commercial and leisure activities but is based on the weight and specification of the drone itself. Operating a drone comes with rights and obligations to ensure that drone surveys are carried out safely. The European Union Aviation Safety Agency (EASA) provides detailed information on the safe operation of drones. EASA distinguishes between Open Category – Civil Drones, for drone activities of leisure nature, the Specific Category – Civil Drones for riskier operations that are not covered in the Open Category, and the Certified Category – Civil Drones where the operating of the drone requires a certified drone operator due to the high risk involved in flying the drone.

3.2.1. Open Category

The Open Category – Civil Drones classifies UAS by their weight class, depending on their class and maximum take-off mass (MTMO) the drone operator may have to register their drone and undergo some training modules before operating a drone safely. Most drones used for leisure activities or low risk commercial activities fall under the open category.

Until January 1, 2023, drone operators may fly drones without any class identification labels which specify the weight class and determine operational restrictions. Operational restrictions depend on the subcategory under which the drone operation may fall. The drone operations are divided into three subcategories: A1 (drone operator may fly over people but not over assemblies of people); A2 (drone operatory may fly close to people); and A3 (drone operator may fly far from people). The sub-categories have additional requirements that the drone operator should familiarise themselves with (EASA, 2021a). Table 1 shows the limited open category for drones without class identification labels, drone operation subcategories, operational restrictions, and additional information on drone operator competence valid until January 1, 2023.

Table 1: Limited open category valid until January 1st, 2023 using drones without class identification label (EASA, 2021a)

UAS		Operation		Drone Operator/pilot		
Class	MTOM	Subcategory	Operational restrictions	Drone Operator registration	Remote pilot competence	Remote pilot minimum age
Privately built	< 250 g	A1 (can also fly in subcategory A3)	- No flying expected over uninvolved people (if it happens, should be minimised) - no flying over assemblies of people	No, unless camera / sensor on board **and** a drone is not a toy	- no training needed	No minimum age
Drones without class identification label	< 500 g			Yes	- read user manual - complete the training and pass the exam defined by your national competent authority	16*
Drones without class identification label	< 2 kg	A2 (can also fly in subcategory A3)	- no flying over uninvolved people - keep horizontal distance of 50 m from uninvolved people (this can be reduced to	Yes	- read user manual - complete the training and pass the exam defined by your national competent authority	16*
Drones without class identification label or privately built	< 25 kg	A3	- do not fly near people - fly outside of urban areas (150 m distance)	Yes	- read user manual - complete the training and pass the exam defined by your national competent authority	16*

Table 2 shows the open category for drones with class identification labels, drone operation subcategories, operational restrictions, and additional information on drone operator competence valid after January 1, 2023.

Table 2: Open category after January 1, 2023 (EASA, 2021a)

UAS		Operation		Drone Operator/pilot		
Class	MTOM	Subcategory	Operational restrictions	Drone Operator registration	Remote pilot competence	Remote pilot minimum age
Privately built	< 250 g	A1 (can also fly in subcategory A3)	- may fly over uninvolved people (should be avoided when possible) - no flying over assemblies of people	No, unless camera / sensor on board **and** a drone is not a toy	- no training needed	No minimum age
C0					- read user manual	16*, no minimum age if drone is a toy
C1	< 900 g		- No flying expected over uninvolved people (if it happens, should be minimised) - no flying over assemblies of people	Yes	- read user manual - complete online training - pass online theoretical exam	16*
C2	< 4 kg	A2 (can also fly in subcategory A3)	- no flying over uninvolved people - keep horizontal distance of 30 m from uninvolved people (this can be reduced to 5 m if low speed function is activated)	Yes	- read user manual - complete online training - pass online theoretical exam - conduct and declare a self-practical training - pass a written exam at the NAA (or at recognized entity)	16*
C3 C4 Privately built	< 25 kg	A3	- do not fly near people - fly outside of urban areas (150 m distance)	Yes	- read user manual - complete online training - pass online theoretical exam	16*

More information on class identification labels is expected to become available in January 2022 (see EASA for more information: https://www.easa.europa.eu/home).

3.2.2. Specific Category

Specific Category – Civil Drones require operational authorisation from the national aviation authority. This means that any drone operation that falls into the specific category requires a risk assessment prior to the drone operation, unless the operation falls under Open Category or is a Standard Scenario (STS)[9]. If the drone operation qualifies as specific category, risk assessment will have to be carried out (EASA, 2021b). See Section 4.1.2. Site Survey and Risk Assessment for details on the Specific Operations Risk Assessment (SORA).

3.2.3. Certified Category

Drone operations within the certified category require the operator to be a licensed remote pilot and operator that is approved and certified by their national aviation authority due to the high risk of the drone operation. Drone operators intending on conducting surveys falling into this category are subject to the rules and regulation of the national aviation authority.

3.3. Drone Regulations and Aviation Authorities

Drone operators should always check their national aviation authorities when planning drone operations. National drone operation rules have been replaced by common EU rules as of July 2020. This means that once a drone operator has been certified and completed the necessary training in their national state, they may operate the drone safely within the European Union. More information can be found on the national aviation authority websites (table 1).

In Ireland, as of February 2021, registered drones may not be flown above 120 metres (394 feet) and they may not be flown within 30 metres (98.4 feet) of people, crowds, vehicles, or buildings. Drones can also not be flown over national monuments (Irish Aviation Authority, 2021). In Northern Ireland and Iceland the height restrictions remain at 120 metres (394 feet) and the drone may not be flown within 50 metres (164 feet) of buildings and/or people (Police Service of Northern Ireland, 2021; UAV Coach, 2020). Whereas in Finland, drones may not be flown above 120 metres (394 feet) and may not be flown within 30 metres (98.4 feet) from people and crowds or 1:1 ratio distance to height (Traficom, n.d.). The drone should always be operated within the visual line of sight (VLOS), or in the VLOS of an assisting observer should the flight path be beyond VLOS.

Table 3: Aviation Authorities within the project partner regions and website

Aviation Authority	**Website**
European Union Aviation Safety Agency (EASA)	https://www.easa.europa.eu/light/topics/flying-drone-how-be-safe-drone-pilot
Irish Aviation Authority (IAA)	https://www.iaa.ie/general-aviation/drones
United Kingdom – Civil Aviation Authority (CAA)	https://www.caa.co.uk/Our-work/About-us/UK-EU-transition/
Icelandic Transport Authority	https://www.icetra.is/aviation/drones/
Finland Traficom	https://www.droneinfo.fi

[9] Standard Scenario (STS) refers to pre-defined operations, to date there are 2 STS: STS-01 "*covers operations executed in visual line of sight ("VLOS"), at a maximum height of 120 m over a controlled ground area in a populated environment using a CE class C5 UAS.*" STS-02 "*covers operations that could be conducted beyond visual line of sight ("BVLOS"), with the unmanned aircraft at a distance of not more than 2 km from the remote pilot with the presence of airspace observers, at a maximum height of 120 m over a controlled ground area in a sparsely populated environment, and using a CE class C6 UAS*" (The European Commission, 2020).

4. Pre-Flight Fieldwork

The design and planning of drone operations requires careful considerations as it ensures the safe drone operations within the natural and built environment. Outlining the flight purpose and study design will help in the planning process of the pre-flight fieldwork.

4.1. Planning

Some drone operations require the permission of the national aviation authority prior to conducting the drone survey. This means that the drone operator will have to prepare and submit an operations manual and conduct a site survey and risk assessment. Once approved by the national aviation authority, the operator may safely conduct the survey. This is not necessary for all flight operations, but it is required for drone operations that are beyond the limits prescribed in the regulations. In that case the drone operator may apply for a Specific Operating Permission (SOP) which is issued to commercial drone operators and allows the operator to fly the drone within specific windows of time without breaking the law. To qualify for SOPs the operator has to undertake additional safety training to minimise risk and ensure high safety standards for some drone operations (Irish Aviation Authority, 2019).

Natural heritage sites can include Special Areas of Conversation (SAC) and Special Protection Areas (SPA) where different rules and regulations for natural protection of animals such as nesting birds or grey sales may exist during different times of the year. The drone operator may have to seek permission to fly in these areas and may only operate a drone following specific guidelines to protect the wildlife. Please check with your local aviation authority before operating a drone in these areas.

4.1.1. Operations Manual

The Operations Manual (OM) is necessary when the drone operator intends on using the drone for different or alternative purposes than allowed in the certified category. OMs explain to the national aviation authority how the drone operator will conduct themselves when operating drones. OMs are comprehensive detailed documents that set out their internal procedures in relation to safety, equipment, and operation, among others, to ensure that operations are conducted safely and do not pose a risk to people and property. Any organisation or commercial drone operator that uses drones will most likely have prepared an OM. OMs detail the pilot competency and include: 1. Administration, control, and responsibilities; 2. Crew composition and requirements; 3. Operational procedures; and 4. Aircraft operation. OMs will be prepared for each specific survey as the objective of the survey, and risk assessment vary depending on the flight purpose. A detailed example of an OM can be found in the Appendix.

A key part of the operational procedures includes a detailed site survey and risk assessments to ensure the safe and successful operation of drones in the field.

4.1.2. Site Survey and Risk Assessment

Depending on the category under which the drone falls and the flight purpose, site survey and risk assessment may have to be carried out. If the used drone falls under the open or certified category, or if the drone operation falls under STS in specific category, different safety procedures may have to be undertaken.

The Joint Authorities for Rulemaking on Unmanned Systems (JARUS) represents an expert group of National Aviation Authorities (NAAs) and regional aviation safety organisations. Together they have developed risk assessment guidelines for safe drone operations: Specific Operations Risk Assessment (SORA). Other risk assessment procedures equivalent to SORA may also be used by the drone operator. SORA is systematic approach to risk assessment and provides a 10-step procedure that ensure that any potential risks for drone operations are considered prior to conducting a survey. The SORA process with detailed explanations, illustrations, and additional information can be found here: https://www.easa.europa.eu/document-library/easy-access-rules/online-publications/easy-access-rules-unmanned-aircraft-systems. Be advised that drone operation safety the guidelines are being constantly reviewed.

4.2. Practical Considerations Pre-Flight Fieldwork

After having designed and planned a drone survey and having completed the operations manual, it is time to carry out the drone survey. Before going into the field and carrying out the drone survey, it is advisable to follow these simple steps to ensure safe and successful drone surveys.

4.2.1. Adjusting and Saving Data Settings

The data settings, i.e. resolution of the captured imagery, flight route, etc. should be adjusted pre-flight. This ensures that the drone operator is familiar with the settings of the drone and can produce the drone surveys efficiently in the field.

Most drones will enable the saving of the data settings to ensure that the same settings can be used more than once without having to reconfigure the settings for the survey. The data settings depend on the application and flight purpose, the needed resolution, and the desired output. Saving the data settings ensures that the drone survey can be repeated or replicated should the need arise or should more data with the same resolution be necessary. Saving the data settings, and including them in an output, also ensures that similar surveys with comparable data of the same site can be produced.

4.2.2. Plan Flight Route

A plan flight route is the survey pathway on which the drone will collect data points. The drone operator determines the plan flight route prior to entering the field through the use of available plan flight route applications. Typically plan flight route is a pathway that covers the survey site by flying parallel lines above the site at a certain elevation.

Figure 4: Example of plan flight route showcasing the flight pathway (UgCs, n.d.)

Planning the flight route in advance enables the operator to start the survey automatically without having to manually operate the drone. Following the flight route, the drone will collect imagery systematically surveying the entire site. Planning the flight route in advance maximises the operator's time in the field as the operator activates the automated flight path and can, if they wish, record the same flight path several times. Depending on the drone and the available software, different options compatible with the drones are available.

4.2.3. Drone Data Storage and Data Back-Up

The available storage on a drone depends on the model and make of the drone, most drones will have limited onboard storage available and may require additional data storage which can be installed using Secure Digital Cards (SD Cards). A wide range of these are available, however, a drone may not be able to read certain SD cards or may only operate with class 10 micro SD cards that are able to record 4k imagery. It is important to consult with the drone manufacturer, or documentation provided by them, regarding appropriate storage extensions for each drone make and model.

One parameter to consider for appropriate drone data storage is the resolution at which the imagery is acquired. This will determine how much storage is necessary to perform the survey; typically, a higher resolution drone survey requires more storage. Other factors include the format used for the survey, the frame rate of the video or the number of images required when carrying out a photogrammetry survey. The number of images required for the survey depend on the flight height, field of view (FOV) of the camera lens, the sensor size, and the amount of pixels. It is advisable to have additional storage or additional SD cards available, should you need to change the storage between surveys. Once the surveys are completed, it is advised to create data back-ups of the recorded data. Follow the instructions of the drone manufacturer to ensure that the data are safely stored.

4.2.4. Informing About the Survey

Drone surveys, while typically causing minimal impact on the environment or on people, can cause nuisance or disturb people. It is advisable to inform anyone that could be impacted by the drone survey prior to operating the drone to minimise the nuisance or disturbance. As drone operations are a still new occurrence, many people may be surprised and interested in learning more about the drone operation. It is recommended for the drone operator to wear a clearly labelled visibility jacket to easily identify them. Using signs in the area to inform people could also be considered. The use of regional information boards to inform the public about the planned and ongoing drone surveys are also recommend, see for example AVIAMAPS, currently used in Finland to track all airspace activity, including drone surveys (https://aviamaps.com/map?lang=en#p=3.92/64.96/26.1).

4.2.5. Weather monitoring

Monitoring the weather prior to conducting the drone survey is one of the most important tasks. The weather conditions of the day such as wind and precipitation could negatively impact the survey outcome. Monitoring the weather is therefore a vital task for the drone operator to avoid any unnecessary delays when operating the drone. This is particularly important in high-wind areas or where the wind direction could change quickly, such as in coastal areas or in areas with little to no wind-protection. This is to ensure the safety of the drone operator and to minimise risks of crashing the drone. Mobile applications, such as UAV Forecast (https://www.uavforecast.com/) can be used to monitor the weather and update the windspeeds (figure 6). Most drones are not able to operate in strong winds and/or precipitation. The drone should not be operated outside the manufacturer's limits for temperature, wind, precipitation, or any other limits provided by the manufacturer.

Figure 5: Mobile applications such as UAV Forecast can also be used on mobile devices available for IOS devices https://apps.apple.com/us/app/uav-forecast/id1050023752 and Android devices: https://play.google.com/store/apps/details?id=com.uavforecast

5. Conducting the Drone Survey

The following sections outline some of the practical considerations the drone operator will have to make in the field. Battery logging is survey independent and a vital part of operating drones safely. The use of ground control points depends on the purpose of the survey, and may not always be necessary.

5.1. Battery Logging, Charge State, and Battery Health

Batteries are a vital component of drones, keeping them healthy is very important. A faulty battery can produce incorrect readings, drain much faster, or lead to crash landings. It is recommended that batteries are always kept at storage charge when not in use. Batteries should never be fully drained during a flight. Draining the battery completely during a flight will trigger the battery failsafe function which causes the drone to return home automatically. However, this reduces battery life and can result in crash landings. In windy conditions, the drone requires more battery to return home safely. If the failsafe function has been triggered, there may not be enough battery charge left for the drone to return safely. Returning the drone with some battery charge left is good practice, as this minimises the risk of crash landings in case the drone cannot land immediately due to unexpected reasons such as crowds of people too close to the landing area or wind gusts.

A battery log is a record of drone batteries and charging cycles of them, this is particularly useful when the drone operator owns more than one battery and wants to keep track of the safety and health of the batteries. The battery log should detail when and how often the battery has been used and charged, and the percentage of battery life during take-off and landing to avoid crash landings or battery failures during drone operations. It is advisable to check that batteries are fully charged before going to the field to ensure that the survey can be carried out efficiently and with maximal aerial flight time. The battery log is a requirement within the OM (see Appendix).

5.2. Ground Control Points

Ground control points (GCPs) are used to mark targets placed strategically on the ground to improve the absolute accuracy of photogrammetry. The use of GCPs depends on the flight purpose and the desired output, i.e. GCPs are required when the drone surveys are used to plan restoration on historic buildings, monitoring coastal erosion or for comparison with other georeferenced data, to name a few. Hence, a 3D model of a building or of coastal features will require GCPs. A drone survey produced for promotional visual tourism will not require GCPs. The use of GCPs for promotional videos could potentially disturb the imagery, as the GCPs could seem out of place. Hence, GCPs are not always necessary to use but they are helpful to “calculate the scale, orientation, and absolute position information” (Madawalagama, Munasinghe, Dampegama, & Samarakoon, 2016, p. 3). This ensures that the modelling of the site is accurate. GCPs are visual targets and should have two high contrasting colours that make them visible from the air (figure 7). The targets are typically about one metre in diameter, smaller targets may also be used, and are typically made out of heavy plastic or wood panels. GCPs should be heavy enough to not be moved through light winds. GCPs are available in shops that sell aerial survey equipment but can also easily be home-made.

Environmentally friendly marking paint is an alternative solution, where signs will be painted directly on the ground or on a road. This is important to not obstruct traffic flow and to ensure traffic safety.

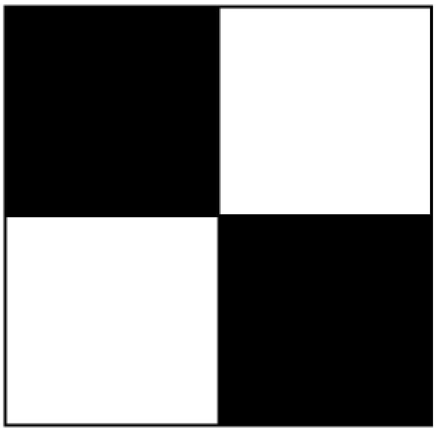

Figure 6: Example of Ground Control Point (GCP)

To ensure high accuracy for the drone data at least 3 GCPs should be placed carefully around the survey site. They should be placed offset from one another, i.e. in good distance from the to-be-surveyed site. If a building is to be surveyed, it would be advisable to place the coordinates on each of the corners of the survey site. If surveying a natural site, such as a beach or a cliff, the GCPs should not be placed in a line. Placing the GCPs across the surveyed area and in the middle will help 'pin' the captured images to the points.

GCPs should be placed in plain sight of the survey site and throughout the entire survey site. GCPs should be placed on different elevation points of the site, even if the area that is of most interest is clustered in one corner of the site. It is advisable to place GCPs in a configuration where the points could easily be connected. If the GCPs are placed as suggested in figure 8, the operator runs the risk of reducing the accuracy of the survey as a large area of interest is omitted, whereas GCPs laid out as in figure 9 will increase the accuracy of the drone survey (Propeller Aero, 2018).

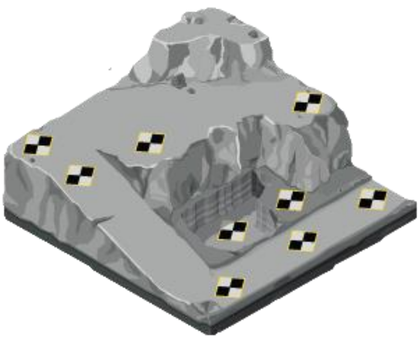

Figure 7: Example of 'badly' used GCPs (Propeller Aero, 2018)

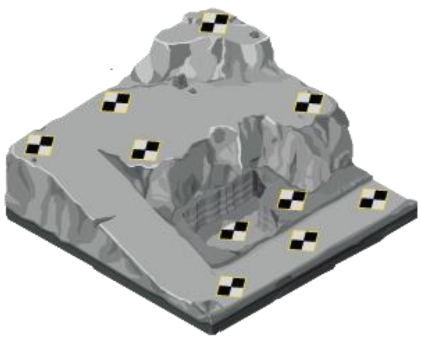

Figure 8: Example of well-placed GCPs (Propeller Aero, 2018)

Once put into place, the coordinates of the GCPs should be measured using geolocation measurement devices, such as multi frequency survey grade GNSS devices. The GCPs and their coordinates are then used in the mapping software to increase accuracy and positioning of the data collected through the drone survey. This will ensure that the model will be accurately positioned and mapped in relation to the real world around it. A range of GNSS devices are available.

5.3. Pre-Operational Safety

As some of the drone surveys may be carried out in remote places that are difficult to access, be aware of the surroundings and ensure personal safety at all times, ideally by working in pairs or teams. It is advised to let others know where you will be operating the drone and, in case a SOP has been granted, ensure that the drone is being flown within the windows that the national aviation authority specified.

5.4. Deploying the Drone

On site, or in the field, a suitable spot for the take-off and landing of the drone should be chosen. Before deploying the drone, the operator has to ensure that there are no risks or hazards that could impact the drone operation. Once this has been confirmed, the drone operator may initiate take-off. The drone will take-off to 1-1.5m or 4-6ft height when the performance of the propellers is checked before the operator can activate the planned flight path. The take-off height depends on the drone that is being used. Please consult with your drone manufacturer for details.

Most drones will have automatic flight features such as take-off options and return-to-home (RTH) or sometimes called return-to-launch (RTL). The return-home feature ensures that the drone will automatically return to the location from where the drone has taken off, either in case of a malfunction, low battery, or when the operator calls the drone back. These features depend on the make and model of the drone, it is advised that the drone operator becomes familiar with the available features of the drone before deploying the drone. It is also important that the drone operator does understand the limitation of drone operations and is ready to take over manual control in case there is a serious malfunction that makes the RTH function not work properly.

During the drone survey, the operator has to always be in the VLOS of the drone or use observers to ensure VLOS and follow the safe operation of the drone survey. The drone operator has to adhere to national aviation regulations and ensure the safe operation of the drone. The operator has to ensure that during the flight operation there are enough battery reserves for the drone to safely return to the starting point, see section 5.1. battery logging, charge state, and battery health.

Before landing the drone, the operator has to ensure that there are no risks or hazards to landing the drone before safely bringing it down.

6. Processing of Aerial Data

Data processing occurs when the collected data and footage from the drone survey is translated into usable information through data processing software and data analysis. Several data processing software are available, these include ArcGIS Drone2Map (https://www.esri.com/en-us/arcgis/products/arcgis-drone2map/overview), Pix4D (https://www.pix4d.com/), Drone Deploy (https://www.dronedeploy.com/), Precision Hawk (https://www.precisionhawk.com/), and Agisoft Metashape (https://www.agisoft.com/) among others. It is advisable to have a good understanding of how these software operate or consider investing in training for the software. This ensures that the collected drone survey data can be used for the desired output, prior to deploying the drone.

Mapping software can produce 3D point clouds which are the default data created in photogrammetry for any surface or object through geo-referenced aerial pictures. In essence, this means that the pixels are turned into points, all data is exported using point clouds, including orthomosaics. The mapping software creates the aerial pictures that are corrected to accommodate lens distortion, camera tilt, perspective, and topographic relief influenced by the elevation of the Earth's surface (Hawkins, 2016; Hung, Unger, Kulhavy, & Zhang, 2019). Once the survey data are collected, and data back-up is ensured, data processing can commence. The data can be put into the software and the software operator can create and catalogue the desired output. The operator needs to be trained in a way where they will be able to identify and mitigate any potential errors or failures that may occur, further information can be found in 3.1.1. Photogrammetry parameters.

6.1. Data Management and Data Sharing

Managing and organising the drone data appropriately on the computing device used for processing data will simplify the process. The INSPIRE Directive, a European directive on spatial data management[10], aims to standardise the data organisation of spatial data so that specific areas i.e. Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting, adhere to the same Implementing Rules (IR) (European Commission, 2007). This way the survey data collected by Member States is ensured to be compatible and usable by a wider community and can be used in transboundary contexts. Standardising data organisation could also contribute to promoting sustainable development by enabling local authorities to access the data and enable informed monitoring and managing of the natural and built environment.

The data processing software may require a dedicated data management structure to be able to process the data efficiently. A well-thought through folder structure to manage the data effectively should be considered as this could ensure smooth and efficient processing of the data. Embedded data management technology exist and may be useful for some applications.

Data sharing and storing are both among the initial and the final considerations of drone surveys. The sharing of the data is largely informed by the chosen output that has been decided in the planning phase. Yet, there may be opportunities to use the collected raw data for similar survey operations or to use the data for operations in a different way than originally intended. Considering how the data could be shared and would be accessible for other drone operators may therefore be helpful.

6.2. General Data Protection Regulations (GDPR)

According to the General Data Protection Regulations (GDPR), when processing data that are publicly available, any personally identifiable information, including vehicle license plates, clearly identifiable faces, etc. are required to be removed. Please familiarise yourself with the national GDPRs.

[10] The full INSPIRE Directive can be accessed here: https://inspire.ec.europa.eu/inspire-directive/2

7. Quality Assurance

Drone technology is still considered a fairly new technology and no standardised version to assure quality in the use of drones and their data exists. Currently, there is no need for a detailed survey report post-operation or final product assessment (Tmušić et al., 2020). Collected imagery of drone surveys therefore does not adhere to any standardised regulations, which becomes problematic when considering the use of drones for environmental management or monitoring where legally binding standards may exist.

Local authorities have an opportunity to design best practices for quality assurance of drone operations in the natural and built environment. Together with following the implementing the standardisation of the INSPIRE Directive, local authorities could ensure that the use of drones to monitor and manage coastal regions is also promoting sustainable development goals.

8. Drone Operator's Checklist

Flight purpose

- Understand purpose of survey
- Be familiar with national aviation regulations

Study design

- Design and plan aerial survey from start to finish
- Consider drone survey output
- Be familiar with the drone specifications

Pre-flight fieldwork

- If necessary, prepare and submit operations mantual
- Consider practicalities of pre-flight fieldwork

Conducting drone survey

- Consider practicalities in the field
- Deploy drone safely

Processing of aerial data

- Manage data effectively by considering the INSPIRE Directive
- Adhere to GDP regulations

Quality assurance

- Use best practice guidelines for quality assurance

9. References

Banfi, F. (2016). *Building information modelling–A novel parametric modeling approach based on 3D surveys of historic architecture.* Paper presented at the Euro-Mediterranean Conference.

De Vet, J. M., Edwards, J., & Bocci, M. (2016). *Blue Growth and Smart Specialisation: How to catch maritime growth through 'Value Nets'*. S3 Policy Brief Series No. 17/2016 Retrieved from https://s3platform.jrc.ec.europa.eu/documents/20182/154989/Blue+Growth+and+Smart+Specialisation.+How+to+catch+maritime+growth+through+%27Value+Nets%27/17053ed6-705f-4905-9963-c63a78df26bc

EASA, E. U. A. S. A. (2021a). Open Category - Civil Drones. Retrieved from https://www.easa.europa.eu/domains/civil-drones-rpas/open-category-civil-drones#:~:text=The%20'open'%20category%20is%20the,the%20new%20European%20drone%20rules.

EASA, E. U. A. S. A. (2021b). Specific Category - Civil Drones. Retrieved from https://www.easa.europa.eu/domains/civil-drones-rpas/specific-category-civil-drones

European Commission. (2007). INSPIRE Directive. Retrieved from https://inspire.ec.europa.eu/inspire-directive/2

Fino, E. R., Martín-Gutiérrez, J., Fernández, M. D. M., & Davara, E. A. (2013). Interactive tourist guide: connecting web 2.0, augmented reality and qr codes. *Procedia Computer Science, 25*, 338-344.

Flyability. (2021). Drones camera resolution: Three metrics you should know about. Retrieved from https://www.flyability.com/articles-and-media/drones-camera-resolution-three-metrics-you-should-know-about

French, J., & Burningham, H. (2009). Coastal geomorphology: trends and challenges. *Progress in Physical Geography, 33*(1), 117-129.

Gevaert, C. M., Persello, C., Sliuzas, R., & Vosselman, G. (2016). Classification of informal settlements through the integration of 2D and 3D features extracted from UAV data. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 3*, 317.

Giglio, S., Bertacchini, F., Bilotta, E., & Pantano, P. (2020). Machine learning and points of interest: Typical tourist Italian cities. *Current Issues in Tourism, 23*(13), 1646-1658.

Google. (n.d.). Rathlin Island East Lighthouse. Retrieved from https://www.google.com/maps/@55.3012459,-6.1722128,334m/data=!3m1!1e3

Hawkins, S. (2016). *Using a drone and photogrammetry software to create orthomosaic images and 3D models of aircraft accident sites.* Paper presented at the ISASI 2016 Seminar.

Hung, I., Unger, D., Kulhavy, D., & Zhang, Y. (2019). Positional precision analysis of orthomosaics derived from drone captured aerial imagery. *Drones, 3*(2), 46.

Ilkhanizadeh, S., Golabi, M., Hesami, S., & Rjoub, H. (2020). The Potential Use of Drones for Tourism in Crises: A Facility Location Analysis Perspective. *Journal of Risk and Financial Management, 13*(10), 246.

Irish Aviation Authority. (2019). *Basic Guidance Material for Small Unmanned Aircraft (SUA) Permission, Pilot Competency Certificate (PCC) & Special Authorisation / Approval (SA)*. Retrieved from https://www.iaa.ie/docs/default-source/misc/update-guidance-material-for-small-unmanned-aircraft-sop-pcc-sa-051119.pdf?sfvrsn=d3d201f3_0

Irish Aviation Authority. (2021). IAA says 'Know the Drone Safety Rules Before You Fly'. Retrieved from https://www.iaa.ie/news/2020/12/17/drone-safely-this-christmas#:~:text=10%20drone%20safety%20tips%20from%20the%20IAA%3A&text=Do%20not%20fly%20your%20drone%20within%205%20kilometres%20of%20an,your%20direct%20line%20of%20sight.

Jiménez López, J., & Mulero-Pázmány, M. (2019). Drones for conservation in protected areas: present and future. *Drones, 3*(1), 10.

Joyce, K., Duce, S., Leahy, S., Leon, J., & Maier, S. (2019). Principles and practice of acquiring drone-based image data in marine environments. *Marine and Freshwater Research, 70*(7), 952-963.

Kandrot, S., & Holloway, P. (2020). Applications of Drone Technology for Sustainable Development of the Coastal Zone: A Literature Review.

Kitonsa, H., & Kruglikov, S. V. (2018). Significance of drone technology for achievement of the United Nations sustainable development goals. *R-economy, 4*(3), 115-120.

Liao, Y., Mohammadi, M. E., & Wood, R. L. (2020). Deep Learning Classification of 2D Orthomosaic Images and 3D Point Clouds for Post-Event Structural Damage Assessment. *Drones, 4*(2), 24.

Madawalagama, S., Munasinghe, N., Dampegama, S., & Samarakoon, L. (2016). *Low cost Aerial Mapping with consumer grade drones.* Paper presented at the 37th Asian Conference on Remote Sensing.

Manfreda, S., McCabe, M. F., Miller, P. E., Lucas, R., Pajuelo Madrigal, V., Mallinis, G., . . . Ciraolo, G. (2018). On the use of unmanned aerial systems for environmental monitoring. *Remote Sensing, 10*(4), 641.

Nuyts, S., Murphy, J., Li, Z., & Hickey, K. (2020). A Methodology to Assess the Morphological Change of a Multilevel Beach Cusp System and their Hydrodynamics: Case Study of Long Strand, Ireland. *Journal of Coastal Research, 95*(SI), 593-598.

Palaigeorgiou, G., Malandrakis, G., & Tsolopani, C. (2017). *Learning with Drones: flying windows for classroom virtual field trips.* Paper presented at the 2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT).

Pitman, S. J., Hart, D. E., & Katurji, M. H. (2019). Application of UAV techniques to expand beach research possibilities: A case study of coarse clastic beach cusps. *Continental Shelf Research, 184*, 44-53.

Police Service of Northern Ireland. (2021). Small Unmanned Aircraft - Drones. Retrieved from https://www.psni.police.uk/advice_information/drones---small-unmanned-aircraft/drone-faqs/

Propeller Aero. (2018). How to Optimize Your Ground Control Point Placement. Retrieved from https://www.propelleraero.com/blog/how-to-optimize-your-ground-control-point-placement/

Simic Milas, A., Cracknell, A. P., & Warner, T. A. (2018). Drones–the third generation source of remote sensing data. In: Taylor & Francis.

Tap2Assist. (2014). How to scan a QR code on iPhone and iPad. Retrieved from https://www.tap2assist.me/MoreInfo/ScanningQRCodes

Templin, T., & Popielarczyk, D. (2020). The use of low-cost unmanned aerial vehicles in the process of building models for cultural tourism, 3D web and augmented/mixed reality applications. *Sensors, 20*(19), 5457.

The European Commission. (2020). *II (Non-legislative acts) Regulations - Commission implementing Regulation (EU) 2020/639 of 12 May 2020 amending Implmenting Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight*. Official Journal of the European Union

Themistocleous, K., Ioannides, M., Agapiou, A., & Hadjimitsis, D. G. (2015). *The methodology of documenting cultural heritage sites using photogrammetry, UAV, and 3D printing techniques: the case study of Asinou Church in Cyprus.* Paper presented at the Third International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2015).

Tmušić, G., Manfreda, S., Aasen, H., James, M. R., Gonçalves, G., Ben-Dor, E., . . . Mészáros, J. (2020). Current practices in UAS-based environmental monitoring. *Remote Sensing, 12*(6), 1001.

Traficom. (n.d.). Droneinfo. Retrieved from https://www.droneinfo.fi/fi/

UAV Coach. (2020). Drone Laws in Iceland. Retrieved from https://uavcoach.com/drone-laws-in-iceland/

Van Rijn, L. (2011). Coastal erosion and control. *Ocean & Coastal Management, 54*(12), 867-887.