European Union Aviation Safety Agency

Guidelines on static population density data for the determination of the ground risk of UAS operations

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Contents

The following guidelines have been developed in collaboration among:

- EASA;
- JRC;
- EUROSTAT;
- EUSPA;
- NAAs representatives: DGAC, ENAC, FOCA, LBA;
- Drone Alliance Europe.

List of acronyms

- **SORA**: specific operational risk assessment
- **iGRC**: intrinsic ground risk class
- **UAS**: unmanned aircraft system
- **JRC**: Joint Research Centre
- **EUSPA**: EU Agency for the Space Programme
- **EC**: European Commission
- **Copernicus**: Earth Observation component of the EU's space programme
- **GHSL**: Global Human Settlement Layer
- **MS**: Member States
- **NAA**: National Aviation Authority
- **ENACT**: ENhancing ACTivity and population mapping
- **IAM**: Innovative Air Mobility

EASA
European Union Aviation Safety Agency

1. Background, motivations and goals

With the adoption by EASA of the version 2.5 of the SORA methodology (specific operation risk assessment), population density data become necessary in support of the quantitative approach introduced for the determination of the iGRC of UAS operations. Population density maps may be static (e.g. providing information on population density during a specific time of the day, season, year, etc., which are based on historical data collected by the data provider), or dynamic (providing information on temporal variations of population density). The scope of this document is limited to static population density data, while a future activity will be conducted to address dynamic population density data.

The goal of these guidelines is to describe how static population density data, tailored to conduct a risk assessment of a UAS operation (using SORA 2.5), may be developed, and eventually utilised– directly or through a data provider, by any EASA Member State.

These guidelines also describe the static population density maps, tailored for UAS operations, developed using data provided by the JRC of the EC, which are publicly available. They meet the intent of these guidelines and are therefore recommended as EU-wide baseline of static population density data. EASA is also developing a web-based platform, referred as IAM (innovative air mobility) hub, that will include among several functions the display of population density maps and the possibility for UAS operators to automatically carry out the required ground risk assessment (using the risk assessment methodology that is going to be adopted by EASA, SORA 2.5). Therefore, the IAM Hub will display the maps related to those MS that will accept to use the maps provided by the JRC or that will provide an alternative source, as described in more details in the next sections.

2. Reference Scenario

Preliminarily to elaborating recommendations and guidelines related to *what* data are recommended to be provided, it is important to clarify the scenario in which the data will be utilised, i.e., to define clearly *how* and *by whom* they will be used. It is also important to clarify the role of the different stakeholders. These elements are elaborated in the present Section.

The static population density data recommended in this document will be displayed in a single digital map in the IAM Hub for all EASA Member States that will accept to participate to the IAM Hub project. The maps will be available to UAS operators and NAAs in a single platform. The IAM Hub may display the maps developed by JRC or any other map that each MS would like to develop, as long as a compatible interface will be developed.

Therefore, one of the goals of these guidelines is to provide recommendations for the establishment of maps with static population density data tailored for the use of UAS operators to assess the intrinsic ground risk of UAS operations. The mentioned maps covering all EASA MS, developed by JRC, are compliant with these guidelines. MS wiling to develop national maps may also consider these guidelines.

The current release of the IAM Hub maps provides a single population density value for each area, future releases may include multiple layers with spatio-temporal data (e.g. layer for population density during day, night, holiday, summer etc…). An abstract view of the IAM Hub architecture in relation to the population density maps is depicted in Figure 1 along with the main groups of stakeholders that are relevant for this document (other stakeholders' groups are omitted).

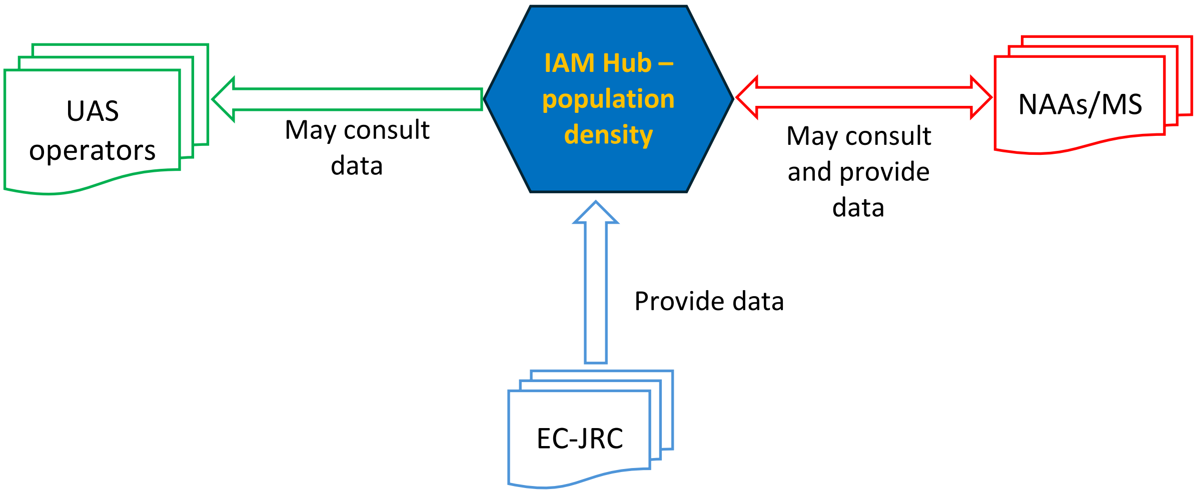

Figure 1 - Scheme of the IAM Hub, in relation to population density data, with the main stakeholder groups

The following stakeholders are therefore considered:

- **UAS operators**: may consult, through the IAM Hub, the static population density data. In addition, the IAM Hub will provide the possibility to define in a digital map the area where they intend to operate a UAS, providing as an output the relevant population densities values in such areas[1];
- **NAA/MS**: are considered as users of the service and possibly as data providers as well. NAA/MS may provide population density values to correct information in some areas where the census data (i.e. resident population) are not accurate enough (e.g. parks, beaches etc..) or provide population density data other than those developed at EU-wide level by the JRC, and recommended in these guidelines, to be used for the purpose of authorising UAS operations. MS will have their own statistical sources, as an example, information on population during working hours. This type of data is not available currently EU-wide at a sufficient resolution, so MS may find such information within their own government entities. This type of data may be more accurate than census data and may be included in future release of the maps in the IAM HUB. If this is the case, it is recommended that such data are provided to the IAM Hub to be displayed over the territory of the MS which is using them. On the other hand, this stakeholder group is considered a user as the maps displayed on the IAM Hub may be used by NAAs to review and confirm the population density at risk assessed by UAS operators when applying for an operational authorisation;
- **JRC**: as will be covered in detail in the next sections, the EU-wide data recommended in these guidelines are provided by the Joint Research Centre (JRC) of the EC in collaboration with EUSPA (Copernicus).

[1] eSORA functionality of the IAM Hub, under development at the time of the publication of this document.

3. Characteristics and limitations of static population density data

Static population density data provide a reliable representation of the population density in certain locations and at certain times of the day, season, year, etc., depending on the source of such data. As an example, when the data source is the census, the data provide an overview of where the population resides, and therefore may be considered a reliable source of population density when people are expected to be in their homes (e.g. during night), while they may not provide the same level of reliability in representing the actual population density in other times of the day or may not represent the actual population density in some locations such as sport venues, recreational areas like parks or beaches. It is acknowledged that some nations are in possess of statistical data related to workplaces and can produce a reliable presentation of population density also during different time of the day or day of the year. This may result in the development of multiple static population density maps providing a sort of picture of the distribution of population density in a specific day of the year (e.g. working day vs holidays) or time of the day (e.g., day vs night). These examples are made to highlight the main limitations of static data when they are utilised to assess the presence of uninvolved people during UAS operations: the actual population density in certain areas and at certain times may significantly differ from the one displayed by the data. This limitation reduces the effectiveness of ground risk assessments conducted utilising static data.

It is important to highlight that the recommendations and guidelines included in this document must cope with a scenario where data availability and quality are heterogeneous across EU Member States and anyway subject to evolve in time. It is recommended that the baseline data should rely on the latest resident population census data collected by the national statistical offices[2]. Certain data sources may be uniformly available at the European level (e.g., those obtained solely from satellite data) while others may be based, partially or fully, on administrative data produced at national level. The spatial granularity of such data, their timeliness and their quality may vary from one MS to another, depending on numerous country-specific factors, including technical capabilities and administrative practices. Furthermore, it may be expected that data quality and availability improve over time, both at the European and national level, as new data collection processes are launched, or legacy ones get upgraded. Notably, all such considerations about the heterogeneity across MS and the temporal variability of 'quality' hold regardless of how 'quality' is defined or evaluated. In other words, while a conceptual 'quality framework' that defines unambiguously and assess quantitatively the 'quality' of the data is highly desirable for the operation of the recommendations included hereby, the proposed approach to the use of static data remains largely independent from the detailed aspects of such quality framework.

When utilising static data to assess the presence of uninvolved people during UAS operations an extra step is needed at least to identify those areas where the data is more likely to be inaccurate.

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[2] Currently, the last census took place in 2021 and is planned to be updated every ten years. EUROSTAT is producing the GEOSTAT Census grid 2021 that represents key figures from the 2021 Census on an EU-wide 1 km² grid (https://ec.europa.eu/eurostat/web/gisco/geodata/population-distribution/geostat)

4. Data resolution and aggregation

This section covers the following topics:

- how the data are recommended to be provided to EASA to be included in the IAM Hub;
- how the data will be elaborated by the IAM Hub to be displayed to UAS operators and NAAs and used to assess the risk of UAS operations.

These two aspects should be considered independently from one another, as one can evolve without affecting the other.

In relation to the provision of data, to promote the use of a single grid for the representation of population density data, it is recommended to provide the data according to a common EU-wide grid compliant with the INSPIRE regulation (https://inspire.ec.europa.eu/theme/gg). It is recommended to adopt the Lambert Azimuthal Equal Area (LAEA, EPSG:3035). This is an equal area projection applicable for the entire territory of Europe and allows a correct calculation of population densities. To be in line with the INSPIRE directive, the population density data to be provided should be hierarchically nested (e.g. 10, 100, 1000 m - see https://inspire.ec.europa.eu/theme/gg) to facilitate data aggregation. If input data is available in intermediate spatial resolutions compared to the ones defined by INSPIRE, it is recommended to aggregate them to the next higher hierarchical level (e.g. input data with a spatial resolution of 60 m should be aggregated to 100 m). Once data are collected and encoded in accordance with the INSPIRE directive, the IAM Hub provides the possibility of aggregating and displaying to the users at the desired resolution. SORA 2.5 suggests adjusting the grid resolution based on the maximum operating heights as follows (SORA v2.5, Annex F, Table 11 "Suggested Optimal Grid Size"):

Max. Height (AGL)		Suggested Optimal Grid Size (meter x meter)
Feet	Meters	
500	152	>200 x 200
1,000	305	>400 x 400
2,500	762	>1,000 x 1,000
5,000	1,524	> 2,000 x 2,000
10,000	3,048	>4,000 x 4,000
20,000	6,096	>5,000 x 5,000
60,000	18,288	>10,000 x 10,000

Table 1 – SORA 2.5 Suggested grid size for population density maps

Such aggregation should be performed by the IAM Hub so to have one single entity performing this activity. Appendix 2 provides further information on how the aggregation is performed.

5 Provision of static data by JRC and Copernicus

The latest population density grid developed by the JRC (JRC-Census population grid 2021[3]), based on the 2021 census, has been produced in November 2024 and constitutes the most up to date EU-wide static population density map at 100 m resolution. The dataset represents population counts per regular 100 x 100 m cells at their place of residence, as per the latest census. As such, this grid is akin to a static population density at night-time, assuming that everyone is at their official place of residence. This grid was produced by downscaling the originally available population counts at 1 km resolution from the 2021 census grid published by Eurostat (release of 16 June 2024)[4]. To downscale population counts from 1 km to 100 m cells, an ad-hoc, residential built-up volume layer was used. This layer combines building footprints data from multiple sources, land use information (to distinguish residential from non-residential areas) and building height data from Copernicus products GHSL and Urban Atlas.

Future updates of the static population density shall continue being provided in coordination with JRC and Copernicus.

As stated in the previous chapters, static data have limitations that reduce their reliability when they need to be utilised to assess the population density in, potentially, all territories of the EASA MS at all times. This might not be sufficient in the context of SORA 2.5, as UAS operations will occur also during the day, when people are outside their places of residence (e.g., in transit, or at locations of employment, study, shopping, recreation, etc.).

In order to mitigate such limitations, the information on residential population should be complemented with detailed land use or landcover information. The additional information given by the land use maps allows to identify the areas where data based on census are not suitable to represent population density, as the areas with high utilization in daytime or certain seasons.

For this purpose, the LUISA Base Map 2018[5] is proposed to be used, as it is the most detailed, complete and consistent land use/land cover map for Europe. Compatible with the CORINE Land Cover (CLC) nomenclature recognised by the EC[6], the LUISA Base Map offers a considerable higher spatial and thematic detail. It was produced by employing an automated, reproducible and structured geographical data fusion approach, integrating land use data from diverse, trusted, off-the-shelf geospatial data sources, notably Copernicus products such as CLC, High Resolution Layers and Urban Atlas. It is available at 50 m resolution and employs a Minimum Mapping Unit of 1 ha for artificial surfaces and 5 ha for non-artificial surfaces (compared to 25 ha in the original CLC).

The LUISA Base Map includes almost 50 land use and land cover classes (see table 2), and their definitions may be consulted at this link. These classes have been analysed to identify those that are more likely to cover areas where the population density value is substantially underestimated compared to the population density

[3] Pigaiani, Cristian; Freire, Sergio; Batista, Filipe (2024): JRC-CENSUS population grid 2021. European Commission, Joint Research Centre (JRC) [Dataset] doi: 10.2905/98336641-fd1c-4992-8c7b-c470dd5eb81e PID: http://data.europa.eu/89h/98336641-fd1c-4992-8c7b-c470dd5eb81e

[4] https://ec.europa.eu/eurostat/web/gisco/geodata/population-distribution/geostat

[5] https://publications.jrc.ec.europa.eu/repository/handle/JRC124621; Data: Batista, Filipe; Pigaiani, Cristian (2021): LUISA Base Map 2018. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/51858b51-8f27-4006-bf82-53eba35a142c

[6] More details may be found here: https://land.copernicus.eu/en/products/corine-land-cover

map based on the census for certain time frames. This is particularly the case for those areas that do not contain resident population, and therefore have a low population density, but which are likely to present a higher number of people that may vary depending on the typology of area, times of the day/year/season or other factors. Those areas are referred in Table 2 below as “critical land use”. Moreover, the land use data can also be used to highlight areas that might contain recurrent outdoor assemblies of people (e.g. a beach during summer period, a stadium during a football match etc..).

Class code	**Class label**	**Critical land use (Pop. density likely higher than shown on the population density map)**	**Share of total land surface (%)**	**Potential recurrent presence of assemblies of people outdoor**
1111	High density urban fabric	Yes[7] - only if no census data are already assigned to the area	0.09%	No
1121	Medium density urban fabric	Yes[10] - only if no census data are already assigned to the area	0.36%	No
1122	Low density urban fabric	No	1.01%	No
1123	Isolated or very low density urban fabric	No	2.15%	No
1130	Urban vegetation	Yes	0.07%	No
1210	Industrial or commercial units	Yes	0.91%	Yes
1221	Road rail networks and associated land	No[8] - displayed in the maps only for information (no assigned value)	0.57%	No
1222	Major stations	Yes	0.0001%	Yes
1230	Port areas	Yes	0.03%	No
1241	Airport areas	No[11] - displayed in the maps only for information (no assigned value)	0.06%	Yes
1242	Airport terminals	Yes	0.0002%	No
1310	Mineral extraction sites	No	0.13%	No
1320	Dump sites	No	0.02%	No
1330	Construction sites	Yes	0.03%	No
1410	Green urban areas	Yes	0.13%	Yes
1421	Sport and leisure green	Yes	0.21%	Yes
1422	Sport and leisure built-up	Yes	0.06%	Yes
2110	Non-irrigated arable land	No	21.15%	No
2120	Permanently irrigated land	No	0.82%	No
2130	Rice fields	No	0.13%	No
2210	Vineyards	No	0.71%	No

[7] These land use classes are predominantly of residential nature. Thus the static population density map represents generally well the actual population distribution in these areas, especially in night-time. In daytime, the static population density map may even overestimate population density in these land use classes, as a meaningful share of the residential population commute to work and other activities in daytime. Such overestimation in fact implies a conservative assessment of risk in daytime. Conversely, in instances where the urban fabric land uses contains a high mix of residential and commercial/business land uses, or attract visitors/tourists (e.g., city centres), the static population density map may actually underestimate total population in daytime, resulting potentially in underestimated risk scores.

[8] Even though it is acknowledged that in certain cases high population density values may be present in these areas, recommending an appraisal every time a road/railway or airport area is overflown has been deemed too conservative. The UAS operators remain still responsible to ensure that the population density at risk during the operation remains within the limits authorised by the competent authority.

2220	Fruit trees and berry plantations	No	0.53%	No
2230	Olive groves	No	0.92%	No
2310	Pastures	No	9.38%	No
2410	Annual crops associated with permanent crops	No	0.08%	No
2420	Complex cultivation patterns	No	2.54%	No
2430	Land principally occupied by agriculture	No	2.40%	No
2440	Agro-forestry areas	No	0.60%	No
3110	Broad-leaved forest	No	14.60%	No
3120	Coniferous forest	No	16.54%	No
3130	Mixed forest	No	3.54%	No
3210	Natural grassland	No	2.33%	No
3220	Moors and heathland	No	3.24%	No
3230	Sclerophyllous vegetation	No	1.77%	No
3240	Transitional woodland shrub	No	2.88%	No
3310	Beaches, dunes and sand plains	Yes	0.11%	Yes
3320	Bare rock	No	1.41%	No
3330	Sparsely vegetated areas	No	2.76%	No
3340	Burnt areas	No	0.03%	No
3350	Glaciers and perpetual snow	No	0.31%	No
4000	Wetlands	No	2.64%	No
5110	Water courses	No	0.29%	No
5120	Water bodies	No	2.38%	No
5210	Coastal lagoons	No	0.05%	No
5220	Estuaries	No	0.01%	No

Table 2 - Land use classes. Assessment based on the land area covered by EU27 Member States, Switzerland, Norway, Iceland, UK, Serbia, Albania and North Macedonia.

When displayed in the IAM Hub, those areas will be highlighted by providing a warning and, in addition, an assigned population density value will be associated to replace the value displayed in the same areas by census data[9]. As the values to be assigned to each land-use class may be dependent on the characteristics of the territory in which such land-use classes are located, it is recommended that these values are provided to the IAM Hub directly by MS. In this way, the local characteristics and the experience of every MS can be taken into account and reflected in the values given to each critical land-use class.

To support MS in the assignment of the population density values to the critical land use classes, Appendix 1 to this document provides an analysis of such areas based on a study developed by the JRC.

[9] With the exception of high and medium density urban fabric land use classes, see Table 2

Therefore, the maps on the IAM HUB will show a population density value assigned to each critical land use class. It may happen that two different locations are classified as the same critical land use class (e.g. two industrial areas) so the maps will show the same population density value. However, these areas may be quite different and in reality have a different population density value either at all times or under certain conditions. When UAS operators intend to operate over such areas they may take one of the following actions:

1) Rely on the assigned population density as provided via the IAM Hub (e.g. no correction of the maps is required and the resulting level of risk of the operations is compatible with the safety measures that the UAS operator is capable to put in place without performing any additional assessment);

2) When performing step#2 of SORA, justify a reduction of the population density value assigned to the critical land use classes that is not dependent of time or condition of flight, and for which therefore there is no need to introduce operational restrictions and additional procedures. In these cases, the UAS operator may perform an appraisal of the operational volume and ground risk buffer, complementing the information given by the static maps in the IAM Hub, to justify a correction of the population density value. The correction of the value given by the IAM hub map can be as extensive as it can be justified.

   This can be done in several manners, on a case-by-case basis, depending on the characteristic of the area(s) being assessed. Here below a non-exhaustive list of information that may be provided by UAS operators to competent authorities during this appraisal:

   — Collect from local sources detailed information on population density data to identify a more accurate value of population density at risk;

   — Utilise other qualitative data to justify a lower population density.

   A log of such correction will be made available for the benefit of all other UAS operators, and it will be considered for the improvement of the maps accuracy.

3) When performing step#3 of SORA, introduce operational restrictions and procedures allowing to reduce the number of people at risk during the operation, this may be done by:

   — Justifying that the population density of certain areas may be reliably expected to be lower at a specific time of the day, or in a specific day of the year (e.g. if flying over skiing facilities during summer vs. during winter, or over sporting facilities when no activity is taking place);

   — Using dynamic population density data;

   It is highlighted that the justifications provided to assess the population density as above-mentioned may consist in a limitation proposed by the UAS operator (e.g. fly on beaches only during night or in the winter) or having procedures allowing to assess the actual population density (e.g. fly over sport facilities after having checked that there is no event) or other means accepted by the competent authority authorising UAS operations. Once an acceptable justification has been provided by the UAS operator, it should be allowed a reduction of the iGRC of as many orders of magnitude as needed to correctly reflect the actual population density at risk during the operation. This would be classified as an M1(B) mitigation during Step#3 of SORA.

If UAS operators intend to apply the ‘sheltering mitigation’ (i.e. M1(A) defined in step#3 of SORA 2.5), they should check if the operation is taking place over an area where potential assemblies of people are possible.

In this case people may not be sheltered, and the IAM HUB will include an automatic function to inform UAS operators.

In total, the land use classes for which these guidelines recommend further population density assessments and/or indicate an assigned population density represent less than 2% of the total land surface (on average for the whole area of the countries considered in table 2). However, it must be noted that the land area occupied by these land use classes may not represent the true likelihood of flight paths over them. In fact, the likelihood of UAS operation over areas of socioeconomic activity could be higher than their land share.

In summary, the data deployed to represent static population density represents the state-of-the-art as of early 2025, combining residential population density at 100 m resolution, and indication of conservatively assigned population density for certain land uses. This is the possible approach with the readily available data. Substantial data gaps persist, preventing the appraisal of population density in comprehensive and consistent manner, especially for the daytime frame, when most UAS operations will likely take place ultimately. The estimation of population density in night and daytime frames and for different seasons has been attempted successfully by the JRC, mobilizing data from multiple sources. However, such exercise was done for the census year 2011 (now outdated) and at 1 km resolution (100 m would be needed).

6. IAM Hub: implementation of these guidelines

To support UAS operators in carrying out the risk assessment in support of their application for an operational authorisation, a functionality will be included in the IAM Hub, called eSORA. This functionality includes a map, covering all MS willing to participate in the project, displaying the population density data provided by the JRC modified using the land usage layer as described in section 5.

The IAM Hub will allow UAS operators, through the eSORA, to define their operational volumes, ground risk buffers and adjacent areas and to receive the information needed to assess the iGRC of their operation in accordance with these guidelines. Therefore, when an operational volume, ground risk buffer and adjacent area will include one of the areas where the static map values are not accurate enough, the IAM Hub will provide a warning and the assigned population density value. The UAS operator will have the possibility of modifying it, directly through the eSORA, depending on the outcomes of any additional information/appraisal provided, either as part of Step#2 or Step#3 of SORA, as described in section 5 of this document.

This functionality is aimed at facilitating the assessment of the iGRC for UAS operators and its review from the NAAs, reducing the effort to identify areas where the ground risk may be higher, in particular when the size of the operational volume, ground risk buffer and adjacent area are significant.

In the following sections are reported two examples to provide more clarity on how the data described in this document may be utilised, in practice, by UAS operators.

EXAMPLE 1 (generic authorisation: no ‘critical land use’ areas in the operational volume)

A UAS operator intends to operate in locations where:

— the map does not show any ‘critical land use’ in the operational volume and ground risk buffer, or;

— the maps shows some ‘critical land use’ in the operational volume and ground risk buffer, and the UAS operator is capable to demonstrate that a correction to the assigned population density values to such areas (as part of SORA Step#2) is possible, or;

— the map shows some ‘critical land use’ in the operational volume and ground risk buffer however the resulting iGRC is acceptable to the UAS operator (e.g. there is no need to reduce the population density value through the verification of the correctness of the population density value as described in paragraph 5.2 or to apply a mitigation M1(B) in SORA step #3);

— moreover, some ‘critical land use area’ may be present or not in the adjacent area (most likely the presence of a critical land use in the adjacent area may not affect the containment requirements as it is based on the average population density of the adjacent area).

The eSORA then provides the iGRC value and the UAS operator may proceed to apply the ground risk mitigations, if any, in Step#3. If the operational authorisation is approved, the UAS operator may:

1. receive from the NAA of the MS of registration an operational authorisation with ‘generic locations’;
2. operate in all areas compatible with the received authorisation, as long they avoid ‘critical land use’ areas in the operational volume, and;
3. when planning a flight, they will check that the GRC of the operational volume, ground risk buffer and adjacent area is consistent with the limits of the operational authorisation.

When UAS operators intend to operate in a state different from the one of registration, they will apply the same logic. Also, UAS operators:

1. will check presence of local conditions published by the MS of operation, and;
2. will inform the NAA of operation of the location where they intend to operate showing compliance with the local conditions.

EXAMPLE 2 (operation over or close to a ‘critical land use’ area)

A UAS operator intends to operate over a beach in a southern European state, that in the maps is displayed as a ‘critical land use’ with an assigned population density value of <50.000 people/km^2 and with potential recurrent presence of outdoor assemblies of people. The UAS operator will carry out the eSORA:

1. SORA step#2: the UAS operator draws the operational volume, and the eSORA will show a high intrinsic ground risk class (iGRC) if operating directly over the beach (since the maximum population density be driven by the value of the beach) or a need for a high containment (if flying within 1 km from the beach). Through an appraisal and the collection of additional information, the UAS operator may demonstrate that the population density in such area is lower than the one assigned (at all times), and therefore correct the value assigned to the ‘land use class’ in that specific location (see paragraph 5.2);
2. SORA step#3: once the population density value has been assessed in step#2 and if the UAS operators still need to reduce the iGRC, they may apply the M1(B) mitigation justifying that during the time of the operation the actual population density at risk during the operation over the beach is lower than the one defined in step#2. The UAS operator should be allowed to reduce the iGRC of more than 2 orders of magnitude if they are able to justify it (e.g. a beach in winter may have a pop density of 0.5 people/km^2 meaning 5 times less than the one showed).

   There may be multiple ways to mitigate the ground risk, some examples are:

   — The UAS operation is conducted over a beach in winter time. Moreover a physical appraisal is carried out during sunny days and non-working days when more people may be expected on the beach: the UAS operator will provide as evidence a limitation (e.g. operate from October to April) and a procedure requiring the remote pilot to check the weather conditions during the non-working days and, in case of sunny days, physically inspect the area for presence of people;

— The UAS operation is conducted over a sport and leisure build up: the UAS operator has a procedure to verify the stadium schedule of events and avoid flying when there is an event;

— The UAS operator makes use of dynamic population density accepted from the MS of operation, verifying, before each flight, that the actual population density meets the limitations defined in the operational authorisation.

3. A similar approach may be followed in SORA Step#8 to reduced the required level of containment, if the critical land use class is within 1 km from the operational volume.

Appendix 1

In this section is reported the outcome of the analysis conducted to the critical land use classes to identify which population density values may be assigned by MS. This analysis is based on the data resulting from the ENACT (ENhancing ACTivity and population mapping) project, which aimed at producing consistent, seamless, multi-temporal, high-resolution and validated population density grids for Europe taking into account major daily and monthly variations.

The project produced, for the reference year 2011, 1 km raster maps with estimated population counts in daytime and night time per month (i.e. total of 24 grids), considering the presence of residents, workers per different sectors, students, and tourists, and locations of residence and socioeconomic activity. These grids were produced for all EU-28 countries by combining official statistical data at regional level with geospatial data from conventional and non-conventional data sources, and are publicly available in two coordinate systems: ETRS89 LAEA (EPSG:3035) and WGS-84 (EPSG:4326).

The analysis was conducted as follows:

1. from the ENACT 12 monthly daytime grids, it was created a single population density grid displaying the maximum population density values identified for each cell;
2. For the selected LUISA critical land use classes, patches with at least four contiguous 100 m cells were considered in the map;
3. For the considered LUISA patches obtained in 2. above, their centroids were selected and, for each centroid, the corresponding population density value was extracted;
4. Using the data obtained above, the following information was collected:
   - The median population density value for each of the considered classes;
   - The population density in the 90th and 95th percentile for each of the considered classes;
   - The maximum value of population density, throughout all EU, for each of the considered classes. These values are reported for information, however they may be considered corner cases.

The approach described above is not applicable for some of the critical land-use classes, as:

- Population density in 'Major stations' (class 1222) would be overestimated, as the analysis has been conducted using maps at 1km resolution. Being usually located in city centres, the corresponding 1km cells would be a large part composed by dense residential areas;
- Population density in class 'Airport terminals' would be underestimated, and these are anyway already covered by Geozones, which facilitates their identification;
- Population density in beaches would be underestimated, as:
  - ENACT has not modelled comprehensively the occupation of beaches by all potential beachgoers, and;
  - the corresponding LUISA class 3310 contains significant areas of dunes and inland sand plains (e.g. dry river beds).

The table 3 below summarises the outcome of the analysis:

LUISA code	LUISA Class label – critical land use classes	ENACT – median (ppl/km²)	ENACT - 90th (ppl/km²)	ENACT - 95th (ppl/km²)	ENACT – max (ppl/km²)
1111	High density urban fabric	2.940	9.960	13.340	55.693
1121	Medium density urban fabric	1.472	5.298	8.402	46.323
1130	Urban vegetation	573	2.839	3.937	56.022
1210	Industrial or commercial units	385	4.127	6.436	59.874
1222	Major stations	Not applicable			
1230	Port areas	1.338	5.421	7.297	22.478
1242	Airport terminals	Not applicable			
1330	Construction sites	210	2.216	3.443	31.124
1410	Green urban areas	1.909	6.981	9.912	59.131
1421	Sport and leisure green	281	3.050	4.475	45.142
1422	Sport and leisure built-up	770	5.434	8.128	40.155
3310	Beaches, dunes and sand plains	Not applicable			

Table 3 – Critical land use classes and their estimated population density value

It is also reminded that, when utilising the maps recommended in these guidelines, UAS operators are not mandated to rely on the assigned value but have the options to perform further appraisals to better assess the population density at risk during the operation.

MS may provide to the IAM Hub the assigned population density values for each land use classes using the following form:

EASA MS	**Class label**	**Recommended assigned population density value** (people per km²)	**Share of total EU land surface** (%)
Include here MS name	High density urban fabric	*To be completed*	0.09%
	Medium density urban fabric	*To be completed*	0.36%
	Urban vegetation	*To be completed*	0.07%
	Industrial or commercial units	*To be completed*	0.91%
	Major stations	*To be completed*	0.0001%
	Port areas	*To be completed*	0.03%
	Airport terminals	*To be completed*	0.0002%
	Construction sites	*To be completed*	0.03%
	Green urban areas	*To be completed*	0.13%
	Sport and leisure green	*To be completed*	0.21%
	Sport and leisure built-up	*To be completed*	0.06%
	Beaches, dunes and sand plains	*To be completed*	0.11%

Table 4 – Critical land use classes population density value to be defined by EASA MS

Appendix 2

This Appendix details how the census data provided by the JRC are aggregated at the resolution recommended by SORA 2.5. Population density data are provided by the JRC at a spatial resolution of 100 x 100 m. Through a Python script, taking as input the raster data (at 100 x 100 m) provided by the JRC, a new raster at 200 x 200 m is generated, which for each cell provide a value of people/km^2.

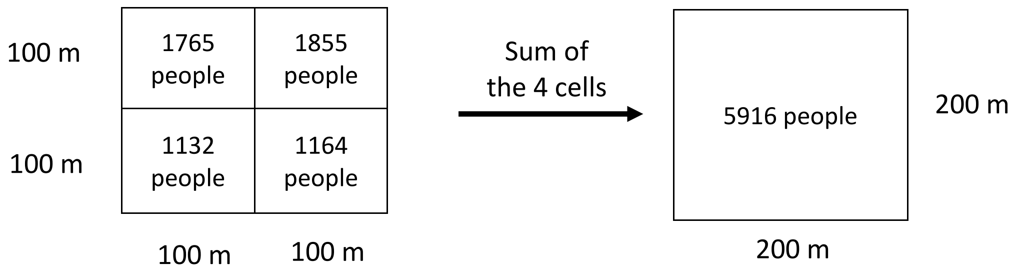
The script first aggregates the 100 x 100 m cells to 200 x 200 m cells creating a new raster image by summing the values in the 100 x 100m cells in a new 200 x 200 m grid. The script then creates another raster which converts the values from people per 200 x 200m cell to a people per square kilometer. This is achieved by multiplying the value in the 200 x 200m cell by 25 (there are twenty-five 200 x 200m cells in a 1km block) to get the people per km^2.

The process is visualized as follows:

— STEP 1: the input data (100 x 100 m) provides, for each cell, the number of people which are present;

1765 people	1855 people
1132 people	1164 people

— STEP 2: each block of four 100 x 100 m cells is aggregated so to become one 200 x 200m cell. The number of people is summed to obtain the number of people present in the new cell:



— STEP 3: the value in each cell is converted from “number of people/cell” to “people/km^2”. This is done my multiplying by 25 the value in each cell;

— STEP 4: the final output is provided:

147.900 people/km^2