ITU GUIDELINES

International Telecommunication Union
Telecommunication **Development Bureau**

Establishing or Strengthening National Broadband Mapping Systems

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1. Introduction

1.1 Background

Ensuring universal connectivity has become an imperative for most countries striving to compete in a globalized and digitalized world, to empower citizens, and to address some of the most pressing challenges of our time, including the global pandemic.

To this end, over the past 10 years, many countries across the globe have implemented *broadband mapping systems* aimed at facilitating investments in broadband networks and addressing the gaps in coverage, quality, affordability and uptake, among others.

Broadband mapping systems can be broadly defined as "*any digitized information system that gathers, structures and represents georeferenced data about the reach or quality of telecommunication networks in a given geographical area. A broadband mapping system may include an infrastructure, service or investment layer, or a combination of those.*"

Though simplified, this definition explains that georeferenced data validated by public authorities are at the heart of telecommunication policy today. Such data supports decision-making processes of a variety of stakeholders such as regulators assessing market competition or quality of experience, government authorities allocating funding, operators planning investments, and citizens considering new housing locations or choosing the best service provider for any given area. Moreover, such use of geo-referencing and transparent data for regulation and decision-making fits in a wider trend of evidence-based regulation, that is also aligned with the wider digitalization of almost every aspect of life, including public administration.

Across both fixed and mobile markets, different types of broadband mapping systems and different particular use cases can be encountered. For example, these are i) identifying gaps in coverage and quality of service ii) identifying opportunities to invest iii) increasing transparency of broadband markets iv) reducing the cost of investments through infrastructure sharing and other regulations v) efficiently allocating governmental support for broadband development vi) increasing attractiveness towards foreign investors vii) ensuring effective integration between national, regional and local policies and markets, just to mention a few. Following the study conducted by the EU level, broadband mapping systems can be categorized into four different types as described in the table below. The correct implementation of these systems is now widely recognised as a game changing factor for policymaking and regulation at the national level.

Infrastructure Mapping	Service Mapping
The activity entailing the gathering, structuring and representing: georeferenced data on passive physical infrastructure (e.g., pipes, ducts, poles, manholes, base stations, mobile towers, etc.) represented in lines and nodes; information about the type of infrastructure deployed (fiber/copper, water pipes, electricity); information about the owners of that infrastructure (fixed/mobile telecommunications, other network operators, national and local government, etc.)	The activity entailing the gathering, structuring and representing: data about service availability (including bandwidth and or type of technology used to offer the service), data about the number of broadband service offers from operators data about the estimated quality of service available for a specific address and/or a specifically defined geographical area (e.g., 100m x 100m grid)
Investment Mapping	**Demand Mapping**
The activity entailing the gathering, structuring and representing: data about planned investments aimed at developing broadband infrastructure and services in a defined geographical area (e.g., region, municipality), including relevant information about publicly and/or privately funded projects. Investment maps may include reports about areas characterized by market failure or sub optimal outcomes	The activity entailing the gathering, structuring and representing: data about the quantity and quality of broadband demand for bandwidth desired by the end user. the level of financial allocation foreseen in association with that given broadband fixed service.

Table 1 **Four Types of Broadband Mapping Systems**

1.2 Context

ITU has been active in the broad domain with the Interactive Transmission Maps project[1] in place since 2012 to map the global data highways that are the national and international backbone transmission networks. The project now maps over 3,944,376 Km of backbone networks globally from over 540 operators.

Within this framework, ITU has been recently expanding its research and data collection by adding a new layer to the Interactive Transmission Maps that provides information on the existence, type and

1 https://www.itu.int/bbmaps/

institution in charge of broadband mapping systems targeting the access network. This initiative considers all 6 ITU Regions, expanding ITU's overall knowledge of the current practices that exist globally, to build a repository of information accessible to all stakeholders and to identify gaps. The first results were compiled in the following report titled "New layer of the ITU Interactive Transmission Maps on National Broadband Mapping Systems Initiatives".

Throughout this effort, Europe has emerged as a leader due to the European Union (EU)'s efforts to harmonize approaches to broadband mapping across its 27 members thanks to the work of the European Commission, Body of European Regulators for Electronic Communications (BEREC), and thanks to the work and innovations of several National Regulatory Authorities. In many ways, the EU's leadership in terms of coverage, affordability and uptake of telecommunication services, can be explained by the smart use of information not only by operators but also by public authorities. Moreover, this harmonization has already generated positive externalities outside of the EU-27 block, with non-EU countries modelling their policies and strategies, benefitting from the body of knowledge and expertise produced within the EU and making notable improvements over the past 5 years[2]. Even outside Europe, many administrations are looking at the old continent for guidance, standardized methods, and proven practices in this field.

1.3 Problem statement

According to ITU research, significant gaps remain beyond Europe when it comes to the implementation of broadband mapping systems with a very *heterogeneous* scenario. Few administrations can fully leverage state of the art systems which support a variety of use cases, while many others still rely on questionnaires to gather market and technical information. More precisely, according to ITU research, it appears that around 30% of national regulatory authorities (NRAs) across the globe has developed mapping systems intended as per the definition above, to advance the achievement of national objectives. These are mostly high-income countries such as Germany, the UAE, and New Zealand or large countries such as Brazil or Canada. Again, a high concentration in these systems can be found in Europe where 38 out of 46 countries in the region are leveraging at least some type of broadband mapping system, whether to facilitate infrastructure sharing, identify service gaps in rural areas, or for other purposes.

In addition, ITU research shows that despite some great innovations and use cases encountered in some countries there exists a substantial lack of *harmonization* in how these systems are developed and used, from both a technical and project management perspective as well as from a regulatory standpoint. Differences are encountered in objectives, governance, management of the project, sustainability, IT system used, regulation underpinning the systems. This results in i) lack of cross border information

2 https://www.itu.int/go/EUR_RRF-20

sharing, ii) a very restricted community of experts, and therefore iii) poor scalability of best practices across the globe.

Lacking sound data for decision making nowadays means operating blind or with sub-optimal information for all stakeholders involved, and particularly for policymakers and regulators in low resource settings that focus on efficiency. In fact, any policy aimed at enhancing broadband networks requires careful evaluation to identify the right incentives to foster new investments in coverage and network upgrades whilst maintaining the conditions for markets to operate competitively and seize appropriate returns on investments (ROIs).

In other words, on the one hand, policymakers and regulators are caught between citizens' demand for broadband and the necessity to apply competition rules to avoid market distortion, while on the other hand operators are pressured by high costs of deployment, especially in areas where investments are not cost-effective due to uncertain revenues and uptake. Hence, the need to support countries in this field is becoming more and more the cornerstone of any regulatory and policy framework which requires sound actions to provide certainty to the market.

1.4 Purpose of the Guidelines

As it will be argued throughout this paper, the main barriers to setting up broadband mapping systems can be grouped in regulatory, technical and project-related. In this regard, the lack of harmonized knowledge and reference practices in these domains prevents action from being taken in developing countries, where it would be most needed. With these Guidelines, ITU seeks to fill this gap and provide the international community of stakeholders with a robust albeit simple reference document containing a set of indications on regulatory, technical and project management aspects of broadband mapping.

Utilising the EU's experiences as the main reference for practices that are already harmonized across a variety of countries, the Guidelines will seek to generalize minimum requirements and milestones for the implementation of broadband mapping systems at the national level. Chapter 2 will start by addressing the policy and regulatory harmonization efforts in Europe, identifying clear steps that National Regulatory Authorities or other government authorities ought to take to create an enabling environment for broadband mapping that is fit for purpose. Chapter 3 will then address the technical requirements and specifications of broadband maps, including proprietary, open-source and in-house solutions, and the necessary linkages with the regulatory framework. Finally, Chapter 4 will offer insights into project management aspects of broadband mapping projects from the perspective of National Regulatory Authorities or other competent authorities, addressing the recurring challenges of project financing, human capacity building and sustainability.

The overall objective of this paper is to respond to the gaps identified and the needs of the international community by empowering decision-makers with a broad understanding of broadband mapping systems from a regulatory, technical, financial and human resource perspectives, and providing them with the necessary reference knowledge to take action at the national level or at the very least investigate this matter further, eventually with the support of the ITU.

1.5 Disclaimer

Although broadband comprises both fixed and mobile markets, the paper will discuss broadband mapping with a focus on fixed networks mainly, for four main reasons. The first is that fixed networks are more reliant by nature on physical infrastructure which has substantial civil engineering costs, and thereby have a relevant impact on coverage and quality of the delivered fixed services. The second reason is that in the age of COVID-19, reliable household access to the Internet has become an essential part of life, enabling families to cope with restrictions to the extent possible. Although efficient broadband mapping will not secure fibre-to-the-home (FTTH)/fibre-to-the-building (FTTB) coverage in all areas, it nevertheless supports the efficient identification of alternative solutions. The third reason is that with the shift to 4G and more recently 5G networks, backhaul and backbone costs have been rising substantially for the mobile sector. Looking at the future, as fixed and mobile infrastructure are rapidly converging, and considering that realising the full potential of 5G will require upgrading from the current non-standalone to standalone services, the role of backhaul will be determinant. Fourthly, fixed broadband mapping for infrastructure is more complex by nature and therefore the discussions and analysis for this domain can also be extended and are applicable to mobile broadband mapping. It is worth mentioning that there are some countries that have decided on a comprehensive mapping system that includes both fixed and mobile infrastructure (such as the case of Poland and Georgia). The combination of fixed and mobile broadband mapping, as well as the type of mapping exercise undertaken, can however be various, depending on the objectives and type of system implemented. More on this topic will be said in Chapter 3.

Finally, another point that must be clarified is that utilising the EU as a reference is not an arbitrary decision, but rather a methodological choice to rationally identify good practices that are based on already harmonized efforts of 27 countries undertaken over the past 7 years. To incorporate feedback and perspectives from other countries and regions, the Guidelines have also been reviewed and validated by a panel of institutions covering all 6 regions of the ITU[3].

[3] Full list available in Annex/Acknowledgments

2. Strategies, policies and regulatory environment for broadband mapping

2.1 Strategic and policy drivers for broadband mapping

Broadband mapping systems have mostly arisen in Europe in follow up to legal requirements and obligations placed upon competent authorities and operators at the national level. From another angle, the obligations that broadband mapping systems set for market players would not be possible without provisions enshrined in EU law. As this holds true, the roots for the existence of broadband mapping systems must be researched firstly in the underlying *strategic policy drivers* which have equipped lawmakers and regulators with a clear mandate.

In 2010, the first Digital Agenda for Europe (DAE)[4] identified “lack of investments” and “low take-up of broadband”, as key challenges to be addressed by the EU in the timeframe 2010-2020. The Commission Communication called the Member States “to stimulate private investment, complemented by carefully targeted public investments”. Moreover, it added that policies to be rolled out in the context of the Digital Agenda for Europe “should, in particular, lower the costs of broadband deployment in the entire EU territory, ensuring proper planning and coordination and reducing administrative burdens”. For instance, the competent authorities should ensure: “that public and private civil engineering works systematically provide for broadband networks and in-building wiring; clearing of rights of way; and mapping of available passive infrastructure suitable for cabling.”

In 2016, the European Commission updated the 2010 DAE strategy with a Communication on “Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society,”[5] thereby kickstarting reform of the EU’s regulatory framework for electronic communications. Beyond setting 2025 targets for broadband coverage and speed, the Gigabit Society strategy established “access to and take-up of very high-capacity connectivity as a regulatory objective” to be achieved through appropriate incentives for investment in connectivity. In this context, it is worth quoting at length that “Regulation will be more effective if it is based on in-depth local knowledge of an increasingly diverse network landscape, with a variety of different local, national and multinational actors. Interventions will be tailored to geographic areas where market dominance persists and to the real prospects of network deployment by incumbent and alternative operators. Mapping will allow more joined-up policy, identifying private investment opportunities or public investment needs, or areas where local initiative can remove obstacles or promote demand. It will allow regulators to increase transparency about network deployment plans and to provide investors with more predictability and protection. This will be especially important in ensuring that less densely populated communities’ benefit from better Internet connectivity”.

[4] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0245:FIN:EN:PDF

[5] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17182

This provision builds upon the 2010 DAE strategy, expanding on the notion of mapping on the utility and scope of mapping exercises. Moreover, the 2016 strategy sets concrete priorities to:

i. Require regulators to map network investment intentions;
ii. Require public authorities to seek investors in under-served areas;
iii. Require network access remedies to directly support competitive infrastructure deployment wherever feasible;
iv. Provide retail choices already available to end-users;
v. Promote co-investment and wholesale-only business models facilitating deployment in suburban and rural areas.

The Gigabit Society strategy of 2016 therefore more clearly identifies mapping as a key tool insofar it endows public authorities at all levels of government greater with a more precise knowledge of market failures and connectivity gaps, thereby supporting decision making of targeted public initiatives.

In 2020, the European Commission published its latest digital strategy "Shaping Europe's Digital Future",[6] which focuses on a consumer-centric approach, securing competitive digital markets and fostering an open, democratic, and sustainable society. It is interesting to notice that in this context, beyond reiterating the need for adequate investment to achieve the 2025 connectivity targets through an efficient combination of public resources unlocking private investment, no particular reference to mapping as such is made. Although at a first glance, it may be interpreted as a sign of discontinuity compared to previous strategies, this fact only proves the maturity of the EU's regulatory framework, since broadband mapping has been fully embedded into the regulatory framework and does not necessitate further strategic impulse. Therefore, the core focus is now on methods and practices to increase investment in very high-capacity networks which necessarily rely on broadband mapping. The current revision of the state aid guidelines[7] (in Public consultation from 19 November 2021 to 11 February 2022) includes an annex on mapping with very detailed and demanding requirements.

In September 2020, in fact, the European Commission published a Recommendation[8] calling Member States to boost investment in very high-capacity broadband connectivity infrastructure, including 5G, which is the most fundamental block of the digital transformation and an essential pillar of the recovery. The Recommendation recognises the importance of "georeferenced information (maps and digital models) and integrating information from different sources (in particular, information provided by

6 https://ec.europa.eu/info/sites/info/files/communication-shaping-europes-digital-future-feb2020_en_4.pdf

7 More information can be found at the following link https://ec.europa.eu/competition-policy/public-consultations/2021-broadband_en

8 https://ec.europa.eu/digital-single-market/en/news/commission-recommendation-common-union-toolbox-reducing-cost-deploying-very-high-capacity

competent national authorities at any level, public sector bodies and network operators)", sets out the guidance for developing a toolbox to support connectivity development. Preliminary feedback[9] from the Connectivity Special Group composed by authorities from all Member States, contained a number of references mapping as a means of spurring investment, although more definitive provisions were released in May 2021 and will be addressed at a later stage.

Takeaway: regulatory developments in the field of broadband mapping in the European Union stem from a strategic policy driver. In the case of the EU, it materialized through the impulse given by the European Commission and national activities. At the national level in non-EU countries, the strategic rationale for broadband mapping could emerge through a more concrete wording introduced in national strategies for digitalization or in national broadband plans. Broadband strategies that do not contain any reference to mapping risk of not having the necessary mandate to implement an enabling environment for broadband mapping.

2.2 A regulatory framework for mapping

Although the first DAE strategy was established in 2010, traces of the founding building blocks for mapping of electronic communications, and more particularly of infrastructure, can be found in EU legislation since 2007, with the INSPIRE Directive[10]. Originally established to create an EU spatial data infrastructure for the purposes of EU environmental policies, the Directive also mandates that the spatial data on the infrastructure of the Member States should follow a series of common Implementing Rules (IR) aimed at ensuring interoperability and cross border usage of the data, which includes telecommunication infrastructure[11].

Together with the Public Sector Information (PSI) Directive[12] approved in 2003 (then updated in 2013[13] and 2019[14]), which provides a framework for open data in government, an important merit of the INSPIRE Directive was to set the framework for the establishment of a data-driven approach to public administration across EU Member States. Thus, it is important to recognise that the subsequently emerged regulatory framework pertaining to broadband mapping builds upon a wider trend and on the principles and provisions contained in these other regulations.

The principles of open data in government have been further strengthened by the more recent "European Commission digital strategy: A digitally transformed, user-focused and data-driven Commission"

[9] https://ec.europa.eu/digital-single-market/en/connectivity-toolbox-foster-eu-wide-advanced-connectivity

[10] https://inspire.ec.europa.eu/inspire-directive/2

[11] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02007L0002-20190626&from=EN

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0098&from=en

[13] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013L0037&from=FR

[14] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L1024&from=EN

published in 2018.[15] A data-driven strategic approach to public administration is needed to enshrine a culture of information-based decision making at the country level. Moreover, the introduction by the Commission of a framework legislation on open data in government and on technical specifications for the development and usage of data in the public sector supports the overall claim for a data driven approach for public administration and for envisaging closer collaboration from the private sector.

The enabling environment for broadband mapping cannot emerge by itself and must rely on other ongoing public sector digitalization policies. Based on the rationale for a harmonized data-driven approach to public administration and elaborated under the impulses of the EU digital strategies as well as several pieces of EU legislation that has emerged over the past eight years, they all constitute the regulatory setting for broadband mapping systems and their use cases.

2.2.1 The EU Guidelines on State Aid for Broadband (2013)

Following an unsatisfactory assessment of the investments in broadband networks for the period 2007-2013, the European Commission announced the "EU Guidelines for the application of State aid rules in relation to the rapid deployment of broadband networks" in January 2013. The Guidelines were released with the aim of providing clarity to unlock the investments needed to achieve the policy goals set by the DAE back in 2010, whilst maintaining a consistent application of EU competition law enshrined in the EU treaties. Although state aid rules are rather specific to the EU's setting, this act sets the tone for determining underserved areas and the criteria for efficient allocation of funding.

The European Commission noted that one of the main obstacles to investment was uncertainty on the application of EU state aid rules in the field of telecommunications. To provide more clarity and transparency, the Guidelines therefore broadly define the following essential points for the correct definition of state aid packages:

1) Identification of the viable options for public funding of broadband projects;
2) The distinction between "basic broadband" and next generation access (NGA).
3) The distinction between white, grey and black areas, both for basic broadband and NGA; and
4) The key criteria applied for the assessment of State aid such as compatibility principles "step change" the proportionality of a broadband measure, and the balancing test.

Although it is not in the scope of this paper to linger on all the provisions contained in the guidelines, it is worth elaborating on compatibility principles (Art. 2.5) to identify the framework for broadband mapping. Compatibility principles are, in fact, the most important condition to be met in order to ensure compliance with an aid measure. These include (i) Contribution to the achievement of objectives of common interest,

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15 https://ec.europa.eu/info/sites/info/files/file_import/digitally-transformed_user-focused_data-driven_commission_en.pdf

(ii) Absence of market delivery due to market failures or important inequalities, (iii), Appropriateness of State aid as a policy instrument, (iv) Existence of incentive effect, (v) Aid limited to the minimum necessary, (vi) Limited negative effects, and (vii) Transparency.

In this context, the EU State aid guidelines (Art. 3.4) state that in order to fulfil such compatibility principles, among other actions, Members States should first conduct a) "**detailed mapping and analysis of coverage**", which broadly encompasses all the four points outlined above. The same article further specifies that "Member States should clearly identify which geographic areas will be covered by the support measure in question, whenever possible in cooperation with the competent national bodies. […]".

Originally, the challenge was finding a way of performing this task with the lowest costs possible. Hence the creation in many countries of a "central database of the available infrastructure at a national level thereby increasing transparency and reducing the costs for the implementation of smaller, local projects."

Moreover, the same article defines other conditions to fulfil compatibility principles, including a public consultation (b), a competitive selection process (c), identifying the most advantageous offer (d), ensuring technological neutrality (e), facilitating the use of existing infrastructure (f), wholesale access (g), enabling wholesale access pricing (h), monitoring mechanisms (i), transparency (j) and reporting (k). Point (f) is particularly relevant here as it creates the link to another piece of legislation, the Broadband Cost Reduction Directive (2014), that focuses on co-deployment and infrastructure sharing and which will be outlined in the next section. What is important to underscore is that the mapping and analysis of coverage is at the top of the list and is an essential element for performing all other provisions (b-k) at the lowest possible cost provided the commitment to initial investment and some operational budget.

Beyond the detailed mapping and analysis of coverage, another important concept which is established by the Guidelines (Art. 3.2) is the possibility for administrations to **gather information on operators' investment plans**, mainly for the purpose of identifying white, grey and black areas and to further ensure that public aid does not hinder private sector investment.

This is a very critical aspect of broadband mapping because the amount of data and the intended use set by regulation will determine the shape of a broadband mapping system, the extent to which it will serve different use cases, and the consequent obligations for operators. This is, in fact, often the most argued-against point by operators which consider the location and quality of networks as a business secret and are therefore reluctant to share such information. Although this sentence may prove to be a solid point for the operators, in reality, evidence shows that this is not an issue because the information may be reserved for the regulatory authority and treated in an aggregated form for public viewing. Not only that, accessing this type of information with greater granularity is essential for the sector's regulation to understand the existing infrastructure telecommunications on terrain.

Going back to the provisions (Art. 3.2), authorities should verify whether private investors have concrete plans to roll out their own infrastructure over the 3 years after the entry into force of the aid package.

Operators should express their interest in investing in a specific area once the aid measures are submitted before them for consultation. In order to avoid walkouts which would hit that specific area that is not in the scope of the aid measures, authorities may require the operators for commitments or even a corresponding contract with conditions. While this provision may partially solve the problem of identifying future plans of operators and consequently address the challenge of future allocation of public funding it also may create a disincentive for operators to express their interest in investing in a specific area.

Following the publication of the Guidelines, the Commission released a report on "The broadband State aid rules explained: An eGuide for Decision Makers,"[16] an important tool where further explanation is given enabling all policymakers involved to develop a solid understanding of the Guidelines and the wider competition regulatory framework are provided.

This also signals the importance of not only legislating and regulating, but also explaining to various stakeholders how rules are intended to be applied. Such a proactive approach coupled with the inclusion of all stakeholders in parts of the decision-making process and the transparency in the use of the gathered mapping system information, depending on the governance setting at the national level, is very important for the good success of a broadband mapping project. With particular regards to operators, such dialogue will allow understanding the requirements but also the benefit of increased cooperation with public authorities, and possibly with other operators from other sectors.

Takeaway: the "EU Guidelines for the application of State aid rules in relation to the rapid deployment of broadband networks" establish two firm principles for application of state aid rules which underpin the need for broadband mapping for administrations: (i) the mapping and analysis of coverage entailing an assessment of service availability and how that service is brought about (infrastructure), (ii) the identification of investment plans in a given geographical area. Considering that state aid rules are an essential element of attention for accession countries, the broadband mapping component deriving from these deserves equal attention.

2.2.2 The Broadband Cost Reduction Directive (2014)

Just over a year after the guidelines were published, the European Commission finalized a foundational piece of legislation which more strongly contains provisions relevant to broadband mapping. The "Broadband Cost-Reduction Directive" (BCRD) adopted in May 2014[17] primarily "aims to facilitate and incentivise the roll-out of high-speed electronic communications networks by promoting the joint use of existing physical infrastructure [intended as "any element of a network which is intended to host other

[16] https://ec.europa.eu/regional_policy/sources/conferences/state-aid/broadband_rulesexplained.pdf

[17] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0061&from=EN

elements of a network without becoming itself an active element of the network"][18] and by enabling a more efficient deployment of new physical infrastructure so that such networks can be rolled out at lower cost" (Art. 1)[19].

The Directive's impact assessment,[20] which is carried out for all draft directives one year prior to finalizing the final legal instrument, highlighted that the major cost factors for broadband deployment is due to inefficiencies and bottlenecks, and consequently identified clearer rules around co-deployment and infrastructure sharing as the main solution to the problem.[21]

In this context, it is also worth mentioning that the impact assessment for the first time takes stock of advanced open-access and digital infrastructure atlases, including "not just telecom products but also other utilities and all physical infrastructures suitable for broadband", at that time only present in Germany and Portugal, while in other 18 countries partial systems were identified. The fact that policymakers already identified best practices while drafting the legislation is relevant as it highlights the EU's approach to policymaking that is grounded in evidence from authorities operating at the national level.

The BCRD identifies four main pillars for change to be transposed with appropriate legislation at the national level:

1) Access to existing physical infrastructure (e.g., ducts, manholes, etc), including those belonging to energy and other utilities, for telecom operators willing to deploy high-speed broadband networks;[22]
2) Efficient coordination of civil works;[23]
3) Faster, simpler and more transparent permit-granting procedures; [24]

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[18] https://ec.europa.eu/digital-single-market/en/news/report-implementation-broadband-cost-reduction-directive

[19] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0061&from=EN.

[20] https://ec.europa.eu/digital-single-market/en/news/impact-assessment-accompanying-document-proposal-regulation-european-parliament-and-council

[21] For more information on co-deployment and infrastructure sharing in Europe please consult the background paper on "Infrastructure sharing and co-deployment in Europe: good practices based on collaborative regulation" available at https://www.itu.int/go/EUR_RRF-20

[22] The impact assessment identified that civil engineering costs may amount up to 75% of total cost of deployment of telecommunication infrastructure.

[23] The impact assessment identified that the potential savings from co-ordinating civil engineering works when the project is shared between two parties at 50% of the civil engineering works cost, or up to 40% of the total cost.

[24] The impact assessment found that the high number of authorities, scarce collaboration among them and lengthy administrative procedures are among the factors augmenting the burden of permit-granting processes.

4) Equipment of new buildings and major renovations with high-speed physical infrastructures (e.g., mini-ducts, access point) and access to in-building infrastructure.[25]

For the purposes of the analysis of the roots of broadband mapping in Europe, provisions under points number 1 and 2 of the list above are most relevant since creating a space for sharing information on existing or planned physical infrastructure as well as access to it is key to the overall scope of the directive.

The Directive recognises (comma 8) that "the roll-out of high-speed fixed and wireless electronic communications networks across the Union requires substantial investments, a significant proportion of which is represented by the cost of civil engineering works," up to 80% of the total cost, and that (comma 13) "It can be significantly more efficient for electronic communications network operators, in particular new entrants, to re-use existing physical infrastructures, including those of other utilities".

To address this challenge, the BCRD mandates the establishment of a Single Information Point (SIP) at the National level (commas 20-22), which would request network operators to provide minimum information on infrastructure where not available and make the information available to network operators, and telecom operators, in particular. This would enable telecom operators to assess the potential for using existing infrastructure in a specific area and reduce damage to any existing physical infrastructures for any planned civil works.

In particular, with Article 3 on "Access to existing physical infrastructure", the Directive establishes that "a network operator [including service providers of gas, electricity, public lighting, heating, water, disposal or treatment of wastewater and sewage, and drainage systems as well as transport services, including railways, roads, ports and airports] has the right to offer to undertakings providing or authorised to provide electronic communications networks access to its physical infrastructure with a view to deploying elements of high-speed electronic communications networks."

Moreover, Article 4 on "Transparency concerning physical infrastructure" provides that each telecommunication network operator "has the right to access, upon request, the following minimum information concerning the existing physical infrastructure of any network operator:

(a) location, and route;

(b) type and current use of the infrastructure; and

(c) a contact point."

Article 4 is crucial insofar as it proactively paves the way for minimum data to be procured to the SIP by allowing Member States to independently interpret the directive. The European experience has showed that, in this context, several Member States interpreted this directive by providing minimum geo-

[25] The impact assessment found that standardizing procedures for in-building infrastructure procedures would avoid duplication of costs and approval of each owner of the building.

referenced data on the existing infrastructure in their country and, not only for telecom operators, but for all network operators, including those from other industries, and relative public sector bodies alike.

The provisions are then completed by Article 6 on "Transparency concerning existing or planned civil works" mandates that "Member States shall require any network operator to make available […] the following minimum information concerning on-going or planned civil works related to its physical infrastructure for which a permit has been granted:

(a) the location and the type of works;

(b) the network elements involved;

(c) the estimated date for starting the works and their duration; and

(d) a contact point.

Although this does not provide information on planned investments to either operators or public administrators, it facilitates the transparency of the data gathered by the SIP thereby setting a strong incentive for the emergence of co-deployment and infrastructure-sharing practices[26]. The Directive mandates that the SIP has to publish the information by 1 January 2017.

Takeaway: the "Broadband Cost Reduction Directive" established a strong legal basis and a mandate for the creation of information systems gathering geo-referenced data on the infrastructure of all network industries at the national level. While it left to the Member State the decision on the most appropriate authority for the SIP, the Directive enshrines in EU law the important principle of a data-driven approach to regulation of network industries, including telecommunication. Moreover, the BCRD seeks to create an enabling environment for the emergence of collaborative practices among different types of network operators to primarily save cost and lower administrative burdens.

2.2.3 The European Electronic Communications Code (2018)

In the Gigabit Society Strategy released after the EU Guidelines on State aid for broadband and the BCRD, the European Commission proposed a major reform of the regulatory framework for electronic communications which would take the form of a European Electronic Communications Code (EECC). The Code would, among many other objectives, ensure consistency with the other EU policies and in particular set "out measures, such as mapping of network deployments, that also provide useful information for State aid purposes and thereby enhances the coherence of the two policies [the EU Competition Law and

[26] For more information on co-deployment and infrastructure sharing in Europe please consult the background paper on "Infrastructure sharing and co-deployment in Europe: good practices based on collaborative regulation" available at https://www.itu.int/go/EUR_RRF-20

the EECC]".[27] In addition, the EECC foresaw to endow BEREC with additional responsibilities among which is to set guidelines and standards for the conduction of geographical surveys of the reach of electronic communications.[28] In other words, the EECC empowers BEREC to set regulatory standards for the implementation of the EECC, thus covering the 2013 State aid guidelines and the 2014 BCRD.

Two years later, in December 2018, the European Electronic Communications Code was finally approved and has come into application on 21 December 2020[29], though several Member States were late in its implementation. In this context, the provisions touching upon the regulatory framework of broadband mapping are:

- Article 20 on "Information request to undertakings": this article sets for the first time the obligation for Member States to ensure that electronic communications networks and services providers, yield all the information necessary, including financial plans for future network service deployment, for national regulatory authorities, other competent authorities and BEREC to ensure conformity with the provisions of the Code, in accordance with article 22. Moreover, the article states that, depending on the NRA's approach, confidentiality should be ensured. This article reinforces the provisions of the BCRD, empowering NRAs and formalizing the regulatory tools they can deploy.
- Article 22 on "Geographical surveys of network deployments": this article mandates that "each National regulatory and/or other competent authorities shall conduct a geographical survey of the reach of electronic communications networks capable of delivering broadband ('broadband networks') by 21 December 2023 and shall update it at least every three years thereafter." The article further mandates that BEREC should issue guidelines to assist national regulatory and/or other competent authorities on the implementation of this obligation. This article clearly sets a mandate to map service availability in the EU and creates a legal obligation thus reinforcing the EU Guidelines for State aid for broadband, which required in 2013 "detailed mapping and analysis of coverage" but not specifying accurate definitions and parameters. Article 29 gives right to the Member States to issue penalties in case of submitting "misleading, erroneous or incomplete information" in the course of such geographical surveys. Articles 64 to 67 on "Market analysis and significant market power" [SMP]: these articles address significant market power and mandate that geographical surveys are to be taken into consideration where relevant. The article is relevant insofar expands on one of the functions of geographical surveys which is to support the application of EU Competition Law and SMP regulation.

[27] https://eur-lex.europa.eu/resource.html?uri=cellar:c5ee8d55-7a56-11e6-b076-01aa75ed71a1.0001.02/DOC_3&format=PDF, p.3

[28] Ibidem, pp. 13, 147-148

[29] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=EN, art. 124

- Article 76 on "Regulatory treatment of new very high-capacity network elements" focuses on creating regulatory requirements for co-investment from SMP operators and requires BEREC to publish guidelines to foster NRA's consistent application of the conditions to be met when assessing co-investment offers.
- Articles 84 to 92 on "Universal service obligations" (USO): these articles address universal service obligations, mandating that Member States should take into account the results of geographical surveys to identify the availability at a fixed location of adequate broadband Internet access. Similarly, to the significant market power, these provisions expand the functions of geographical surveys in supporting the application of universal service obligations.

Though there would be other provisions indirectly touching on the regulatory framework for broadband mapping as in the case of SMP or USO, suffice to notice that the most comprehensive EU reform in the field of electronic communications reiterates that information about the geographical attributes of electronic communications services is a cornerstone of regulation underpinning the work of National Regulatory Authorities.

Takeaway: the "European Electronic Communications Code" importantly established the requirement for NRAs or other competent authorities to conduct geographical surveys of electronic communications, which in essence consists of mapping total service availability" and confers BEREC more power in this field. Moreover, the Code attributes more power to NRAs and other competent authorities to demand information from network operators in the field of electronic communications. **These two main elements may foster the application of the EU Guidelines on State Aid for broadband and also strengthen the provisions of the BCRD.**

2.3 Regulatory improvements and developments

Considering more than 7 years since their elaboration, the EECC coming into play, the progress in strategic objectives of the EU and the ever-changing market landscape, many stakeholders argued in favour of a revision of both the State aid guidelines and the BCRD. This section will take a look at such ongoing processes and illustrate how initial approaches are evolving into even more sound and robust legislative frameworks that support the operations of National Regulatory Authorities whilst preserving balanced market conditions and innovation.

In addition, this section will also address the implementation aspects of the EECC, particularly outlining the work undertaken by the BEREC which took significant steps forward in coordinating and harmonizing the position of several NRAs, thus leading to the publication of two detailed guidelines on geographical surveys.

2.3.1 Revision of the EU Guidelines on State aid for broadband

In a press release from September 2020,[30] the European Commission noted that following the adoption of the EU Guidelines on State aid[31] for broadband in 2013 and the General Block Exemption Regulation (GBER)[32], technologies have significantly improved, and users' needs have increased, requiring larger bandwidth as well as an improvement of the networks in terms of other parameters such as latency, availability and reliability. This posed an issue to EU lawmakers and competition practitioners as markets need to be defined necessarily not only by the type of service offered, but also by its quality, which is constantly being improved in the telecommunications sector. Questions, therefore, arise regarding the type of aid and its entity, and for which type of service, for which quality and in which specific geographical area, such aid can be deployed in compliance with EU state aid rules.

The Commission has therefore launched two consultations. The first is a public consultation,[33] to check whether regulation in this field has met objectives, whether regulation has had an impact on the market and competition and whether these need to be updated in light of recent technological and market developments, as well as the new EU digital policy goals set by the "Shaping Europe's Digital Future" agenda. The second is a technical consultation[34] which supports the first by collecting information on specific provisions of the Guidelines. Section 6 (questions 39-48) specifically addresses the notion of "mapping" as inserted in the original Guidelines. Both consultations were open until 5 January 2021 and results were published on the 7th of July 2021[35].

It is worth underlying that a public consultation process is currently open for comments to revise the Guideines on State aid for broadband networks until the 11th of February 2022. This consultation process is targeting all EU stakeholders, with particular focus on Member States and the associated authorities involved in this field (aid granting authorities and NRAs) and the private sector representatives. The

30 https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1576

31 Public consultation is ongoing as of January 2022.

32 the General Block Exemption Regulation (GBER) is an additional piece of EU legislation which mandates that regional aid for broadband network development can be granted only in areas where there is no network of the same category and where no such network is likely to be developed on commercial terms within three years from the decision to grant the aid. This exempts Member States from the obligation to notify aid packages for deployment broadband networks, provided that the above conditions are met. As GBER is very specific to application of EU Competition Law, it falls out of the scope of this paper.

33 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12398-Evaluation-of-State-Aid-rules-for-broadband-infrastructure-deployment

34 https://ec.europa.eu/eusurvey/runner/TargetedPublicConsultationBBGLs

35 "COMMISSION STAFF WORKING DOCUMENT EVALUATION of the State Aid rules for broadband infrastructure deployment": full version and executive summary available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12398-Evaluation-of-State-Aid-rules-for-broadband-infrastructure-deployment_en

consultation, among other elements, will clarify on the introduction of new speed thresholds for public support to achieve the Gigabit fixed network and mobile networks and of a new aid mechanism, in the form of vouchers, associated with demand-side measures to enhance the adoption of fixed and mobile networks in the EU.

Overall, the State aid guidelines were assessed against the five criteria of effectiveness, efficiency, relevance, coherence and EU added value, the European Commission concluded that overall, the rules "are fit for purpose" and should not be overhauled entirely. Nevertheless, "they should be adapted to reflect recent legislative developments [such as the BCRD and EECC], current priorities [the EU's new digital strategy], as well as market and technology developments". With particular regard to broadband mapping, private stakeholders are only partially convinced of the effectiveness of the mapping exercise (63%) whereas public authorities state that mapping exercises enable the identification of areas for intervention either totally (36%) or partially (36%). Among others, their concerns refer primarily to the scope and methodology of the mapping exercise, and then also to the reliability of the information on planned investments and the level of granularity of the mapping exercise. The issue is rather connected to the way the mapping is carried out by authorities at the national level, which suggest a lack of guidance by the state aid guidelines[36].

Another notable analysis has been developed around this matter in recent times. The CERRE Report on "State Aid for Broadband Infrastructure in Europe: Assessment and Policy Recommendations" (2018), for example, highlights that the "mapping exercise", which is required to define white, grey and black areas, has caused some difficulties to national authorities in obtaining accurate responses from operators. Another important study, relevant to these matters is "The role of State Aid for the broadband networks rapid deployment of broadband networks[37]", which was mandated by the Commission in 2016 and concluded in 2020[38].

36 Ibid, p. 38, 43-45.

37 https://data.europa.eu/doi/10.2763/050506

38 https://ec.europa.eu/competition/publications/reports/kd0420461enn.pdf

Date of last mapping exercise and granularity

Country	Last mapping exercise	Granularity[69]
Austria	May 2019	Address
Bulgaria	1 January 2012	Municipality
Denmark	5 August 2019	Address
Estonia	22 December 2017	Address
France	30 September 2019	Address
Germany	18 November 2019	Address
Hungary	1 June 2015	Address
Ireland	8 October 2019	Address
Italy	9 February 2019	Address
Latvia	1 December 2014	Municipality
Poland (SA. 43484)	2019	Address
Portugal	30 September 2018	Municipality
Slovakia	3 May 2019	Municipality
Slovenia	11 February 2019	Address
Spain	1 April 2019	See footnote[70]
Sweden	October 2018 - March 2019	N/A
United Kingdom	December 2014[71]	Address

Table 2 **Mapping exercises in EU and granularity (retrieved from the background paper Broadband Mapping Systems in Europe and the Status of Harmonization in the Region, November 2020)**

Beyond taking stock of mapping activities in Member States according to Guidelines' provisions (see Table 1 above), the study also provided some recommendations to address the main identified challenges, which are ensuring the completeness and accuracy of coverage data alongside ensuring the accuracy of forecasts or aim of enforcement. Among others, some of the most relevant recommendations include:[39]

- Setting out clear expectations regarding the technologies that will be considered when identifying zones as white vs grey or black, based on the principle of technological neutrality;
- Providing **a consolidated mapping system so that there is a single system for a given country. Ideally, this system could bring together mapping of passive infrastructure** (in line with the **BCRD** and any SMP obligations applying to ducts and poles) **as well as mapping broadband infrastructure inter alia to identify State Aid zones and conduct geographic analyses of markets** which may be susceptible to ex-ante (SMP) regulation (see article 22 of the **EECC**);

[39] https://ec.europa.eu/competition/publications/reports/kd0420461enn.pdf, p.83

- Establishing a regular mapping exercise (at least annual) with mandatory participation and penalties for failure to provide data on current deployment and forecasts within a given period
- Including a wide range of stakeholders within the data-gathering exercise including municipalities, where relevant.
- Cross-checking viability of given areas for commercial deployment through bottom-up modelling.
- Collecting data at the lowest level of aggregation which is realistically achievable. This should preferably be at the address level and follow the BEREC Guidelines mandated under Art. 22 EECC;
- Aggregation of data should be based on an administrative unit that is sufficiently granular to distinguish areas of market failure and which reflects operators' existing footprints and deployment targets. It would be helpful to pursue an approach that is consistent with the approach taken by NRAs in geographic segmentation of markets in the context of Single Market Program (SMP) analysis;
- Reporting on actual deployment against forecasts and setting a deadline after which zones previously identified as NGA grey or black could be open to state intervention;
- Taking action to apply penalties in accordance with article 29 of the EECC (or under competition law as appropriate) in cases where operators knowingly mislead the authorities as regards their deployment plans, e.g., whether they deploy, extend or upgrade their network, or fail to do so without objective justification and with negative consequences for competition, while ensuring that legitimate network extension e.g., to address specific business demand can still occur.

In light of the above, there is plenty of relevant content that will allow decision-makers to decide upon any eventual revision of the State aid guidelines. Suffice to say that this process is very relevant to those stakeholders which are looking to create an enabling environment for broadband mapping as it contains many answers and highlights the remaining challenges that a group of countries has been facing for years.

Takeaway: The European Commission is looking for ways to ensure that the EU Guidelines on State aid for broadband are fit for purpose. The combination of consultations and recent studies on the matter will lead to a way forward, most likely in Q3 2021.

It is relevant to notice that the Commission is placing an emphasis on better detailing the notion of "detailed mapping and analysis of coverage". Particularly interesting is the recommendation of the study carried out for the Commission for Member States to consolidate a mapping system that brings together mapping of passive infrastructure (in line with the BCRD and SMP obligations) and mapping infrastructure and available services in line with the EECC article 22 and the EU Guidelines on State aid for broadband, to serve the purposes of application of State aid rules and avoid duplication of efforts. Non-EU and accession countries could anticipate this trend and already take necessary steps to integrate all functions into one effort.

2.3.2 Revision of the Broadband Cost Reduction Directive

In fulfilment of Art. 12 of the Broadband Cost Reduction Directive (BCRD), in June 2018 the European Commission published a first Report[40] on the implementation of the BCRD. This included a summary of the impact of the measures and an assessment of the progress made towards achieving the Directive's objectives, including whether and how the Directive could further contribute to reaching the DAE and Gigabit Society targets.

The report notes that as the Directive touches upon cross-sectoral competencies affecting not only the telecommunications sector but also utilities, building laws, administrative law, among others, transposition resulted in complex venture and required numerous adaptations at the national level. Notably, the deadline for implementation at the national level of 1 January 2016 was not met by all Member States except one. The assessment also noticed that the assignment of the Single Information Point has been given to the National Regulatory Authority in the field of telecommunications only in 50% of cases while for the rest cases, Ministries were put in control of the SIP. These two elements are enough to highlight the sensitive nature of this Directive as its provisions lie between governmental policy and independent regulatory action, and cross the boundaries of the telecommunication sector, impacting other network industries.

Moreover, the European Commission's implementation report recommended that "for existing infrastructure, the **single information point could further be enhanced to a mapping exercise and include data on availability and capacity**", in line with the "Study on Implementation and monitoring of measures under Directive 61/2014" which recommended to expand the mapping exercise to support a large number of potential access seekers and/or access providers[41] and the BEREC "Report on the implementation of the Broadband Cost-Reduction Directive" published in December 2017[42] which suggest that SIPs managed by NRAs should grant the user the possibility to (i) browse a graphic presentation of the data, (ii) choose between several scales, (iii) export data, and (iv) select the infrastructure in the area in which they request access to information.

These are very important elements suggesting a stronger emphasis on service mapping and alignment with the provisions of the EU Guidelines on state aid for broadband expansion. Moreover, the Commission recommended that "in the case of co-deployment, Member States should consider a pro-active approach, whereby relevant public (and also private) actors are required to pre-notify deployment plans and invite interested parties to respond." This testifies the importance of anticipating investment plans to ensure better coordination between public and private entities and support the creation of joint ventures in civil

40 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=53109

41 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=53090

42 https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/7534-berec-report-on-the-implementation-of-the-broadband-cost-reduction-directive

works. Hence the overlaps, or at least point in common, with the discussion about the State aid guidelines appear evident.

Finally, it must be noted that the nature of the legal instrument (a Directive which leaves space for interpretation and adaptation for Member States) has opened for very different transposition at the national level, partially undermining the sought harmonization within the EU in this field. The fact that the mandate to implement the SIP was left to Member States to decide and that this resulted in a 50/50 balance of NRA/Ministry share is an evident element of the lack of harmonization.

For all the reasons outlined above, the Commission has initiated a review[43] of the Directive with the objectives of:

- Fostering a more efficient and faster deployment of very high capacity networks;
- Strengthening and maximising the potential of current measures with a focus on potential synergies across sectors;
- Ensuring consistency with the European Electronic Communications Code; and
- Introduce sustainability measures contributing to the greening of the ICT sector.

The consultation received 22 contributions from stakeholders between June and July 2020 and was followed by a Feedback period between December 2020 and March 2021. Within this framework, the European Commission’s DG CNECT organised two stakeholder workshops in February focusing on i) gathering feedback about the drivers, the persisting barriers and the possible solutions for accelerating the deployment of very high-capacity broadband networks, and ii) focusing on institutional aspects and will address the role those public administrations play in the deployment of electronic communication networks and how it can be improved in the future. Over 300 stakeholders representing operators, industry associations, local, regional and national authorities, regulatory bodies, and many more, actively engaged in this process which culminated in a third workshop[44] organised in June by WIK-Consult, together with ICF and Eco-Act, the contractors in charge of the study for the review of the Broadband Cost Reduction Directive (BCRD). The areas of debate under which the discussion was structured are reported below:

- Access to physical infrastructure
- Transparency for physical infrastructure provisions and the Single Information Point (SIP)
- In-building physical infrastructure and access
- Procedures for granting permits for civil works and rights of way
- Co-ordination of civil works and transparency of relevant information

43 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12463-High-speed-broadband-in-the-EU-review-of-rules

44 https://www.wik.org/fileadmin/Konferenzbeitraege/2021/Review_of_BCRD/BCRD_workshop_16062021.pdf

- Promoting the deployment of sustainable electronic communications networks

The review process is expected to end in September/October 2021 and the new proposed Directive submitted for adoption by Q1 2022.

While it is too early to linger in possible modifications and improvement to the enabling environment for broadband mapping, it is important to underscore the multi-stakeholder and transparent approach to policy development efforts undertaken at the EU level, which in turn, will reinforce the validity of the regulatory decisions that will be taken. Therefore, not only the BCRD will be the result of the negotiations of 27 member states, but also will embed the considerations and concerns of a wide variety of stakeholders. This is important for stakeholders outside the EU seeking to mirror or improve their measures for broadband cost reduction, as they will have a broad pool of evidence to ground their arguments in favour of better rules for broadband cost reduction that have broadband mapping at their core.

In parallel, the European Commission has released in March 2021 a **Common Connectivity Toolbox**[45] of best practices aimed at reducing the cost and increasing the speed of deploying very high-capacity networks (VHCNs), as well as ensuring timely and investment-friendly access to 5G radio spectrum, in fulfilment of the Commission recommendation of 18 September 2020. The document was based on the preliminary inputs [46] received in 2020 by a variety of member states and among the 39 recommendations/best practices identified, recommendations 11 to 15 which cover transparency through the SIP, summarise several key aspects and best practices emerged in the context of BCRD implementation.

Although this might seem an overlap, the Toolbox is more of a strategic driver to prompt stakeholders, and public authorities, in particular, to act according to a common reference point. In fact, an important part of this initiative is that member states need to provide the Commission with roadmaps for the implementation of the Toolbox and are, therefore, required to acknowledge and report on the implementation of the best practices. This is an additional element strengthening the harmonization efforts across the 27 countries.

Takeaway: The European Commission's stance towards strengthening infrastructure mapping and investment mapping to ensure better future co-deployment and consequent abatement of costs emerged clearly in the implementation assessment. In addition, integration of service mapping into the work undertaken by the SIP on infrastructure mapping was also mentioned. As the revision of the BCRD

45 https://digital-strategy.ec.europa.eu/en/policies/connectivity-toolbox

46 https://ec.europa.eu/information_society/newsroom/image/document/2020-51/compilation_report_special_group_-_summary_and_annex_002_A201FFA5-9ACE-4742-1ACCE7F8A8EC2438_72388.pdf

is undertaken in 2021, EU countries as well as accession countries should monitor developments closely and be ready to adapt their efforts to avoid delays or duplication of efforts in the future.

2.3.3. BEREC's implementation of the EECC

BEREC Guidelines on Geographical surveys of network deployments

As mentioned earlier, Article 22 of the European Electronic Communication Code (EECC) requires Member States to conduct geographical surveys of the reach of electronic communications by 21 December 2023, which includes (comma 1) the current reach of electronic communications capable of delivering broadband, (comma 2) optionally a forecast on investment plans in the deployment of electronic communications, including VHCNs, and (comma 6) the requirement to publish the information electronic format considering the level of the confidentiality of the data.

The article (comma 7) further sets the mandate upon the BEREC to produce a set of Guidelines on these matters by 21 June 2020 to support Member States, and NRAs, in particular, in the fulfilment of their obligations under article 22 with the indirect consequence of supporting Member States' application of State aid rules.

Thanks to NRAs common effort in coordination with the BEREC Statistics and Indicators Expert Working Group, and following a public consultation on draft Guidelines carried out in Q4 2019, BEREC released the "BEREC Guidelines to assist NRAs on the consistent application of Geographical surveys of network deployments"[47] in March 2020.

The Guidelines first provide a set of epistemological definitions, such as a description of the concepts of "address and premise passed" or "geographical information system" and importantly define "broadband service mapping" as "systems that gather, analyse and present information on the supply side of broadband service provision, including the available bandwidths (speed), technologies, operators/service providers and quality of service in a specific area". The Guidelines then define that consistently with Art. 22, NRAs or other competent authorities (OCAs) should characterize the capability of an electronic communications network to deliver a broadband service of a certain quality by requiring information to operators on Quality of Service 1 indicators (QoS-1), i.e. calculated availability of service, which is theoretical network performance of existing infrastructure. NRAs/OCAs should consider whether the information from wholesalers is sufficient and in case exempt access operators from providing the data, although this depends on the market and technology characteristics at the country level.

47 https://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/9027-berec-guidelines-to-assist-nras-on-the-consistent-application-of-geographical-surveys-of-network-deployments

Concerning the spatial data, the Guidelines go on to provide technical definitions of the parameters to be used for both fixed and mobile spatial data recommending geocoded address-level data for fixed broadband, at 100m x 100m grid level of granularity for mobile broadband and either address-level or a 100m x 100m grid for fixed wireless broadband (FWA). Moreover, Section 2.5 defines and characterizes GIS systems and their functions and list a set of layers relevant to broadband mapping:

- Addresses (points);
- Grids, 100m x 100m or smaller;
- Premises passed per operator, medium technology, speed, VHCN class and other parameters for fixed broadband in reference address points;
- Areas covered per operator, medium technology, VHCN class, speed and other areas for fixed and mobile broadband in reference grids;
- Aggregated grid coverage 1km x 1km (for publication only);
- Aggregated grid speed 1km x 1km (for publication only);
- Other (to be decided by the National Regulatory Authority).

Accordingly, and with regard to the minimum data to be collected for each of the three types of services, indicators are reported in section 2.4 as well as Annex 2 and Annex 3 of the Guidelines. For the purposes of this paper, it is interesting to note that for fixed networks, the minimum indicators are as follows:

- Operator code (*according to the list possessed by the NRA*)
- Technology code (*DSL, VDSL, VDSL vectoring, DOCSIS 1.0 or 2.0, DOCSIS 3.0 or 3.1, FTTH/FTTB, FWA, WIFI, Other*)
- Maximum download speed class per subscription (*≥ 2 Mbit/s and < 10 Mbit/s, ≥ 10 Mbit/s and < 30 Mbit/s, ≥ 30 Mbit/s and < 100 Mbit/s, ≥100 Mbit/s and < 300 Mbit/s, ≥300 Mbit/s and < 1 Gbps, More or equal to 1 Gbit/s*)
- Maximum upload speed class per subscription (*same as above*)
- Expected peak-time download speed class per subscription (*same as above*)
- Expected peak-time upload speed class per subscription (*same as above*)
- Number of premises passed by the operator at the address (*optional*)
- VHCN class at the address (*not covered by VHCN, fibre rollout to the address, fibre rollout to the base station, no fibre rollout but VHCN equivalent service to criterion 3 of BEREC's VHCN Guidelines*[48]*, no fibre rollout but the VHCN equivalent service to criterion 4 of BEREC's VHCN Guidelines*)

Another important component of the Guidelines is the section on forecasting the reach of broadband networks including VHCN, which is not mandatory under Art 22. EECC, though would reinforce the

48 https://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/9439-berec-guidelines-on-very-high-capacity-networks

investment mapping layer identified by Art. 3.2 of the EU Guidelines on State aid for broadband. In this regard, the Guidelines provide a series of recommendations for forecasts reiterating their importance for (i) identification of designated areas where no undertaking is planning to deploy a VHCN or significantly upgrade the network (see paragraph 2 in Article 22 EECC), or for (ii) state aid proceedings to avoid, in particular, distortion of incentives to private investors. These recommendations are:

- Information should be requested to all entities who are potential investors, beyond operators or public authorities;
- Information on a designated area should be requested where no VHCN network is available and where there are no known development plans (in fulfilment of the EECC) or should be collected wherever public authorities intend to intervene (in fulfilment of state aid rules);
- Information should be collected annually, or even more frequently according to specific national requirements;
- Information should be collected in a high resolution (address level or 100m x 100m squares);
- Information should be collected from operators on type of technology, maximum download speed, VHCN class, expected start date of the rollout and expected end date of the roll-out;
- Information from the forecast should undergo ex-ante and ex-post verification to ensure an appropriate assessment has been made.

Finally, the Guidelines conclude with indications as to the publication, data resolution, confidentiality issues, aggregation of the data and access to information by other public authorities (section 2.7).

Beyond supporting Member States in their obligations to conduct geographical surveys of the reach of electronic communications by 21 December 2023 (EECC), the Guidelines are a unique document in that they harmonize language and standardize the practices around service mapping of broadband capability at the address/grid level. Therefore, they are of use outside Europe as they can greatly support countries in their efforts to define the broadband mapping exercise.

BEREC Guidelines on Geographical surveys: Verification of information

Although the level of harmonization between the core guidelines and the verification mechanism of the information is different, with the former more and the latter less harmonized, BEREC recognises that there are many reasons why the raw data provided may be partial or incorrect and so ensuring the quality of the data is an integral part of the process of publishing and updating broadband maps, in fact, entails the development of verification guidelines of the data that operators will provide under the scope of the "Core Guidelines" outlined in the previous section, as they have come to be named in the second document, the

"BEREC Guidelines on Geographical surveys of network deployments. Verification of information", that was published in June 2021.[49]

In particular, the guidelines propose five steps to ensure the quality of data:

1) Validation of the internal consistency of the database;
2) Resorting to external agents to report data inaccuracies;
3) The verification phase, where the data is contrasted against external sources of data
4) Deciding after external validation that the data is not correct;
5) Changing the data if necessary and other consequences.

While the other steps are rather self-explanatory, it is worth highlighting the requirements of the so called "STEP 3" on verification, which recommends (i) gathering data on infrastructure location and type of access nodes and base stations to be confronted with raw data, (ii) gathering data from operators on declared services by the operators and access connections, (iii) conducting active network measurements, eventually by using sampling to reduce costs, and (iv) establishing methods for measurements which take into account the end user environment, through crowdsourcing measurement tools.

Finally, the Guidelines stress that "Authorities should publish their verification methodologies and outline the verification results in order to establish transparency and help make their proceedings plausible to market participants." As in any compliance and verification exercise, the more trust is established among stakeholders the lesser number of complaints or litigations are generated once the verification is operational. No indication is given to this last issue as dispute settlement depends on each country's particular juridical setting.

Overall, the verification Guidelines are an important complementary tool to the core guidelines, expanding the potential toolbox at NRA's disposal to ensure verification of data. Similar indications would be useful for infrastructure mapping, particularly under the obligations of the BCRD.

Takeaway: The **BEREC Guidelines** provide **detailed epistemological and technical information** with regards to the implementation of Art. 22 EECC and to support Member States in fulfilment of their obligations pertaining to service mapping in accordance with the EU Guidelines on State aid for broadband. These indications **are a first attempt to ensure better harmonization** in the field of service mapping at the level of the European Union. In addition, relevant provisions on forecasting imply the recognition that investment mapping is an important component for efficient use of public sector

49 https://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/9980-berec-guidelines-on-geographical-surveys-of-network-deployments-verification-of-information

resources in line with state aid rules. Accession countries as well as non-EU countries **should keep these Guidelines as an important reference** while embarking in initiatives relating to service mapping.

2.3.4 The European Experience in the field of dispute settlement mechanism

The European Experience with the work developed under the EU's Directive 2014/61/EU on measures to reduce the cost of deploying high-speed electronic communications networks (2021), commonly known as the Broadband Cost Reduction Directive, and then further reviewed by BEREC on the "BEREC Opinion on the Revision of the Broadband Cost Reduction Directive (2021)," demonstrate the importance of establishing a dispute settlement body (DSB) in the field of broadband mapping. BERECR emphasizes that the DSB is equally as vital as the SIP, and it also observes that EECC art.5 delegates to the NRA the task of properly resolving any potential dispute in the most expedient manner through the use of the DSB while taking into account the case, the timeframe, and the proposed procedures for an effective resolution of the problem between the parties involved (such as obligations from an operator to report on physical infrastructure).

The BCRD also notes that several European nations have previously demonstrated experience in the field of DSB mechanisms, which can be viewed by other countries that have yet to develop their own DSB. The examples of France, Portugal, and Splain show that having clear rules and processes results in a more defined framework within which to function.

BEREC corroborates the position of the EU’s directive by stating that the DSB is a positive mechanism that should be considered by any country since "the instrument is important to ensure the enforceability of the obligations laid out in the BCRD." As a result, it assists market participants in bringing their services to clients." BEREC further underlines and emphasizes that the DSB's efficacy is also tied to the pre-existing legislative framework under which the various parties already function. If one country already has a more binding legal framework, the DSB's impact will be smaller than in another country where precise norms and procedures have yet to be developed in this subject.

Finally, another important aspect worth mentioning for the importance of a DSB mechanism is the work done by the DSB in setting up general references aiming at a holistic approach that are then used on a case-by-case basis, thus demonstrating iterum the role the DSB could play in countries interested in developing their national capabilities in the field of broadband mapping systems.

2.4 Minimum policy and regulatory requirements to implement a broadband mapping system

In consideration of the items highlighted up to now, it is fair to state that broadband mapping is a complex regulatory issue which impacts the often-diverging interest of various stakeholders. It is not the scope of these Guidelines to provide normative indications into how to implement a robust enabling environment for broadband mapping at the national level. However, the European experience already allows identifying where the conversation, discussion and negotiation at the national level ought to take place.

The following checklist provides in fact guidance on the necessary actions required at the national level from a strategic, policy and regulatory standpoint, to lay the foundations for sustainable broadband mapping systems serving the achievement of national objectives.

Checklist 1 - Policy and Regulatory Checklist

1. Define the rationale and objectives for broadband mapping at the country level
2. Identify relevant institutions and stakeholders and their roles
3. Include the rationale and mandate in strategic documents (e.g., broadband plans, ICT strategies)
4. Provide a platform for long term engagement and consultation with all stakeholders (operators, regional and local administrations, etc.)
5. Analyse the legislative framework and propose reform as needed - Infrastructure sharing (infrastructure mapping) - Allocation of public funding (service mapping) - Objective of the map - Obligation for the authority to deliver the map - Obligation for stakeholders to provide information - Other
6. Ensure the NRA (or other Competent Authority) has the necessary mandate, budget and human resources to implement the provisions of the law
7. Define common technical definitions and methods to carry out the broadband mapping exercise. Consult with stakeholders.
8. Establish a dispute settlement mechanism fit for the national context
9. Plan regular evaluations of the mapping and of its the usefulness in fulfilling its objectives**.** adjust the map and any related normative provisions, if necessary, in accordance with the assessment, changes in objectives or legal/regulatory framework every 4-5 years to ensure they are fit for purpose
OUTPUT: review of enabling environment and recommendations and/or report describing existing boundaries of the regulatory framework for broadband mapping

In the light of the above, it is worth mentioning that all efforts are linked to **point 5**, or the creation of a sound regulatory environment for implementing broadband mapping systems, which is the cornerstone of this whole process underpinning the boundaries and scope of the broadband mapping exercise.

This chapter has provided substantial evidence into key pieces of legislation that are implemented at the EU level and which support country authorities' efforts. While also effective guidance is in place regarding mapping service availability in both fixed and mobile markets, there still remains a gap in concrete guidance on how to implement the Single Information Point, and therefore carry out the infrastructure mapping exercise in support, mainly, of infrastructure sharing.

This said, it must be noted that there is no one-fits-all solution. Even within the EU, there is broad heterogeneity in compliance with the regulatory framework as just described, with very diverse implementation laws. This suggests that indeed the European experience provides harmonized guidance revealing the key areas for action within a regulatory framework, but also highlights that it is left to each country to find the right solutions that fit the national context. Interested authorities beyond Europe would therefore ideally take the harmonized regulations across 27 developed economies as a starting point, and then adapt to the national context and objectives.

3. Project setup and technical requirements for broadband mapping

3.1 Project setup

To facilitate investment in broadband networks, reliable and up-to-date data on existing infrastructure and existing broadband services is essential. As anticipated in the introductory chapter, such data can support planning and decision-making processes as well as inform citizens and authorities about the current broadband situation. Overall, appropriate mapping of broadband infrastructure and other related data will help identify gaps in broadband coverage in a country, identify appropriate investment areas, and lower investment costs. In addition, it will avoid duplication of infrastructure and ensure that subsidies are allocated to areas that are affected by market failures. One other element worth noticing relates to the fact that it appears to be easier to set up a project in this field, should the NRA already have internally some level of general knowledge – starting, for instance, with a simple prototyping exercise with the use of GIS tools and then gradually complexify of the system. Broadband service and infrastructure mapping is generally a very heterogeneous field with different mapping approaches as well as different regulatory and data security challenges. Providing relevant data and ensuring its accuracy against predefined levels of detail is critical to creating a reliable and usable broadband mapping system and infrastructure. Such mapping initiatives focus on: facilitating broadband network development, transparency of the broadband market and generating synergies, reducing investment costs and state aid planning. The data is also used to identify areas of market failure by mapping the initiatives themselves and also to identify areas where there are market failures or where there is no broadband network. In conclusion - there are many answers to the question "Why broadband mapping is important":

- to increase investment in the telecommunications sector, in a targeted and geographically sound manner;
- to remove barriers to investments in telecommunications infrastructure;
- to accelerate the construction of new generation networks (NGA/NGN);
- to enable verification of objects (lines, nodes) for sharing purposes;

Setting up a broadband mapping exercise is not a simple undertaking as it must balance many factors and variables which concur to what can be implemented and with what scope. This chapter seeks to provide an overview of the key aspects of setting up a broadband mapping system within a given country to equip stakeholders with knowledge about the various steps which ought to be taken.

3.1.1 Project framework and objectives

When starting broadband mapping initiative, there are some crucial decisions that have to be made at the preliminary stage. The mapping concepts should be discussed holistically, and the authority should choose the best-fitting option depending on the requirements typical for the country. Below there have been described solutions which guarantee to set up pragmatic broadband mapping for any category, including infrastructure, services, investments, and demand. Referring to the definitions developed within the methodology framework of the global gap analysis exercise in the field of broadband mapping systems, these guidelines define **infrastructure mapping** as the activity entailing the gathering, structuring and representing georeferenced data on passive physical infrastructure (e.g. pipes, ducts, poles, manholes, base stations, mobile towers, etc.) represented in lines and nodes and i) information about the type of infrastructure deployed (fiber/copper, water pipes, electricity), and/or ii) information about the owners of that infrastructure (fixed/mobile telecommunications, other network operators, national and local government, etc.); **service mapping** as the activity entailing the gathering, structuring and representing data about service availability (including bandwidth and or type of technology used to offer the service), the number of broadband service offers from operators and/or the estimated quality of service available for a specific address and/or a specifically defined geographical area (e.g. 100m x 100m grid); **Investment mapping** as the activity entailing the gathering, structuring and representing data about planned investments aimed at developing broadband infrastructure and services in a defined geographical area (e.g. region, municipality), including relevant information about publicly and/or privately funded projects. Investment maps may include reports about areas characterized by market failure or sub optimal outcomes; and **demand mapping systems** as the activity entailing the gathering, structuring and representing data about the quantity and quality of broadband demand for bandwidth desired by the end user and the level of financial allocation foreseen in association with that given broadband fixed service.

Data sources

Relevant data sources for broadband mapping may include infrastructure owners, telecommunication operators, public utility entrepreneurs, local government authorities. With the data provided by the main group of data sources, the challenging aspects are mainly low willingness to provide data and a tendency to present the situation better than it is or hide some important data which hamper the state aid interventions. To deal with these, two solutions may be considered: the first one pertaining to the use of a legal reporting obligations to be imposed; the second one would aim for a voluntary basis approach which the literature has shown to be effective in some national settings. Data quality checks should be implemented in the broadband system. Additionally, administrative rules on penalties including financial penalties should be laid down in the national telecommunication law.

Information to be collected

The information that can be collected from operators within broadband mapping can be divided into three levels. The first level (i) is the type of information, i.e., nodes, lines, services.

The second level (ii) of information might relate to the master description which is added to the basic information about the very existence of the infrastructure or the availability of broadband service. This type of information is called attributes. The third layer (iii) should contain defined values or terms for the second level attributes.

In order to achieve broadband objectives, it is fundamentally important that there is reliable and valid data on existing broadband infrastructures and services offered. Data on broadband infrastructure and services are crucial to identify gaps of broadband coverage and quality of service level and identify suitable areas of investment. Gathering infrastructure data will be particularly useful to avoid duplication of financing as subsidies can be allocated to areas truly affected by market failure. Mapping infrastructure and services data usually is not comparable across countries and often public authorities lack detailed data to set policies, to ensure that public funding is compliant with relevant regulation, to programme funds and successfully monitor the execution of these actions at regional and national level. This lack of accurate data risks resulting in policy paralysis, in regulatory uncertainty, and poor planning of broadband projects. To avoid negative consequences of broadband data shortage the mapping platform have to collect data sets concerning broadband infrastructure and services. Data collection on the investment and demand can be performed on voluntary basis. Exemplary scope of data can include:

A) infrastructure mapping owner

The following tables are for fixed broadband value chain (including radio backhaul) and FTTA for what concerns mobile broadband.

NODES	
Field	Description
Node address – province	
Node address – commune	
Node address – unique identifier of commune (if possible)	
Node address – name of town	
Node address - unique identifier for town name (if possible)	
Node address - street name	
Node address - unique identifier of street (if possible)	
Node address - number of the building	
Node geometric center coordinates	Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m
Building type or structure where the node is located	Location of node: • office building; • residential building; • industrial building; • service building; • public building; • sacred object; • power grid object; • tower; • mast; • container;

	• pole; • cable well
Possibility of sharing surface area in the facility where a node is located	Yes/No
Layers of the telecommunications node	Layer: • backbone; • distribution; • access
Transmission medium	Transmission medium: • fibre optic; • coax, copper; • radio
Technology for mediums	fibre optic: • 10 Mb/s Ethernet; • 100 Mb/s Fast Ethernet; • 1 Gigabit Ethernet; • 10 Gigabit Ethernet; • 40 Gigabit Ethernet; • 100 Gigabit Ethernet; • GPON; • EPON; • DWDM; • CWDM; • SDH; • PDH; coax, copper: • (EURO)DOCSIS 3.x; • (EURO)DOCSIS 2.x; • (EURO)DOCSIS 1.x 1; • 10 Mb/s Ethernet; • 100 Mb/s Fast Ethernet; • 1 Gigabit Ethernet; • 10 Gigabit Ethernet; • VDSL2; • VDSL; • ADSL2+; • ADSL2; • ADSL; • HDSL;

	• PDH; • POTS/ISDN radio: • radio link, • WiFi 2.4 and 5 GHz; • WiFi - 5 GHz; • Wi-Fi - 2.4 GHz;
Maximum bandwidth for a single interface download	
Maximum bandwidth for a single interface upload	
Number of interfaces	
Source of node funding	Source of funding: • commercial • state aid

LINES	
Coordinates of the bending points of linear elements	Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m
Destination	Layer of cable: backbone; distribution; access
Type of line	Transmission medium: • fibre optic; • coax, copper; • radio
Fibres	Fibres of the optical cable
Source of line funding	Source of funding: • commercial; • state aid

MOBILE TOWERS	
Object geometric center coordinates	Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m
GSM cell technology	• 2G; • 3G; • 4G; • 5G
GSM cell identifier	Unique identifier of the corresponding GSM cell

Variable	*Coordinate*	*Grid code*	*Zone code name*
Description	*Coordinate and geometry of the polygon in the WKT format.67,68*	*Code of the grid. Has to be unique per grid*	*Code of the zone, considering the lowest administrative unit in the Member State.* *For aggregation usage*
Data type	*Multipolygon*	*Character varying (50)*	*Character varying (70)*

B) Service mapping

On the other hand, the coverage of fixed-line networks is best analyzed through the availability of services and the provision of telecommunications services in individual buildings.

BUILDINGS WHERE THE FIXED NETWORK ENDS OR END-USER TERMINAL EQUIPMENT IS INSTALLED	
Building address – province	
Building address – commune	
Building address – unique identifier of commune (if possible)	
Building address – name of town	
Building address - unique identifier for town name (if possible)	
Building address - street name	
Building address - unique identifier of street (if possible)	
Building address - number of the building	

Building geometric center coordinates	Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m
Medium	Medium: • fibre optic; • coax, copper; • radio
Technology of access network	fibre optic: • 10 Mb / s Ethernet; • 100 Mb / s Fast Ethernet; • 1 Gigabit Ethernet; • 10 Gigabit Ethernet; • 40 Gigabit Ethernet; • 100 Gigabit Ethernet; • GPON; • EPON; • DWDM; • CWDM; • SDH; • PDH; coax, copper: • (EURO)DOCSIS 3.x; • (EURO)DOCSIS 2.x; • (EURO)DOCSIS 1.x 1; • 10 Mb/s Ethernet; • 100 Mb/s Fast Ethernet; • 1 Gigabit Ethernet; • 10 Gigabit Ethernet; • VDSL2; • VDSL; • ADSL2+; • ADSL2; • ADSL; • HDSL; • PDH; • POTS/ISDN radio: • radio link, • WiFi 2.4 and 5 GHz; • WiFi - 5 GHz; • WiFi - 2.4 GHz; • WiMAX

Possible services	• fixed Internet access; • fixed line POTS and ISDN; • VoIP telephony; •
The maximum download bandwidth that can be offered to the end user for fixed broadband Internet access	• 30 Mbit/s • 100 Mbit/s • more than 100 Mbit/s less than 1 Gbit/s • 1 Gbit/s

On top of data for households passed, information on households connected (where services are already provided) is to be collected.

SERVICES ALREADY PROVIDED	
Building address – province	
Building address – commune	
Building address – unique identifier of commune (if possible)	
Building address – name of town	
Building address - unique identifier for town name (if possible)	
Building address - street name	
Building address - unique identifier of street (if possible)	
Building address - number of the building	
Medium	Medium: • fibre optic; • coax, copper; • radio
Technology of access network	fibre optic: • 10 Mb / s Ethernet; • 100 Mb / s Fast Ethernet; • 1 Gigabit Ethernet; • 10 Gigabit Ethernet; • 40 Gigabit Ethernet; • 100 Gigabit Ethernet; • GPON; • EPON;

	• DWDM; • CWDM; • SDH; • PDH; coax, copper: • (EURO)DOCSIS 3.x; • (EURO)DOCSIS 2.x; • (EURO)DOCSIS 1.x 1; • 10 Mb/s Ethernet; • 100 Mb/s Fast Ethernet; • 1 Gigabit Ethernet; • 10 Gigabit Ethernet; • VDSL2; • VDSL; • ADSL2+; • ADSL2; • ADSL; • HDSL; • PDH; • POTS/ISDN radio: • radio link, • WiFi 2.4 and 5 GHz; • WiFi - 5 GHz; • WiFi - 2.4 GHz; • WiMAX
Provided services	• fixed Internet access; • fixed line POTS and ISDN; • VoIP telephony; • IPTV or DTV
Speed downstream	
Type of client	• individual client; • business client
Number of clients	

Regarding **mobile networks**, the scope of mast data has already been discussed. An important element is the range of mobile networks. These issues are discussed in detail in the BEREC guidelines on Article 22 EECC. According to the guidelines:

This information can be collected in GIS form (can be a shapefile or a raster/grid) or a table form, or. o GIS form

Technology digital maps with resolution of 100m x 100m or smaller, preferably using multiple designations or more to characterize each geographical point. This grid can be enriched with speed coverage.

Ultimately, the dataset to be collected in order to characterize the mobile network is presented in the next table For each 100m x 100m (or smaller) area, the following information has to be provided from the operator's data :

- *Operator code*
- *Grid code or polygon ID*
- *Technology availability*
- *VHCN class*

Data formats

The two most commonly used data formats for providing data within the broadband mapping process are DSV (mainly CSV) and XML.

DSV (mainly CSV)

Delimiter-separated values (DSV) is a text file that stores two-dimensional data, where values are separated by specific delimiter characters.

In the DSV file each row is one database record. Any value can be used as delimiter character that separates the values. Most popular delimiter characters are comma (CSV, – Comma-separated values) and tab (TSV, - Tab-separated values). Colon, semicolon, pipe and space are also sometimes being used as delimiters.

It is very important to choose a delimiter that is not being used in data in order to avoid later issues with data read. It is possible to use double quotes for string values. All records should have the same number of fields and the same value order.

This format is easy to read by databases and spreadsheet applications. It is very easy to create also.

Please see below a sample of CSV file:

```
DP,"IL-1","7251801126","000132629","","30032","0000023456","łódzkie"
PO,"TK_Region","Telekomunikacja Regionalna Sp. z o.o.","2474771419"
WW,"WEZEL_WLA_01","Węzeł własny",,,"łódzkie","Skierniewice"
WW,"WEZEL_WSP_01","Węzeł współdzielony z innym podmiotem","TK_Region"
WO,"WEZEL_OBC_01","Umowa o dostęp do sieci telekomunikacyjnej","TK_Region"
```

XML

Extensible Markup Language (XML) is a universal markup language designed to represent various data in a structured way. It contains textual data. It is platform- independent, which enables easy document exchange between different systems. Using XML also means that the user may easily design a data hierarchy. This format is appropriate for large amounts of data and when one wants to emphasize the hierarchy of data.

XML also supports data validation, especially structure validation. XSD (XML Schema Definition) is a file, where the user specifies the structure and description of an XML file. It is used for verification of the main XML file.

The XML file is more complex than the CSV file, but it also gives more possibilities.

This is a sample of an XML file:


```
▼<dokument wersja="5.68" oznaczenie="test">
  ▶<podmiot_przekazujacy_dane>
   ...
   </podmiot_przekazujacy_dane>
  ▼<dane>
    ▼<zakonczenie_sieci>
       <identyfikator>Budynek_1</identyfikator>
       <wlasnosc>Własna</wlasnosc>
       <id_wezla>Węzeł_numer_1</id_wezla>
       <wojewodztwo>łódzkie</wojewodztwo>
       <powiat>Skierniewice</powiat>
       <gmina>Skierniewice</gmina>
       <TERC>1063011</TERC>
       <miejscowosc>Skierniewice</miejscowosc>
       <SYM>0976942</SYM>
       <szerokosc_geograficzna>53.998000</szerokosc_geograficzna>
       <dlugosc_geograficzna>23.740000</dlugosc_geograficzna>
       <medium_transmisyjne>kablowe parowe miedziane</medium_transmisyjne>
       <siec_dostepowa>VDSL</siec_dostepowa>
       <telefonia_POTS_ISDN>Nie</telefonia_POTS_ISDN>
       <telefonia_VoIP>Nie</telefonia_VoIP>
       <telefonia_mobilna>Nie</telefonia_mobilna>
       <stacjonarny_internet>Nie</stacjonarny_internet>
       <mobilny_internet>Tak</mobilny_internet>
       <tv_IPTV_DTV>Tak</tv_IPTV_DTV>
       <przepustowosc_stacjonarny>2</przepustowosc_stacjonarny>
       <przepustowosc_mobilny>4</przepustowosc_mobilny>
     </zakonczenie_sieci>
    ▶<usluga>
     ...
     </usluga>
   </dane>
 </dokument>
```


There are a few different types of GIS data:

- vector spatial data,
- spatial raster data (e.g., orthophoto map),
- attribute tables that are represented in tabular format.

At this point, it's worth taking a look at the *BEREC Guidelines on Geographical surveys of network deployments* again. The recommended data format will be vector data because it has numerous advantages, including location accuracy, less disk space requirements, faster service (saving, loading, displaying, editing, copying, deleting), unlimited symbolization possibilities (practically unlimited possibilities of using colours, fillings, shades, etc.) and the ability to perform complex calculations and analyzes (e.g., surface area, perimeters, etc.).

The vector data model is a direct numerical representation of real-world objects by the corresponding geometric objects in the spatial data model. The objects of a simple vector model are:

- point,
- line,
- surface.

The location of point features is determined by the coordinates of the point locating the feature. In the case of linear and area objects that are defined by a larger number of points, apart from their coordinates, it is important to arrange them properly, which is determined by the shape of the object. Because of having only a group of points without information about their arrangement, it was not possible to clearly define the shape of the object, which is illustrated in the figure below.

The most common vector data formats used are:

- DGN is the name used for CAD file formats supported by Bentley Systems' MicroStation and Intergraph's Interactive Graphics Design System CAD programs.
- (AutoCAD DWG is the proprietary native file format for AutoCAD, one of the most popular computer-assisted design (CAD) packages.
- DWG is a compact binary format that stores and describes the content of 2D and 3D design data and metadata.
- Shapefile - Esri vector data storage format for storing the location, shape, and attributes of geographic features. It is stored as a set of related files and contains one feature class. Shapefiles often contain large features with a lot of associated data and historically have been used in GIS desktop applications.
- GeoJSON - a format for encoding a variety of geographic data structures. GeoJSON supports the following geometry types: Point, LineString, Polygon, MultiPoint, MultiLineString, and MultiPolygon. Geometric objects with additional properties are Feature objects. Sets of features are contained by FeatureCollection objects.
- Keyhole Markup Language (KML) - an XML-based markup language designed to annotate and overlay visualizations on various two-dimensional, Web-based online maps or three-dimensional Earth browsers (such as Google Earth).
- Extensible Markup Language (XML) - a file format used to create common information formats and share both the format and the data on the World Wide Web, intranets, and elsewhere using standard ASCII text.
- A comma separated values (CSV) - contains different values separated by a delimiter, which acts as a database table or an intermediate form of a database table. In other words, a CSV file is a set of database rows and columns stored in a text file such that the rows are separated by a new line while the columns are separated by a semicolon or a comma.

Raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps. The most popular raster data formats are:

- Tagged Image File Format (TIFF) - the extensible feature of this format allows storage of multiple bitmap images having different pixel depths, which makes it advantageous for image storage needs. Since it introduces no compression artifacts, the file format is preferred over others for archiving intermediate files.
- Joint Photographic Experts Group (JPEG) - it is commonly used for storing digital photos and used by most digital cameras to save images.

Tabular format data is represented by data organized into columns and rows. It can be said that it is the simplest data format, but it can be considered the easiest for operators to handle. An example of software that allows you to process tabular data is Excel.

Data supply process

To ensure the most efficient data provision within the broadband mapping process, the collecting body should elaborate a designated platform for data transfer. This is a core component of a mapping project and a key determinant of its success within a given country.

The platform has to fulfil rigid safety and security criteria for data transfer, but also balance the user experience to facilitate compliance by operators, particularly in contexts where the voluntary approach is adopted.

On the entity validation aspect, one basic method is using a logging-in system, which may be significantly strengthened by a separate procedure of obtaining usernames and passwords by the reporting entities. Importantly, only logged in users should be able to report data. Simultaneously, the reporting system should give the possibility to log in only to entities that report data. The platform should allow access to view data, as well as to edit them and update for reporting entities.

The platform should enable to transfer data in two basic ways – manual and automated.

The first way should allow reporting data manually by a browser. It would be dedicated to entities that have a small amount of data to report and to those, whose data changes only a little between reporting periods.

The second, automated method should allow transferring data by entities via pre-prepared files. These files should have an appropriate structure, which has to be determined in advance. These data files could be for example CSV or XML files, or both. The precise reporting set up regarding the way of reporting in an automated way via files would be determined by the specific design of the reporting platform. This method should be dedicated to entities that have large amounts of data to report.

Data conversion

The platform should support and assist with the data reporting. It should make it possible to report data manually by hand and to automatically import prepared data files.

The first way ensures functionalities that allow entering data manually through the browser. This method is mainly dedicated to small entrepreneurs and public entities.

The second way can be a dedicated tool that helps to prepare data files for reporting. This tool should not be complicated to use and should allow generating files with large data volumes. This method is aimed at medium-sized entrepreneurs. This tool could represent a mix of manual and automatic data preparation.

The third way can be a dedicated tool for large operators. This tool should be able to transfer large amounts of data to the platform. Entrepreneurs have to prepare data files (e.g., CSV or XML) on their own, based on their inventory systems. The tool would assist in checking the correctness and structure of the data.

Quality checks in Broadband mapping

Data obtained from public and private sources are at the core of high-quality broadband mapping. Therefore, it is imperative to check all data used in the process. Thus, it is not a question of whether or not to check data in the broadband mapping process, but rather, which quality check process or which combination of processes to install. The three basic quality checks methodologies applied to broadband mapping are:

- plausibility checks

- manual checks
- additional user feedback

Plausibility checks

Plausibility check is a method of data quality verification, where a value is checked to determine, whether it is plausible or not, that is if it is acceptable for the type of information being collected. It is not always possible to check the correctness of every data in such a way, but this type of check will allow detecting any obvious inaccuracy.

Data collection tools used for broadband mapping ought to be designed to automatically check a range of plausibility rules. The validity of particular data can be either rejected by the software or flagged as being unlikely to be valid. In the broadband mapping process, it is the second approach that is more applicable, as flagged data may be additionally verified both by the supplier at the point of entry, and then by the data collecting body, when verifying full data sets obtained through the process.

Plausibility checks may be done manually, but most commonly are automated and are incorporated into the software of the collection tool used in the process.

Manual checks

Manual checks are not compulsory to be used within the broadband mapping process, but under certain circumstances, it may be useful to improve data quality for the process. They may be carried out using different approaches and intensities.

A relatively simple approach is to cross-check data with data otherwise published by the same operator or infrastructure owner or check the same set of data provided by two different sources. When it comes to services provided, operators frequently publish the availability of their services on their own websites – this may be used to compare with the data provided by the operators through the data collection process. Address data on the other hand may be cross-checked by comparing address databases shared by various public institutions. For example, address data may be collected by local administrative governmental units such as municipalities and regions, and also independently collected by national statistical offices.

However, it is worth noting the main challenge for some European countries in delivering a broadband map is a lack of appropriate address data resources at the national level. Even when those exist, different operators may not be using them or be resorting to their own address data resources, which creates a problem in common georeferencing. In the latter case, some solutions can be suggested but it is more difficult to overcome the former case. Due to such problems, the BEREC's Guidelines accepted small grid information temporarily despite the overall advantages of data at the address level, particularly in the context of state aids.

Nevertheless, it is the collecting body's decision, if the additional labour-intensive effort is outweighed by the scale and level of data quality improvement achieved by this type of check.

Additional user feedback

User feedback offers another additional route to check and potentially improve data quality. There is a number of routes that the user feedback may be obtained from, such as:

- functionality of the broadband mapping visualisation tool – the interested public may provide feedback directly through the map functionality, if they feel that information is not accurately presented for their situation
- communication channels directly to the data collecting body – via collecting body's website, contact point or any other route offered
- e-government contact routes for public – general routes of contacting governmental units provided by e-government tools

This type of checks requires long term maintenance efforts on the collecting body's side.

Access to data

Publication of broadband data is an important tool by which end-users can obtain information about the availability and selection of services and the location of the telecommunications infrastructure. At the same time, in accordance with national laws on commercial confidentiality and personal data protection, some information collected as part of the broadband mapping may be considered confidential and should be protected by the national regulatory/national competition authorities.

The choice any mapping initiative has to make with regard to data publication is about who should have access to the data. There are three options for data access:

- internal use - data is collected only for analysis purposes
- limited access to data - data made available in justified cases, upon request
- public access - all data collected within broadband mapping is publicly available

The goals of the broadband mapping initiative, as well as the level of detail that is theoretically available from the data collected, usually determine the choice of these options. If the goal is to inform the public or even generate interactions with the public, e.g., through a feedback function, then detailed data access that does not reveal any company secrets seems to be the most obvious choice.

Conversely, if the information could harm the revenue or business development of a particular stakeholder by providing classified information to competitors or be used for criminal purposes, it would be more prudent to restrict access. A good solution is for all (potential) data providers to be offered the opportunity to engage in negotiating an approach with authorities prior to starting a mapping project and also whenever changes to the publication format are planned.

A good incentive from the regulatory authorities would be to publish reference infrastructure sharing offers thus providing an incentive for public sector institutions (e.g. local governments) and other public or private institutions to publish the data. This would provide an incentive for traditional telecom operators to come forward finding that benefits outweigh the costs of sharing information about one's own network.

In addition to the issue of commercial confidentiality and protection of personal data, the particularity of critical infrastructure should also be taken into account in data publication.

A minor problem is found with the publication of data on mapping services and demand. The information can, in principle, be available to everyone, including users who are not logged in.

When considering publishing data on telecommunications infrastructure in the context of critical infrastructure, three options can be mentioned:

1. define in the act what the critical infrastructure is and:

- collect information about it and do not publish it,
- do not collect this information,

2. collect information about critical infrastructure with the attribute, whether the infrastructure is critical (yes/no) and provide such information only in justified cases.
3. do not collect information about critical infrastructure and decide what critical infrastructure is left to network operators.

It is recommended to consider a scenario which mixes three possible options of the confidentiality, i.e., defining the critical infrastructure in the legal act, introducing an attribute (yes/no) where the operator can indicate on the basis of the elements of the critical infrastructure described in the act and determining which collected information on the critical infrastructure cannot be publicly available.

Also in the BEREC guidelines to Art. 22 EECC there are recommendations for publishing data that are worth quoting here:

"It should be noted that the requirements of the GS information system should reflect the guidelines of the INSPIRE Directive , given that all public institutions of a Member State that have spatial information are obliged to manage and make available the data and the GIS in accordance with common principles and rules

The interests liable to be harmed by disclosure must, objectively, be worthy of protection. It is highly recommended that operators establish their claims for confidentiality, and that the NRAs/OCAs settle those claims according to clear and nondiscriminatory criteria. The assessment of whether a piece of information constitutes confidential information should be made on a case-by-case basis by the relevant authority (depending on the kind of information, and the circumstances).

Some examples of information that could qualify as business secrets and may be deemed to be confidential in the context of GS are:

1. *Operators' deployment forecasts; Operators' detailed information regarding the position and type of different network elements, with the exception of network elements that are subject to a wholesale access obligation that requires the publicising of this information; and*
2. *Operators' production secrets and processes, as well as information relating to an undertaking's know-how, such as the tools and methods it uses to calculate coverage information.*

   Some examples of information that may not be considered confidential in the context of GS are:
3. *Information which is publicly available. The coverage area of an operator will usually be available to customers and should therefore not be considered to be confidential;*
4. *Information that has lost its commercial importance, for instance due to the ageing of information because of the passage of time;*
5. *Information which is common knowledge among specialists in the field (for example, in relation to mobile propagation models); and*

Statistical or aggregate information, in so far as it does not allow for the identification of business secrets.

What this shows is that the European Electronic Coommunication Code is designed with in mind to allow room for actions for European countries to find the optimal balance with the network operators.

Publication format

The choice of the form of data publication depends mainly on the preferences of potential users. One way to facilitate access to data may be to present the data in various publication formats. For some stakeholders, it may be important to visualize the data on a map and download it in vector form, for another group of entities, a report presenting a subset of results and analyzes may be more useful. It is also worth verifying which group of potential recipients depends on the already processed and which on the raw data. Raw data can be provided in the form of tables, geographic files or web services. Web services have the advantage of being always up-to-date as the data is stored on the initiative's web server and is made available on request over the network for display in the user's GIS. Therefore, if errors in the dataset are corrected, it is guaranteed that external users will also receive updated information. The website allows the use of many different forms of visualization, from text, tables and picture map to dynamic maps, e.g. with the zoom function, to fully interactive maps that also allow us to access additional data or perform data analyzes.

BEREC Guidelines on Geographical surveys of network deployments suggests several options for publishing GIS data:

- Interactive maps published in a dynamic web application;
- Interactive address search published in a dynamic web application;
- Application Programming Interfaces ("APIs") for accessing data;
- Datasets in open and generalized formats such as CSV;
- Statistical reports, including tables and analyzes.

Update frequency of data supply

The frequency of reporting data by entrepreneurs and public entities should correspond to the needs of the government administration. Data reporting should be done at least once a year. It is viable to set up a large reporting window, i.e., a quarter, however with presumed reporting the status of data as of a set date. This enables smooth monitoring of the telecommunications market, as well as meeting most reporting needs.

Depending on the collecting body’s needs, semi-annual or quarterly reporting might be considered. However, it should be noted that more reporting obligations mean greater workload and costs for reporting entities. The possibility of reporting and updating data should be continuous, and the reported data should be up to date for the time reported.

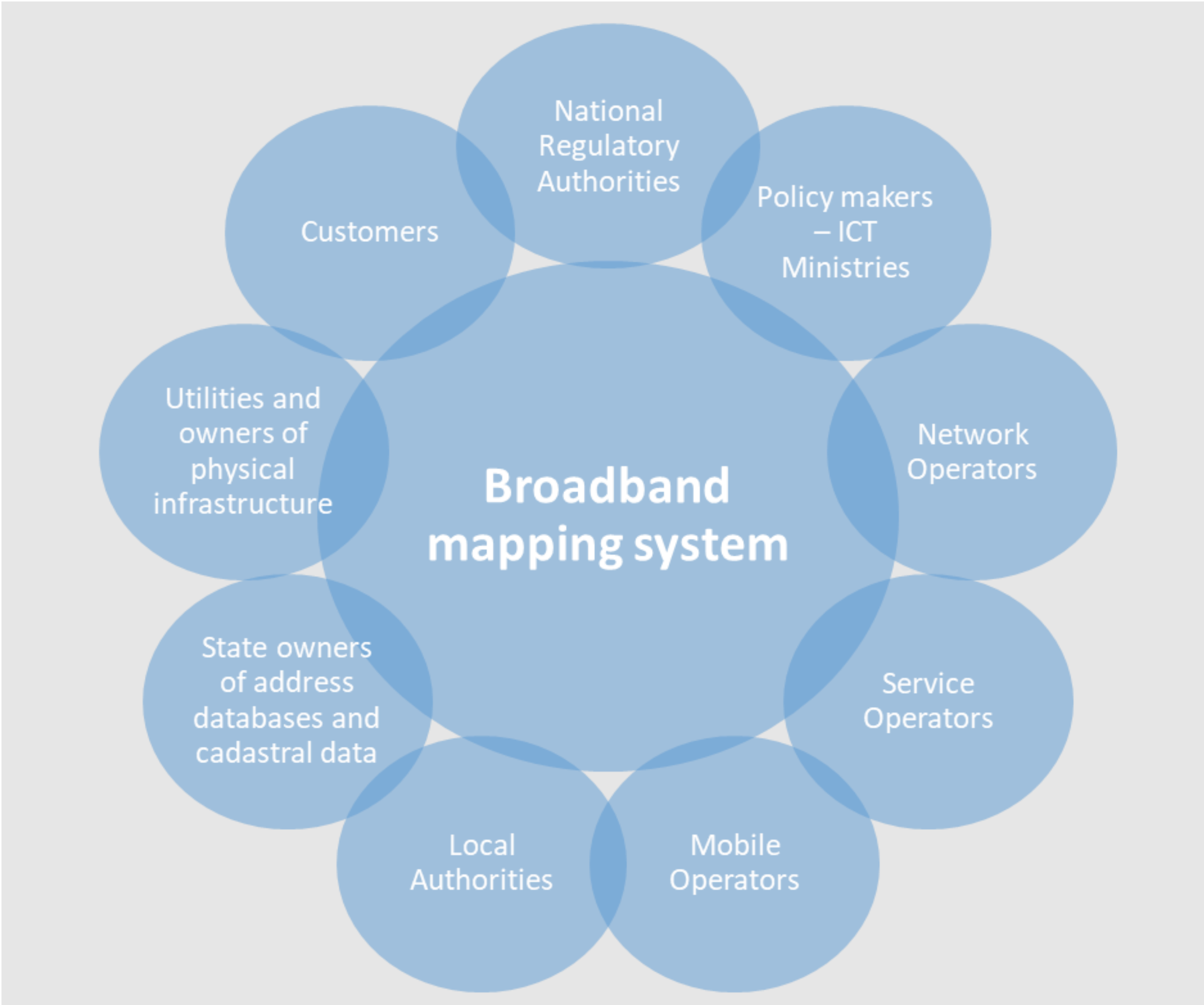
3.1.2. Project design

When initiating a broadband mapping system project, in addition to defining the reasons for undertaking a project, one should start with the stakeholder analysis. It is an important stage because it is worth starting with a consultation with interested parties, especially when there are no regulations regarding the implementation of such a system in a given country. Stakeholders are parties who will be affected by the project at any point in its life cycle, and their input can directly impact the outcome. It is essential to practice good stakeholder management and continuously communicate to collaborate on the project.

Listening to stakeholder concerns and feedback is a valuable source of information that can be used to improve projects and outcomes and help to identify and control external risks. For stakeholders, the consultation process creates an opportunity to be informed, as well as to inform the company about local contexts that may not be obvious, to raise issues and concerns, and to help shape the objectives and outcomes of the project.

The more a stakeholder group will be materially affected by the proposed project, the more important it is for them to be identified, properly informed, and encouraged to participate in the consultation process. It is therefore critical to determine who the various stakeholders are, as well as their level of interest in the project, the potential impact it will have on them, and the power they have to shape the process and outcome.

In the case of broadband mapping system projects, identifying the stakeholders is not difficult, as it can be based on the experiences of other countries. The diagram shows the main stakeholders:



When describing the stakeholders, it is undoubtedly necessary to start with the NRAs. In most countries that are advanced in infrastructure mapping, NRAs are responsible for these systems.

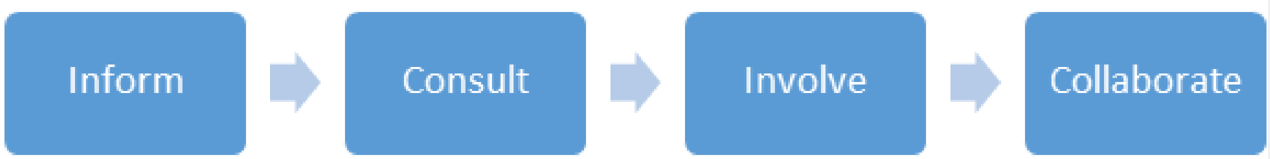
There are also examples where ICT ministries undertake building systems. However, there are not many of such examples. The role of these ministries in the discussed process may also be different - in countries where the provision of data on telecommunications infrastructure and services is obligatory by law, ministries are responsible for elaborating the provisions regulating the necessity to transfer data.

Finally, there are other stakeholders such as operators (mobile and fixed), internet providers, local authorities and consumers. These are the main stakeholders of the system. Data providers, i.e., operators and sometimes local authorities, will usually be dissatisfied with system users, especially in cases where the transfer of data is obligatory and they do not notice the advantages of building broadband mapping systems. It should be also noted that customers will only be stakeholders in cases where the broadband mapping system includes a demand reporting tool.

It is also worth mentioning the providers of reference data. Ideally, they will be state institutions to make it easier and low-cost to obtain geodetically or address data.

There are cases that geodesy institutions, despite the fact that they have useful data in the broadband mapping process, do not want to share them. It often results from the fact of earning on these data. Nevertheless, it is recommended to conclude an agreement between the NRA and state owners of cadastral and address data because cadastral data and address databases are extremely important in the construction of the broadband mapping system. Cooperation could start with the signing of an agreement between those institutions. That agreement should provide NRAs with the possibility to use the cadastral and address database for the purpose of mapping infrastructure and telecommunications services.

As already mentioned, it is particularly important to involve stakeholders at various stages of the project.



Informing phase: Providing stakeholders with balanced and objective information to help them understand the project, the problem, and the solution alternatives.

Consulting phase: Gathering feedback on the information provided. Contribution levels can range from minimal interaction (online surveys etc) to extensive. It is also possible to consult the scope of collected information or data formats.

Involving phase: Working with stakeholders during the process of defining system requirements to ensure that their ideas and concerns are fully understood and taken into account.

Collaboration phase: While stakeholders will not be useful when developing the system, they can be very useful at the stage of system testing. It is therefore worth involving them in this phase.

One of the most important decisions to be made in the project is the choice of the system implementation formula. This decision must depend on the internal factors of various countries and their institutions, the strategic and regulatory objectives that the country seeks to achieve, and the financial means and available human resources. In fact, before setting up a project, broad objectives should be defined.

First, an assessment of the existing regulatory environment based on provisions touched upon in chapter two (or similar) should be conducted. This will allow the establishment of the boundaries within which the project should be established and a rough governance framework with lead authority and other authorities. Beyond existing regulations, such boundaries may account for ongoing regulatory reform, which may also have been implemented to facilitate the establishment of a broadband mapping system (see chapter 2). For example, without any legal system on infrastructure sharing, it would not be possible to implement any infrastructure mapping exercise.

Secondly, the strategic and regulatory objectives should be clearly defined and the broad scope of the broadband mapping system established. This will allow for a focused and rational approach to project design that informs key decisions that will have to be taken. If it is not the regulatory objective to publish data for consumers, this should not fall in the scope of the mapping system exercise. Or if there is no state aid programme/ funding for telecom services providers, this should not be part of the scope.

Thirdly, the range of financial and human resources needs should be broadly estimated. This will depend on the previous two segments but will also largely depend on the size of the country, the size and the budget of the competent authority.

Once the operating framework exists and the boundaries and objectives have been set up, the design phase can be undertaken. It is possible to implement the system in the form of a proprietary solution or commission the construction of such a system through a public tender. To implement the broadband mapping system, it is also possible to use the hybrid model, for example: the outsourcing of development, in-house system design and management. Each approach has advantages and disadvantages.

	Pros	**Cons**
outsourced solution	· Responsibility for guaranteed results for the other party · No need for additional manpower on your own	· More expensive upfront · Less upfront · Less flexible in development Smaller understanding of the authority needs · Data confidentiality may be compromised.
In-house solution	· Cheaper initial costs · More flexibility in design and development · Creates detailed knowledge of the system	· Additional IT resources to maintain · A multidisciplinary team
hybrid approach	· Responsibility for guaranteed results for the other party · Understanding of business needs	· Additional resources to maintain · Less flexible in development

Hence, before adopting such decisions, it is necessary to answer the following questions:

- Do I have the right team including programmers and GIS specialists?
- If not, can I hire the necessary people?
- What is my actual budget?

Simply put, it can be said that the decision on how to implement a project will be largely related to the budget and the availability of human resources, including the possibility to re-purpose human resources from other tasks to the project. The analysis will now dive into outsourced systems, which are largely dominant, and then proceed with discussing in-house solutions.

<u>Outsourced</u>

If a responsible institution has a budget for this purpose, it will be easier to implement this project by announcing a tender. However, they should not forget about the advantages in-house solution. These include, above all, lower costs and greater flexibility, as well as the possibility of implementing the system in batches.

Therefore, software competition should be stimulated through tendering. The software bidding process consists of a set of common software engineering practices that cover engineering requirements. Preparation of the requirements for the system is extremely important when announcing tenders. If this stage is not properly weighted, the implementation of the system will run in a scenario with uncertain and incomplete information.

Therefore, the processes for inviting tenders should include research results in terms of what is happening in the industry in a given country today. To avoid these problems, the bidding process should be divided into the following stages:

- Gathering organizational needs including business strategies.
- Estimation of budget and time to build the system. The procedure for preparing a general group offer should take into account the context and early estimation methods. Special methods should be used, such as the interoperability of system applications and the reuse of libraries or software.
- Providing a document of consent to submit bids and start the tender. It is important to strike a balance between collecting enough information for vendors to produce a satisfactory solution to the problem, and the cost of gathering that information.
- Questions & answers. Typically, the public invitation to tender process includes a public question and answer process where suppliers can resolve concerns about the interpretation of invitation to tender documents. The questions and answers are published, and thus new variables are added to the process.
- Selecting an offer (supplier). Once suppliers have submitted their applications, a selection process begins in accordance with national legal and procurement systems and procedures.
- Signing the final contract. The contract should take into account factors such as: indirect payment, engineering products, intellectual property and its use, availability of stakeholders, services subject to penalties.
- Software development. At this stage, the traditional software lifecycle is activated.

When concluding a contract with an external company, it is imperative to remember the following aspects:

- the correct identification of the parties to the contract,
- the subject of the contract with a detailed specification of the system (waterfall) or general initial assumptions regarding its implementation (agile),
- period of performance,
- work schedule,
- the rules of cooperation,
- the way the work is carried out, i.e., the rules of cooperation between the parties during the implementation of individual stages,
- issues related to the staffs and project managers,
- issues of using subcontractors by the contractor,
- tests (errors and corrections),
- acceptance of the application,
- withdrawal from the contract (often confused with termination),

- intellectual property (transfer of proprietary copyrights; license – it is important to make sure that the intellectual property of the software and inputs belong to the Authorities,as well as the data if the collection of data is also outsourced)
- remuneration,
- contract performance security,
- guarantee, warranty, error handling,
- confidentiality,
- issues related to the development and maintenance of the completed system,
- issues related to the contractor's liability,
- method of dispute resolution.

When deciding to entrust the construction of the broadband mapping system to an external contractor, it is worth remembering that the NRA must also provide an appropriate team. In this case, the minimum set for a small mapping system project should consist of (at least):

- 1 telco expert;
- 1 GIS expert;
- 1 legal advisor (mainly for the preparation of the contract and other documentation for the tender)

<u>In house</u>

Developing an in-house development team provides greater control over software development and intense project involvement in the team. However, there are certain conditions to be followed in order for this to work: Properly estimate the amount of post-delivery work or other similar projects to hire the right team later. The advantage of this approach is undoubtedly having full control over the project. The management has an insight into the daily progress and current knowledge about the team's work. This allows the management to react quickly if there are any obstacles along the way. The main advantage is therefore the knowledge gained during the project. This approach ensures that the product - broadband mapping system is not a "black box" and facilitates post-system support. The team remains involved with the project after delivery and is always available for further maintenance, bug fixes and updates as needed. However, it should be remembered that employing one programmer takes 30-35 days on average, and the task is complicated by high demand for them. In order to attract the best talent, it is imperative to compete with other companies and offer better working conditions. The challenge is therefore not only to acquire qualified specialists, but also to ensure that their skills and personality match in order to be effective as a team. Moreover, before they can achieve high levels of productivity, they will need time to become familiar with their work style. When deciding on an internal solution, you should take care of the expenses for maintaining the internal team and minimize the risk of rotation. The minimum team composition for proprietary software is;

- 1 project manager;
- 1 telco expert;
- 1 legal advisor;
- 1 system architect;
- not less than two GIS experts;
- 1 developer;
- 2 testers
- DBA Administrator

In general, it should also be noted that the solution will never be purely internal or fully outsourced, because even in the context of in-house solutions, the external software will be integrated with the existing one, while for fully outsourced solutions, specialists within the organization will be needed as they will be the technical experts who will ensure the proper functioning and operation of the system.

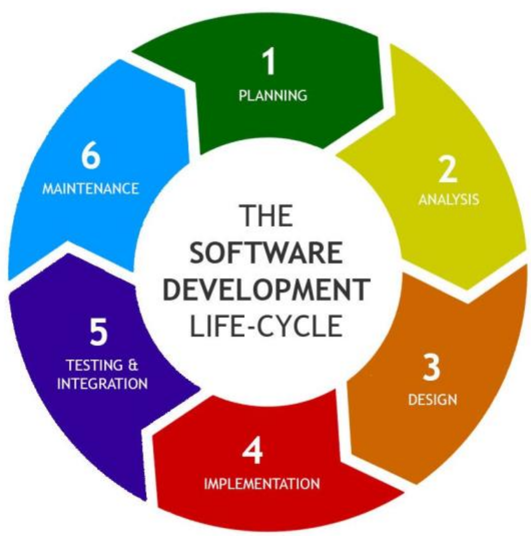
Hybrid

With this approach, the NRA's team of employees will play an important role. It is crucial that the qualified persons cooperate with the system contractor at every stage, from the pre-implementation analysis to the testing stage.

In this case, the minimum set for a small mapping system project should consist of:

- 1 project manager;
- 1 telco expert;
- 1 GIS expert;
- 1 tester;
- DBA Administrator

Most of the analyzed countries decided to implement a broadband mapping system with the participation of an external company. Regardless of the chosen model of the system implementation (outsourcing, in-house solution or hybrid solution), it is important to remember about building the system taking into account the system development life cycle (SDLC). SLDC process should consist of the following stages:



1. Planning. The purpose of this step is to determine the scope of the problem and identify solutions. At this stage, it is imperative to consider resources, costs, time, benefits, and more.

2. Analysis. In this step, the system analysis is performed. This phase is essential for identifying the needs as well as how they can be met, who will be responsible for each element of the project, and what kind of schedule to expect.

3. Design. The third phase focuses on creating the functional requirements of the proposed system. When creating requirements, it is necessary to take into account the existing hardware or software, or network capabilities.

4. Implementation. The fourth phase covers the work of programmers.

5. Testing and integration. The fifth phase includes system integration with the existing environment and tests of the developed software.

6. Maintenance. The sixth and final stage includes maintenance and regular required updates. At this stage, end users can tune the system to increase performance, add new capabilities, or meet additional system user requirements.

Each country will have its unique set of parameters and variables, and ideal solutions have to be identified on a case by case basis.

Budgeting

A budget plan is the total estimated cost needed to complete a project within a specified period of time. It is used to estimate project costs at each stage of the project. The budgeting exercise will have to be undertaken in parallel to design. Based on the overall budget capabilities of the organization and the human resources, technical expertise conditions available in a given institution, the budget should be forecasted adopting a project lifecycle approach (e.g., 10 years: capex, hours of expert work needed, maintenance.). The budget plan must be subject to periodic verifications and updates throughout the project duration.

There are several aspects to consider when creating a budget. First, the use of historical data. The broadband mapping project is not the first of its kind. Therefore, it is worth taking advantage of budgets in other countries. Using budget information in such projects in other countries is a great way to start building a budget.

These guidelines will present an approach to rough system cost estimation, based on the experiences of other countries. Due to the fact that one of the stages of the preparation of these guidelines was conducting interviews with representatives of several countries advanced in the broadband mapping process, inter alia the following information was obtained and then analyzed:

- implementation formula;
- system components;
- number of system users; number of operators;
- number of records in the system;
- system costs;
- average man-day price in the country;
- annual maintenance costs.

It should be noted that in most cases the system was built by an external company, so the prices of the systems are the result of public tenders. Initially, it was planned to develop a model estimating the costs of building the system, taking into account, for example, GDP, but after the analysis it was decided that the main factor influencing the cost of the system was its advancement. Therefore, calculating the average cost of the system and then converting it using, for example, GDP is not the correct approach. For that reason, a simplified classification of systems depending on the advancement is presented in the further part of the guidelines:

- simple – This mapping system does not take into account all elements, e.g., only telecommunications infrastructure, without information about the services provided and without information about the ranges of mobile networks. There is no interface for uploading files (e.g. files are sent via email). The level of detail of the data is general - such as a square grid;

- medium – This mapping system does not take into account all the elements, e.g., it does not take into account investment plans or demand. It includes the file upload interface, but the limitation is 1 file exchange format;
- advanced – This mapping system takes into account all elements (divided into fixed and mobile networks), i.e., telecommunications infrastructure, services provided, investment plans and demand. It includes an advanced interface for uploading files in several formats. The interface uses advanced data validation rules;
- complex – This mapping system contains similar elements as the advanced system, but it is expanded with elements allowing the collection and visualization of the data, not only pertaining to the telecommunication field but also to other SIP elements, such as passive infrastructure of various industries, like power grids or water supply systems.

Complexity of the system	simple	medium	advanced	complex
Scope of mapping: • infrastructure mapping • service mapping • demand mapping • investment	1-2 items	2-3 items	all	all
A separate model for mobile networks	NO	YES	YES	YES
Form of data transfer: • data transmission, e.g., e-mail data • transfer interface	e-mail	transfer interface	transfer interface	transfer interface
Number of supported data formats	1	1-2 formats	2-3 formats	more than 3
Data detail: • grids • buildings • points • lines	grids	grids/points	points; buildings; lines represented in one or many layers	points; buildings; lines represented in one or many layers
Data presentation portal	NO	NO	YES	YES
Data validation rules	NO	simple	advanced	advanced
Additional tool supporting data preparation	NO	YES	YES	YES
Helpdesk system	NO	YES	YES	YES
Mobile app	NO	NO	YES	YES
The level of detail of the system documentation	low level	medium level	high level	high level

Availability of analysis, reports and maps	NO	NO	YES	YES
Single Information Point with geospatial connections between passive and active infrastructure	NO	NO	YES	YES

During further analysis, correlations between the data were looked for. Undoubtedly, the number of records in the system is correlated with the area of the country and the number of system users. The costs of building the system in different countries were also compared, taking into account their complexity (eg average). This analysis led to the conclusion that the number of developer's man-days results from the quotient of the system costs and the average price of man-days in the country. This is of course a simplified approach, but taking into account the fact of the rapidly changing earnings of programmers (including the COVID-19 pandemic era), it seems to be universal and applicable in any year.

The analyzes also showed that the annual cost of maintaining the system ranges from 1.2% to 2.5% of the total cost of the system. The model assumes the average annual cost of maintaining the system is 1.8% of the system cost.

An annex to these guidelines is a simplified cost calculator for building a broadband mapping system. After determining the complexity of the planned broadband mapping system, the area of the country (in thousands of square kilometers), the number of system users and the average man-day price of a developer in the country (in any currency in any currency - the model result will be calculated for this currency), the user will receive the following information:

- number of man-days of a developer;
- broadband mapping system costs;
- the annual cost of maintaining the system.

The broadband mapping system construction cost calculator view is presented below

Annex to the ITU Guidelines

Establishing or Strengthening National Broadband Mapping Systems

1. Please choose how complicated the broadband mapping system should be:

simple
medium
advanced
complex

2. Please indicate the area of the country (in thousands of km^2)

Area of the country: 150

3. Please indicate the number of users of the broadband mapping system (e.g. telecommunications operators)

Number of users of the system: 100

4. Please indicate the average men-day price of a developer in your country

Average men-day price of a developer:* 300

**It is possible to indicate the amount in any currency - the model result will be calculated for this currency*

Complexity of the system	simple	medium	advanced	complex
Scope of mapping: • infrastructure mapping • service mapping • demand mapping • investment	1-2 items	2-3 items	all	all
A separate model for mobile networks	X	V	V	V
Form of data transfer: • data transmission, e.g. e-mail/data • transfer interface	e-mail	transfer interface	transfer interface	transfer interface
Number of supported data formats	1	1-2 formats	2-3 formats	more than 3
Data detail: • grids • buildings • points • lines	grids	grids/points	points; buildings; lines	points; buildings
Data presentation portal	X	X	V	V
Data validation rules	X	simple	advanced	advanced
Additional tool supporting data preparation	X	V	V	V
Helpdesk system	X	V	V	V
Mobile app	X	X	V	V
The level of detail of the system documentation	low level	medium level	high level	high level
Availability of analyzes, reports	X	X	V	V
Single Information Point with geospatial connections between passive and active infrastructure	X	X	X	V

System cost calculation results

1. Number of men-days of a developer: 1 500
2. Broadband mapping system costs* 450 000 **The model result is calculated for chosen currency*
3. The annual cost of maintaining the system* 8 100 **The model result is calculated for chosen currency*

Annex to the ITU Guidelines

Establishing or Strengthening National Broadband Mapping Systems

1. Please choose how complicated the broadband mapping system should be:

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medium
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Average men-day price of a developer:* 300

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Complexity of the system	simple	medium	advanced	complex
Scope of mapping: • infrastructure mapping • service mapping • demand mapping • investment	1-2 items	2-3 items	all	all
A separate model for mobile networks	X	V	V	V
Form of data transfer: • data transmission, e.g. e-mail/data • transfer interface	e-mail	transfer interface	transfer interface	transfer interface
Number of supported data formats	1	1-2 formats	2-3 formats	more than 3
Data detail: • grids • buildings • points • lines	grids	grids/points	points; buildings; lines	points; buildings
Data presentation portal	X	X	V	V
Data validation rules	X	simple	advanced	advanced
Additional tool supporting data preparation	X	V	V	V
Helpdesk system	X	V	V	V
Mobile app	X	X	V	V
The level of detail of the system documentation	low level	medium level	high level	high level
Availability of analyzes, reports	X	X	V	V
Single Information Point with geospatial connections between passive and active infrastructure	X	X	X	V

System cost calculation results

1. Number of men-days of a developer: 1 500
2. Broadband mapping system costs* 450 000 **The model result is calculated for chosen currency*
3. The annual cost of maintaining the system* 8 100 **The model result is calculated for chosen currency*

As mentioned, it is a simplified model, and therefore universal. Additionally, although the calculator was created based on the experience of countries that decided to implement the system by an external company, it presents information about the number of man-days of a developer, which may be useful for planning human resources for an in-house solution.

It can be seen that this analysis does not take into account the hardware components. In the digital era and cloud solutions, the choice of approach to servers depends on the solutions used in a given organization. In addition, it should be noted that the budgeting chapter is based on the assumption that open source solutions will be used to build the broadband mapping system, therefore no license fees were calculated here.

3.3 Minimum technical and project requirements to implement a broadband mapping system

This chapter is meant to help the reader to set up a project that is tailored to the mandate and objectives of the mapping in the country and the regulatory framework. The two checklists: “Minimum project requirements” and “Minimum technical requirements” provide a brief yet complex description of the key elements that should be considered while establishing the minimum project and technical requirements. Going step by step along the list and ticking the boxes allow to be properly prepared and ready to proceed with a mapping system development.

Checklist 2 – Minimum project requirements

1) Ensure legal compliance
The legal compliance process aims to ensure that venture for introducing the mapping system is following relevant laws. The first step is to establish the source and limits of existing regulations. Should the process identify the shortfalls, gaps or obstacles it allows the decision-makers to address them within adequate legislative actions. The exhaustive guidelines on the legal compliance process are given in Chapter 2 with a concise summary featured in Chapter 2.4, concluded in Checklist 1 – Policy and Regulatory Checklist. Even though that point is introduced at the beginning of the checklist, the legal compliance process is continuous for the mapping system. Delving into the specifics often rises a need for supplementary regulation.
2) Ensure reasonable cost of implementation and maintenance
In the cost estimation process, one should consider the existing mapping systems available in particular countries that already map the existing infrastructure (roads, railways, electrical grids etc.) and services. For instance, INSPIRE geoportal is available at the EU member states level, providing spatial data on 34 different themes to facilitate the exchange of data and improve decision making. In particular, the concept of the Single Information Point may turn out to be a significant facilitation and efficiency factor across sectors to be considered by public administrators. The Single Information Point concept has already proven itself for every type of mapping mainly thanks to the cost reduction

approach. In some countries that have implemented SIP in regard to telecommunication infrastructure, there are actions taken to merge infrastructure and service mapping as an integrated entity. It is as well worth noticing that at the EU level, some stakeholders argue that service mapping should be included in the SIP. The chapter devoted to budgeting provides further explanation of assumptions that should be taken into account, however not before establishing the scope of mapping exercise (see point 6 of that checklist). In regard to maintenance, it is advisable to aim for knowledge transfer whenever an external party – the contractor is involved. The crucial part is maintaining complete and consistent documentation.
3) <u>Establish a project governance</u>
Project governance is considered a top success factor[50]. The Project Management Institute has it all covered in detail, however, the key points to focus on while establishing the project governance are: a) Defining roles and responsibilities, in particular, highlighting and appointing the leader. Domains to be covered in governance are management, system architecture and design, system implementation, GIS (Geographic Information Systems), communication with service providers (network operators), communication with governing bodies, communication with state administration units. b) Stakeholder engagement and communication – project board or steering group with regular meetings and minutes (reporting with emphasis on key points - milestones statuses). c) Setting up a risk management process. Risk management itself is a broad subject, however its foundation is identifying, monitoring, and managing potential risks and their negative impacts on a project. It is always worth to have a brainstorm for identifying and writing down a risk set, ideas on how to avoid and mitigate them, assess their influence on a project and then just have them monitored (e.g., include in reporting). d) Setting up a change management process. Change is inevitable but often very beneficial. In a minimal yet sufficient form it is advisable to establish just a simple guide beginning with: – the change request form including its description and point of the request, – description (e.g., in a form of a diagram) of consideration and decision process. For this type of venture, it must be stressed that formal establishment of the team at the highest possible level is highly advisable. Along with a ministry-level project sponsor or owner, that gives the team proper legitimacy and builds an awareness of the project's importance at the government level.
4) <u>Create a roadmap for implementation</u>
The roadmap should act as a means of communicating of the project's strategic objectives to stakeholders, ensuring that their expectations are addressed and executed accordingly as well as an

[50] Alie, S. S. (2015). Project governance: #1 critical success factor. Paper presented at PMI® Global Congress 2015—North America, Orlando, FL. Newtown Square, PA: Project Management Institute.

ongoing reference guide to keep everybody on track with the project's progress. That is the key element of keeping the project team on track and meeting deadlines. While elaborating the roadmap the key element of operators' involvement should be considered. Good practices show that a complementary roadmap should consist of:

a) The project's scope and objectives: The big picture of what is desired to achieve by the end of the project.
b) Deliverables: The output or the end results of a project's activities.
c) Resources: Indicate how many personnel and resources are assigned to this venture. That information is a key element for more detailed project planning and e.g., allows for budget planning and control, resources allocation as well as scheduling. It is worth mentioning that the operators are significant assets in such projects and can provide resources depending on their incentives.
d) Schedule: The high-level, key points, processes and milestones focused, chronological order in which project activities are done.
e) Milestones: The events on the timeline that indicate achievement of the objective or completion of an important process. In general, reaching a milestone implies a change in the project's phase.
f) Risks: The challenges that may cause the project to veer off schedule or budget.

5) Design a centralized reporting and presentation points

The BEREC recommendations as well as the recent report "*The role of State Aid for the rapid deployment of broadband networks in the EU"* published on the 10th of September 2020 by the European Commission all underline the need for a centralized point of reporting and presentation of services availability. The centralization was introduced in BCRD introducing a Single Information Point and the approach is worth following.

6) Define the scope of the mapping exercise

The venture of building a complex mapping system should be planned thoroughly to avoid a pitfall of incomplete implementation. It is advisable to begin with addressing the most important needs emerging from sustainable and optimal network development.

To facilitate the process of project's scope definition one should consider three main division areas, answering a question of whether it is desirable to map:

a) infrastructure and/or services
b) fixed and/or mobile networks
c) completed investments (existing infrastructure and/or services), investments in progress and/or planned investments.

It is worth noting that covering each of the above areas in the mapping project will require appropriate and considerable expenditure of time and money.

The key product arising from this checkpoint should be a dataset that will be subject to acquisition from reporting parties (i.e., operators), required to fulfil the desired scope.

7) Define a set of functionalities

One should define a closed catalogue of functionalities while being a prudent realist with a scope. The shared experience in mapping systems development proves that such endeavour is never a finished process, and it is strongly recommended to start with complete but minimal scope.

The minimum functionalities are:

a) Data submission – enable form-based reporting for small scale reporting entities (network operators/service providers) as well as a mass import for large ones. For a minimal functionality implementation one can introduce a tabular file submission functionality for all reporting entities.
b) Reporting and aggregation of raw data – lists, summaries facilitating data interpretation, drawing conclusions and supporting the decision-making process. Both functionalities are given in one point as they are related closely in regards of system's architecture and technical implementation. Both reporting and aggregation should be synergized by design.
c) Visualization – e.g., web browser-accessible, GIS-based presentation of assets defined in point 4 of this checklist, facilitating in particular regional coordinate system, such as ETRS89 as well as map scales (representative fraction or graphic scale bar).
d) Searching and filtering – e.g., including geocode services, layers names and contents, attributes, points of interest, addresses.
e) Export capabilities of filtered data or search results.

8) Define availability requirements

Availability levels can be regarded in two main aspects:

a) Conventional classification of High Availability, Continuous Operations and Continuous Availability.
b) Classification of nines derived from a percentage-expressed quotient of the time of system's availability to the time taken into consideration. Usually, the time is considered on a daily, weekly, monthly, quarterly or yearly basis – long enough to have at least one downtime (system's unavailability) incident occurrence. In practice, the system's availability is concerned at level 90% and above. That is why it is being called "class of nines".

The convention of High Availability means that the system is available during specified operating hours without any unplanned downtimes. The Continuous Operations assumes that the system is available 24 hours a day, 7 days a week without any unplanned downtimes. At last, the Continuous Availability poses requirement of the system's availability 24 hours a day, 7 days a week without any downtimes, neither planned nor unplanned.

The following table shows the translation from an example availability percentage to the corresponding amount of time a system would be unavailable:

	Allowed downtime		
Availability	Per year	Per month	Per week
90% (one nine)	35d 12h 00’ 00”	3d 01h 00’ 00”	16h 48’ 00”
99% (two nines)	3d 15h 36’ 00”	0d 07h 18’ 0”	01h 40’ 48”
99.5% (two nines five)	1d 19h 48’ 00”	0d 03h 39’ 0”	00h 50’ 24”
99.9% (three nines)	0d 08h 45’ 36”	0d 00h 43’ 48”	00h 10’ 05”
99.95% (three nines five)	0d 04h 22’ 48”	0d 00h 21’ 54”	00h 05’ 02”
99.99% (four nines)	0d 00h 52’ 33”	0d 00h 04’ 23”	00h 01’ 00”
99.995% (four nines five)	0d 00h 26’ 16”	0d 00h 02’ 11”	00h 00’ 30”
99.999% (five nines)	0d 00h 05’ 15”	0d 00h 00’ 26”	00h 00’ 06”

The requirements of the availability level should be set in an affordable way considering the budget of the projects. There is no universal formula to assess the cost of a given availability level, but a good estimate is that the cost increase resulting from “adding one nine” could be close to exponential. Summarising, the four factors should be considered in the availability definition process:

a) Legal requirements for public services if existent in each country.
b) Security requirements and recommendations. The engagement of an expert in this field is advisable. Nevertheless, the reference information and help can be gained from:
   i) An RFC2350[51]-compliant state Computer Security Incident Response Teams (CSIRT[52]).
   ii) Open Web Application Security Project (OWASP[53]) beginning with its Top Ten Web Application Security Risks, Software Assurance Maturity Model, Testing Guide and many more.
   iii) Center for Internet Security (CIS[54]) provides prioritized & simplified best practices within *CIS Controls* solution as well as vendor-neutral configuration guides within *CIS Benchmarks* along with system conformance to CIS Benchmarks assessment tools.
c) Risk and cost analysis. The experiences of the Google Site Reliability Engineering team shared on dedicated web site[55] can help build an informed approach to the problem of

[51] RFC 2350 document Expectations for Computer Security Incident Response: https://datatracker.ietf.org/doc/html/rfc2350

[52] CSIRTs by Country - Interactive Map for Europe and listing worldwide: https://www.enisa.europa.eu/topics/csirts-in-europe/csirt-inventory/certs-by-country-interactive-map

[53] Open Web Application Security Project’s Web site: https://owasp.org

[54] Center for Internet Security Web site: https://www.cisecurity.org

[55] Google Site Reliability Engineering https://sre.google

availability cost and risk assessment. In particular, the key notes are given in Chapter 3 of Site Reliability Engineering[56] - Embracing Risk. d) Best practices. Regardless of the approach to establishing the requirements for the system's availability, either in-house or outsourced, an experienced specialist or best practices reference will greatly help to form a set of requirements[57].
9) Account for technology-neutral approach
The pragmatic regard is that while establishing requirements one should have in mind that every current technology evolves, and a technology-neutral approach is critical to encourage innovation and efficiency in broadband services. Thus, the mapping system implementation should enable for indicating range and quality of service in general groups such as fixed, mobile networks or small-area wireless access points, satellite and others.
10) Account for population density
Considering the recent preparations for Recovery and Resilience Facility – RRF at the EU level and progress in the digitization of the countries, an emerging need of synergizing broadband services availability provided by both is arising: mobile and fixed networks with special regards to public facilities. The population density provides fundamental information for planning on the appropriate type of network (fixed vs. mobile) as well as desired BTS density (number and location of new BTS).
11) Define a catalogue of specific facilities to account for
One of the main applications of mapping systems is network development planning. Depending on the level of telecommunication network development in a particular country as well as the source of funds it may be crucial to take into account specific facilities, schools, hospitals, and other public institutions, or even businesses per type and size if a database is available, to name a few.
OUTPUT: Establishment of a <u>project document</u> and <u>roadmap for implementation</u> and include operators and other key stakeholders

Checklist 3 – Minimum technical requirements

1) <u>IT Resources</u>
This item can be judged easily by the tech team that is able to assess the availability of required resources given that they are acquainted with the requirements established in points covered within Checklist 2, i.e., 5 - centralized reporting and presentation points, 6 - the scope of the mapping exercise, 7 - a set of functionalities, 8 - availability requirements as well as taking into account cost reasoning

56 B. Beyer, C. Jones, J. Petoff, N.R. Murphy, Site Reliability Engineering, Chapter 3 https://sre.google/sre-book/embracing-risk/. The book is freely available online (https://sre.google/sre-book) as well as in print.

57 Andre B. Bondi. 2007. Best Practices for Writing and Managing Performance, Reliability, and Availability Requirements. In Proceedings of the Sixth Working IEEE/IFIP Conference on Software Architecture (WICSA '07). IEEE Computer Society, USA, 42. DOI: https://doi.org/10.1109/WICSA.2007.19

(point 2 of Checklist 2). On that basis, one can decide whether to implement the mapping system using an on-premises model or a cloud environment.

Regarding implementation, a justified assumption must be made that none of any government bodies have the resources competent to design and implement a mapping system solution. Thus, regarding cost reasoning, it is advisable to seek for partnership with national technical institutes, universities or other dedicated national companies or competence centres if existent. Regardless of the choice of the entity responsible for design and development, the project team should elaborate a tender-like document incorporating the requirements posed for a mapping system implementation in the preparation stage.

A very cost-efficient and competence building approach is to involve own personnel within a mapping system team in a maintenance stage. Although a technical aspect of dealing with identified errors and vulnerabilities are usually within a domain of a specialized entity (contractor), other areas such as helpdesk, users assistance, change requests, requests for features, public records errors can be covered by a dedicated mapping system team personnel. The added value gained by such approach is the competence and expertise of the mapping system team built thanks to the experience and knowledge gained in active participation of mapping system's life cycle.

2) Compliance with common technical standards

The general advice proven to keep the maintenance cost at a reasonable level is to rely on open standards. Even though the initial analysis can show that using proprietary architecture and software solutions yield a promising advantage of shortening the implementation time and keeping the maintenance cost at acceptable level, one should be aware of a potential pitfall of such solution. If the implementation based on proprietary software and architecture is not compliant with common technical standards, it is most likely that integrating with other systems e.g., operators', government entities' will be difficult or inefficient if not impossible. The other important factors are potential limitations or additional mark-ups to the cost of development, introduction of new functionalities, sometimes broadening a scope of data, etc.

Open Source software does not mean free of cost, and often represents a higher initial expense compared to proprietary technology, due to the need for tailored developments, thoroughly planned and tested upgrade operations involving not only system administrators but also software developers and depends significantly on the collection volume of geo-referenced digital information. Hence a mapping system is not an off-the-shelf product. In practice it will be built with the use of readily available modules, components and software libraries. The most common Open Source set of elements available to use for building a mapping system is provided within the *Open Source Geospatial Foundation* (OSGeo)[58] including MapServer, GeoServer, PostGis, QGIS etc.

Nevertheless, while considering software standards, one must ensure compliance with the standard formats recommended by the OGC[59] (WFS, WMS, etc.).

The final decision upon software and system flavour depends on the scale and evolution plans for a Mapping System (commercially known as *GIS Enterprise System*) that is to be implemented. For a small-scale system with no expansion plans in the next 5 years using a proprietary software and architecture while ensuring compliance with common technical standards states as a justified approach. If there is

[58] The Open Source Geospatial Foundation web site: https://www.osgeo.org

[59] Open Geospatial Consortium standards and resources web site is available at https://www.ogc.org/standards

any prediction that the solution may expand, open standards are always a better choice regarding competitiveness in the specialists and contractors selection processes. The general rule of thumb is that compliance with common technical standards greatly limits a burden with data interchange, systems integration as well as vendor lock-in prevention. With that in mind, a proprietary software should be allowed only at full awareness and agreement on future cost and/or license limitations.
3) Include accessibility requirements
The best reference in the field of web-enabled or web-based solutions' accessibility is Web Content Accessibility Guidelines (WCAG)[60], developed through W3C process[61] in cooperation with individuals and organizations around the world, with a goal of providing a single shared standard for web content accessibility that meets the needs of individuals, organizations, and governments internationally. The WCAG documents explain how to make web content more accessible to people with disabilities. Accessibility requirements can also be identified in a process of establishing the availability requirements (see point 8 of Checklist 2). What is worth pointing out is that by design the system implementation should not pose difficulties in regard to reporting and gaining information. Easy-to-use systems save a great amount of time, build confidence and are less prone to mistakes which in effect causes fewer perturbations with data correction.
4) State registers integration
It is important to note that every country has its own competent bodies regarding administrative, geographic and statistical records. The general idea of the technical requirement baseline is to rely on those records and avoid creating an additional data set. Assess reference registers' reliance and possible communication/integration means. A special example of using an existing register is Single Information Point implemented in the EU countries as a result of BCRD. Other examples are National Mapping, Cadastre and Land Registry Authorities affiliated under EuroGeographics[62].
5) IT Environment scalability or overprovisioning
In reference to IT Resources, one should either provide scalability of an IT Environment or assess the resources with the overprovisioning approach, accounting for the peak load of the system.
6) Strict data formats and validation
Service mapping relies on collecting data from many parties. Setting a strict data format enables comparability and data validation and simplifies error tracking. The guidelines provided in chapter 3.1.1. (Project framework and objectives) give ready-to-use examples of data types as well as their validation prerequisites. On the other hand, specifying the output data format enables public information sharing and systems integration.
7) Accountability

60 Web Content Accessibility Guidelines (WCAG) Overview, https://www.w3.org/WAI/standards-guidelines/wcag/

61 W3C Process for Developing Standards, https://www.w3.org/WAI/standards-guidelines/w3c-process/

62 EuroGeographics web site: https://eurogeographics.org

The basic factor of introducing accountability is to implement and keep a record of changes yielding information of what and by whom was reported, modified and removed. In regards of removal, it is advisable to handle the delete functionality either by marking a given entity as deleted without erasing it or keeping a conclusive record of what has been removed (e.g., keeping at least a metadata for large, storage-consuming objects that were being removed). For the context, it is not uncommon to discover an error in submitted data and considering its sheer volume, determining a source of an error will be infeasible without a proper register. On the other hand, such information is valuable from an audit point of view.
8) Data collection timelines
While designing a Mapping System data model it is advisable to account for every status update after each reporting interval. The system should allow for presentation of the current state of services and/or infrastructure as well as historical state for comparison. If possible, it is desirable to collect data regarding planned investments and provide distinction for ongoing, planned as well as statuses of the investments.
OUTPUT: technical specifications for foreseen mapping system (either for internal use or for tender specifications)

4. Project management

Successful implementation and execution of the broadband mapping process requires deciding the best ways to combine regulatory and technical requirements after a thorough assessment and analysis. The project management approach may allow the identification of some critical points for successful methodology choice for the mapping process that will satisfy regulatory environment and technical possibilities. It is worth noting that there is no one-fits-all approach and methodology should be adapted to national and organizational particularities.

4.1 Common challenges and solutions

Data quality

The broadband mapping process requires a collection of large amounts of data from a number of reporting entities. This poses data quality challenges, one due to large amounts of data, two – due to various types of data being collected, i.e., numerical, geographical coordinates, varchar etc., and three – due to the fact that data is being collected from various sources, private and public, which may have different data quality available to them.

The most common issues encountered with data quality are:

- Duplicated data – multiple data occurrences frequently encountered due to data volume and numerous data sources being used
- Incomplete data – missing data due to the system or human-made errors

- Inconsistent formats – differing formats of the same category of data i.e., date format may prevent successful data processing
- Errors arising from human error – biggest obstacle to data quality, very difficult to process
- Data timeliness – issue arising from collecting data from numerous sources, which may themselves use data valid for varying times

Each data quality challenge requires a different approach to combatting it. For example, there are dedicated tools allowing data cleaning, including deduplication. In case of incomplete data, some data, such as address data, may be filled in by alternative sources, meaning using multiple public sources available from geodetic and cartographic public offices or local governments. Inconsistent formats require the data collection body to use tools compatible with various formats, which may require the tool to have built-in mechanisms to automatically recognise numerous data formats. Date format is an example of the type of data frequently provided in varying formats and therefore often requiring additional attention while being processed and analysed. Other ways to minimise data errors are applying automation tools, AI-based solutions and data cross-checking techniques.

Data confidentiality

Data collected as part of the broadband mapping process usually have varying levels of confidentiality. Data regarding infrastructure details and services provided often constitutes operator's confidential data and is only shared due to regulatory reasons. It is crucial for the data collection systems to provide a secure reporting environment, which requires taking into account such areas as access levels, cybersecurity or user identification process.

Data confidentiality is particularly important to regard when sharing the obtained data in a safe way. There is a number of solutions that can be applied to solve this issue, starting with appropriate data marking within the system, through data access management to relevant data user training within the data collecting body. Data aggregation levels might be considered in relation to sharing local specific data. Even aggregated data may prove to be useful for operators while planning their investments, so this is not only about data visualisation. A rigid anonymization process will ensure safe data sharing and will support infrastructure development.

Data sources

The broadband mapping process requires combining data from various sources and of various nature. Some data sources are public, some private, they may have various formats and systems requirements to be readable. Various data providers also have differing data detail levels available to them. All these have to be taken into consideration when collecting and processing data for broadband mapping.

It is advised to use publicly available data as much as possible. Frequently, address and location-related data is collected by governmental bodies, and even if not made publicly available, they might be shared between governmental bodies. Broadband mapping requires a lot of data to be collected, so it is important to use already available data not to duplicate data sources, which may increase data error rate, and to reduce data load to be obtained from telecommunication operators.

Reporting types

When considering broadband mapping, one should design a system that takes into account four types of reporting: infrastructure, demand, supply and investment mapping. Each of these requires a collection of different types of data with varying degrees of detail and coming from various sources. When laying out the broadband mapping process it is important to note, which data is essential and could be the best to fulfil each of the above types of reporting.

The challenge in this area is to apply the right type of data to each reporting type and also efficient processing of collected data to be able to present it in a clear form. When presenting, usually in a form of a map, the data governing body has to take into account confidentiality issues. These may be tackled by appropriate aggregation techniques. For example, infrastructure reporting will require the provision of data at the household level such as type of cable available (medium and technology), internet speeds provided via fixed and mobile networks, type of network ownership and more, however, this type of reporting will not require such data as planned investments or price of services.

Regulation

The broadband mapping process requires a clear definition of what data is necessary to be collected to successfully fulfil the process. Obtaining publicly available data does not pose any major accessibility issues, however, it is privately owned data that present the main challenge. Frequently, data needed for effective broadband mapping is confidential and private operators will not share them on a voluntary basis.

The solution is governmental regulation that would clearly state, what data, to what detail and with what frequency has to be provided by the operators to the data collecting body. State-level regulation is the most effective way to obtain such data, however, with building trust between governing bodies and private sectors, some additional, non-compulsory data may be obtained.

When designing regulation for data reporting, one has to consider such data aspects as:

- type of data to be collected;
- level of detail of data (i.e., to the household level);
- frequency of data collection (once a year, twice a year, quarterly, on a rolling basis);
- list of legal entities that are obliged to provide data, meaning network owners and providers such as private operators, local governments or cooperatives.

Dispute Settlement Body

To maximize the benefits of broadband mapping systems in a specific country, not only should a single information point be established, but also a dispute settlement body (DSB). The role of the DSB, as mentioned in chapter two and assigned to the NRA, would be critical in ensuring that all parties involved would abide by the rules and legal framework under which the broadband mapping systems would operate, both by setting general references when rules and procedures may raise questions and by playing an active role as the mechanisms that would ensure the resolution of any litigation.

Stakeholder costs

Regular data provision might constitute a significant burden for the institutions that have to provide the data. Telecommunication providers include small businesses providing broadband networks in a very limited, small area (even as small and one cooperative), as well as nationwide broadband providers. The varying size of broadband providers pose the following challenges:

- varying level of detail of data available within an organisation;
- level of automation of data management within an organisation (from paper-based to automated data warehouses);
- varying formats of data storage within an organisation;

- varying skillset for data management within an organisation.

The above-mentioned challenges have to be taken into account when designing the data reporting tool, which should accept various data format loads (i.e., csv, xls, pdf, via API etc.). It should also accommodate for automatic, semi-automatic and manual reporting.

Due to varying sizes of reporting bodies, it might be considered what data is compulsory for all entities to report and what data should only be reported by the largest telecommunication operators.

4.2 General success factors

Stakeholder involvement

For any system to work efficiently, it is not enough to just put requirements (even just legal) onto parties involved. In order to ensure stakeholders' involvement, which may contribute to the quality of data provided, it is necessary to take action to secure commitment to the process. This may be achieved through the following (not an exhaustive list):

- clear communication about why the data is collected;
- providing education about the goals and benefits that will be achieved by broadband mapping;
- providing visible outcomes of gathered data, i.e., by the provision of reports and publicly available maps;
- disclosing gathered data on request, given the confidentiality clauses.

The more purpose of broadband mapping is understood by stakeholders and the more involved they are in the process, the better quality of data they are likely to obtain. In order to achieve this, it is worthwhile engaging them in consultations as early as when the broadband mapping process is being designed. This may give a unique insight into what is available to be used by the process as well as may strongly engage stakeholders as they will share emotional ownership of the whole project and therefore provide solid data to feed the system in the future. Also providing tools, platforms and information that may be then used and applied by telecommunication operators in their private businesses is likely to stimulate their involvement.

Clear definition on types of mapping

A clear definition of types of mapping is needed for structured and clear identification of the type of data to be collected. Each type of mapping requires a different set of data to be collected to be provided efficiently. Data requirements have to be communicated clearly to data providers, so there is no ambiguity in data reporting and further in processing and compilation of data from multiple sources and providers. Four main types of mapping include:

- Infrastructure – i.e., telecommunication infrastructure, other relevant infrastructure (e.g., energy network), construction works
- Investment – i.e., private, funded, planned, completed
- Service – i.e., bandwidth and access technologies, provider, data volume usage
- Demand – i.e., demand for bandwidth, quality of service, willingness to pay

Although the four different types of mapping systems presented above can be integrated into one single broadband mapping system platform, these guidelines try to explain each type of mapping system separately to provide clear and distinctive information for the ease of readers. Without this clear distinction, data obtained might not be comparable and, in consequence, not fully represent the situation in the market.

Internal sponsorship

Successful execution of the broadband mapping process requires solid internal sponsorship within the data collecting body. As the project requires the involvement of a number of governmental bodies, as well as private organisations, it has to have a high priority within the leading organisation. High-level representation is required both, with regards to internal project management of the data collecting body, to ensure efficient project execution, as well as with regards to external representation, as the data collecting body has to cooperate with other public entities and with private sectors.

Efficient reporting tool

Considering that the data collecting body has to obtain data from multiple organisations (numbers may go as high as a few thousands legal entities), it is vital to use an efficient reporting tool. Ideally, there should be one tool available to all reporting bodies that accept various data formats and has reporting options tailored for smaller and larger organisations. Tools using data bus solutions might be considered for efficient data integration. It has to be noted that significant IT investment is required in order to provide an efficient and reliable tool for reporting.

The following aspects should be taken into account:

- ability to report data in automatic, semi-automatic and manual manner;
- possibility to load data in numerous formats (i.e., csv, pdf, via API etc.);
- simplified reporting for small operators;
- initial data quality check mechanisms within the tool.

Reporting support

Broadband mapping process reporting has a tendency to be a rather complicated procedure, especially for smaller data providers. This is due to the complexity of data provided, varying legal requirements regarding various legal entities and the actual data volume that has to be reported.

In order to facilitate efficient reporting, the data collection body should provide support to the reporting organisations. Recognised channels of reporting support include an openly available instruction manual, phone help desk and dedicated online Open Source Ticket Request System (OTRS). Other solutions might include video instruction manuals, training provided by the data collection body or online assistants using AI applications.

4.3 Long term sustainability

Designing and implementing an efficient broadband mapping system is a process that requires a lot of financial, time and people investment on part of the governmental body. However, it has to be kept in mind that the new system, once introduced at a great expense, requires long term attention in order to be useful and relevant over the coming years. There are some important aspects that need attention to ensure the long-term sustainability of the broadband mapping process.

Investment in reporting tools

Continuous investment in reporting tools is required to maintain their operating efficiency in a constantly developing IT solutions world. Reporting tools have to be up-to-date with current technologies, IT scripts and programme versions in order to read and process provided data correctly. As data providers update their internal data warehouses, the reporting tool has to reflect that in order to be able to process data supplied.

Collection tool adaptability and development

This point is closely linked to the previous one. As technologies change, the reporting tool has to be developed and adapted to new requirements on regular basis.

In this area, compatibility aspects have to be taken into account as well. Broadband mapping is a long term, cyclical process, which may be enriched by analysing current data in combination with past data and therefore giving a basis for trend analyses. This may only be possible, if the reporting tool is compatible with its previous versions or if developing a new version of the tool included transcription of old data into new formats.

Visualisation tools

The broadband mapping may gain long term support through the development of visualisation tools that can be used by individual consumers as well as data providers. Visualisation tools usually constitute maps and online platforms, which may act as another communication link between consumers and service providers.

Clean visualisation of telecommunication data may also promote efficient network development in the future as it can provide detailed information about the existing network as well as indicate areas, where such network is in demand. Open-source data available from public sources may be successfully combined with data obtained as a part of the broadband mapping process and visualised after required anonymization.

Tools' promotion

Investing in the development of data-rich and individual relevant tools requires taking action to promote the usage of the said tools. The public has to be aware of the fact that those platforms are available to them.

The data collecting body that oversees the broadband mapping process and develops platforms and tools for private individuals and for businesses should plan out marketing and promotional campaigns, perhaps including press releases, dedicated training workshops and other activities to reach the target audience for the developed solutions.

Data application

Broadband mapping requires the collection of a wide range of data coming from multiple public and private sources. This provides an opportunity to transform such data into useful information. Examples include:

- creation of a platform to plan investments – platform presenting and visualising, depending on the adopted approach, existing network, services provided, perhaps allowing simple calculation of potential investment in a chosen area;
- creation of a tool for verification of services available – a tool presenting services available at the level of household, combining data obtained from all reporting operators;

- creation of a tool allowing to report services demand – a tool with the functionality available to individual consumers to easily report demand for a service at an address;
- creation of a platform acting as a single telecommunication information point – platform presenting information on the formal and legal side of the investment (including the terms and conditions of investment), the current condition of the infrastructure, its location, access conditions and the planned expansion.

Open-source solutions

In line with the open data strategy applied across the EU, it is advised that the reporting tool uses open-source solutions. This is not mandatory, but such approach should make the long-term sustainability of the reporting tool more viable. This is with regard to the cost of maintenance of the tool itself, as well as obtaining specialists that could maintain the tool itself.

The most common way of presenting broadband mapping data is visualising the data in form of a map, i.e., Ireland's High Speed Broadband Map[63] or France's Carte Des Déploiements Fibre[64].

Change management

In order to ensure the long-term sustainability of the broadband mapping process, the governing body should develop a long-term strategy regarding change management. This is with regard to changing market conditions, changing data sets to be reported (i.e., internet speeds' increase over the years), changing IT requirements and changing legal circumstances.

Due to the fact that this process is a complex one, it needs to be managed with a long-term view. Implementation of any adjustments and updates to the process will always involve many stakeholders, therefore has to be planned carefully and with an appropriate amount of time for every party to adjust.

Talent management

The complex and wide impact of the broadband mapping process also means that it has to be managed and executed by a highly qualified team. As it is important to invest in efficient reporting and processing tools, it is also essential to create a team that will have the skills to execute the process correctly and efficiently and will be able to carry out numerous applications and outcomes of the process. Competencies and skills that should be covered by the internal team members should include deep and thorough knowledge of telecommunication markets, legal regulations relating to the telecommunication market, IT skills related to specific tools used in the broadband mapping process, analytical abilities and data management skills.

In long term, internal sponsors of the project should take part in creating a nurturing environment for a stable and knowledgeable team that could efficiently support the process.

5. Conclusion

63 https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=99c229dc4c414971afc50818b25337ef

64 https://cartefibre.arcep.fr/index.html?lng=2.3&lat=46&zoom=6.5&mode=normal&legende=true&filter=true&trimestre=2021T2

Despite the positive impacts of broadband mapping systems networks, international reference for their set up has been lacking. Therefore, these ITU guidelines present themselves as a readily implementable document to try to fill such gaps by offering simple but comprehensive reference indications covering regulatory, technical and project management aspects in the field of broadband mapping. First, the legal basis of the EU and their harmonization efforts in building broadband mapping systems were introduced as good practices of the regulatory framework. Second, technical requirements and specifications in setting up a broadband mapping system were given with various steps to follow. Lastly, critical points and challenges within project management aspects were identified from the perspective of National Regulatory Authorities (NRAs) or other equivalent authorities for successful methodological choices for the mapping process.

The European Region has been the only region across the globe in which a substantial degree of harmonization in the field of broadband mapping systems has taken place. Regulatory developments in the EU originate from the need of strategic policy drivers to build the Digital Single Market in Europe. Since the first Digital Agenda for Europe (DAE) identified the "lack of investments" and of "low take-up of broadband" as main challenges in the European region, building broadband mapping systems gained more attention. In 2016, the updated 2010 DAE strategy "Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society" clearly indicated mapping as a key tool to give precise information on market failures, connectivity gaps to the public authorities, and to support their decision making with evidence. As harmonized data-driven approach to public administration has been emphasized in the above-mentioned EU agenda, EU digital strategies and legislation have emerged over the past years and constituted the regulatory setting for broadband mapping systems and their use cases.

Chapter 2 introduces three main sets of EU legislation on broadband mapping. First, the EU Guidelines on State Aid for Broadband in 2013 aimed at providing clarity to unlock the investments needed to achieve the policy objectives set by the DAE back in 2010, whilst maintaining consistent compliance with EU competition law. These EU Guidelines establish three major principles for the application of state aid rules in broadband networks, highlighting the need for broadband mapping systems to public administrations across the EU, which are (i) the mapping and analysis of coverage entailing an assessment of service availability, (ii) the mapping and analysis of the quality of networks to determine which areas should be prioritized, and (iii) the identification of investment plans in a given geographical area. Second, in 2014, the Broadband Cost Reduction Directive (BCRD) of the European Commission finalized a foundational piece of legislation for creating information systems collecting geo-referenced data of the infrastructure and all network industries at the national level. Particularly, the BCRD offers the legal basis of establishing a SIP at the national level that would make the minimum information on the existing infrastructure available. Not only does the BCRD set the important principle of a data-driven approach to regulation of network industries, including telecommunications, it also calls for the creation of enabling environment for collaborative practices among different types of network operators to both save cost and avoid administrative redundancy. Lastly, following the previous legislation, in 2018, European Electronic Communications Code (EECC) established requirements for NRAs and other competent authorities to conduct geographical surveys of electronic communications, which consists of mapping total service availability. The EECC also endowed the Body of European Regulators for Electronic Communications (BEREC) to play a significant role in coordinating and harmonizing the position of several NRAs.

These three main EU regulations have evolved to even more sound and robust legislative frameworks, supporting the operations of NRA whilst preserving balanced market conditions and innovation. To summarize a few remarkable developments, the European Commission recommended the Member States consolidate a mapping system that brings together mapping of passive infrastructure and mapping infrastructure and available services in line with the EU regulatory framework. Through the implementation process of BCRD, the European Commission also put their stance towards strengthening infrastructure and investment mapping. In addition, BEREC Core Guidelines provide detailed information concerning the implementation of EECC and support Member States to fulfil their obligation in mapping service availability in both fixed and mobile markets complying with the EU Guidelines on State aid for broadband. Although such European experience offers guidance revealing the key action areas of creating a broadband mapping system, the EU regulatory framework also highlighted that each country should find suitable solutions considering their country-specific contexts. Finally, a policy and regulatory checklist was given to offer guidance on the required actions from a strategic, policy and regulatory standpoint, and to help achieve national objectives of the broadband mapping system, as summarised below.

First checklist - Policy and Regulatory Checklist
1. Define the rationale and objectives for broadband mapping at the country level
2. Identify relevant institutions and stakeholders and their roles
3. Include the rationale and mandate in strategic documents
4. Provide a platform for long term engagement and consultation with all stakeholders
5. Analyse the legislative framework and propose reform as needed
6. Ensure the NRA has the necessary mandate, budget and human resources to implement the provisions of the law
7. Define common technical definitions and methods to carry out the broadband mapping exercise
8. Establish a dispute settlement mechanism fit for the national context
9. Adjust the objectives and legislative/regulatory framework every 4-5 years to ensure they are fit for purpose
OUTPUT: review of enabling environment and recommendations and/or report describing existing boundaries of the regulatory framework for broadband mapping

These guidelines have shown how the European experience in creating usable digital maps to report on the national broadband landscape for policymakers and informed citizens is vast and varied. Needless to say, such a body of knowledge, composed of clear and proactive, unifying and harmonizing EU regulations, would not be utilized to the finest potential use if proper project management consisted of technical requirements was not in place. In chapter 3 and 4 of this paper, a detailed explanation was given on the project setup and technical requirements, together with the strategies for correct project management in this field.

In summary, clear unidirectional steps should be followed: starting from the acquisition of reliable broadband data sources on what already exists (i) to its actual use, i.e., to reduce costs, and to localize gap areas (ii) for market intervention (iii) both for new telco infrastructures (iv) as well as for new investment opportunities (v). The sources of such data are varied: from the private sector to public authorities, passing by the citizen themselves (when it comes to the investment and the service mapping systems). Such activity is factored with the risk of overestimating the quality of the service or the unwillingness of stakeholders to share the data. Legal obligations or financial penalties coupled with quality check measurements for the reliability of the data can be considered to solve those issues.

Beyond the differentiations of the data requested depending on the type of broadband mapping system one wants to develop, the data workflow also entails activities concerning the choice of the data format, the data supply process and the frequency for which data are updated and supplied.

For what concerns the project design, which is another fundamental aspect of an effective implementation of a broadband mapping system, it is necessary to run a stakeholder analysis to understand the parties that ought a place in this table. Following what other European countries have done so far, it is most commonly considered that the broadband mapping system stakeholder analysis will produce a list of 9 actors to engage with, i.e., the National Regulatory Agency (NRA) (i), the policymakers represented by the government (ii), the private sector represented by the telco operators (iii), the internet providers (iv) and the mobile operators (v). On the other hand, the public authorities are represented by local authorities (vi), the State owners of cadastral data (vii) and of address databases (viii). Finally, the last actor are the end-users or simply referred to costumers (ix).

When designing the project, this paper describes the four different phases that are necessary in this field. The first phase, pertaining to the information phase, allows the stakeholders to understand the project and its objective; the second phase pertains to the consultation, where stakeholders are encouraged to provide comments and contributions to better leverage their needs; the third phase entails the actual involvement of the interested parties to ensure that their needs are well integrated within the scope and action plan of the project. Finally, the last stage is the collaboration phase, where interested parties will utilize the early version of the platform to validate its functioning.

In this same chapter, another element was described as essential component for a successful project design: the choice of the system implementation formula by firstly assessing the existing regulatory environment (i), secondly by defining the aimed scope for the creation of a broadband mapping system (ii), and lastly, the financial budget and human-resources workforce needed depending on the size of the country (iii).

Having achieved the desired governance and framework in which to operate, there are three paths to follow to develop any mapping system: the first possible approach is to decide to outsource and externalize the development of the digital maps (defined as outsourced solution). Such approach entails the certainty of securing the deliverable from the third-party company assigned to develop the map as well as limiting the additional costs associated with new staff personnel within the organization. On the other hand, however, this option risks being costlier and lacks the flexibility associated with internal management of the project or the grasping of the nuances and reiteration that any project may have in the different development phases. The second solution, described as in-house solution, presents the advantage of being more flexible, utilizing a lower financial budget and allowing for continuous reflection of the digital maps if any details or new information are added. However, for the effectiveness of an in-house solution, additional IT staff and capabilities may be required together with the creation of a multidisciplinary team for clear workflows and to avoid any overlapping of the activities or assignments. Finally, a third possibility has been presented in these Guidelines, which is an alternative hybrid approach, where the positive elements of achieving the expected deliverable by the external company is maintained while simultaneously having an in-depth clarity of the organizational need. On the other hand, extra financial means are required, and such setup may lack flexibility in the different iterations and software development. Overall, a series of three main questions need to be answered in order to decide which approach to follow: the first question assesses whether the team is eligible to take on the development of the digital map, and for that programmers and GIS specialists are necessary. What follows is the second and third questions, which respectively investigates the ability to hire the right people and analyses if a financial budget exists to develop this project.

Budgeting is fundamental for a successful project implementation. In chapter 3, it has been highlighted how interested actors should follow the example of what other countries have already done, to leapfrog and get up-to-speed with the latest strategies in this field. The body of knowledge on this subject shows that it is important to adopt an implementation formula; to understand the number of systems users and of operators that will engage with the platform; to choose what records will be stored in the system and to forecast what costs the systems may entail, both from the man-day price perspective as well as the annual maintenance costs.

Since the broadband mapping system can be developed with different degrees of complexity, chapter 3 also addressed the complexity of such development touching upon different aspects: first of all, it is essential to narrow down the scope of the digital map, as such map could focus on four different spheres. It could focus on the infrastructure area; it could analyse and report on the service and coverage of the access to the internet; but it could also report on the citizens' demand of accessing the web or also the financial investments that are planned in specific geographical area to strengthen the broadband landscape. The system should also take into account if the model aimed for considers only fixed-broadband or may leave room for an integration with the mobile networks. One other element worth recapping is the importance of the choice of the data transfer form, the transfer interface and the level of data detail one would choose as well as the way the data is presented and how the system collects, organizes and validates the data. A supportive system such as a helpdesk is also desirable as well as the use of a mobile application for ease access. The complexity of the system would also be reflected in the system documentation itself and the level of software development and use on the SIP and the data associated with it, i.e., the geospatial connections between passive and active infrastructure.

As part of the work on these guidelines, a simplified cost calculator for building the broadband mapping system was also developed. The mentioned calculator was created after a comparative analysis of information on the implementation of the broadband mapping system in European countries. The report has highlighted multiple times the complexity pertaining to the creation of a broadband mapping system. The level of complexity of this work is also influenced by the number of days needed and the IT workforce capacity of the institution. The country area, which correlates with the number of elements in the system, or the number of system users is another factor that makes the design of broadband mapping systems even more challenging. The simplified cost calculator for building a broadband mapping system is annexed to these guidelines.

Finally, a minimum technical and project requirements check list was developed to implement a broadband mapping system. For ease of access, it is summarized below with the key areas of intervention:

Second checklist - Minimum project requirements
1. Ensure legal compliance
2. Reasonable cost of implementation and maintenance
3. Project governance

4. Roadmap for implementation
5. Centralized reporting and presentation of services availability
6. Define scope of mapping exercise
7. Define set of functionalities for the map
8. Availability requirements for accessing the data and the map
9. Neutral approach of the technology
OUTPUT: Project document and implementation roadmap

Third checklist - Minimum technical requirements
1. IT Resources
2. Compliance with common tech standards
3. Accessibility Requirements
4. State registers integration
5. IT environment scalability or overprovisioning
6. Strict data formats and validation
7. Accountability
8. Data collection timelines
OUTPUT: Technical specifications for planned mapping system

In chapter 4, the project management for a successful broadband mapping system implementation was outlined. This chapter analysed this activity by focusing on three essential pillars. The first pillar pertains to the common challenges and associated solutions to them. Indeed, such project management requires attention around the quality of the data collected (i), the confidentiality associated with the data (ii), the sources of those (iii), what reporting mechanisms are in place (iv), the applicable regulation (v) in place that is associated with the mechanisms revolving around the data themselves, the stakeholder costs (vi) and the mechanism to enforce to settle any potential dispute. The second pillar, on the other hand, considers the elements for a successful stakeholder involvement (i), narrows down the scope with a clear definition on the different types of mapping systems(ii), suggests potential avenues for internal sponsorship (iii), elaborates on ways to efficiently report on the groundwork with reporting tools mechanisms (iv) and by suggesting ways for the reporting mechanisms to be deployed (v). Finally, the third pillar, i.e., long-term sustainability practices was highlighted. What results from the long-term approach is the importance of the tools to be utilised once the digital map is developed: from the investment in reporting tools (i), to the importance of collection tools for adaptability and development (ii), to the tools for visualization (iii) and promotion (iv), to the use of open-source solutions (v), change (vi) and talent (vii) management.

To conclude, the ITU Guidelines for establishing or strengthening national broadband mapping systems aim to be a set of readily implementable guidelines supporting NRAs in Europe and across all ITU Regions in their journey towards the establishment and/or strengthening of broadband mapping systems. Its goal is to constitute a concrete reference basis for further technical assistance aimed at supporting Eastern Partnership countries (EaPs), Western Balkan countries, Least Developed Countries (LDCs), Landlocked Developing Countries (LLDCs) and Small Island Developing States (SIDs) in all ITU Regions. These guidelines, developed in consultation process with European and International interested stakeholders and partners, are designed to be a readily implementable product to be deployed in any project in the field of broadband mapping systems. They guidelines are meant to proactively catalyze the energy of interested parties in delivering concrete actions in the field of digital and infrastructure development.

Annex 1 - cost calculator for building a broadband mapping system