GOPA
WORLDWIDE CONSULTANTS

Development, implementation and demonstration of a reference processing pipeline for the future production of official statistics based on multiple Mobile Network Operator data (TSS multi-MNO)

Service Contract Number – 2021.0400

Deliverable D3.2 - Updated version of technical documentation for Business Processes and Quality Framework

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\ ABSTRACT

The Multi-MNO project aims to **develop, implement and demonstrate a proposal for a reference standard processing pipeline for the future production of official statistics in Europe based on Mobile Network Operator (MNO) data from multiple operators**. If successful, the proposal developed by the project may be endorsed as European Statistical System (ESS) standard by the relevant ESS bodies. The term "processing pipeline" refers to the combination of a methodological framework and a reference open-source software adhering to such a framework. The processing pipeline developed in this project will cover an initial set of use cases; nonetheless, it will be designed to be general enough to provide the flexibility and growth capability required to cover other future use cases. The pipeline will be demonstrated and evaluated on real data from multiple MNOs in various EU countries.

This report defines the business processes and quality framework proposed for the production of official statistics based on MNO data. The quality framework for statistics based on MNO data will be the first one of its kind in the ESS and it will be an inseparable complement to the proposal for a common ESS methodological standard for the processing of MNO data for the reference scenario developed by the Multi-MNO project.

This updated version of the quality framework introduces the concept and perspective of quality in the context of European official statistics and provides a detailed analysis of the applicability of the current ESS Common Quality Framework to the specificities of the statistical production based on MNO data, along with exploring the possibility to integrate new elements in the existing ESS quality framework. Furthermore, the report introduces the approach and a detailed inventory of quality aspects of MNO input data (namely, MNO event data and MNO network topology data) and a focused section on the throughput quality for the main pipeline methods. The report also defines the business process model (i.e. the organisational, technical and management processes for exploiting MNO data for their reuse for official statistics) and introduces software quality aspects. The quality of output will be defined for the final project deliverables, along with proposals for templates to be used during the statistical production.

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On behalf of the contractor, project management is ensured by Florabela Carausu (GOPA).

***DOCUMENT VERSION STATUS AND FUTURE UPDATES**:*

The document is a work-in-progress updated version of the first project deliverable. Therefore, its content may change in the final version. This document and any future updates will be publicly disseminated on the Multi-MNO project webpage: https://cros.ec.europa.eu/multi-mno-project

Readers are invited to submit comments and corrections or share their views via email to multimno-project@gopa.de

Abbreviations

BREAL	Big Data Reference Architecture and Layers
CAPI	Computer Assisted Personal Interviewing
CATI	Computer Assisted Telephone Interviewing
CQF	Common Quality Framework
EC	European Commission
EG-NQAF	UN Expert Group of National Quality Assurance Frameworks
ESGAB	European Statistical Governance Advisory Board
ESAC	European Statistical Advisory Committee
EHQMR	ESS Handbook for Quality and Metadata Reports
ES CoP	European Statistics Code of Practice
ESS	European Statistical System
EU	European Union
GDPR	General Data Protection Regulation
GSBPM	Generic Statistical Business Process Model
GSIM	Generic Statistical Information Model
IMSI	International Mobile Subscriber Identity
ID	identifier
IoT	Internet of Things
ISO	International Organisation for Standardisation
M2M	Machine to Machine
MCC	Mobile Country Code
MNC	Mobile Network Code
MNO	Mobile Network Operator
MNO-MINDS	ESSnet on "Trusted Smart Statistics: methodological developments on new data sources"
MoU	Memorandum of Understanding
MS	Member State
NSI	National Statistical Institute
ONAs	Other National Authorities
QPIs	Quality and Performance Indicators
RMP	Reference Methodological Pipeline
SIMS	Single Integrated Metadata Structure
TEF	Total Error Framework
TFMNO	ESS Task Force on the use of MNO data for Official Statistics
TS	Ticketing System
TSE	Total Survey Error
UN	United Nations

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1 INTRODUCTION

1.1 THE MULTI-MNO PROJECT: BACKGROUND AND OBJECTIVES

The data collected by mobile network operators (MNOs) can be a valuable source for the production of official statistics in various policy domains where it is crucial to provide reliable and up-to-date indicators on population presence and mobility. Spatial planning, transport and mobility, health and environment, economy and tourism are relevant examples. In recent years, a number of National Statistical Institutes (NSIs) within the European Statistical System (ESS) have started to conduct exploratory activities aimed at **using MNO data for the development of innovative statistical products**. The activities conducted by ESS members have shown that the use of MNO data for official statistics calls for the development of a set of standardised reference methods and tools adhering to the requirements and principles of statistical production, such as quality, transparency, privacy and scientific rigour.[1] Methodological standardisation provides several benefits:

1. **Comparability**: the use of standardised definitions, classifications, and measurement techniques will ensure that statistical products based on MNO data produce consistent and comparable outcomes.
2. **New business models**: standardisation will favour open-source business models from which both private and public organisations will benefit. Contributions from the open source community will contribute to building reputation and generating new business opportunities for the private companies specialised in MNO data analytics products.
3. **Accuracy and reliability:** the application of sound methodologies in the pipeline will improve the process quality and, consequently, the accuracy and reliability of statistical products based on MNO data. Uniform methodologies, guidelines, and quality standards for data collection, processing, and dissemination will reduce errors, biases and inconsistencies, enhancing the credibility and trustworthiness of official statistics based on MNO data.
4. **Transparency, privacy and accountability:** standardisation promotes transparency and accountability in the production of official statistics. By adopting open and well documented methodologies statistical agencies abide to the requirement of documenting how data are processed. This will allow scrutiny, validation, and reproducibility of statistical methods by independent experts and stakeholders.
5. **Data integration and exchange:** standardisation will facilitate data integration and exchange at national and international levels. When statistical data adhere to common standards, it becomes easier to combine and aggregate data from different sources, enabling the development of indicators across various domains. Standardised data also supports international comparisons and harmonisation efforts, helping countries align their statistical systems with global frameworks.
6. **Policy formulation and evaluation:** standardised official statistics serve as essential inputs for policy formulation, implementation, and evaluation. Standardisation will ensure that policymakers have access to relevant, up-to-date, and comparable statistical products based on MNO data, enabling evidence-based decision-making.
7. **Public understanding:** standardised official statistics enhance public understanding of complex issues. By presenting data in a consistent and accessible manner, statistical agencies enable individuals, communities,

[1] See position paper prepared by the ESS Task Force on the use of MNO data for Official Statistics: Reusing mobile network operator data for official statistics: the case for a common methodological framework for the European Statistical System – 2023 edition - Products Statistical reports - Eurostat (europa.eu)

and organisations to comprehend and interpret information effectively, promoting informed discussions on societal challenges.

The Multi-MNO project aims to **develop, implement and demonstrate a proposal for a reference standard processing pipeline for the future production of official statistics in Europe based on MNO data from multiple operators**. If successful, the proposal developed by the project may be endorsed as ESS standard by the relevant ESS bodies. The term 'processing pipeline' refers to the combination of a methodological framework and a reference open-source software implementation adhering to such framework. The processing pipeline developed in this project covers an initial set of use cases; nonetheless, it is designed to provide the modularity, flexibility and growth capability required to cover other future use cases. The pipeline will be demonstrated and evaluated on real data from multiple MNOs in various EU countries.

1.2 SCOPE AND OBJECTIVES OF THE DOCUMENT

This document defines the business processes and quality framework proposed for the production of official statistics based on MNO data. The quality framework for statistics based on MNO data will be the first one of its kind in the ESS, due to the following particularities:

\ COHERENCE WITH THE ESS COMMON QUALITY FRAMEWORK WHILE BEING SPECIFICALLY TAILORED TO MNO DATA

The quality framework for the production of official statistics based on MNO data will be defined taking into account all aspects framed in the ESS Common Quality Framework (CQF). It will, therefore, go beyond previous initiatives within the ESS, which addressed specific quality aspects related broadly to new data sources, without integrating in a structured and comprehensive manner the particularities of MNO data. The systematic examination of the principles and indicators of the European Statistics Code of Practice (ES CoP) and of the correspondent methods of the ESS Quality Assurance Framework (QAF) will allow the identification of the main quality requirements for MNO data-based statistics in the three relevant areas in which the principles of ES CoP are organised: institutional environment, statistical processes and statistical outputs. Whenever the peculiarities of MNO data that have an impact on quality are not properly addressed in the current ESS quality framework, recommendations for their integration will be given.

\ COMPREHENSIVENESS TO GUARANTEE THE QUALITY OF THE ORGANISATIONAL, TECHNICAL AND MANAGEMENT PROCESSES FOR EXPLOITING THIS DATA

The alignment of the quality framework for MNO data based official statistics along the ESS CQF does not target strict compliance. Instead, the methods in the ESS QAF suggest good practices that need to be operationalised. Additional quality issues, specifically related to the different components of the production pipeline (i.e. input data, processing methods and statistical output quality) will be considered for producing a first nucleus of quality guidelines for statistics based on MNO data.

Furthermore, quality assurance tools that can be used by statistical authorities to improve the quality of statistics based on MNO data will be developed.

\ CLOSE COORDINATION WITH AND INTEGRATION OF RESULTS FROM OTHER EUROSTAT RELATED INITIATIVES

The quality framework will benefit from the results of other projects implemented by ESS partners, such as the ESSnet on "Trusted Smart Statistics: methodological developments on new data sources" (MNO-MINDS), which aims to guide and facilitate the integration of MNO data with other non-MNO data to produce regular official statistics.[2]

[2] See for further information: MNO-MINDS | Eurostat CROS (europa.eu)

\ INSEPARABLE COMPLEMENT TO THE (PROPOSAL FOR A) COMMON ESS METHODOLOGICAL STANDARD FOR THE PROCESSING OF MNO DATA FOR THE REFERENCE SCENARIO – AN (EVOLVABLE) QUALITY STANDARD ITSELF

The quality framework will be fundamental for the reference scenario, for which the data processing pipeline is developed. The reference scenario is based on the assumption that conditions for access to MNO data will be favourable for the re-use of data for statistical purposes by statistical authorities (see for further details the deliverables from Task 2[3]).

1.3 DOCUMENT STRUCTURE

The overall structure proposed for the report on the quality framework and business process model for statistics based on MNO data is introduced in the lines below. The current deliverable (updated version) covers only part of the content envisaged for the final version (i.e. some of the chapters are still not completely developed).

- **The first chapter** serves as an introduction on both (1) the overall project and (2) the related quality framework the document aims to define.
- **Chapter 2** introduces the concepts related to quality in official statistics, so that the reader can familiarise with the terminology used in the European common quality framework. It also reports experiences of how quality frameworks of other statistical organisations are evolving to encompass the use of new data sources in the production of official statistics.
- **Chapter 3** presents past work on quality research related to MNO data, especially within ESS projects.
- **Chapter 4** and the related **Annex 1** make a review and analysis of the ESS common quality framework (already introduced in the previous chapters) as starting point / main foundation of the proposal for a quality framework for statistics production based on MNO data. These highlight, on one hand, what is still needed to fulfil the European Statistics Code of Practice principles and indicators for statistics based on MNO data, and, on the other hand, what can be integrated in the quality framework in order to better cover the specificities of the production of official statistics based on MNO data.
- **Chapter 5** describes the entire business process model defined in support of the pipeline developed in Task 2. The relationship between the proposed quality framework and the process pipeline developed in Task 2 is underlined in several parts of this document, starting with this Chapter 5.
- Starting from **Chapter 6**, the quality layer that should accompany and be integrated to the pipeline will be defined. Following a distinction that is common in quality literature, quality aspects of the overall process are approached identifying three main areas: **quality of the input data (Chapter 6)**, **quality of the throughput** (**Chapter 7** – *[draft content]*) and **quality of the output** (**Chapter 8** – *[draft content]*).
- Unlike in the case of the processing of traditional data sources, in the context of MNO data specific IT aspects become preeminent, especially the software and the implementation of algorithms. A complete quality framework cannot ignore them: indeed, the aspects concerning **software quality** will be covered in **Chapter 9**.
- **Annex 2** introduces a proposal for the collaboration agreement between MNOs and the statistical authority.
- Last, **Annex 3** lists the throughput quality issues following a structured classification by stage, groups, etc.

Chapters 6, 7 and 8 will be further developed in the final version of the report on the quality framework and business process model (Deliverable D3.3). As well, the other chapters included in this version may be enriched and improved in the next releases of the document.

[3] Methodology framework: high-level architecture, requirements, use cases and methods | Eurostat CROS (europa.eu)

2 QUALITY IN EUROPEAN OFFICIAL STATISTICS

2.1 THE CONCEPT OF QUALITY IN OFFICIAL STATISTICS

The concept of quality in official statistics has evolved over the last decades. Initially, it referred essentially to the accuracy of the estimates, i.e., their closeness to the true values they intended to measure. This led to the development of methodologies, firstly, to estimate the impact of sampling errors, and, afterwards, of non-sampling errors on output estimates. Over time, the multi-faceted nature of quality has led to considering new criteria or dimensions, such as timeliness and accessibility, in consideration of the fact that highly accurate statistics released too late or not easily accessible are not very useful. This approach has led to the adoption, in the ESS, of the ISO 9000's definition of **quality**, i.e. **the degree to which a set of inherent characteristics of an object fulfils requirements**.[4] Relevant requirements that official statistics should fulfil have then been identified, harmonised and also codified in binding legislation for ESS partners. These requirements are represented by the quality criteria defined in article 12 of Regulation (EC) 223/2009 on European statistics (including further integrations and modifications)[5], namely:

- *(a) 'relevance', which refers to the degree to which statistics meet current and potential needs of the users*
- *(b) 'accuracy', which refers to the closeness of estimates to the unknown true values*
- *(c) 'timeliness', which refers to the period between the availability of the information and the event or phenomenon it describes*
- *(d) 'punctuality', which refers to the delay between the date of the release of the data and the target date (the date by which the data should have been delivered)*
- *(e) 'accessibility' and 'clarity', which refer to the conditions and modalities by which users can obtain, use and interpret data*
- *(f) 'comparability', which refers to the measurement of the impact of differences in applied statistical concepts, measurement tools and procedures where statistics are compared between geographical areas, sectoral domains or over time*
- *(g) 'coherence', which refers to the adequacy of the data to be reliably combined in different ways and for various uses.*

The next step in the evolution of the quality concept in official statistics was the recognition of the importance of the **quality of statistical processes**. Good statistics are the output of good statistical processes, and the investment on improving the statistical process gave great impulse to the production of standardisation tools, such as quality guidelines and handbooks of recommended practices on the different phases of the statistical process. The adoption of sound methodologies and appropriate statistical procedures was fostered, together with the definition of quality assurance systems to prevent, monitor and reduce errors in statistical processes for obtaining higher quality outputs.

Nonetheless, assuring product and process quality was still not sufficient. A statistical authority subject to political pressure or without a clear legal mandate to access data cannot produce trustworthy statistics. Thus, the concept

[4] See also ESS Quality Glossary: ShowVoc (europa.eu)
[5] See: EUR-Lex - 02009R0223-20241226 - EN - EUR-Lex (europa.eu)

of quality in official statistics has been further extended to encompass the necessary **requirements at institutional level** and become a comprehensive quality framework.[6] The different quality aspects are complementary, and all are important. In line with this thinking, the ISO 9000's definition of **quality** can be interpreted, in the context of the ESS, as follows:

\ *The object* may be a statistical output, service, process, system, methodology, organisation, resource, or input.
\ *Characteristic* means distinguishing feature.
\ *Inherent* means existing in the object (not assigned to it).
\ *Requirement* means need or expectation that is stated, generally implied or obligatory.

The term *characteristic*, in this context, is usually mentioned in reference to aspects related to statistical outputs, e.g. the characteristics of the final (or provisional) data in terms of how accurate, timely or coherent such data are or should be. However, the concept of quality, as intended in the ESS, goes beyond this output-oriented approach to consider the statistical processes that produce the outputs themselves, along with the broader context in which the statistical offices operate. Indeed, the European approach to quality in official statistics examines in depth the following three aspects, on the idea that they cannot be disconnected:

\ The **institutional environment** in which the statistical authorities operate
\ The **statistical processes** that produce them
\ The **statistical outputs**.

2.2 THE COMMON QUALITY FRAMEWORK OF THE EUROPEAN STATISTICAL SYSTEM

"*The common quality framework of the European Statistical System is composed of the European Statistics Code of Practice, the Quality Assurance Framework of the European Statistical System and the general quality management principles (such as continuous interaction with users, commitment of leadership, partnership, staff satisfaction, continuous improvement, integration and harmonisation)*"[7].

The **European Statistics Code of Practice** (ES CoP)[8] is a non-legally binding self-regulatory instrument, which sets the standards for developing, producing and disseminating European statistics. The ES CoP is intended for national and EU statistical authorities, and it includes 16 principles and 84 indicators belonging to the areas mentioned in the previous section: the institutional environment, statistical processes and statistical outputs. The principles of the statistical outputs area coincide with the quality criteria reported in Regulation (EC) 223/2009 on European statistics. For the statistical process area, the principles recommend the use of sound methodologies and appropriate statistical procedures while limiting respondent burden and costs. Institutional environment principles assure professional independence, mandate for data access, adequacy of resources, statistical confidentiality and data protection, impartiality and objectivity and promote coordination and cooperation as well as commitment to quality. The ES CoP principles are also coherent with the United Nations (UN) Fundamental Principles for Official Statistics[9]. The ES CoP indicators are good practices and standards that provide guidance for the implementation of the related principle.

The ES CoP was initially established in 2005, representing a milestone in the quality related work in the ESS. The ES CoP was revised in 2011, and subsequently in 2017, currently incorporating an enhanced Quality Declaration of the ESS, which expands the commitment to statistical excellence. The enhanced Quality Declaration

[6] Eurostat (2009): "Guidelines for the implementation of quality assurance frameworks for international and supranational organisations compiling statistics", 14th session of the Committee for the Coordination of Statistical Activities (document SA/2009/12/Add.1, November 2009).

[7] ES Code of practice (2017) Preamble

[8] See ES CoP – 2017 edition: e7f85f07-91db-4312-8118-f729c75878c7 (europa.eu)

[9] See: https://unece.org/statistics/FPOS

communicates more firmly the value of European statistics to users, highlighting the qualitative advantages of European statistics over those produced by other entities, as well as the commitment to cultivate the good cooperation with data providers and cooperate closely with stakeholder groups. In the 2017 revision of the ES CoP, attention was given to introducing indicators related to privately held data, in order to start promoting and facilitating their use.

The implementation of the ES CoP is supported by the **ESS Quality Assurance Framework** (QAF)[10], which provides methods to guide implementation and verify compliance. Similar to the ES CoP, the ESS QAF applies to statistical authorities of the ESS, comprising the EU Statistical Authority (Eurostat), the National Statistical Institutes (NSIs) and Other National Authorities (ONAs), which are responsible for the development, production and dissemination of European statistics. The ESS QAF is a collection of methods, tools and good practices suggested for use by the statistical authorities of the ESS. It accompanies the ES CoP by providing guidance and examples in the form of more detailed methods and tools, as well as good practices for the rather high-level principles and indicators of the ES CoP.

The ESS common quality framework has been developed to assure that quality requirements for European statistics are fulfilled and the ESS periodically verifies the level of compliance by statistical authorities with the principles and indicators of the ES CoP through the mechanism of Peer Reviews[11].

The ES CoP and the ESS QAF cover the first three levels of quality assurance out of the four introduced in the Eurostat's quality policy[12]. These four levels of quality assurance are applicable not only for Eurostat, but in the ESS as a whole. As can be observed in **FIGURE 1**, the fourth level is represented by sector-specific quality assurance methods and tools.

The ESS CQF is, indeed, supported by additional tools and guidelines, which provide operative indications to implement in practice the QAF methods. Relevant examples are the ESS Handbook for Quality and Metadata Reports (EHQMR)[13] and the Single Integrated Metadata Structure (SIMS)[14] recognised as ESS standards[15]. Additional standards, such as, for example, the Generic Statistics Business Process Model (GSBPM) – approved as ESS standard in February 2017 – can be equally relevant.

Other specific quality assurance tools, e.g. checklists for quality assessment, quality guidelines for specific types of statistical processes, handbooks of recommended practices for specific phases of the statistical process, etc. have been developed mainly under the umbrella of different European research projects (e.g. BLUE-ETS, ESSnet Komuso[16]).

[10] See ESS QAF - 2019 edition (v2.0): ESS-QAF-V2.0-final.pdf (europa.eu)

[11] https://ec.europa.eu/eurostat/web/quality/peer-reviews

[12] https://ec.europa.eu/eurostat/documents/64157/4392716/Eurostat-Quality-Policy-EN.pdf

[13] See ESS Handbook for Quality and Metadata Reports (2021 re-edition): European Statistical System handbook for quality and metadata reports (europa.eu)

[14] See SIMS Guidelines v2.0 (2019) : https://ec.europa.eu/eurostat/documents/64157/4373903/Single+Integrated+Metadata+Structure+Guidelines+v2.0

[15] See also: Commission Recommendation/Reference (EU) 2023/397 of 17 February 2023 on reference metadata and quality reports for the European Statistical System: EUR-Lex - 32023H0397 - EN - EUR-Lex (europa.eu)

[16] https://wayback.archive-it.org/12090/20231228161552/https://cros-legacy.ec.europa.eu/content/essnet-quality-multisource-statistics-komuso_en

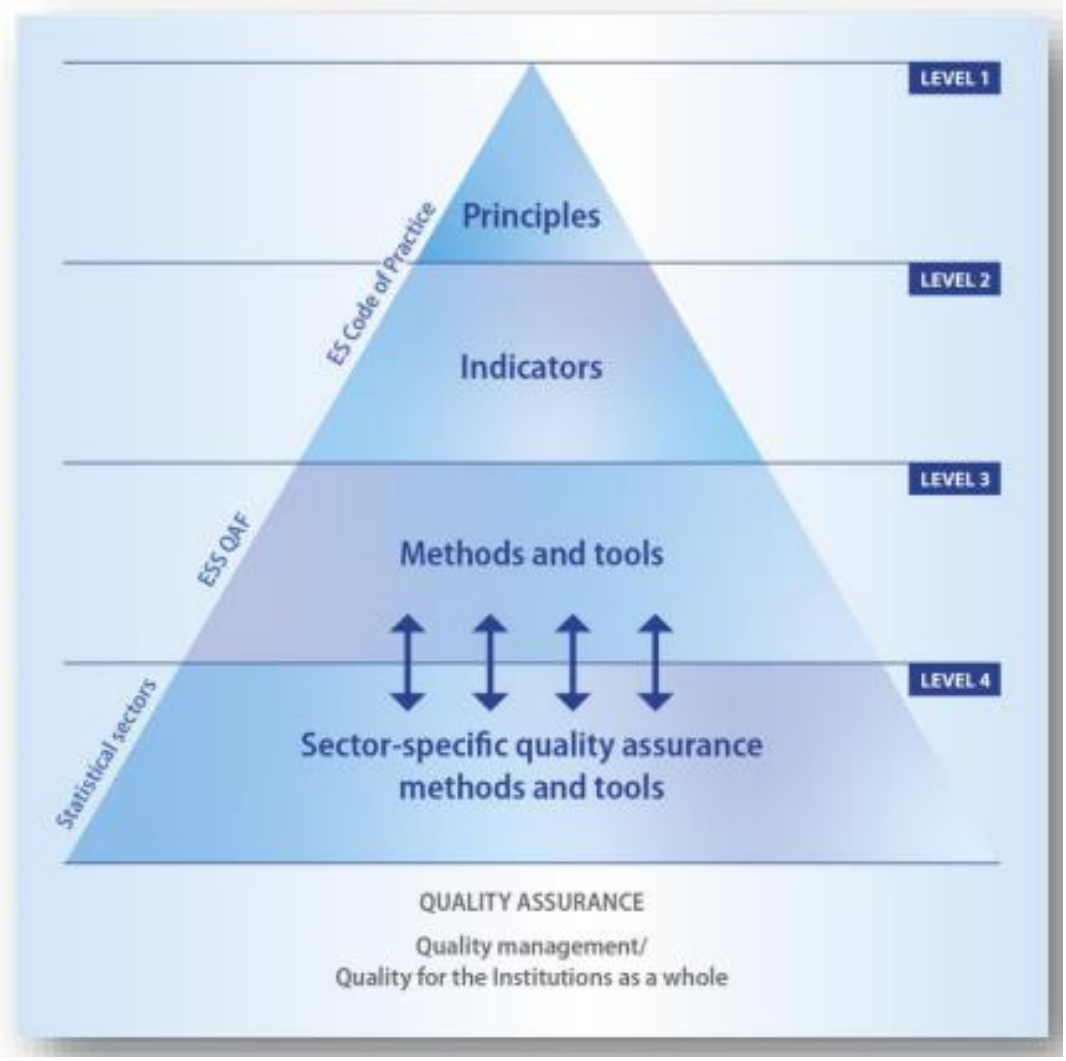

Figure 1: The four levels of quality assurance

Source: Eurostat's quality policy

The main quality assurance tools that have been taken into account for the definition of the quality framework for statistics based on MNO data are briefly described in the next section.

2.3 OVERVIEW OF QUALITY ASSURANCE METHODS AND TOOLS

An established practice in the ESS is to develop quality related guidelines and other tools that are relevant for specific contexts and follow the evolution that European official statistics have undergone in the past few years. The tools are often a product of the joint effort by representatives of various NSIs collaborating under a common research project. Depending on the main focus of the project, the related quality tools can take different forms and address the needs or tasks of statistical offices' staff at various levels of expertise. In the next paragraphs, we introduce few examples of such tools which, despite being quite consolidated for statistics based on more traditional data sources, can still be useful for the statistics based on MNO data, subject to proper adaptations or extensions. These quality tools are relevant even if only serving as inspiration for quality assessment practices of MNO data and related statistical processes.

A first well-known tool in the field of quality of official statistics is the already mentioned EHQMR. The handbook provides indications and recommendations for the drafting of quality reports following the current standard. It also presents general indications on how to assess the quality of statistical processes according to the quality criteria that should be followed in the report. Over the years, different versions of the handbook followed the evolving ESS standard template for quality reports, which in turn has expanded to incorporate modernisation initiatives in the official statistical production. The latest EHQMR version (2021 re-edition) promotes the SIMS standard for quality and metadata reports. The SIMS standard itself derives from two previous templates (the Euro-SDMX Metadata Structure – ESMS and the ESS Standard for Quality Report Structure - ESQRS) that were addressed respectively to users and producers of official statistics based on more traditional statistical processes. In the current version of the handbook, specific guidelines, built as well on the existing SIMS structure, have been introduced for measuring and reporting quality issues related to administrative sources and multi-source processes.

Despite this effort, however, there is awareness that the work on quality is ongoing and the existing tools need further developments or updates. One of the appendices of the EHQMR discusses quality aspects of statistics produced based on big data, emphasising the fact that these are different from the administrative data sources. The term "big data" encompasses various categories of data, for which specific quality assessment practices are needed. As stated in the handbook, future versions of the quality reporting template, should consider issues that are relevant to big data sources. Attempts in this direction have been made in the past within the ESSNet Big Data II[17] research project (for more details, please refer to the next chapter).

*[**Upcoming content**: A proposal for adapting the SIMS to MNO data and the possible impact on the EHQMR will be developed in Chapter 8 in the next release of this deliverable.]*

The BLUE-Enterprise and Trade Statistics (BLUE-ETS) research project developed measurement methods for the quality indicators of administrative data sources, when used as input source for statistical production.[18] These, although designed particularly for administrative data sources, may be useful for MNO data as well. More specifically, the BLUE-ETS Deliverable 4.2, introduces a series of methods to assess the quality of administrative data used as input. It was developed in 2011 by experts from different European NSIs under the coordination of CBS. Since its release, it has proved as a solid tool for assessing the quality of administrative data, and part of its success may be due to its flexibility; the methods proposed cover different dimensions of the quality of input data, ranging from accuracy to completeness and time related aspects. The NSIs can design their own customised checklist of methods to assess the quality of their administrative input data sources. Therefore, it may be interesting to carry out a similar exercise for the quality of MNO data as input source. In Chapter 6, the approach of the BLUE-ETS research project is used to scan relevant quality dimensions of the input data, that go beyond the ones more strictly connected to accuracy issues. It proves that most dimensions introduced for administrative data are relevant for MNO data and, while some methods cannot be applied directly (due to the absence of necessary elements such as, for example, a reference list of records), others are fully applicable or require only minor changes.

In the end, it may be useful to look beyond the ESS and observe other international experiences and frameworks. It is worth noting that some international quality assurance methods and frameworks unify administrative with 'alternative' data sources, due to their non-statistical nature. This is the case, for example, of the work carried out within the UN Expert Group of National Quality Assurance Frameworks (EG-NQAF), which is developing a module for quality assurance for the use of such sources, that complements the general UN National Quality Assurance Framework developed in 2019[19]. One of the objectives of the module is to provide guidance and best practices for statistical authorities using administrative and other sources, including a combination of them. Following

[17] Eurostat (2019). ESSNet Big Data II, Work Package 4. Deliverable K4. *Quality report template draft*.
[18] Daas, P. and Ossen, S. (2011). BLUE Enterprise and Trade Statistics, grant agreement n. 244767. Deliverable 4.2. *Report on methods preferred for the quality indicators of administrative data sources*.
[19] https://unstats.un.org/unsd/methodology/dataquality/un-nqaf-manual/

national and international practices, the main actions to undertake, for the use of administrative and other new data sources in official statistics, have been identified along with a set of critical requirements, covering aspects such as the cooperation with data providers, evaluation of the quality of input data, metadata, joint use of different sources and so on. The UN approach will be used as a reference in the development of the business process model in Chapter 5.

In line with the UN approach, the FAO Statistics and Data Quality Assurance Framework dedicates a principle to 'Suitable and trustworthy data sources', which includes non-statistical data in its scope. The principle emphasises the need for a procedure in place to assess the adequacy of non-official data sources using methodologies that are transparent and made publicly available.[20]

Finally, the quality of alternative sources of data has been the point of focus also for the OECD and its Smart Data Quality Framework.[21] Relying on the previous Quality Framework for OECD activities, the new framework tries to capture the evolving context of alternative sources for official statistics and related good practices. For each identified type of source, emphasis is put on objective-specific quality metrics and quality reports that can be compiled from those measures. The framework aims to be responsive in its capacity to adapt to the rapidly evolving data landscape.

In conclusion, many international statistical organisations have shown interest in the use of alternative data sources, provided that their quality meets the standards of official statistics. The above-mentioned quality frameworks are provided as examples only of the initiatives undertaken to address the quality assessment of new data sources. A quality framework specific for MNO data should take into consideration the lessons learned from these international experiences, while adopting procedures that are tailored to the specificities of this privately held data source. Furthermore, a quality framework aimed at a specific data source, in this case MNO data, could serve as an inspiration for future frameworks dedicated to other 'new' data sources, especially privately held data. Although each data source poses its own challenges, some of the insights and activities described in this document may indeed be conveyed to other initiatives that require assuring the quality of statistics derived from new data sources that are less familiar to official statistics.

*[**Upcoming content**: Section 2.3 – Overview of quality assurance methods and tools will be extended for the final version of this deliverable, with other quality assurance methods and tools that will be taken into account in the definition of the quality framework for statistics based on MNO data.]*

[20] FAO (2023). FAO Statistics and Data Quality Assurance Framework. https://openknowledge.fao.org/server/api/core/bitstreams/467e9cc0-0b77-4741-99d5-7f044bac7f13/content

[21] Dupont J., Bohossian N., Zerbe A. (2024). Statistical quality and new data sources – Towards a new quality framework for OECD statistical activities. Presented at the 2024 European Conference on Quality in Official Statistics, Estoril, Portugal.

3 QUALITY OF STATISTICS BASED ON MNO DATA IN ESSNET AND OTHER RESEARCH PROJECTS

The high-level references described in the previous section, such as the ES CoP and the ESS QAF, are useful to provide general guidance on the common quality approach in the ESS. In addition, the EHQMR, offers more detailed advice on how to assess and report the quality of a statistical process. However, none of these tools focuses on specific categories of data. Broadly, they provide recommendations that could be adopted either for sample-survey processes, for administrative data-based processes or, sometimes, for statistical processes using privately held data. This high level of abstraction is inevitable for a multi-faceted production system such as the one in the ESS. The trade-off, of course, is the lack of details in favour of flexibility. As presented in Section 2.3, more specific tools and methods have been developed for evaluating the quality of statistics based on administrative data or of statistics combining survey results and administrative data, for example. These tools are relevant as guiding materials to define similar methods and guidelines for statistics based on MNO data, even if the use of MNO data in the official statistical production implies additional quality challenges, mainly due to the peculiar characteristics of these data; their volume and sensitive (i.e. privacy and confidentiality) nature.

Similarly to administrative data, MNO data are generated out of the control of statistical authorities and for non-statistical purposes. Differently from administrative data, and due to the peculiarities of MNO data, the first part of raw data processing is usually managed by MNOs themselves, outside of the direct control of the statistical authority. In the reference scenario that is assumed here and described in the Technical Documentation for scenarios, requirements, use cases and methods[22], one of the main assumptions is that NSIs cannot access nano or microdata; instead, they can only obtain aggregated data that have already been pre-processed by the MNO data holder. This off-premise custody limits the quality assurance activities that can be carried out by NSIs along the statistical production process and alternative solutions should be identified to assure the quality of the statistical output.

Related research activities at European and international levels have already produced some relevant results. The '*Quality guidelines for the acquisition and usage of big data*'[23], developed within the ESSnet Big Data II research grant, offer recommendations on how to integrate the so-called big data sources for the production of European official statistics. In these guidelines, the term 'big data' covers many categories of high-volume data sources that range from Earth observation data to web-scraped data, including MNO data.

Due to the vast differences between these sources, the guidelines break down 'big data' into specific classes, out of which MNO data represent one class. This way, these guidelines offer more tailored recommendations for specific types of big data (compared to those that target broadly big data). This research project can be considered as one of the first attempts within the ESS to tackle the quality issues that come along with the use

[22] See Volume I in Methodology framework: high-level architecture, requirements, use cases and methods | Eurostat CROS (europa.eu)

[23] ESSNet Big Data II, Work Package K (Methodology and Quality). Revised version of the quality guidelines for the acquisition and usage of big data (2020).

of MNO data in official statistics. Therefore, it follows naturally that a great part of the approach described in this deliverable owes to that experience and the recommendations that were derived from it.

The most relevant orientation, based on this previous work, is probably the approach to the statistical process that makes use of MNO data, among other data sources. In these quality guidelines the traditional input-throughput-output view was further detailed by breaking down the throughput into two distinct phases: one covering the processing of the raw data, namely the *lower* throughput, and the other dealing with the intermediate statistical output, the *upper* throughput. Indeed, the quality issues that may affect both throughput phases are usually different and should be investigated separately. This will be also the approach considered in this deliverable. In addition, we note that the distinction, in the case of the use of MNO data, roughly corresponds to the MNO premise and NSI premise processing of the data considering the intermediate data delivered to NSIs from MNOs as the output of lower throughput.

Another foundation laid by the Big Data and Big Data II ESSnet experiences is the identification and description of the main categories of errors that characterise the main big data classes, including MNO data. To this purpose, potential errors related to linking procedures, coverage issues, comparability and other kinds of errors were investigated, and recommendations were provided. Furthermore, within these ESSnet projects, specific attention was also given to other aspects that could affect the final output quality, such as the access and the availability of MNO data sources within the ESS and how to adapt the existing standards of quality reporting for statistical outputs based on MNO data. Concerning the latter aspect, it should be highlighted that quality reporting and the SIMS template (i.e. one of the ESS standards) are output-oriented tools, while generally the output quality aspects of a statistical process should not be altered by the introduction of a new data source. This is why, for example, the quality guidelines on the usage of big data did not consider the output phase in their assessment. In the context of MNO data and especially at the stages of the Big Data ESSnet, the output was compared to a throughput dataset, requiring further processing and, therefore, without becoming a final published statistical output. However, further developments and research on the use of MNO data for official statistics and, especially, in the reference scenario, will generate more appropriate outputs to be published and the standard quality reporting tools could be applied to them.

The promising potential of MNO data for official statistics implies that research on their usage is being carried out not only within the ESS, but also in other international communities. Therefore, it is useful to shortly consider such experiences to gather additional insights that could be useful for the purpose of this deliverable and the overall project.

The UN and its statistical division, for example, have been developing interesting ideas on the use of mobile phone data in application to specific statistical domains. The result of this research, carried out within a dedicated task force, was presented in the 2022 publication '*Methodological guides on the use of mobile phone data*'[24], consisting of different sections exploring the use of mobile phone data in tourism, migration, population and other statistical domains. Among other aspects, for each statistical domain, quality assurance elements were addressed, in some cases with considerable detail. The quality recommendations developed in that context addressed exclusively the specific statistical outputs. The quality framework proposed by the Multi-MNO project aims to provide an overarching framework for quality issues encompassing the use of MNO data for different purposes, focusing especially on institutional aspects, on the input and throughput phases. To this aim, this framework is tailored to the methodological pipeline and integrates it by exploring the quality issues related to its modules and the mentioned phases, in addition to more general aspects such as the business process model and software quality.

Finally, academic and independent research, outside the ESS and NSI-level projects, should not be forgotten, as valuable ideas on quality aspects on the use of MNO data continue to be developed. For example, a great effort

[24] United Nations, Statistics Division. Task team of the UN Committee of experts on big data and data science for official statistics. Methodological guides on the use of mobile phone data (2022).

is being carried out to extend the traditional and well-known Total Survey Error (TSE) approach from sample survey to new data sources, although not strictly considering the MNO case or the context of official statistics. An example of this work is the recent attempt by Amaya et al. (2020)[25], in which a Total Error Framework (TEF) for big data is proposed; some of the errors mentioned in that work, such as the coverage and measurement errors, should be considered when using MNO data sources.

Beside the research projects mentioned above, Eurostat and the ESS are investing to pave the way for enabling the use of privately held data, and in particular of MNO data for official statistical production. The Final Report of the High-Level Expert Group on facilitating the use of new data sources for official statistics[26] identifies four areas to be developed: partnerships, modernisation of statistical production, social validation and involvement of a wider data ecosystem in the innovation of official statistics. In the action connected with the modernisation of statistical production, the definition of a transparent methodological and quality framework is also envisaged, being recognised that the current one it is not sufficient. Indeed, the solutions proposed for traditional data and processes (surveys, censuses, administrative records) may be different from the ones related to the use of privately held data; as such, the reassessment of the existing frameworks is encouraged.

The activities of the ESS Task Force on the Use of MNO data for Official Statistics (TFMNO) are also particularly relevant and go in the same direction. The recently published position paper 'Reusing Mobile Network Operator data for Official Statistics: the case for a common methodological framework for the European Statistical System' (Eurostat, 2023) provides a clear analysis of the challenges, describes the current state of play and defines a roadmap to enable the use of MNO data in official statistics. One of the pillars of the proposed approach is the development of an overarching quality framework providing a set of requirements on the input data, on the process and on the final output, coherent with the current ESS CQF, nonetheless tailored and integrated in the methodological pipeline for the production of statistics based on MNO data.

[25] Amaya A., Biemer P., Kinyon D. (2020). Total error in a big data world: adapting the TSE framework to big data. Journal of Survey Statistics and Methodology 8(1):89-119.

[26] Eurostat (2022) Empowering society by reusing privately held data for official statistics — A European approach https://ec.europa.eu/eurostat/documents/7870049/14803739/KS-FT-22-004-EN-N.pdf

4 APPLYING AND EXTENDING THE ESS COMMON QUALITY FRAMEWORK TO THE PRODUCTION OF MNO-DATA BASED OFFICIAL STATISTICS

4.1 INTRODUCTION

MNO data are one of the most appealing privately held candidate sources for (re)use in official statistics – nonetheless, also one of the most challenging. Current Eurostat initiatives target expanding the explorative studies and research projects developed by the different ESS statistical authorities along the last decade towards regular production of official statistics based on MNO data. The work on establishing **a common ESS methodological standard** defined at the European level for the processing of MNO data, and further transformation of MNO data into official statistics (with the involvement and under the coordination of the NSIs in each country), shall be coupled with an adequate **quality framework** for this specific statistical production initiative (Eurostat, 2023)[27].

Actually, standardisation of statistical activities (i.e. the proposal for the common ESS methodological standard for the processing of MNO data, in this context) is a powerful way to facilitate quality assurance. It improves quality, efficiency, and contributes to better coherence both in statistics production and outputs.

The quality framework for the production of official statistics based on MNO data is to be seen as part of the proposal for the standard itself, without excluding the opportunity for its evolvement along with future needs and improvement requirements. It shall also serve as an example for upcoming statistics based on new data sources (including other data generated and held by the private sector).

In line with the commitment to quality within the ESS, the statistical production (despite its specificities) should be aligned with the ESS CQF which shall serve as backbone for the quality framework for the production of MNO-based official statistics.

Nevertheless, the use of the current framework as backbone for the development of a quality framework for statistics production based on MNO data will not act as a restrictive structure. Rather, it will represent the common thread that will, on one hand, provide guidance on what is needed for the statistics based on MNO data to become compliant with the existing framework (and thus with the current quality requirements for European Statistics) and, on the other hand, allow the identification of where the current framework can be integrated or extended to take into account the peculiarities of MNO data.

Quality framework, in this document/deliverable, is designating the **entire frame that allows for the identification of quality challenges and actions for their resolution** undertaken for the production of official statistics based on MNO data. The punctual review of the ESS quality assurance framework that is presented in the Section 4.2 and reported in Annex 1 will pave the way to the following sections that will focus specifically on the Reference Methodological Pipeline (RMP) defined in Task 2. Firstly, there will be a focus on the processes needed to be put in place to integrate the RMP in the regular official statistics production. In this sense, the quality framework requires, as complementary tool for the systematic quality work, a **business process model**. Secondly, an overarching quality assurance system, including metrics to identify quality issues and possible

[27] https://ec.europa.eu/eurostat/web/products-statistical-reports/w/ks-ft-23-001

mitigation actions, is proposed for the different phases of the RMP, as defined by the ESSnet Big Data II: input, lower and upper throughput, and output.

The definition of methods for the upper throughput and measures for the assessment of the quality of the statistical output (i.e. final statistics based on multiple MNO data) are, however, not the main focus of the present deliverable, which concentrates more on the input and lower throughput quality. More advanced methods for the transformation of MNO data aggregates into statistical indicators are in the scope of the MNO-MINDS ESSnet research project. Nevertheless, possible plausibility checks involving the intermediate data provided by the different MNOs will be considered in this deliverable. In addition, to the extent possible, some initial reflections on output quality will be reported, taking into account the *ESS Handbook for metadata and quality reports*[28] (particularly the last chapter on the main sources of errors in the statistical processes using Big Data) and the recent Total Error Framework (TEF) for Big Data[29] - an adaptation of the Total Survey Error (TSE)[30] framework to Big Data[31].

A specific focus will be finally reserved to a relevant issue in the production of statistics based on MNO data, namely the impact of software-related aspects on the quality of the results. In the same section, indications on how to maintain the quality level of the software that implements the methodological pipeline in the reference scenario will be also given.

4.2 ES COP AND ESS QAF: PRINCIPLES, INDICATORS AND METHODS OVERVIEW AND ANALYSIS

Annex 1 provides a detailed analysis of the ES CoP principles and indicators and the ESS QAF methods. Principles, methods and indicators are analysed with regards to their relevance and completeness as quality requirements for the statistical production based on MNO data. The objective is to develop the first 3 levels of the quality framework analysing the requirements of the ESS Common Quality Framework (ES CoP and ESS QAF) in the light of the use of MNO data in Official Statistics.

As will be observed, many elements of the ES CoP and ESS QAF are general and not specifically related to the case of statistics based on MNO data. In other situations, the framework element is peculiar and can suggest the need to develop a specific tool in order to implement the method or the indicator or to fulfil the principle for statistics based on MNO data.

Many of the needed tools are being developed in the framework of this project, in this or in other tasks, and/or are being developed in parallel research projects. In these cases, in the overview tables that are included in Annex 1, the reference to the specific section of the deliverable (to other deliverables or to other projects) will be reported. For other elements proposed in the ES CoP and ESS QAF, consolidations are recommended to better focus relevant quality issues for the MNO data based statistical production. Finally, some recommendations are proposed for methods or indicators that could be added in the ESS CQF in order to extend it and cover the particularities of the production of official statistics based on MNO data.

A table of contents of ES CoP principles that are analysed in detail in Annex 1 (including their related QAF methods and indicators) is included here for easier navigation through the document.

[28] See European Statistical System (ESS) Handbook for Quality and Metadata Reports — re-edition 2021 - Products Manuals and Guidelines - Eurostat (europa.eu)
[29] See: Total Error in a Big Data World: Adapting the TSE Framework to Big Data | Journal of Survey Statistics and Methodology | Oxford Academic (oup.com)
[30] See: Total Survey Error: Past, Present, and Future | Public Opinion Quarterly | Oxford Academic (oup.com)
[31] See: MNO-MINDS | Eurostat CROS (europa.eu)

\ LIST OF ES COP PRINCIPLES

N°	PRINCIPLE TITLE	LINK TO THE REPORT SECTION
1	Professional independence	**Principle** 1
1bis	Coordination and cooperation	**Principle 1bis.**
2	Mandate for data collection and access to data	**Principle 2**
3	Adequacy of resources	**Principle 3**
4	Commitment to quality	**Principle 4**
5	Statistical confidentiality and data protection	**Principle 5**
6	Impartiality and objectivity	**Principle 6**
7	Sound methodology	**Principle 7**
8	Appropriate statistical procedures	**Principle 8**
9	Non-excessive burden on respondents	**Principle 9**
10	Cost effectiveness	**Principle 10**
11	Relevance	**Principle 11**
12	Accuracy and reliability	**Principle 12**
13	Timeliness and punctuality	**Principle 13**
14	Coherence and comparability	**Principle 14**
15	Accessibility and clarity	**Principle 15**

4.3 SUMMARY OF FINDINGS

[This subsection, which provides an overview of the main findings (e.g. which integrations would be needed to the current ESS CQF to address the peculiarities of the MNO data and assure that the statistics produced based on these comply with the quality requirements of official statistics and how the project helps fulfil current quality requirements included in the ESS CQF,) may be further enhanced in the final version of the deliverable]

The detailed analysis of the principles, indicators and methods of the ESS CQF (ES CoP/ESS QAF) – see Annex 1 - exposed few highly relevant aspects to be taken into account, namely:

1. **New requirements**, particularly **at the institutional level**, that need to be fulfilled, such as guaranteeing by law the access to MNO data by statistical authorities. It has been underlined that the recent revision of the Regulation (EC) No. 223/2009 on European Statistics[32] is providing such needed legislation.
2. **A set of methods and tools** has been identified for development to ensure compliance with the ES CoP for the statistics based on MNO data, which includes, among others, the following:
    a. **A robust methodological framework** that guides the development of specific procedures for producing the statistical outputs.
    b. **A comprehensive Business Process Model** that explains how to integrate the MNO data within the existing statistical production process.
    c. **A set of quality guidelines**, integrated with the methodological framework, serving as the quality assurance system for monitoring the difference phases of the statistical production process.
    d. **Detailed and unambiguous documentation** of the production process.

It should be noted that the fulfilment of all these requirements is achieved through the integration of results from the ongoing Eurostat initiatives related to MNO data, specifically Multi-MNO, MNO-MINDS and JOCONDE. Each of these initiatives addresses different stages (phases) in the setup of a common open reference methodological pipeline defined at the ESS level, which can be applied across the various EU member states.

A widely adopted RMP will also contribute to safeguard several fundamental quality principles outlined in the ES CoP, such as: professional independence, coordination and cooperation, as well as impartiality and objectivity. This can be derived from the fact that the entire statistical production process will rely on an open methodology defined by ESS partners, thereby ensuring transparency and replicability across all national contexts within the EU, ultimately improving coordination among the ESS.

Finally, it is essential to address more explicitly in the ESS CQF several pertinent issues related to the goal of producing official statistics based on MNO data.

One significant aspect at the institutional level is the promotion of partnerships between MNOs and statistical authorities, which is crucial for fostering a collaborative environment. The amended Regulation (EC) No. 223/2009 on European Statistics establishes the obligation for private data holders to collaborate with NSIs to establish a mutual agreement, serving as a foundation for developing such partnerships. The new regulation foresees that MNOs may receive financial compensation for their data processing service. Nonetheless, the advantages for MNOs or private data holders, more in general, extend beyond the monetary compensation for the processing service; they can gain insights into the quality of their data and benefit from the sound methodological tools to produce high-quality statistics beyond the official ones.[33]

Furthermore, it is essential to examine the characteristics of the organisational process. MNO data (and other privately held data) are classified as administrative data, being generated outside the control of statistical authorities. Nonetheless, in contrast with administrative data, MNO data are also partly processed at the MNO's

[32] EUR-Lex - 02009R0223-20241226 - EN - EUR-Lex (europa.eu)

[33] See also Ricciato, F. (2023): "Master class – Quality for new data sources: Progress, challenges and directions for the European Statistical System" in 2nd-Workshop-on-methodologies-for-official-statistics-Proceedings-1.pdf (istat.it)

premises. Therefore, it is crucial to ensure the quality of both the input data and the processing carried out by the data holder. This should be explicitly requested by the CQF.

Moreover, due to the high granularity and substantial volume of MNO data, the methodology can only be implemented in an automated manner, i.e. through software solutions. Therefore, emphasis should be placed as well on maintaining the quality of the RMP software following its deployment.

This summary does not encompass all the issues identified in the analysis of the ESS CQF, but only highlights the main findings. In the eventuality of a revision of the ES CoP and ESS QAF, the full set of recommendations outlined in the tables in Annex 1 should be considered.

5 BUSINESS PROCESS MODEL

5.1 SCOPE OF THE CHAPTER

This chapter describes in detail how the reference methodological pipeline (RMP)[34] based on MNO data and developed for use by the MNOs and NSIs will fit into the normal business process of an NSI. It considers and proposes a structure for a business process model (BPM) for using MNO data for producing statistics in the Multi-MNO reference scenario, defining and describing concrete processes and paths for the statistical production based on such data.

In this chapter, the RMP denotes the (methodological) data processing pipeline developed for implementation in a future context where the assumptions set out for its deployment at MNOs are met. The assumptions that define the context as 'favourable' for the RMP's implementation are recalled in Section 5.4 -Main features of the Multi-MNO reference scenario.

The high-level requirements established for the RMP emphasise a Multi-MNO orientation, which accommodates the design of a standard that allows the combination/aggregation of information from multiple MNOs within and across EU countries. This requirement brings a series of benefits by ensuring a better representativeness of the total population (i.e. reducing the risk of population coverage bias in the final statistics), improving the robustness of the final statistics to anomalies, glitches and interruptions of data availability caused by technical flaws of single MNOs, and ensuring equal treatment of competing MNOs. Additionally, the combination of multiple MNOs data offers an extra layer of protection for business sensitive information.[35] At the same time, this requirement deepens the need of a strengthened and harmonised BPM for use by the MNOs and NSIs.

5.2 STRUCTURE OF THE CHAPTER

This chapter takes a top-down perspective, starting with an overview of the whole process of producing official statistics, with reference to the existing ESS quality framework and to the General Statistical Business Process Model (GSBPM); though, with an emphasis on what is specific for the use of MNO data in the statistics production.

Relationship with existing, though general, statistical frameworks are discussed. The main features of the reference scenario[36] provide a basis for an overall mapping of its phases, with processes and elements specific for the use of such data, in Section 5.4. A flowchart that also shows the relationship with ES CoP is included and commented upon in Section 5.5.

[The key concepts used along this chapter will be integrated in the common glossary of key concepts and terms].

[34] Please refer to the project deliverable D2

[35] For an overview of the solid reasons behind a multi-MNO orientation, we refer to the position paper by the ESS Task Force on the use of MNO data for Official Statistics.
See: Reusing mobile network operator data for official statistics: the case for a common methodological framework for the European Statistical System – 2023 edition - Eurostat (europa.eu)

[36] See for further details Chapter 3 in Deliverable D2, Volume I.

5.3 EXISTING STATISTICAL FRAMEWORKS

The detailed analysis of the relevance of the current ESS Common Quality Framework (CQF) to the specificities of the statistical production based on MNO data, along with exploring the possibility to integrate new elements in the existing ESS quality framework are available in Chapter 4 and respectively Annex I of this report. Particularly, Annex 1 makes a review and analysis of the **ESS CQF**, as the **main foundation of a proposal for a quality framework** for statistics production based on MNO data.

The ESS CQF based on the European Statistics Code of Practice (ES CoP) and the more extensive Quality Assurance Framework (QAF) are not dependent on the type of source or input data used to produce statistics, and they are not process models. Issues that are specific for the specific source of input data, such as the MNO data in this case, and their use in the statistical process, should be emphasised in the BPM. Quality considerations on such data shall be added. Overall, this deliverable for a business process and quality framework for the use of MNO data for statistics will not replace but complement the ESS CQF.

The ES CoP describes quality of output statistics as fit for use and users of statistics. This is, in principle, different from the quality dimensions to be considered for source or input data, even if some of the concepts used will be the same ones as for output statistics. There is a need to be clear about what the quality concept used refers to, i.e. to output statistics, processes or source or input data. The fact that many of the concepts used for the associated quality dimensions are the same can lead to some confusion if is not clear which use and users the quality dimension refers to (see FIGURE 2).

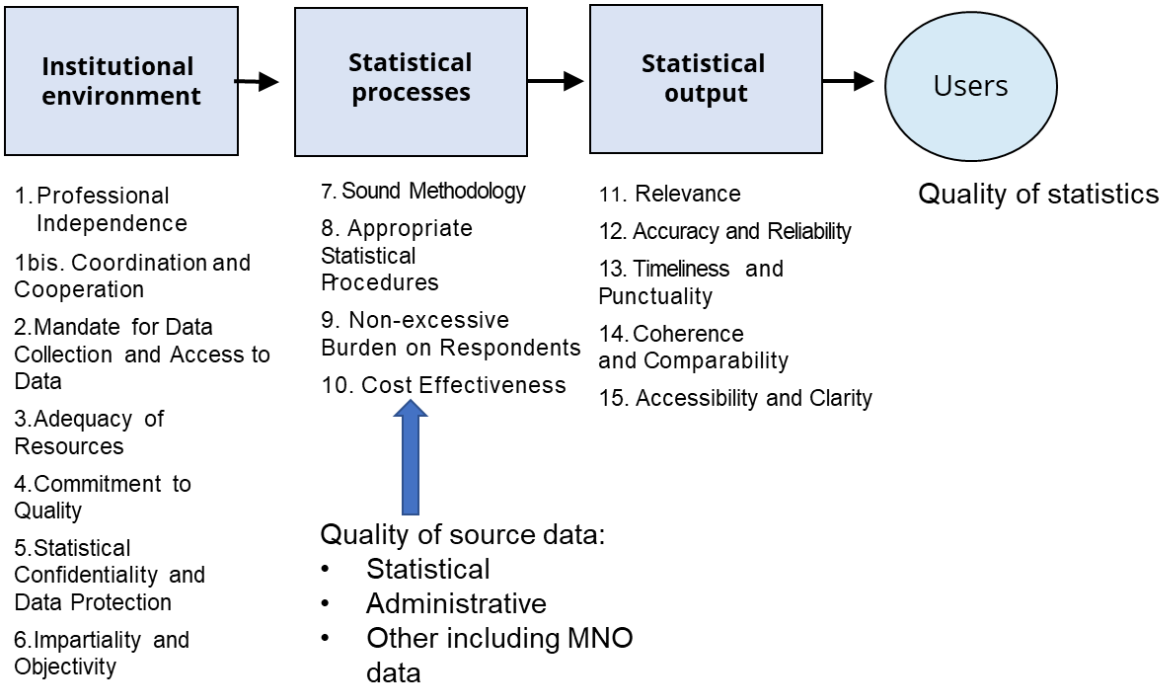

Figure 2: European Statistics Code of Practice

For the quality of source or input data, there are different frameworks with quality dimensions in use; nonetheless, the concepts proposed need harmonisation. This is more in place for output statistics because of over-arching quality frameworks[37].

[37] Such as the ES CoP and the UN National Quality Assurance Framework (UN NQAF).

A thorough examination of the relationship between the QAF and the development of statistics based on MNO data has been carried out and documented in Annex 1 – ES CoP and ESS QAF: Principles, indicators and methods overview and analysis. Even if the ES CoP and the QAF are not process models, this examination provides solid input for such a model for using MNO data for producing statistics.

There are several others generic quality frameworks, e.g. the UN NQAF, OECDs Good Statistical Practice and FAO Statistics and Data Quality Assurance Framework. These detail quality dimensions for output statistics that are very similar to those in the ES CoP. Again, the quality of input data is not covered to the same extent. The FAO framework has a separate principle on 'suitable and trustworthy data sources', but without proposing systematic quality dimensions for such data.

The **Generic Statistical Business Process Model (GSBPM)**[38] can also support the development of a business process model for production of statistics based on MNO data, but as for the quality frameworks most processes described here are valid regardless of the source or input data, even if some are more relevant than others. The same regards the Generic Activity Model for Statistical Organisations (GAMSO) and the Generic Statistical Information Model (GSIM). Additional or more detailed processes have been defined within the ESSnet Big Data II project, with the definition of the Big data Reference Architecture and Layers (BREAL).

Nonetheless, given the widespread use of the GSBPM for mapping the full set of related and structured activities and tasks undertaken by statistical organisations to convert input data into statistical information, this reference model is used as starting point.

Box 1: The GSBPM – introduction, uses and characteristics

GSBPM – GENERIC STATISTICAL BUSINESS PROCESS MODEL

*The original aim of the GSBPM was to provide a basis for statistical organisations to agree on standard terminology for discussions on developing statistical metadata systems and processes. As the model has developed, it became increasingly used for many other purposes, in particular, related to **modernisation** of official statistics. The list below aims to highlight a selection of current **uses**, that are particularly relevant for building a process model for statistics production based on MNO data:*

- *Providing a structure for documentation of statistical processes.*
- *Facilitating the sharing of statistical methods and software.*
- *Providing a framework for process quality assessment and improvement.*
- *Better integrating work on statistical metadata and quality.*
- *Providing the underlying model for methodological standards frameworks.*
- *Providing a tool for aligning business processes of providers of non-statistical data facilitating communication between statisticians and experts from other domains, and for harmonising related terminology.*
- *Providing a tool to build capacity and to build technical knowledge methodically, by referring to each phase's details.*

*The GSBPM is designed to be **applicable regardless of the data source**. While typical statistical business processes include collecting and processing data to produce statistical outputs, the GSBPM also applies when existing data are revised, or time-series are re-calculated, either as a result or improved source data or a change in methodology. In such cases, it is likely that several sub-processes and possibly some (of the early) phases would be omitted.*

*The GSBPM is a **reference model**. It is intended that the GSBPM may be used by organisations to different degrees. An organisation may choose to either implement the GSBPM directly or use it as the basis for developing*

[38] Generic Statistical Business Process Model (GSBPM) | UNECE

GSBPM – GENERIC STATISTICAL BUSINESS PROCESS MODEL

customised version of the model. It may be used in some cases only as a model to which organisations refer when communicating internally or with other organisations to clarify discussions. The various scenarios for the use of the GSBPM are all valid.

Organisations that make use of the GSBPM can develop specific adaptations of the model to fit their context and needs, without any requirement that these specialisations are to be sufficiently generic to be integrated in the reference model.

*The GSBPM should be **applied and interpreted flexibly**. It is not a rigid framework in which all steps must be followed in a strict order, instead it identifies the possible steps in the statistical business process and the inter-dependencies between them.*

Although, the presentation of the GSBPM follows the logical sequence of steps in most statistical business processes, the elements of the model may occur in different orders in different circumstances. Also, some sub-processes will be revisited, forming iterative loops.

*The GSBPM should therefore be seen more as a **matrix**, through which there are many possible paths. In this way, the GSBPM aims to be sufficiently generic to be widely applicable and to encourage a standard view of the statistical business process, without becoming either too restrictive or too abstract and theoretical.*

Source: https://unece.org/sites/default/files/2023-11/GSBPM%20v5_1.pdf

FIGURE 3 shows an overview of GSBPM phases[39] and sub-processes[40], identifying in yellow the ones that are **particularly relevant** in the setting of this report. Although most processes are relevant, few of these, such as dissemination, are very much the same regardless of source data. In practice, almost all processes also regard MNO-data and their processing; nonetheless, some processes are more important and specific for such input data than others.

[39] i.e. GSBPM Level 1 – the eight phases of the statistical business process.
[40] i.e. GSBPM Level 2 – the sub-processes within each phase.

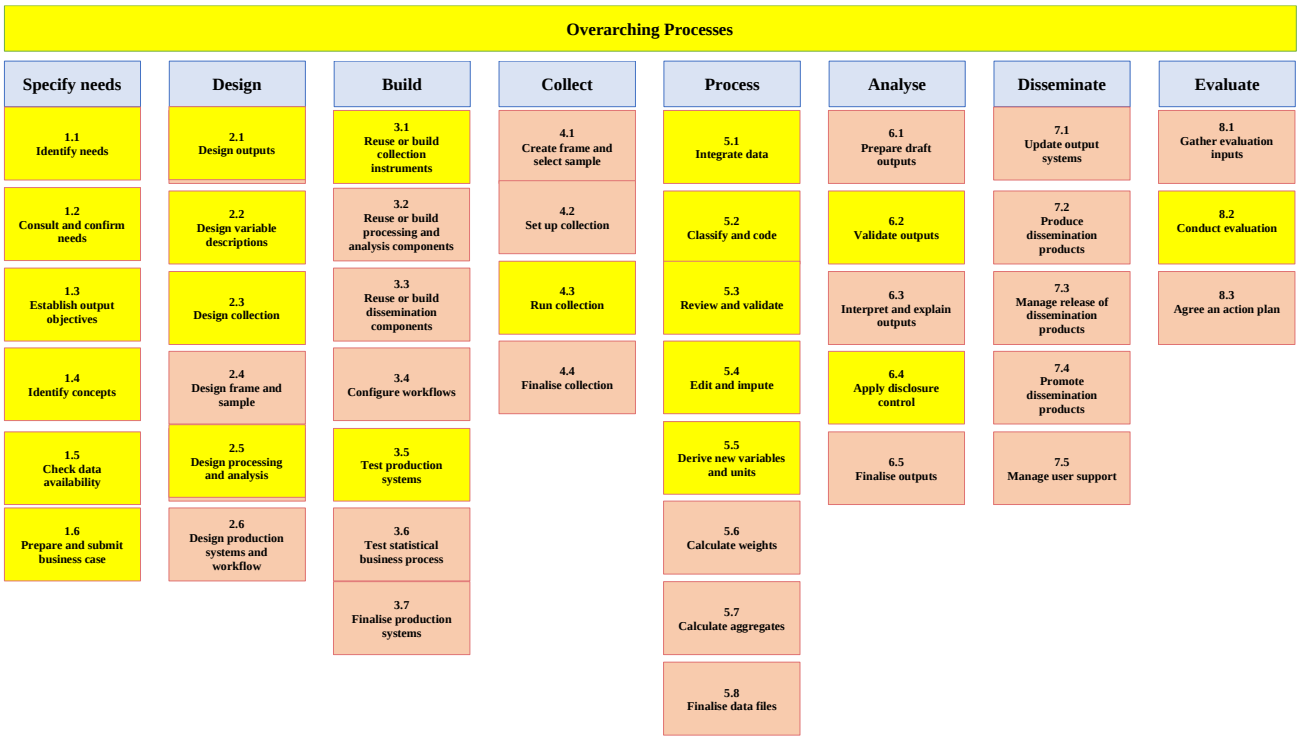

Figure 3: GSBPM processes

To sum up, both the quality frameworks and the process models provide inspirations for a BPM for the use of MNO data for statistics; nonetheless, these need to be further developed and detailed for practical applicability.

5.4 MAIN FEATURES OF THE MULTI-MNO REFERENCE SCENARIO

The **reference scenario** covers the whole production line for statistics based on MNO data, though with emphasis on what is specific or important for using such data. It goes beyond the mere implementation of the RMP, which scopes only one of the processes of the business model for the reference scenario.

Legal basis is a precondition for the reference scenario. As a working assumption and pre-requisite, it is assumed that all data protection aspects have been clarified in a dialogue with the relevant data protection authorities at European level (since the governance of the RMP is expected to be held by Eurostat/the European Commission), and at the national level. In other words, the reference scenario and, therefore, the BPM is based on the assumption that conditions for access to MNO data will be favourable for the re-use of data for statistical purposes by statistical authorities.

Box 2: Legal basis as a precondition for the reference scenario

LEGAL BASIS: RE-USE OF MNO DATA FOR STATISTICAL PURPOSES BY STATISTICAL AUTHORITIES

*The re-use of MNO data by NSIs would be based on a **sustainable partnership model**, **respecting the strongest possible technical and organisation data confidentiality measures to protect individual privacy and business sensitive information**.*

In any case, microdata – including raw MNO event data and any element of individual data – will not leave the protected computation environment at the MNO and will be processed locally at the MNO.

LEGAL BASIS: RE-USE OF MNO DATA FOR STATISTICAL PURPOSES BY STATISTICAL AUTHORITIES

Aggregate data will be accessed by the NSI without any additional protection measures (e.g. SDC), conditional to the availability in place of an appropriate legal basis to allow the NSI to receive such data from all major MNOs in the respective country, to combine them and then apply protection measures (i.e. SDC) to the total aggregate across all MNOs before publication/dissemination.[41]

The **main phases** in the production line cover considerations on **statistical needs, cooperation with the MNOs, data transfer and further processing at the NSIs** leading up to the statistical output. Is to be noted that not all these phases are developed by our project; therefore, the high-level approach of a comprehensive BPM that covers the entire production line without detailing the specifications/guidelines of all processes. It is particularly the case of phases such as data transfer and further processing at the NSI, which are not the focus of this project but are pursued in parallel projects, particularly the MNO-MINDS | Eurostat CROS (europa.eu) and JOCONDE | Eurostat CROS (europa.eu).

Cooperation with the MNOs is a crucial activity. Parts of the work must be carried out by the MNOs. The traditional approach of delivering raw data directly to the NSI is replaced by a model that involves data processing and aggregation at the MNO level. The NSIs will have access only to aggregate data, even if without requiring full anonymisation, assuming that legislation allows this option (i.e. the legal basis as a precondition). Furthermore, processes that require the fusion of the pseudonymised MNO event data with other data sources at the individual level (i.e. contextual data, such as: geographical data, calendar data, etc.) will, therefore, take place within the MNO processing facilities or in a secure processing environment based on Privacy Enhancing Technologies (PET). This comprises most of the data processing steps in the architectural design of the developed processing pipeline[42]. Therefore, **standardisation and transparency are key issues** in this context.

Some processes or actions need to take place during several data processing phases. This regards **quality and metadata** considerations, in addition to **confidentiality and data security measures**. **Dialogue and cooperation between the NSIs and the MNOs** are fundamental throughout all the phases of the statistical production process as needed.

Eurostat has a central role in the development of the standard pipeline and is expected to have an important role to ensure the governance of methodology and software linked to it once the pipeline will be used for current statistical production. A body comprising various ESS partners (such as, for example, the Task Force on Mobile Network Operator data for official statistics) could be established to assess and approve potential future modifications in the pipeline.

5.5 MAPPING OF THE PROCESSES IN THE MULTI-MNO REFERENCE SCENARIO

This high-level approach of a comprehensive BPM that covers the entire production line without detailing the specifications/guidelines of all processes is meant as a tool to guide and facilitate the activities needed to set up and manage the regular execution of the statistical process based on MNO data and on the RMP, including monitoring ones. One of the objectives of the BPM is to contribute to improving the quality and efficiency of the processes leading to the MNO-based statistical output.

The business processes in the Multi-MNO reference scenario are illustrated in **FIGURE 4**. The figure provides an **overarching structure of the typical main phases and processes when using MNO data to produce statistics**. Legal basis and access (i.e. the re-use of MNO data for statistical purposes by statistical authorities,

[41] See for further details Deliverable D2 – Volume I, Chapter 3: Reference scenario.
[42] Seen for further details Deliverable D2 – Volume I, Section 4.4: High-level pipeline definition.

respecting the strongest possible technical and organisation data confidentiality measures to protect individual privacy and business sensitive information) have been added as a precondition, while cooperation within ESS, quality assurance, metadata, confidentiality and data security have been added as considerations and processes that are relevant at different stages in the model.

The **processes in the Multi-MNO reference scenario are based on and compliant with the existing ESS quality framework (ES CoP and QAF)**, nonetheless providing more specific and detailed guidance when using MNO data sources to produce official statistics. The different parts are also consistent and overlap with the **phases and sub-processes of the GSBPM**, which is applicable to the use of any data source.

The flowchart has been inspired by work, still in progress, chaired by the United Nations Statistical Division, in an Expert Group for NQAF (Subgroup for administrative and other data sources), which is openly available.[43]

This work covers the use of administrative data and, in principle, also other data such as MNO data. However, it is not so specific on other data, but similarities can be exploited even if the work is still in progress.

The main links to the most relevant ES CoP principles and indicators have been added to the figure. These are based on the comprehensive comparisons with ES CoP and QAF documented in Annex 1 in Deliverable D3.1.

The figure focuses on the processes that are most relevant and specific for the use of MNO data. However, all phases in the production process, from considerations of statistical needs through requirements for methodology and processes to dissemination, are included. Quality assurance and work to ensure confidentiality and privacy is relevant at several stages in the production process and can be regarded as overarching. The dissemination of output statistics has been included for the sake of completeness.

The processes mentioned are largely the same as those mentioned in Annex 1 where QAF practices are regarded as highly relevant or at least relevant in the case of MNO data. Concepts used in ES CoP, QAF and GSBPM have been used in addition to a few formulations from the corresponding figure in the UN draft document.

[43] See: https://unstats.un.org/unsd/methodology/dataquality/nqaf_gc_2024/

\ FLOWCHART

The flowchart in Figure 3 can be regarded as a checklist focusing important actions, also compared with ES CoP principles and requirements. The main phases are commented upon in the subsequent paragraphs.

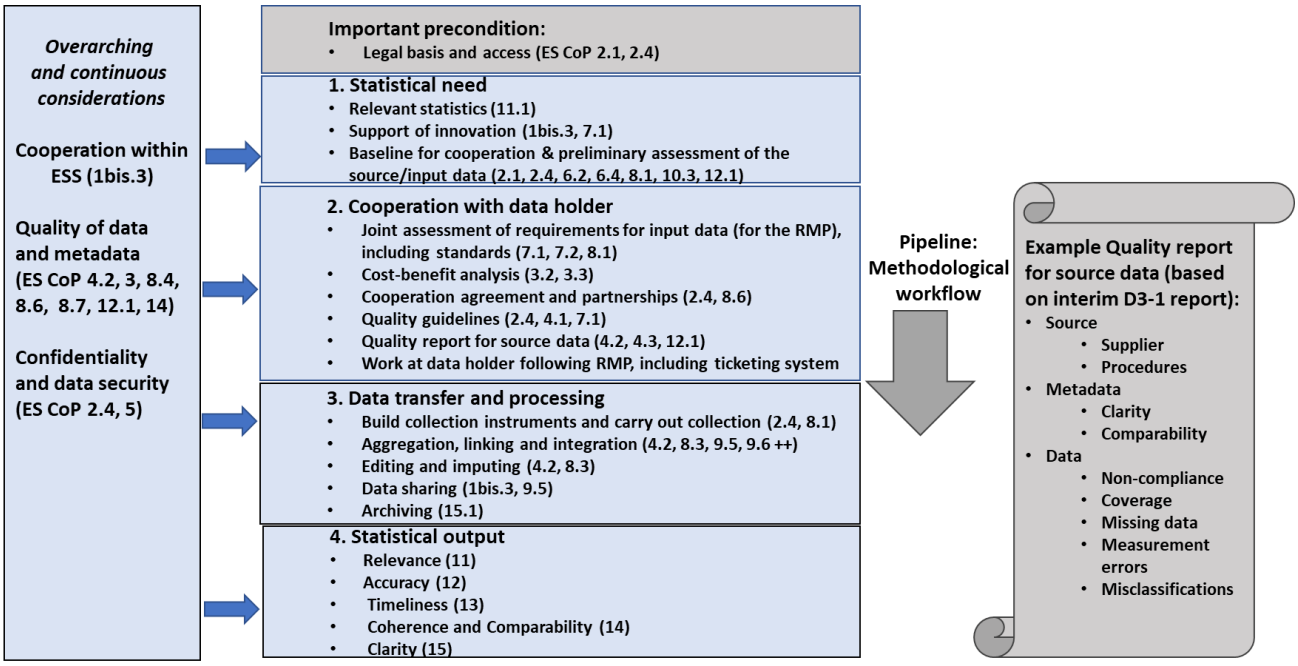

Figure 4: Flowchart/Checklist for assuring quality of official statistics when using MNO source data

Not all steps need to be relevant, and the order may change depending on national conditions.

PHASE 1 – STATISTICAL NEEDS

For the current case, i.e. the re-use of MNO data for official statistics, the first phase of statistical needs, including innovation and preliminary assessment of the source/input data, has been carried out before the decision to utilise MNO data. The preliminary assessment of MNO data as source/input data for official statistics has been carried out at different stages within the ESS, through technical work of specialised group, including the High-Level Expert Group on Facilitating the Use of New Data Sources for Official Statistics (EG B2G4S)[44], previous research initiatives by consortia of ESS partners in the context of the ESSnet Big Data II programme, and particularly the recent position paper of the ESS Task Force on the use of MNO data for Official Statistics[45]. The potentialities of the use of MNO data for the production of official statistics to answer to information needs in different domains have been clearly recognised. Legal and regulatory support is recently ensured through the amended Regulation (EC) No. 223/2009 on European Statistics[46].

Regarding the **preliminary assessment of the source/input data**, it is worth recalling that, in the case of MNO data, and by comparison to the target statistical population, the units (objects of observation) in the input/source data are devices and not individuals. Accordingly, the expected output after the processing of the RMP at the MNOs (in Phase 2) are aggregates related to the population of devices, and do not correspond to the target statistical population for the final statistical indicators. As highlighted in Chapter 6 Quality assurance system -

[44] See: Title: Empowering society by reusing privately-held data for official statistics — A European approach — 2022 edition (europa.eu)
[45] See: Reusing mobile network operator data for official statistics: the case for a common methodological framework for the European Statistical System – 2023 edition - Eurostat (europa.eu)
[46] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009R0223-20241226&qid=1734684433512

input data quality, this difference causes mainly coverage errors in the statistical output that NSIs are aware of. In order to handle them, specific methods are being developed in the MNO-MINDS project to be applied by the NSI when producing the statistical outputs starting from the aggregated data provided by MNOs.

For the reference scenario, the work can start directly in Phase 2 by cooperation with the MNOs, given that apart from the assessment of the potentialities of MNO data as source/input to official statistics, a list of use cases/statistical products has been already developed (see Deliverable D2, Volume II – Use cases).

However, Phase 1 should still be included in the flowchart not only due to completeness, but also to remind about the necessity of having user needs in mind and striving continuously for innovation, and that of a preliminary evaluation of the potentialities of any new (privately held) data source from an overarching perspective.

PHASE 2 – COOPERATION WITH DATA HOLDER(S)

Cooperation with the data holders is the central part of the reference scenario, since this is specific for the use of other than the traditional data sources (i.e. statistical data – census and surveys -, and administrative records). This phase aims to ensure the set-up of a sustainable statistical production process based on a public-private partnership that leads to generating new statistical products by the combination of privately held data with the traditional statistical data.

Setting the **baseline for the cooperation**, through close dialogue and negotiation between the NSIs and MNOs, comes naturally as a first process within this phase. The dialogue shall facilitate the **joint assessment**, by MNOs and NSIs, of the requirements for the input data to the RMP, including standards (e.g. standards for input data metadata, processing, quality requirements, etc.). The joint assessment of the data available at each MNO shall explore aspects such as: the possibility to filter out secondary devices (e.g. tables) and M2M/IoT devices from the event data, the type of event data (signalling, CDR), constant hash function over the observation period, the type of network topology data, technologies used, etc.

This dialogue shall enable the agreement on the specifications to ensure alignment with the output requirements from the RMP execution at the MNO. Output requirements from the MNOs are confined to the operational production stage at the MNOs and, therefore, refer only to the population of devices (not to the final target statistical population of the indicators).

Phase 2 – Cooperation with data holders, also integrates **a cost-benefit analysis**, since running the pipeline involves work at the MNOs. Operators may encounter additional costs due to data preparation and processing operations, so a fair compensation could be considered. Recognising the respective interests and roles, a partnership approach between statistical authorities and private data holders could also be encouraged through incentives such as, for example, improvement of public reputation or actionable feedback for the cooperating holders.[47] In order to be successful, the partnership must be sustainable for both sides, statistical authorities and MNOs.[48]

Setting the baseline for the cooperation (the dialogue and joint assessment of the specifications for the output) and assessing the cost and benefits, are enablers for the **cooperation or partnership agreement**, which is a central element of this phase (see example with requirements in Annex 2). This agreement may be elaborated in several steps, from a preliminary version to the final agreement, which also may be modified as needed. This

[47] Final report prepared by the high-level group on facilitating the use of new data sources for official statistics. Empowering society by reusing privately held data for official statistics – a European approach (2022 edition). https://ec.europa.eu/eurostat/documents/7870049/14803739/KS-FT-22-004-EN-N.pdf

[48] For further details on quality benefits vs quality costs to produce official statistics by re-using MNO data, see: Ricciato, F. (2023): "Master class – Quality for new data sources: Progress, challenges and directions for the European Statistical System" in 2nd-Workshop-on-methodologies-for-official-statistics-Proceedings-1.pdf (istat.it)

process will also cover the exchanges and specifications for setting up the IT environment/infrastructure to allow the regular execution of the pipeline and the data transfer.

Clear **guidelines** are a crucial complement to any cooperation and partnership agreement. Considering the distinction between data providers/producers vs (official) statistics producers[49] and the processing stage taking place at the MNO side, detailed methodological and quality guidelines for the MNOs are needed to ensure the correct implementation of the RMP and integrated quality assurance elements. Regarding the methodological guidelines for the RMP we can refer to the Deliverables of Task 2. In addition, the code developed in Task 4 can be considered as an unambiguous description on how the methods should be implemented. Concerning quality guidelines, we should consider that the general quality frameworks for statistics have a standardised way of describing the quality of output statistics, this is largely missing for input or source data, despite the many existing proposals. In Annex 1, linked to the ES CoP principle 4, there is a recommendation: "*The indicators of Principle 4 cover systematic process and output quality monitoring and assessment. Nonetheless, the systematic assessment of input quality is missing. An additional indicator on this issue could be proposed; this would be applicable not only to MNO data, but also to statistics based on administrative data*".

The following chapters in this report (particularly, Chapter 6 and Chapter 7) can be considered a first nucleus of such quality guidelines related to input and throughput quality, coherent with the proposed RMP defined in the context of Task 2.[50] Methodological and quality guidelines should be provided to the MNOs that, in their turn should contribute by assuring transparency. It could be recommended, e.g. to accompany data provision with a **quality report for source data**. This is also an ambition of the UN project referred to above. In that case an example given is based on the European BLUE-ETS project for administrative data. In the flowchart/**FIGURE 4**, this element is indicated by the process 'Quality report for source data' and illustrated in an additional table to the right of the figure. Here, the quality dimensions for input raw data used so far can be based on the thorough consideration of the relevant MNO data that is reported in **TABLE 8** of Chapter 6. The table identifies the following types of errors: Coverage, Missing data, Measurement errors, Misclassifications, in addition to data not compliant with agreed requirements for the pipeline. However, here with source data we refer to the aggregated data provided to NSI, that are based on input raw data, but have also been processed by the MNO. Thus, the quality report for source data shall also be consistent with and based on metrics which can be produced as a by-product of the pipeline. It could also include general metadata that needs to be provided with the initial data transmission and in case of data structure changes (e.g. type of data, configuration parameter used in the pipeline, technology information, classification used for MNC and MCC, etc.). A **quality report for source data** that is updated regularly could be valuable to provide an overview on what MNO data is compiled and how it is processed to become input to the RMP and along the initial processing conducted by MNOs (i.e. lower throughput quality).

However, a 'static' quality report cannot be the answer to the day-to-day quality issues that will unavoidably arise in the regular running of the pipeline. To this aim, the production of quality metrics and quality warnings has been introduced in the pipeline, and such output will be provided by the MNO to the NSI during the processing of the data, in the operational production stage at MNOs. Through this system, quality issues will be reported in a more detailed and frequent manner than those captured in a 'post-execution' quality report for source data. Furthermore, this more agile and systematic evaluation of the source data and lower throughput processing stage is needed to address the overarching consideration to have in place a bi-directional communication (MNO to NSI and vice-versa) during the **operational production stage**.

The quality information regularly received shall be analysed and handled by the NSI. The appearance of a quality warning can determine different actions from the NSI. Here we describe the main possibilities:

[49] It is distinguished between data providers/producers, who provide an input to the statistics production process and statistics producers, who produce a statistical output.

[50] In addition to the core quality assurance elements for the operational production stage at MNOs, proposed in this report, the present project also provides the software developed in Task 4 that will implement quality controls on input and throughput.

- The first possibility is that the NSI considers the possible impact of the quality issue that caused the warning on the output quality to be negligible and decides to **do nothing**. The statistical process can proceed as planned. In any case, the NSI is aware of the issue. It can also be that if the issue is repeated over time or from time to time, the NSI could than decide to investigate the cause, checking with the MNO.
- The second possible action that can be undertaken by the NSI is to **resolve the issue in the next steps of the process**, by applying corrections that can be based on information from other MNO data or from other auxiliary data.
- Third, the solution of the issue is not straightforward and needs to be **investigated**, thus the NSI first checks if the issue is present in the data from other MNOs. If yes, it could represent the way the MNO data have registered an unexpected phenomenon or event that should be reported in the statistical output; otherwise, a feedback can be sent to the MNO which presented the quality issue, obviously without revealing any business sensitive information from the other MNOs. It is expected that MNOs would find such feedback very useful.
- Fourth, the NSI needs **further information on the quality issues and contacts the MNO for verification and solution**. This is the only case in which the MNO will be directly asked to invest resources in the quality monitoring process. In these cases, a communication channel like the ticketing system that is proposed in Section 5.8 can facilitate the dialogue between the MNO and the NSI. Quality issues that require the involvement of the MNO could arise also independently from the pipeline quality warnings, during the last steps of processing when the NSI is producing the statistical output.
- The last possibility is that the **quality issue is not negligible**, **but the pipeline is still not ready to handle it**. Such cases should be collected and shared at European level, so that the development of their resolution can be planned with next releases of the pipeline.

A more dynamic channel of communication between each MNO and the statistical authority should be set up and maintained to facilitate the efficient management of quality issues that need the intervention of the MNO.

A concrete way to effectively put in practice the bi-directional communication between the MNO and the NSI in a structured way could be based on a ticketing system platform. The primary objective of an issue reporting ticketing system between each MNO and the statistical authority is to facilitate efficient and structured communication and management of issues related to data quality and technical processes of the RMP affecting the quality of the output data resulting from the operational production stage at the MNO. This system will allow the NSIs to guide the methodological workflow, if and when needed, without having access to disaggregated data, while the pipeline runs in the secure infrastructure at the MNO. A proposal for such a system is described in the Section 5.8.

Independently from the tool used for the communication, the dialogue between MNO and NSI should be continuous. It is suggested to identify contact/focal points in the organisations that will be involved in the dialogue. Identifying a limited number of people involved in this task that can oversee the process would be positive also to minimise the number of people allowed to access to data.

[FROM PHASE 2 – COOPERATION WITH DATA HOLDER(S) TO PHASE 3 – DATA TRANSFER AND PROCESSING]

As for the transfer of data from MNOs, a secure multi-party computation system for official statistics could support the data transfer and part of the processing in the future (therefore, the distinction of this phase/step: from Phase 2 to Phase 3). Such a system is being developed and will be piloted in a parallel Eurostat project.[51] The aggregation of data from multiple MNO that provide data to one NSI can be done in the future by the multi-party computation system. Nonetheless, only aggregated individual data will be required to contribute to the data fusion through the multi-party computation system (and by no means any nano-data, i.e. the stream of the MNO events generated by the single mobile network). For example, the daily summaries from each single MNO would be aggregated into the mid-term summaries for multi-MNO, while the single MNO event data are still

[51] See: JOCONDE | Eurostat CROS (europa.eu)

processed by the single MNO in their own environment. For further details, see also in Section 4.4.5 in Deliverable D2, Volume I, the advanced approach for Multi-MNO data fusion.

The cooperation between the NSIs and MNOs may involve several persons at each institution. The agreement specifies the representatives. However, these are often representing the management side, while it is important to have an operative contact at least at the NSI side, responsible for following up quality issues (see for more details Section 5.7).

PHASE 3 – DATA TRANSFER AND PROCESSING

The processed data will be **transferred** by the MNO to the NSI in line with the output requirements defined in the collaboration agreement. Independently of where the part of the processing takes places (i.e. either at the single MNO or through a secure multi-party computation system), the transfer of the data processed at the single MNO to the NSI shall be complemented with information on the specific delivery (metadata) that is not understandable from the data itself (e.g. timeliness aspects, type of data used, technology, comments from the MNOs, etc.). In general terms, the metadata to be provided to statistical authorities shall be defined in the quality guidelines.

In this phase the NSIs receive data that are already aggregated at the MNOs or by a future automatic system. In the first case, further aggregation involves data from several MNOs. Linking and integration with data from other sources are relevant processes anyway. The MNO processed data are only an input, not a replacement of official statistics – and therefore require integration with traditional data sources. Data quality improvement activities such as editing and imputing may also still be relevant and follow the normal NSIs procedures. For example, the great majority of the solutions for ensuring the representativeness of the MNO data to the target statistical population (i.e. addressing the coverage errors) lie outside the operational production stage at the MNOs. For this, the NSIs should define alternative methods based on the practices of statistical offices for similar situations (e.g. ad-hoc surveys for under-coverage estimation, data integration, adjustments through weighting and calibration methods). These are mainly steps to be undertaken by the NSIs in Phase 3 – Data Transfer and Processing. Methods for integrating MNO data with other non-MNO data sources are being developed in parallel project implemented by a consortium of ESS partners, i.e. the MNO-MINDS project.

Data sharing regards both: the national level, if there are several producers of official statistics and the trans-national or European level. The data transfer from MNOs to the NSI (i.e. national level) is covered by the description of this phase. For the data transfer of country level statistical data to Eurostat, for EU aggregates, the standard procedure for transferring aggregated data from other surveys or data collections can be followed.

PHASE 4 – STATISTICAL OUTPUT

Official statistics produced using MNO data will be integrated into the systems already in place at the NSIs for the dissemination of statistical outputs from traditional sources. As for other official statistics, output quality should be evaluated according to the quality criteria of the ESS. For some of the quality criteria, such as relevance, timeliness, punctuality, accessibility and clarity, the same evaluation methods and measures used for survey results or statistics based on administrative data can be used, while for others, and in particular accuracy, not all assessment methods applicable to survey data, e.g. estimation of sampling errors, are meaningful for statistics based on MNO data. However, some best practices like re-interviews, post enumeration surveys, or quality control surveys can be adapted to provide an evaluation. In addition, comparison with traditional statistics in the same domain can be carried out. As for other official statistics, a quality report according to ESS standards should be compiled. A proposal for the adaptation of the standard SIMS and the related impact on the EHQMR will be presented in Chapter 8 *[upcoming content in the final version of the deliverable].*

5.6 OVERARCHING CONSIDERATIONS

The overarching and continuous considerations related to quality control and metadata, confidentiality and data security are pertinent to several of the processes described, as indicated by arrows in the figure.

In this context, data confidentiality is crucial not only for safeguarding privacy but also for preventing the unauthorised disclosure of business secrets. Measures to ensure confidentiality will be implemented at the MNOs and, if necessary, after data transfer by the NSIs, ultimately in relation to dissemination.

There are multiple layers of data protection and safeguarding of business sensitive information. These layers are reflected in the overarching principle of privacy-by-design, which underpins the core methodology of multiscale longitudinal analysis. Firstly, the methodological design incorporates data minimisation and storage limitation; secondly, individual data will never be exported outside the safe computational environment at MNO premises; and, thirdly, additional technical and organisational measures may be introduced, preferably defined at EU level. A concrete initiative, at EU level, addressing this last point is the development of a prototype for a multi-party secure private computing system for processing confidential sets of micro-data across organisations, in support of statistical innovation, as part of the JOCONDE project of Eurostat. The prototype will benefit from an analysis of critical points and legal considerations, including consultations with the European Data Protection Supervisor and the European Data Protection Board.

5.7 DIVISION OF LABOUR: WHO SHOULD DO WHAT?

The flowchart in **FIGURE 4** illustrates the work and responsibilities of the NSIs, with a few exceptions:

- **Most of the data processing according to the pipeline will be executed at the MNO premises**. This regards the steps up to the reception of aggregated data for each MNO, to be further aggregated or integrated with other data.
- **Eurostat** will play a significant role in the development of the standard pipeline and will have a role to **ensure the governance of the methodology and software** linked to it.

The cooperation agreement between NSIs and MNOs will be signed by management staff at an appropriate level. It is essential that this initiative receives support from top management, even if the agreements are formalised at a lower management level. However, day-to-day work should be managed by technical level staff. For instance, within NSIs, a project manager for the production of statistics based on MNO data should be designated. Since MNO data can be used in different domains, an alternative is to designate one project manager for each domain. In any case, a single point of contact (which may be a small team rather than a single individual) shall serve as the coordinator within the NSI or as the focal point for the different MNOs providing data. In addition, support from the NSI's IT and methodology departments is required, potentially including expertise in confidentiality and privacy protection. The exact composition of the team may vary; however, it is important to identify the main competences needed on both the MNO and NSI sides to ensure the smooth running of the pipeline. A proposal is provided in the tables below.

Table 1: Main competences and skills at the NSI side

COMPETENCE	SKILLS
Contact/focal point	• Comprehensive knowledge of the pipeline and of the use of MNO data by the NSI • In-depth understanding of the MNO data and network, of quality metrics and warnings and their possible cause • Ability to effectively address quality issues • Strong communication skills
Methodology expert	• Extensive knowledge of the methods and algorithms within the pipeline and of the methods applied at the NSI
IT expert	• Thorough understanding of the technical aspects related to the RMP

COMPETENCE	SKILLS
	• Proficiency in programming languages such as Python and PySpark • Understanding of technical aspects related to storing and processing of large datasets like MNO data
Geospatial data expert	• Expertise in using GIS software such as ArcGIS, QGIS, or other geospatial tools for mapping, data analysis, and spatial visualisation • Skills in conducting spatial analysis and solving location-based problems using geographic data • Thorough understanding of the geographical aspects of the RMP
Domain expert	• Knowledge of the statistical domain and of traditional statistics available
Quality expert	• Expertise in the evaluation of statistical processes and outputs
IT System expert	• Expertise of the IT infrastructure supporting the RMP • Basic understanding of operating systems, networking principles (including TCP/IP, DNS, firewalls and VPNs) to ensure the smooth operation and security of the network infrastructure and data exchange between MNOs and the NSI

Table 2: Main competences and skills at the MNO side

COMPETENCE	SKILLS
Contact/focal point	• Comprehensive knowledge of the pipeline and of the use of MNO data by the NSI • In-depth understanding of the MNO data and network, of quality metrics and warnings and their possible cause • Ability to effectively address quality issues • Internal coordination of work within the MNO • Strong communication skills
IT expert	• Proficiency in programming languages such as Python and PySpark • Understanding of technical aspects related to storing and processing of large datasets
Data analyst / scientist	• Ability to clean, manipulate and interpret data using data management tools • Skills in data quality assessment and interpretation of data-related issues
Geospatial data expert	• Expertise in using GIS software like ArcGIS, QGIS, or other geospatial tools for mapping, data analysis, and spatial visualisation • Ability to collect, process, analyse and manage geospatial data, including understanding coordinate systems, projections and metadata. • Skills in conducting spatial analysis and solving location-based problems using geographic data • Thorough understanding of geographical aspects of the MNO data processing software
IT System expert	• Understanding of operating systems (especially Linux/Unix, Windows) to perform tasks such as configuring servers, managing users and handling backups • Basic understanding of networking principles (including TCP/IP, DNS, firewalls and VPNs) to ensure the smooth operation and security of the network infrastructure • Ability to identify, diagnose and resolve technical issues efficiently, including hardware, software, or network-related problems
Cellular network specialist	• Strong understanding of radio propagation, signal transmission and frequency spectrum management, as well as of technologies such as 2G, 3G, 4G LTE, and 5G

5.8 PROPOSAL FOR A COLLABORATION TOOL: A TICKETING SYSTEM

Once the RMP is deployed in production in the reference scenario, an open channel for communication between each MNO and the statistical authority (in each country) will be necessary to handle the possible issues that can arise in the regular execution of the MNO data processing pipeline and transmission of the results to the statistical authority. A possible tool to handle such dialogue is the establishment of an issue reporting ticketing system (TS). The primary objective of an issue reporting TS between each MNO and the statistical authority is to facilitate

efficient and structured communication and the management of issues related to data quality and technical processes of the RMP that affect data quality. The systematisation of problem reporting aims to ensure that all issues are properly categorised, prioritised and assigned to the appropriate organisation. This streamlining helps ensure that critical problems are addressed promptly, while less urgent matters are handled in a timely and organised manner.

Another key objective is to enhance accountability and transparency between MNOs and statistical authorities, while keeping the sensitive information of MNOs protected. The TS provides clear visibility into which entity is responsible for resolving specific issues, tracking their progress through each stage and ensuring that deadlines are met. This is especially important for fostering collaboration between two separate organisations, as it helps avoiding miscommunication or delays, while holding both parties accountable for their roles in the process. The system also enforces compliance with Service Level Agreements (SLAs) – to be put in place between the MNO and the statistical authority - ensuring that issues are resolved within agreed timelines and standards.

Finally, the TS provides valuable insights and analytics to help both the MNO and the statistical authority improve their operational efficiency. Detailed reports on the number of tickets raised, common issue types, resolution times and other key metrics can enable both organisations to identify recurring problems and areas where processes can be improved. By fostering collaboration, improving issue resolution processes and providing actionable insights, the system ensures continuous improvement in the management of data quality and technical operations between the organisations. To this end, even if the TS is primarily a communication tool for the issues that cannot be handled by one of the organisations on their own, it would be useful to register and keep track of the issues that are resolved within one of the organisations.

This section of the report targets as main audience the staff from statistical authorities and MNOs who could be involved in the day-to-day implementation of the RMP. The description provided here is meant only as a proposal for a possible TS, with a focus on the key aspects and features of the system (without specifying the organisational set-up, which remains an intrinsic aspect to be decided by each organisation). In other words, the actual implementation and management of any quality-related system are the responsibility of the statistical authority and of each of the corresponding MNOs in the country, that will establish an agreement to collaborate for the production of statistics based on MNO data. Nevertheless, to ensure the quality standards of official statistics, the same TS should be adopted by all the MNOs to facilitate the activity of the staff of the statistical authority, who should manage the communication with the MNOs.

5.8.1 FEATURES OF THE TICKETING SYSTEM

The proposed TS is essentially a communication platform with established rules based on the agreements between each MNO and the statistical authority. For the TS to be effective, the following key features should be integrated to ensure the smooth communication, accountability and resolution of issues:

- The system should allow ticket creation by both parties with additional information and details including priority, classification, status and additional information on the issue to facilitate understanding and handling the issue easier.
- The system should be integrated with basic communication tools like e-mail or other notification tools to support the flow of information on tickets' transmission, status changes, etc.
- Under the hypothesis that the same system is used by different MNOs and the corresponding statistical authority, the system must ensure: i) the separation of the information shared between each MNO and the statistical authority, and ii) role-based access control (RBAC) to restrict access to information based on the user's role within organisations to minimise the risk exposure and breach of sensitive information.
- The system should ensure secure communication, especially as sensitive data or confidential information are involved.
- The system should allow customisation of ticket categories, priority levels, statuses and additional information fields to reflect different types of issues, such as issues related to the specific data quality concerns, missing or

incorrect input data, geographical issues, issues related to the processing pipeline, resulting output data, etc. For example, a ticket category referring to geographical issues, can automatically be assigned to GIS specialists. This ensures issues are classified and potentially delegated to the right competences faster and more efficiently.

- The system should include monitoring and tracking features to ensure the timeline for issue resolution aligns with the service standards agreed-upon. The service standards can be defined in the agreement between the MNO and the NSI (see Annex 2). This helps both parties adhere to predefined timelines and fosters accountability.
- The system should support assigning priority levels (e.g. low, medium, high, critical) to each ticket. This ensures urgent issues receive prompt attention, while less critical ones are handled appropriately. The priority levels and the meaning of those should be agreed between the MNOs and the statistical authority.
- Each ticket should have a clear workflow status (e.g. Open, In Progress, Resolved, Closed, etc.). This allows the statistical authority and MNOs to track the progress of issues in real time and to know when follow-up is needed and solution is expected.
- The system should facilitate communication between both organisations. Features such as comments, file attachments, and notifications ensure that all stakeholders contribute to resolving the issue within the ticket thread.
- Each ticket should have a traceability of communication – an auditable trail documenting every action taken, including who handled the ticket, what actions were taken, and when. This ensures transparency and accountability and provides a detailed history for reference or compliance purposes.
- The system should provide detailed reporting and analytics, such as the number of tickets raised, average resolution time, types of issues reported, etc. These reports help identify patterns and areas for improvement.
- The system could also allow for automatic ticket creation triggered by specific events in the RMP, for example automatic creation of a ticket based on quality warnings. In this case, integration of the RMP and the ticketing system is required.

By incorporating these features, the TS will effectively support communication, collaboration, transparency and efficiency in resolving data quality issues between the statistical authority and MNOs.

The technical assumptions for implementing a TS require that the MNO is equipped with the necessary capabilities to explore input data, various stages of intermediate data (data objects), output data, quality metrics and configuration parameters, to investigate and address issues at their source when possible. Additionally, the MNO should have the ability to observe and intervene in the different modules of the data processing pipeline to effectively troubleshoot issues. The MNO should also be able to manage the technical infrastructure associated with the RMP, including servers, connections and IT resources, such as storage and RAM. It is expected that the MNO utilizes the RMP's functionality for calculating quality metrics and raising quality warnings. Such quality warnings are provided by the MNO to the statistical authority together with the aggregated data. The statistical authority can initiate a ticket based on the quality warnings received.

Statistical authorities should have the capacity to handle the tickets and be able to provide support and know-how on different issues and resolve these in cooperation (as opposed to the full responsibility of the MNO). The RMP is designed to be operated within the infrastructure of MNOs without direct access by the statistical authority. Nonetheless, the statistical authority should be the subject expert both for technical and methodological aspects, and provide support and suggestions, possibly through the TS.

5.8.2 ROLES AND RESPONSIBILITIES FOR THE TICKETING SYSTEM

As described above, multiple competences are needed to resolve data quality issues arising when running the RMP. Some of these are directly associated with technical aspects of data quality and processing. If the TS is chosen as a solution to manage the communication between MNOs and the statistical authority, specific competences are needed, that are the same for MNO and statistical authority as follows:

Table 3: Specific competences for the MNOs and NSIs

COMPETENCE	ROLE RELATED TO TICKETING SYSTEM	SPECIAL SKILLS RELATED TO THE ROLE
Tickets management	Focal/contact point identified in the MNO or the statistical authority for the pipeline.	Overall knowledge of the pipeline to decide: • if to open a ticket on the basis of data and quality warnings • how to handle tickets received. Ability to address tickets to the right expert within the organisation.
Domain-specific expertise (e.g. quality assurance, IT, methodology, etc.)	Experts that can support the resolution of tickets. In their work on the production of statistical output based on MNO data, they can also identify the need to raise a ticket. They can have direct access to the TS or work externally (being notified or notify focal points). The first option is more convenient for tracking the tickets and monitoring purposes.	Different skills, as described in Section 5.7 above
Ticketing system management	IT administrator of the ticketing system	Skills related to the management of the specific TS in use.

5.8.3 TICKETING SYSTEM WORKFLOW

In the production of official statistics based on MNO data, the statistical authorities aim to obtain high-quality statistical outputs and are mainly involved in the process' monitoring to achieve such outputs. In this scenario, the statistical authority regularly receives aggregated data and quality warnings produced by the MNOs through the RMP. The statistical authority analyses the information received. In case of warnings or other quality issues that arise during the further processing of MNO data at the statistical authority, which that cannot be handled within the organisation, the statistical authority can open a ticket towards the MNO. Thus, tickets are usually raised by the statistical authority and directed to the MNO, which is responsible for identifying the root cause of the issue and providing a solution. However, issues may also be raised by the MNO itself. This can be the case, for example, of an event known by the MNO that may have an impact on the data produced by the pipeline and the quality issue can be resolved before transmitting data to the statistical authority. In addition, in a scenario in which the TS is integrated with the pipeline, a ticket could be opened automatically by the system.

The following figure illustrates the simplified process of opening a ticket based on a quality warning and the following activities.

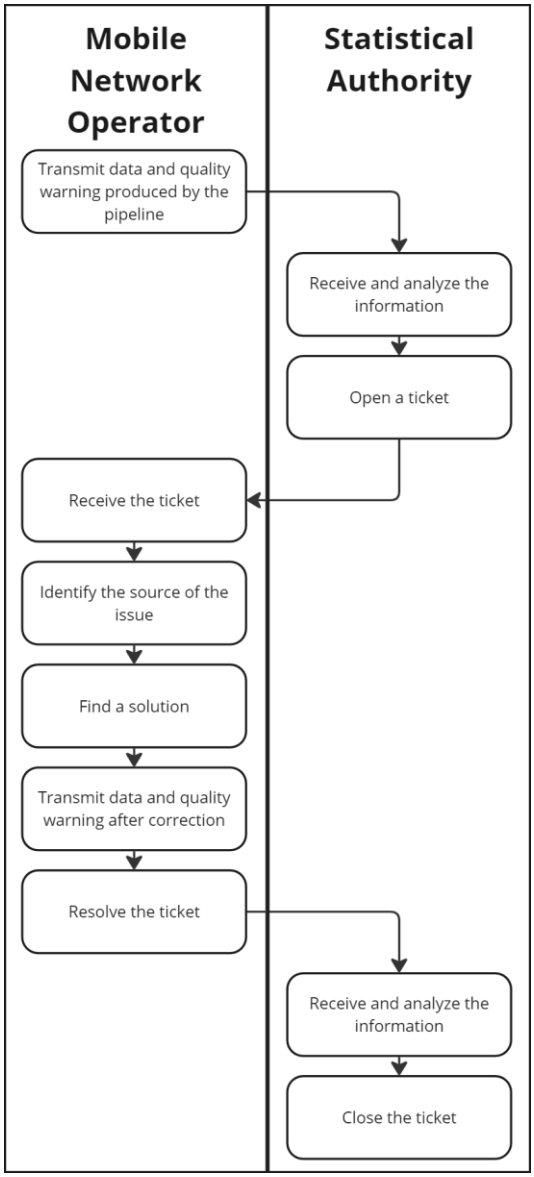

Figure 5: Simplified process of opening a ticket based on a quality warning and subsequent steps

Tickets may be initiated for several reasons, including but not limited to the following:

- The statistical authority may raise a ticket in response to a quality warning received from the MNO.
- The statistical authority may initiate a ticket due to inconsistencies in data transmission, such as delays in receiving data from the MNO, incorrect data formats, or other transmission-related issues.
- The statistical authority may also raise a ticket based on the analysis of the received data, including statistical inconsistencies or other discrepancies.
- The MNO may internally identify an issue and raise a ticket based on a quality warning.
- The MNO may detect an issue unrelated to the processing pipeline, such as infrastructural problems (e.g. server or storage issues), network concerns, or known issues with input data prior to running the pipeline and, subsequently, raise a ticket.

5.8.4 TICKET CATEGORIES

The table below outlines potential ticket categories, each reflecting a general description of the issue. These categories are an example and not exhaustive list and may and should be agreed upon between the statistical authority and all MNOs to ensure consistencies in categories across all MNOs.

Table 4: Potential ticket categories

TICKET CATEGORY	DESCRIPTION
Based on Quality Warning	Ticket raised based on the quality warning. This category could be further detailed in subcategories depending on the quality warning provenience, e.g. related to input data quality (event or network data, syntactic or semantic issue), related to throughput quality (and to which module).
Output Data Quality	Problems related to inaccuracies, missing data, or inconsistencies in the datasets provided by the MNO to the statistical authority that could be identified by the statistical authority even after data delivery (i.e. during the data processing at the statistical authority to produce statistical outputs).
Geographical	Issues involving errors or anomalies in the geographical data, such as incorrect or imprecise location coordinates, coverage gaps, misaligned regions in the data, cell footprint and coverage-related issues, etc.
Transmission or Data Delivery Failure	Failures in data transmission from the MNO to the statistical authority, including delays, corrupted files, incomplete data transfers or issues related to the frequency and timing of data delivery.
Data Format and Compatibility Problems	Challenges related to the format of the data transmitted (e.g. file structure, metadata inconsistencies, or incompatible formats), which prevent proper integration or analysis by the statistical authority.

5.8.5 TICKET PRIORITY LEVELS

The following priority levels are recommended for assigning tickets. These levels should be agreed upon between the statistical authority and all MNOs to ensure consistency in levels across all MNOs.

Table 5: Potential ticket priority levels

PRIORITY LEVEL	DESCRIPTION
Low	No need for correction of the issue or only a simple correction is needed, but the process can continue regardless (e.g. some processing step took more time than anticipated, and this requires investigation, but nevertheless the process can continue; or some process stopped, but after restarting continued as expected, etc.). This priority level may also include notifications about expected future events, such as planned maintenance of infrastructure that may affect the upcoming regular processing schedules.
Medium	Correction of the issue is required, but the process can continue (e.g. slight deviation from normality in quality metrics of some method, which may or may not be realistic, but requires checking, etc.).
High	Correction of the issue is crucial for the continuation of the pipeline and would introduce serious quality issues in the results if not checked and corrected (e.g. missing data for specific periods or regions). If a solution is not found, other substantial actions could be taken to resolve the issue (e.g. imputation or manual corrections, etc.).
Critical	The process cannot continue without correction of the issue (e.g. missing or incorrect input data for an extended period, error in infrastructure or software that is blocking further processing, etc.).

5.8.6 TICKET STATUS

The following ticket statuses are recommended for use as the ticketing process progresses through various stages. These statuses should be agreed between the statistical authority and all MNOs to ensure consistency in statuses across all MNOs.

Table 6: Potential ticket status

TICKET STATUS	DESCRIPTION
Opened	The ticket has been submitted but not yet reviewed.
Under Review	The issue is being evaluated.
In Progress	The ticket has been assigned and work is underway.
Pending	The ticket is paused, waiting for additional information dependent on an external factor, or requires escalation and the involvement of higher-level expertise or authority to resolve it (e.g. decision-maker).
Resolved	A solution has been implemented, but confirmation from the statistical authority is awaited.
Unresolved	There is no acceptable or reasonable solution to the issue; the ticket is pending closure. For example, the issue needs a modification of the pipeline that cannot be implemented; it should be stored as an input for future updates of the pipeline.
Closed	The issue has been resolved and the statistical authority has confirmed the resolution.
Reopened	The issue was thought to be resolved, but has been reopened due to recurrence or incomplete resolution.
Cancelled	The ticket has been cancelled.

5.8.7 EXAMPLES

\ EXAMPLE 1

This example describes the scenario of the statistical authority reporting an issue based on the quality warnings.

	MNO	STATISTICAL AUTHORITY	TICKET STATUS
1	Regular processing of the MNO data, a quality warning is raised based on the quality metrics that exceed pre-defined threshold.		
2		The statistical authority receives a quality warning. After analysis it is confirmed that this is an actual issue. The possible cause and the solution of the issue are discussed with relevant specialists. Any necessary additional information is prepared for submission of the ticket.	
4		The statistical authority ticketing manager creates (opens) a ticket with the following attributes: • Classification of the issue (mandatory) • Priority level (mandatory) • Description of the issue (mandatory)	Opened

	MNO	STATISTICAL AUTHORITY	TICKET STATUS
		• Expected deadline for the solution and recalculated results (if necessary) based on the SLA • Cause of the issue (optional) • Solution to the issue (optional) • Attachment, example, technical details, quality warning description, etc. to further explain the issue (optional).	
5	The MNO receives the ticket and confirms receiving status.		Under Review
6	The MNO starts investigating the source of the issue.		Under Review
7	The MNO identifies the source of the issue and starts looking for a solution.		In Progress
8	The solution is found. The solution to the issue is implemented, data is processed again to correct the issue. No quality warnings are generated.		In Progress
9	The MNO ticketing manager marks the ticket as resolved.		Resolved
10		The statistical authority receives the information about the resolution of the issue. The statistical authority confirms that no new quality warnings have been received and confirms that the issue is resolved.	Closed

It should be noted that, even if the statistical authority identifies a solution for the issue that can be handled within the organisation, it can still open a ticket to inform the MNO and keep track of the issue and of the solution. In such a case, it would be convenient for the ticket to be marked differently, to clarify that it is not to be handled by the MNO.

\ EXAMPLE 2

This example describes the scenario of the MNO correcting the data-related issue internally without any ticket being raised by the statistical authority. In this case, the ticket is opened only to inform the statistical authority, for transparency and to keep trace of the issue for monitoring and improving the pipeline.

	MNO	STATISTICAL AUTHORITY	TICKET STATUS
1	Regular processing of the MNO data. A quality warning is raised based on the quality metrics that exceed pre-defined threshold.		
2	The MNO specialists are able to identify the general source of the issue before data are transmitted to the statistical authority.		
3	The MNO ticketing manager creates (opens) a ticket with the following attributes: • Classification of the issue (mandatory) • Priority level (mandatory) • Description of the issue (mandatory)		Opened

	MNO	STATISTICAL AUTHORITY	TICKET STATUS
	• Expected deadline for the solution and recalculated results (if necessary) based on the SLA • Cause of the issue (optional) • Solution to the issue (optional) • Attachment, example, technical details, quality warning description, etc. to further explain the issue (optional).		
6		The statistical authority receives the information about the opened ticket.	Opened
7	The MNO starts dealing with the issue, identifies the source of the issue and starts looking for solution.		Under review
8	The solution is found. The solution to the issue is implemented, data are processed again to correct the issue. No quality warnings are generated.		In Progress
8	The MNO ticketing manager fills in the information on the cause and solution of the issue, marks the issue as resolved and the resulting data are transmitted.		Resolved
10		The statistical authority acknowledges the solution to the issue, evaluates the resulting data and closes the ticket.	Closed

\ EXAMPLE 3

This example describes the scenario of the statistical authority discovering a data-related issue that was not identified from the quality warnings, but rather from the analysis of the resulting data. The solution is discussed with the statistical authority and corrections are made.

	MNO	NSI	TICKET STATUS
1	Regular processing of the MNO data, no quality warnings are raised and sent to NSI.		
2		The statistical authority receives a set of results of aggregated data for use cases from the MNO for the specific previous period. The statistical authority reviews the results for the specific use case and identifies an issue with the resulting data which is not measured by any quality metrics. The possible cause and the solution of the issue are discussed with other relevant specialists. Any necessary additional information is prepared for submission of the ticket.	
3		The statistical authority ticketing manager creates (opens) a ticket with the following attributes: • Classification of the issue (mandatory)	Opened

	MNO	NSI	TICKET STATUS
		• Priority level (mandatory) • Description of the issue (mandatory) • Expected deadline for the solution and recalculated results (if necessary) based on the SLA • Cause of the issue (optional) • Solution to the issue (optional) • Attachment, example, technical details, quality warning description, etc. to further explain the issue (optional).	
4	The MNO receives the ticket and confirms receiving status.		Under Review
5	The MNO specialists start investigating the source of the issue.		Under Review
6	The MNO identifies the source of the issue and starts looking for solution.		In Progress
7	The solution is found, but the MNO requires consultation with/confirmation from the statistical authority to proceed with the solution.		Pending
8	Consultation(s) between specialists from the MNO and the statistical authority to discuss the possible solutions and make a decision (outside the ticketing system).		Pending
9	The solution to the issue is implemented by the MNO; data are processed again to correct the issue and the corrected results are transmitted.		In Progress
10	The MNO ticketing manager marks the ticket as resolved.		Resolved
11		The statistical authority receives the information about the resolution of the issue. It confirms that no new quality warnings have been received and that the issue is resolved.	Closed

6 QUALITY ASSURANCE SYSTEM - INPUT DATA QUALITY

6.1 THE QUALITY ASSURANCE SYSTEM FOR THE REFERENCE PIPELINE

As explained in Chapter 2 Quality in European official statistics, a statistical quality assurance framework is usually composed of four levels (see **FIGURE 1**). In the ESS, the ES CoP with its principles and indicators covers the first two levels. The ESS QAF methods represent the third level, while the sector specific methods and tools of the fourth level need to be defined for the specific type of production process; i.e. in our case, for the open and reproducible RMP that is being developed with the aim to produce official statistics based on MNO data.

The set of methods and tools that are implemented throughout a statistical process to assure the quality of the statistical output are usually referred to as the quality assurance system of the statistical process. In this and the next two chapters of this report, the quality assurance system associated with the RMP will be presented. It will be structured according to the four phases proposed by the ESSnet Big Data II research project, namely: Input, Lower and Upper Throughput, and Output quality. These phases have proven to be well-tailored for representing the production of official statistics based on MNO data.

A quality assurance system usually includes actions for the prevention, monitoring and correction of the errors that can arise during the statistical production process and for the final evaluation of the quality of the output produced. Prevention actions are usually carried out during the design phase, to limit the occurrence of errors. Monitoring activities are based on quality metrics (or quality indicators) that provide 'alarm bells' for possible errors arising during the process. Correcting actions are traditionally represented by the application of editing, weighting adjustment or integration methods that are applied to data when producing the statistical outputs to reduce the impact of the errors that occurred despite the preventing and monitoring activities, and these can take advantage of the quality metrics collected in previous phases of the process. Evaluation activities include the measurement of the different output quality dimensions (relevance, accuracy and reliability, timeliness and punctuality, etc). The quality aspects are sometimes difficult to evaluate in an objective way (e.g. relevance or accessibility) and are often costly too (e.g. the evaluation of the impact of non-sampling errors on estimates produced).

As the RMP is currently in the design and development phase, the possible actions to prevent errors are being implemented in the software pipeline. Just as an example, the two rounds of tests with MNOs that are planned in the Multi-MNO project will guarantee the soundness and the reliability of the final pipeline.

Since the pipeline is almost totally automated, once installed in the MNO premises, the monitoring activities should be, as far as possible, automated and integrated in the pipeline itself, in the form of quality metrics produced and quality warnings launched as 'alarm bells'. Such monitoring measures and activities will be presented in this and the next chapter, after identifying the main quality issues that can arise in the input data or in their processing, including their possible impact on the quality of output. In fact, the monitoring activities should target those issues that can most affect the output quality.

In the reference scenario, in which the production of statistical output from the aggregated pre-processed data provided by MNOs is carried out by the statistical authority, the correction actions will be applied in this last part of the pipeline (i.e. the upper throughput). For this part, the related methods are currently under development in the MNO-MINDS project. Therefore, in the next chapter there will be only a general mention of such methods, to

highlight which of the errors that occurred in the previous phases they are called to correct. Is not uncommon that a quality issue in the input data can be mitigated with an action only in the last modules of the pipeline. This is not different from what happens in traditional surveys where, e.g. over-coverage errors, which arise from the frame used at the beginning of the process to select the sample, are discovered by monitoring data collection and are corrected at the end by post-stratification or other weighting adjustment methods.

Possible evaluation measures for the different quality dimensions will be briefly presented in Chapter 8 Quality of output, reminding that the output quality dimensions do not change if the data source changes and also that the development of methods for the evaluation of the quality of the statistical output is out of the scope of the Multi-MNO project.

Finally, it is worth mentioning that the measures and actions proposed in the next chapters are not and cannot be exhaustive in identifying and handling all the possible quality issues that can arise in the RMP. In the present deliverable, a relevant set has been considered and it will be further integrated in the final version of this report after the test of the RMP on real-world MNO data, where other issues can arise. Nonetheless, further issues will probably arise in the regular running of the pipeline once deployed in production. This is the reason why it should be considered a learning incremental process, managed through the dialogue between MNOs and NSIs, as proposed in Chapter 5 Business process model.

6.2 INPUT DATA QUALITY

When analysing the quality of input data of a non-traditional source like MNO data, it is convenient to take into account consolidated frameworks operating for traditional data sources, already in use in official statistics. Nevertheless, it is also necessary to depart from them and develop methods more appropriate for the new data sources. A good starting point for the assessment of the quality of MNO data as input data source for official statistics can be, therefore, an analysis of the main differences between them and more consolidated input sources, namely traditional survey data and administrative data. After the identification of such aspects, it will be easier to adapt the existing quality tools to MNO data and/or to introduce new ones.

6.2.1 OVERVIEW OF INPUT DATA REQUIREMENTS

Before starting the analysis, we shall clarify that when referring to MNO input data for which we want to identify methods to evaluate and assure the quality, we refer to two types of data: MNO event data (in particular signalling data) and MNO network topology data. These two types of data feed the RMP defined in the deliverables from Task 2 and implemented into codes in the deliverables from Task 4. The quality of other contextual data (e.g. geographical data, calendar data, etc.) will be taken into account only in connection with their usability in the pipeline. As an example, it is not in the scope of the project to define methods to evaluate and improve the quality of data on administrative boundaries. In addition, we further clarify that in this chapter we refer to input data as the raw data that are input to the pipeline defined in Task 2. Indeed, in the context of the use of MNO data for official statistics the term 'input data' may be interpreted in two ways: the raw data that are input to the pipeline or the pre-processed data that are delivered by the MNO to the statistical authority (at some point of the pipeline). The latter are to be considered intermediate data in our comprehensive business process and the quality of such pre-processed data delivered to statistical authorities will be analysed in Chapter 7 Quality of throughput. This is also a first relevant difference with, for example, administrative data use for official statistics; usually, administrative data are not pre-processed by the data provider and the raw input data coincide with the data transmitted to the statistical authority.

As illustrated in the deliverables from Task 2, the term 'input data' associated with the reference pipeline is a general term that includes different categories of data and different data objects. The three main categories of input data are: MNO data, contextual data and configuration data. Each one of them, in turn, contains different data objects.

The pipeline is structured in a way that most of these data are accessible at any point of the process. An exception is the category of input MNO data, which is ingested at the very beginning of the pipeline and represents raw input data objects[52] that undergo multiple transformations into intermediate objects. For these reasons, issues affecting them can propagate into the transformed objects, thus affecting the rest of the process. Therefore, specific attention has to be given to their quality and to their conformity with the requirements.

The two main objects belonging to the category of MNO input data are network topology data and event data. Both are acquired at the initial stages of the pipeline process, but their roles are different. Network topology data are used to extract information about the cell coverage; event data are the result of the interactions between the mobile devices and the network infrastructure and are at the basis of the operations that will allow to obtain data on the device themselves.

It is important to highlight that all the input data considered here undergo dedicated checks to assess their conformity to the standards required by the reference pipeline. Most of these requirements involve correctness of the format, as the data have to be provided in a standard structure in order to be acquired by the pipeline's modules.

First, the requirements of the input event data will be introduced, followed by the requirements of network topology data.

\ MNO EVENT DATA REQUIREMENTS

At a high level, MNO event data can be thought of as a triplet of information concerning a device, a location and a timestamp. In more detail, the content of an event record includes multiple fields, among which some are optional for the purposes of the pipeline.

The most fundamental information, in addition to the timestamp of the event, concern the identifiers of the device and the cells in which the event has occurred. All these fields should be presented in a specific format, which is the same for all the operators in order to avoid overloading the pipeline's modules with forced conversions; for example, device IDs should be in a 32 bytes binary format derived from hashing the device's IMSI. Furthermore, information about the devices includes the Mobile Country Code (MCC) and Mobile Network Code (MNC). These are codes made up of a predefined number of digits which allow the identification of the MNO and its geographical provenience This information is of great importance when using MNO data to produce statistics in which the geographical origin of subscribers is a relevant detail, such as in tourism statistics. In addition, geographical information in event data may include the latitude and the longitude of the event occurrence in case information from GPS is available, in which case the cell identifier becomes an optional value, and vice versa.

In other words, each raw event record is a series of fields possessing the three aforementioned characteristics: device, geospatial and temporal information. The adequacy of the format in which these fields are provided, along with the completeness of the mandatory values, are assessed through appropriate checks at the beginning of the pipeline, which will be shortly summarised later in this chapter. As described in the Deliverables of Task 2, MNO event data for the pipeline are supposed to be signalling data from different technologies (3G, 4G, etc). CDR can be used only in case signalling data are not available. Data include inbound and outbound roaming events and are pseudonymised in a way that allows their processing for a specific period. Data should only come from mobile phones, as IoT devices are not considered. The quality checks on input data will verify that these requirements are respected.

\ MNO NETWORK TOPOLOGY DATA REQUIREMENTS

The main function of this category of data is to provide information about the coverage area of the network cells – or, alternatively, the information needed for its estimation.

[52] Borrowing the terminology from the UNECE Generic Statistical Information Model (https://unece.org/statistics/modernstats/gsim), we can consider the input MNO data as the Core Input of the RMP.

If the event data do not contain the geographical coordinates of the events, providing instead the identifier of the cell where the event took place, the probable location of the device has to be inferred through the area that is covered by the cell itself. The information required for this operation is included in the MNO network topology data.

As with the raw MNO event data, MNO network topology data have to undergo data cleaning procedures before being processed in the pipeline. This is done by a specific module which carries out syntactic checks on the input topology data. However, a peculiarity of the planned standard for the MNO network topology data is that two main data objects can be differentiated for this category of data: the cell locations with physical properties and the cell footprint with differentiated signal strength coverage areas. The preferred option would be the data object containing information about the area of the cell and the antenna signal strength; alternatively, the object with information on the physical properties of the cell will be used, through which the needed information about the coverage area can be estimated.

In either case, the raw data have to pass a syntactic cleaning module before they can be used. Similarly to the case of event data, the checks mainly focus on the correctness of the format of the data, their completeness and the removal of records with anomalous values. Further semantic checks applied after integration of MNO event and network topology data will be able to identify errors in the MNO network topology data such as missing cells or incorrect associations of cells IDss and locations.[53]

6.2.2 DIFFERENCES WITH TRADITIONAL SOURCES AND IMPLICATIONS

Traditional data sources, both survey and administrative data, treat mainly stock data - which describe a situation at a given time, and need to be updated regularly to follow the evolution of the phenomenon they illustrate, i.e. new rounds of a survey are, usually, carried out at regular intervals and updated administrative data are acquired to obtain new sets of information. Even when traditional sources refer to flow data (e.g. demographic events), they are usually collected over a period of time and acquired by the NSI as a batch dataset. It is also worth noting here that the collection of information by statistical authorities or other entities, whether from surveys or from administrative data, require the active participation of the units that are under study; i.e. respondents to a survey have to think about the answer and fill in a questionnaire or reply to an interviewer, while for administrative data, usually, modules have to be filled in by private citizens, enterprises or public entities and sent through specific procedures before the new data land in the data archive (and, in any case, they can be usually considered as human generated data). Finally, survey and administrative data are, usually, related to units that are at the same level of the statistical unit of interest (e.g. individuals or enterprises or also events like demographic ones whose counting is of direct interest for official statistics).[54]

For MNO data the situation is different on many levels. First of all, the temporal granularity of MNO data – or more appropriately of *MNO event nanodata, that is, data at subindividual level*[55] - makes it more adequate to compare them to streams or flows of data, in contrast to the stocks of data represented by traditional sources. Indeed, MNO event data – especially signaling data - are produced so frequently that an external observer would see streams of data flowing from each mobile user[56], rather than multiple stocks of data from the whole set of

[53] Unfortunately, errors in the MNO network topology data variables that allow the localisation of the device cannot always be identified through syntactic and semantic checks (e.g. if wrong information on an antenna do not cause out of range of incoherence with other data). It could be needed, e.g. a direct check by the MNO to verify the correctness of the information. The identification of these errors goes beyond the scope of the Multi-MNO project; nevertheless, if any signal of this kind of errors arise, the NSI can communicate the issue to the MNOs in the collaborative spirit that should govern the pipeline.

[54] Also for traditional data, derivation of statistical units may be needed, but still in the microdata context (e.g. deriving households from individuals)

[55] Ricciato F, Wirthmann A, Hahn M. Trusted Smart Statistics: How new data will change official statistics. Data & Policy. 2020;2:e7. doi:10.1017/dap.2020.7

[56] With the term Mobile user we refer to the user of the mobile device that not necessarily coincides with the mobile subscriber.

users. In order to be used for statistical purposes, nanodata need to be aggregated at multiple levels, i.e. micro and macrodata. Furthermore, such flows are characterised by a passive origin, in the sense that the information is generated as a byproduct of human activity and there is no active participation or conscious involvement of the mobile users to the data generation process.

The differences illustrated here have implications not only on the operations carried out for the elaboration of the data, but also on quality considerations of the input sources, as mentioned at the beginning. The evaluation of continuous streams of passive data is a different task from the assessment of a survey dataset or administrative register. The continuous nature of the information implies, for example, that any assessment carried out through predefined measures or input quality indicators has to be automated and organised in such a way that the warnings produced are immediately informative and helpful. From this point of view, some similarities exist with the systems for monitoring data collections in CAPI and CATI surveys, where quality indicators e.g. on interviewer behaviour or unit non-response are available and should be checked daily, even if the reaction time in case of warning situations can be longer than with MNO data. Also, being the data generated as a byproduct, it is more difficult to use the instruments for data collection as quality prevention tools; an example is the difference between a situation in which an interviewer can be trained to prevent measurement errors from the case where the events are generated through unconscious user activity and collected by MNOs through the network monitoring system and without any control by the NSIs. Lastly, it should be kept in mind that, unlike the case of other data sources, widespread errors in MNO data (as in the case, for example, of technical failures) usually cannot be recovered and the data can only be used 'as is'. The limitations on the informative potential of the output in situations like this should, therefore, be addressed.

The table below (see **Table 7**) summarises the main differences between traditional data sources and MNO event data from a quality perspective when used as input sources for official statistics production.

Table 7: Main differences between MNO data and traditional data

TRADITIONAL DATA SOURCES (SURVEY/ADMINISTRATIVE)	MNO DATA
Raw data are provided to NSI	Raw data are not provided to NSI
Micro/macro data	Nano data
Stock data	Flow data
Static	Dynamic
Active generation	Passive generation

Given this structural difference between traditional and MNO data, in this chapter, we will start the definition of the quality assurance system for MNO input data by analysing the quality-related issues emerged in the pipeline defined in the deliverables from Task 2. Afterwards, following a bottom-up approach, we will group them to identify main error types. This should help with understanding the impact that such quality issues on input data can have on the statistical output, and hopefully how to mitigate their effect. Indeed, we are not interested in the quality of input MNO data *per sé*, but only in relation to the influence these can have on the statistical output quality.

The focus of this first part of this chapter will be mainly related to aspects (i.e. the different types of errors) that can have an impact on the quality of the statistical output in terms of accuracy, which is maybe also the most challenging quality dimension to be achieved when using MNO data. We will try to identify relevant aspects taking inspiration from the consolidated framework for input data quality for statistics based on administrative data. Despite the differences between administrative and MNO data (introduced above), some commonalities still remain. In particular, both data types are generated out of the control of statistical authorities and not for statistical purposes.

6.3 QUALITY ISSUES IN MNO INPUT DATA

On the basis of the pipeline defined in Deliverable 2, several quality issues have been identified[57] in MNO data when used as input sources for statistics production. These are reported in **Table 8**. Since the potential errors can be many and there are multiple levels through which the data can be looked at, some identification, or better classification, criteria have to be introduced.

First, we differentiate between the **data object** to which the issue is related. Three main categories of data objects have been identified: MNO event data, MNO network topology data, and contextual data. In addition, some issues are meaningful only when considering the data objects together (integrated data). An input data issue can appear in one or more of such categories and it also occurs at a **specific data level**. Four main levels are identified in **Table 8**: nanodata level, microdata level, macrodata level and cell data level (the latter being more a different dimension than an actual different level). **An input quality issue, in other words, can involve a combination of data objects and levels;** the combination of the data object category and data level is used to build the identifier reported in the first column. For example, the identifier E.M.X stands for an issue that appears in the MNO event data at the microdata level, while X is the progressive enumeration of the issue[58]. The complete legend for the identifiers in **Table 8** is provided below:

ID Data Object
- E=MNO Event Data
- T=MNO Network Topology Data
- I=Integrated data
- C=Contextual data

Issue level:
- N=nano (event)
- M=micro (device or user)
- A=macro (aggregated data)
- C=cell

For each quality issue **Table 8** reports a series of indications that can be divided into two parts: (i) a group of descriptive remarks on the definition, identification, measurement and mitigation of the error, and (ii) a second group that builds the necessary links between the issues and the pipeline. The details on the identification, definition, measurement and mitigation of the error help the reader to understand how a particular issue can be detected within the pipeline, what are the possible solutions to reduce its impact and an indication of the relevance of the issue with respect to the needs of the MNOs (it is indicated with (r) in Table 2). This is important for the definition of the roles and the introduction of monitoring and correction measures. It is reasonable to assume that it could be easier to get support from MNOs if the issues to be handled affect their interests as well, in addition to their impact on the statistical output quality. Several fields in **Table 8** provide a direct association with the pipeline's modules, as it includes columns dedicated to the quality metrics data object in which the measure used to detect the issue is contained, the specific method name in the pipeline that analyse such metrics and the quality warning output data object that is returned. Therefore, all the information regarding the quality control actions in the pipeline in relation to the input issues is provided. Furthermore, a column which reports the current proposal for a definition of identifiers for quality modules is introduced, in perspective of a future sharing with other tasks of the project or simply for its use within the quality assurance system.

Lastly, the 'type of error' column maps the quality input issue to the consolidated terminology of non-sampling errors in use in the ESS. In particular, since this classification describes the errors that affect the input data (for example missing data, misclassification, coverage and so on), it has to be read in conjunction with the 'ID & issue

[57] Based on the vast experience of data analytics partners working with MNO data.
[58] Note that whenever an issue is related to multiple data objects combined together the letter *I* (as in "integration") has been used as the first character of the identifier.

level' column to fully understand the implications of the issue on the overall quality of the data. For example, missing data error in the MNO event data can imply at the microdata level either an undercoverage error (if all events related to a specific device are missing) or a measurement error (if only some of the events are missing and the placement of the device is thus wrongly affected).

Although currently incomplete, **Table 8** already provides a deeper understanding of the main issues affecting the diverse categories of MNO input data and the solutions that are offered in the pipeline. For example, from the perspective of the quality modules it can be observed that errors related to the MNO network topology data alone are mainly detected through syntactic checks, while errors that involve topology data in conjunction with other data objects are identified through semantic checks. Also, network topology data errors emerge as a concern especially for the operators, while event data errors, on the opposite, are of interest for statistical offices in many cases.

These are just a few examples of the insights that can emerge from **Table 8**. In conclusion, in its final version (in Deliverable D3.3), the table will be able to offer a comprehensive overview of the quality assurance system built within the pipeline to guarantee the quality of its outputs.

Table 8: Input data quality issues: identification, definition, measurement and mitigation of the error, link between data quality issues and the pipeline

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
T.C.1 (cell) (r)	**MNO Network Topology data** The data object is in the wrong format	Detection: The pipeline is not able to read the file. Mitigation: • quality warning is produced and provided to MNOs to investigate possible causes and adjust for future (to be added)	QM.TopSynt	MNO Network Topology Data Quality Metrics [INTERMEDIATE RESULTS] (to be added)	Method: 2.1 MNO Network Topology Syntactic Quality Warnings (to be added) Output: MNO Network Topology Data Quality Warnings [INTERMEDIATE RESULTS] (to be added)	Data not compliant with agreed requirements for the pipeline
T.C.2 (cell) (r)	**MNO Network Topology data** Cells have invalid coordinates	Detection: It is identified applying initial syntactic checks. Mitigation: • records with errors are removed • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future	QM.TopSynt	MNO Network Topology Data Quality Metrics [INTERMEDIATE RESULTS]	Method: 2.1 MNO Network Topology Syntactic Quality Warnings Output: MNO Network Topology Data Quality Warnings [INTERMEDIATE RESULTS]	Measurement errors
T.C.3 (cell) (r)	**MNO Network Topology data** Cells have missing coordinates	Detection: It is identified applying initial syntactic checks Mitigation: • records with errors are removed • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future	QM.TopSynt	MNO Network Topology Data Quality Metrics [INTERMEDIATE RESULTS]	Method: 2.1 MNO Network Topology Syntactic Quality Warnings (to be added) Output: MNO Network Topology Data Quality Warnings [INTERMEDIATE RESULTS]	Missing data

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
T.C.4 (cell) (r)	**MNO Network Topology data** Missing data for specific period for specific region	Detection: It can be identified through the analysis of checks that monitor the number of cells in MNO topology data over a lookback period (the number of cells should be reduced if a region is missing) Mitigation: • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future • MNO has to verify if it is an issue connected to the delivery or to the availability of the data due to technical issues (network outage) • if possible, data should be restored and analysed after the outage period otherwise information about the outage should be provided to NSI in order to implement compensation methods if possible (such methods should be defined also in ESSnet MNO-MINDS)	QM.TopSynt	MNO Network Topology Data Quality Metrics [INTERMEDIATE RESULTS]	Method: 2.1 MNO Network Topology Syntactic Quality Warnings Output: MNO Network Topology Data Quality Warnings [INTERMEDIATE RESULTS]	Missing data
T.C.5 (cell) (r)	**MNO Network Topology data** Missing data for specific period for whole country	Detection: Data delivery is missing for a day or longer period. Mitigation: • MNO has to verify if it is an issue connected to the delivery or to the availability of the data due to technical issues (network outage) • if possible, data should be restored and analysed after the outage period otherwise information about the outage should be provided to NSI in order to implement correction methods if possible (such methods	-	-	-	Missing data

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
		should be defined also in ESSnet MNO-MINDS)				
I.A.1 (macro)	**Contextual data, MNO event data** Discrepancies between ISO_a2 lists by MNO and NSI	Detection: TBD[59] Mitigation: • in the agreement with MNO it should be mentioned that the classification used should be provided as metadata and should be updated when there are changes	QM.NSIDel	TBD (a specific check should be added in the pipeline when data are delivered to NSI)	Method: TBD (a specific check should be added in the pipeline when data are delivered to NSI) Output: TBD (a specific check should be added in the pipeline when data are delivered to NSI)	Misclassification errors
I.C.1 (cell) (r)	**MNO network topology data, MNO event data** Events have cells that are not present in network topology	Detection: It is identified by applying semantic check after integrating MNO event data and MNO topology data Mitigation: • events with not existing cells are flagged • list of missing cells is included in quality warnings provided to MNOs to investigate possible causes and adjust for future • TBD if the information on cells missing in a specific day or period can be restored from other periods	QM.TopSem	Device Semantic Quality Metrics [INTERMEDIATE RESULTS]	Method: 13.1 MNO Event Data at Device Level Semantic Quality Warnings Output: MNO Event Data at Device Level Semantic Quality Warnings [INTERMEDIATE RESULTS]	Missing data
I.C.2 (cell) (r)	**MNO event data, MNO network topology data**	Detection: It can be identified by applying semantic checks after integrating MNO event data and MNO topology data	QM.TopSem	Device Semantic Quality Metrics [INTERMEDIATE RESULTS]	Method: 13.1 MNO Event Data at Device Level Semantic Quality Warnings	Measurement errors

[59] In the data one can find Acronyms used by MNO that are not present in the NSI's codelists. In addition, metadata provided by the MNO should be compared with NSI metadata.

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
	Illogical changes of the locations based on time and distance difference (incorrect coordinates of cells)	Mitigation: • events and cells with suspect or incoherent coordinates are flagged • quality warnings and list of suspected or incoherent cells are produced and provided to MNOs to investigate possible causes and adjust for future			Output: MNO Event Data at Device Level Semantic Quality Warnings [INTERMEDIATE RESULTS]	
I.M.1 (micro)	**MNO event data, MNO network topology data, contextual data**	Detection: Accidental roaming for inbound data can be identified by detecting foreign subscribers being shortly present in a country of reference in cells near the sea or land borders.	QM.RoamErr	TBD (to be added in the pipeline after integration with information on administrative borders)	Method: TBD (to be added in the pipeline after integration with information on administrative borders)	Coverage
	Accidental roaming for inbound data	Mitigation: • records with errors are flagged • quality warnings are produced • erroneous data are excluded from following estimations			Output: TBD (to be added in the pipeline after integration with information on administrative borders)	
I.M.2 (micro) (r)	**Contextual data, MNO event data** MCCMNC list not up to date	Detection: TBD[60] Mitigation: • request to MNO to update the list	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS] (to be added)	Method: 8.1 MNO Event Data Syntactic Quality Warnings (to be added) Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS] (to be added)	Misclassification errors
I.M.3 (micro)	**MNO event data, MNO network topology data**	Detection: TBD	QM.EvSem	TBD	Method: TBD	Coverage

[60] Are there many MCCMNC in event data that are not present in the list

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
	Scamming (SIM-box type of scammers with large number of foreign SIM cards in one or many locations, from our experience it can be many cells near one location)	Mitigation: • to be removed once identified (these cases, once identified, should be removed to not inflate the estimation of devices in the corresponding land)			Output: TBD	
I.N.1 (nano)	**MNO event data, MNO Network Topology data** Events out of territory but not errors (e.g.: Seamen)	Detection: TBD[61] Mitigation: • records with errors could be flagged • quality warnings could be produced and provided to MNOs to investigate possible causes and adjust for future	QM.TopSem	TBD (Possibly to be added in Device Semantic Quality Metrics [INTERMEDIATE RESULTS])	Method: TBD (Possibly to be added in 13.1 MNO Event Data at Device Level Semantic Quality Warnings) Output: TBD (Possibly to be added in MNO Event Data at Device Level Semantic Quality Warnings [INTERMEDIATE RESULTS])	Coverage
I.N.2 (nano)	**MNO event data, MNO Network Topology data**	Detection: TBD[62]	QM.TopSem	TBD (Possibly to be added in Device Semantic Quality Metrics	Method: TBD (Possibly to be added in 13.1 MNO Event Data at Device Level Semantic Quality Warnings)	Measurement errors

[61] Since cells out of territory are removed from topology, while events with cells that are not present in network topology are flagged, an analysis of that flagged events could lead to identification of these cases. Also, cells near the borders can be considered. It should be evaluated if it is in the scope of the project.

[62] The identification of domestic ghost records is based on comparing the same subscribers' records in outbound roaming data and domestic roaming data. Domestic ghost records appear in domestic data exactly at the same time as outbound records or in close temporal proximity. It should be evaluated if it is in the scope of the project.

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
	Ghost events (incorrect domestic events in temporal proximity of outbound events registered far away)	Mitigation: • records with errors could be flagged • quality warnings could be produced and provided to MNOs to investigate possible causes and adjust for future		[INTERMEDIATE RESULTS])	Output: TBD (Possibly to be added in MNO Event Data at Device Level Semantic Quality Warnings [INTERMEDIATE RESULTS])	
I.N.3 (nano)	**MNO event data, MNO network topology data, contextual data** Accidental roaming issues for domestic/outbound data	Detection: Accidental roaming for domestic and outbound data can be identified by detecting domestic subscribers being shortly present in a neighbouring foreign country Mitigation: • records with errors are flagged • quality warnings are produced • erroneous data are excluded from following estimations	QM.RoamErr	TBD (to be added in the pipeline after integration with information on administrative borders)	Method: TBD (to be added in the pipeline after integration with information on administrative borders) Output: TBD (to be added in the pipeline after integration with information on administrative borders)	Missing data
I.N.4 (nano)	**MNO event data, MNO network topology data** Speed and distance issues (people using phones on planes moving fast during take-off / landing and sometimes even flying)	Detection: TBD[63] Mitigation: *TBD (these residuals cases, once identified, should be removed to not inflate the estimation of devices in the corresponding land, but it is important to distinguish them from Issue I.C.2)*	QM.DevAct	TBD	Method: TBD Output: TBD	Coverage

[63] In multiscale analysis high speed sequence of events can be flagged?

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
E.M.1 (micro)	**MNO event data** Hashed device ID's are not continuous (different IDs are associated to the same device in different days)	Detection: Suspect cases can be detected analysing the frequency of the presence of each ID in lookback period (frequency=1 day is suspicious)	QM.GenAct	TBD in General Event Statistics Metrics [INTERMEDIATE RESULTS]	Method: TBD in XX.1 General Event Statistics Quality Warnings	Data not compliant with agreed requirements for the pipeline
		Mitigation: • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future			Output: TBD in General Event Statistics Quality Warnings [INTERMEDIATE RESULTS]	
E.M.2 (micro) (r)	**MNO event data** Hashed device ID's are not unique per subscriber (two different devices two different subscribers have somehow gotten the same ID's)	Detection: Suspect cases can be detected monitoring over time devices with many cases of illogical changes of the locations based on time and distance difference (I.C.2)	QM.DevAct	TBD (possibly starting with flags in Semantically Cleaned Event Data at Device Level [INTERMEDIATE RESULTS])	Method: TBD	Measurement errors
		Mitigation: • suspect cases are provided to MNOs to investigate possible causes and adjust for future			Output: TBD	
E.M.3 (micro) (r)	**MNO event data** Missing data for some groups of	Detection: It can be identified monitoring MCC and MNC codes over a lookback period for groups of domestic/inbound/outbound	QM.GenAct	TBD in General Event Statistics Metrics	Method: TBD in XX.1 General Event Statistics Quality Warnings	Missing data

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
	devices (e.g., inbound is missing)	Mitigation: • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future • MNO has to verify if it is an issue connected to the delivery or to the availability of the data due to technical issues • if possible, data should be restored and analysed after the outage period otherwise information about the outage should be provided to NSI in order to implement compensation methods if possible (such methods should be defined also in ESSnet MNO-MINDS)		[INTERMEDIATE RESULTS]	Output: TBD in General Event Statistics Quality Warnings [INTERMEDIATE RESULTS]	
E.M.4 (micro)	**MNO event data** Different hashing across MNOs	Detection: TBD[64] Mitigation: TBD	TBD	TBD	Method: TBD Output: TBD	Impact on overall accuracy
E.M.5 (micro)	**MNO event data** MCCMNC of device not related to specified country	Detection: TBD[65] Mitigation: TBD	TBD	TBD	Method: TBD Output: TBD	Measurement errors

[64] If privacy issues prevent us from linking microdata from different MNOs this is not an issue, if it is possible the hashing procedure should be syncronised between different MNOs.
[65] Shall 7-digit IMSI be used? It should be evaluated what is the impact of such cases.

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
	(leased MCCMNC ranges)					
E.M.6 (micro)	**MNO event data** Travel SIM cards (issue for inbound roaming where MCCMNC of the device does not refer to the actual country of the person)	Detection: TBD[66] Mitigation: • The impact on statistical output could be mitigated during grossing-up if information on the spread/frequency of the use of travel SIM cards is known from not-MNO data	QM.NSIAdj	TBD	Method: TBD Output: TBD	Misclassification errors
E.M.7 (micro)	**MNO event data** Machine2Machine and IoT devices representing non-humans	Detection: Suspect cases can be detected analysing the sum of the distances between events: if it is too low, it could be a IoT or M2M device Mitigation: • quality warning should provide information on suspect cases to MNOs that should filter these cases	QM.GenAct	TBD in General Event Statistics Metrics [INTERMEDIATE RESULTS]	Method: TBD in XX.1 General Event Statistics Quality Warnings Output: TBD in General Event Statistics Quality Warnings [INTERMEDIATE RESULTS]	Data not compliant with agreed requirements for the pipeline
E.M.8 (micro)	**MNO event data**	Detection: TBD[67]	QM.RoamErr	-	-	Coverage

[66] If technically is not possible to distinguish this type of SIM, the issue can be managed directly through grossing-up.

[67] A set of roamers will disappear in the data from an MNO and should appear in another MNO. This case is difficult to identify with the RMP. It is recommended to obtain the information through institutional agreements.

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
	The change of roaming partner contracts of MNO (mostly affects outbound data)	Mitigation: • in the agreement with MNO it should be mentioned to inform NSI on changes in partner contracts			-	
E.M.9 (micro)	**MNO event data** Launch of a new offer increase the devices for a MNO	Detection: It can be identified monitoring the size of the events Mitigation: • quality warnings are produced and provided to MNOs that should explain the reason for the increase • in the agreement with MNO it should be mentioned to inform NSI on the launch of offers • it has impact on market share of the MNO	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS]	Method: 8.1 MNO Event Data Syntactic Quality Warnings Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS]	Coverage
E.M.10 (micro)	**MNO event data** Not all population units own a device	Detection: This is a well-known issue that can be measured only through ad hoc studies or derived from not-MNO data Mitigation: The subpopulation without devices could be estimated through specific methods or be available in not-MNO data (such methods should be defined also in ESSnet MNO-MINDS). Aggregated data from MNOs can then be adjusted to compensate the error.	QM.NSIAdj	-	- -	Coverage

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
E.M.11 (micro)	**MNO event data** Duplication of users (a person with 2 SIMs or 2 devices)	Detection: This case is very difficult to be detected. If the SIMs or devices are from the same MNO, they could emerge analysing them longitudinally, otherwise ad hoc studies should be carried out (ESSnet MNO-MINDS could make some proposals) Mitigation: • if the case is detected before aggregation, one of the two devices' data can be discarded, otherwise aggregated results can be adjusted	QM.NSIAdj	TBD	Method: TBD Output: TBD	Coverage
E.N.1 (nano) (r)	**MNO event data** The data object is in the wrong format	Detection: The pipeline is not able to read the file Mitigation: • quality warning is produced and provided to MNOs to investigate possible causes and adjust for future (to be added)	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS] (to be added)	Method: 8.1 MNO Event Data Syntactic Quality Warnings (to be added) Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS] (to be added)	Data not compliant with agreed requirements for the pipeline
E.N.2 (nano) (r)	**MNO event data** Invalid data on device id, location variables, time variables	Detection: It is identified applying initial syntactic checks Mitigation: • records with errors are removed • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS]	Method: 8.1 MNO Event Data Syntactic Quality Warnings Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS]	Measurement errors

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
E.N.3 (nano) (r)	**MNO event data** Missing data on device id, location variables, time variables	Detection: It is identified applying initial syntactic checks Mitigation: • records with errors are removed • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS]	Method: 8.1 MNO Event Data Syntactic Quality Warnings Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS]	Missing data
E.N.4 (nano) (r)	**MNO event data** Timestamps of events have incorrect time zone (not UTC) including events are only 12h and not 24h	Detection: It is identified applying initial syntactic checks Mitigation: • records with errors are removed • quality warnings are produced and provided to MNOs • MNO is asked to provide the data according to pipeline requirement	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS]	Method: 8.1 MNO Event Data Syntactic Quality Warnings Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS]	Data not compliant with agreed requirements for the pipeline
E.N.5 (nano) (r)	**MNO event data** Missing data for specific period for whole country	Detection: Data delivery is missing for a day or longer period. Mitigation: • MNO has to verify if it is an issue connected to the delivery or to the availability of the data due to technical issues (network outage) • if possible, data should be restored and analysed after the outage period otherwise information about the outage should be provided to NSI in order to implement compensation methods if possible	-	-	- -	Missing data

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
		(such methods should be defined also in ESSnet MNO-MINDS)				
E.N.6 (nano) (r)	**MNO event data** Missing data for specific period for specific region	Detection: It can be identified through the analysis of checks that monitor the size of event data or the number of unique cells per day in event data over a lookback period (the size and the number of cells should be reduced if a region is missing) Mitigation: • quality warnings are produced and provided to MNOs to investigate possible causes and adjust for future • MNO has to verify if it is an issue connected to the delivery or to the availability of the data due to technical issues (network outage) • if possible, data should be restored and analysed after the outage period otherwise information about the outage should be provided to NSI in order to implement compensation methods if possible (such methods should be defined also in ESSnet MNO-MINDS)	QM.EvSynt, QM.DevAct	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS] Device Activity Statistics [INTERMEDIATE RESULTS]	Method: 8.1 MNO Event Data Syntactic Quality Warnings 10.2 Device/Event Deduplication Quality Warnings (to be added) Output: MNO Event Data Quality Warnings [INTERMEDIATE RESULTS] Device activity Quality Warnings [INTERMEDIATE RESULTS]	Missing data
E.N.7 (nano) (r)	**MNO event data** Duplication of events	Detection: They are identified through ad hoc syntactic check Mitigation: • Quality warning on duplicated events is provided to MNO. If there are too many duplicated events it could be a network issue that should be verified and resolved by MNO • Duplicated events are removed	QM.EvSynt	MNO Event Data Syntactic Quality Metrics [INTERMEDIATE RESULTS]	Method: 10.2 Device/Event Deduplication Quality Warnings Output: Device activity Quality Warnings [INTERMEDIATE RESULTS]	Event duplication

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
E.N.8 (nano)	**MNO event data** Changes in MNO technology (from CDR to signaling to GPS...)	Detection: Signaling data are supposed to be used for the pipeline (requirements). Nevertheless, some statistics on device activity can identify suspect event data that could be CDR. In the future GPS or other kind of data could be available and the pipeline should be adapted Mitigation: • quality warnings are generated if there is the suspect that data are CDR and not signaling. • in case in the future the technology will change the modular approach of the pipeline could allow to adapt it to the new situation easily.	QM.GenAct	TBD in General Event Statistics Metrics [INTERMEDIATE RESULTS]	Method: TBD in XX.1 General Event Statistics Quality Warnings Output: TBD in General Event Statistics Quality Warnings [INTERMEDIATE RESULTS]	Impact on overall accuracy
C.A.1 (macro)	**Contextual data** Discrepancies between administrative data used by MNO and NSI	Detection: TBD[68] Mitigation: • in the agreement with MNO it should be mentioned that the administrative data used should be provided	QM.NSIDel	TBD (a specific check should be added in the pipeline when data are delivered to NSI)	Method: TBD (a specific check should be added in the pipeline when data are delivered to NSI) Output: TBD (a specific check should be added in the pipeline when data are delivered to NSI)	Misclassification errors
C.A.2 (macro)	**Contextual data** Unknown market share of MNO	Detection: This information is business sensitive and it is not asked to MNO Mitigation: The market share could be estimated through specific methods or be available in not-MNO data (such methods should be defined also in ESSnet MNO-MINDS). Aggregated data from MNOs can then be adjusted to compensate the error	QM.NSIAdj	-	- -	Coverage

[68] Concerning geographical data, and in particular administrative boundaries, this error is relevant only if MNO assigns the data to territorial administrative units and not the NSI. In this case, the discrepancies between administrative data used by the MNO and the NSI should be checked.

ID & ISSUE LEVEL	DATA OBJECT & ISSUE	(D) HOW IS DETECTED/MEASURED (M) HOW IS MITIGATED	ID QUALITY MODULE	QUALITY METRIC OBJECT INPUT	QUALITY WARNING METHOD & QUALITY WARNING OUTPUT	TYPE OF ERROR
C.A.3 (macro)	**Contextual data** Change of the market share of MNO over the time	Detection: This information is business sensitive and it is not asked to MNO Mitigation: The market share could be estimated through specific methods or be available in not-MNO data (such methods should be defined also in ESSnet MNO-MINDS). Aggregated data from MNOs can then be adjusted to compensate the error	QM.NSIAdj	-	- -	Coverage
C.N.1 (nano)	**Contextual data** Boundaries of administrative units change over time (comparability over time)	Detection: TBD (brainstorming: concerning geographical data, and in particular administrative boundaries, this error is relevant only if MNO assign the data to territorial administrative units and not NSI. In this case, auxiliary data should be updated) Mitigation: • in the agreement with MNO it should be mentioned that the administrative data used should updated when there are changes	QM.NSIDel	-	- -	Misclassification errors

6.4 ERRORS IN INPUT MNO DATA AFFECTING OUTPUT

From the table in Section 6.3, it can be deduced that errors in MNO input data are mainly connected to missing data, coverage, measurement and misclassification errors. In their definition we should pay attention to the level of data to which they refer: nano, micro or macro, or if they refer to errors in the topology data.

In this section we analyse the types of errors identified and the possible impact on statistical results.

Table 8 also identifies errors due to the lack of compliance with the pipeline requirements, e.g. the file is not readable, the timestamp is not in UTC, IoT or M2M devices are not filtered. These errors are basically due to incorrect data preprocessing made by the MNO in preparing the data for the pipeline. Therefore, if we adopt a broad definition, they can also be seen as processing errors. In any case, their presence can have considerable impact on the statistical output, if data flows are lost because they are not readable or if the presence of IoT and M2M devices erroneously inflates the estimation of aggregates that should refer only to mobile phone users, leading also to over-coverage errors (see next subsection for this latter case).

Finally, **Table 8** also identifies general issues that can have an impact on the overall accuracy of the statistical output produced with MNO data and cannot be associated to a specific type of error; for example, the possible changes in MNO technology (e.g. from 4G to 5G and prospectively to 6G mobile technologies). The RMP is tailored for signaling data, while with the technology evolution it is possible that more accurate data will become more easily available. This should positively affect the accuracy of the statistical outputs; nonetheless, the pipeline should be adapted accordingly.

6.4.1 COVERAGE ERRORS

As in traditional quality frameworks, coverage errors arise from the discrepancies between the target population and the population in the source data (or in the frame, in case of surveys). Coverage issues can be differentiated in under-coverage and over-coverage. The former is the situation in which units that belong to the target population are not included in the source data, the latter error happens when units that should not belong to the population are present in the source data. Duplications are also in general connected with coverage issues implying more than one unit in the source data corresponding to one unit in the target population.

Coverage issues in MNO data are mainly referred to micro or macro level analysis. This is logical because the target population for the statistical output is usually defined at micro level (i.e. statistics on individuals and not on events) or macro level (e.g. statistics referred to territorial units). In addition, it should be noted that when issues occur at the level of events it is usually less difficult to deal with them, e.g. duplication of events is easily identified and removed.

Maybe one of the main quality challenges in using MNO data for official statistics is the potential bias in the estimates that can be due to under-coverage of some subpopulations, for example children and, to a less extent, the elderly population who do not hold a device. The actual impact of these errors on statistical output will depend on the problem the MNO data are being used for or, in other words, on the use case considered; for example, a general study on the present population may be more affected by the under-representation of the youngest and eldest demographic classes than, say, a hypothetical use case involving only the population workforce. Another source of under-coverage is the availability of data only from a subset of MNOs in the country. In such cases the market share of the MNOs can be used as the simplest way to adjust the estimates until more advanced methods are made available from the project MNO-MINDS[69], but this information is usually considered not reliable enough.

There are two main sources of over-coverage in MNO data: the first one stems from the discrepancy between the carrier of a device and the device itself, meaning that there is not necessarily a one-to-one relationship

[69] MNO-MINDS | Eurostat CROS (europa.eu)

between these two entities. In this context, over-coverage occurs when an individual owns and carries multiple devices, for example, a private and a business one. If we counted such devices as separate ones, we would register an additional human presence which, of course, would determine an overestimation in the final results, if not corrected[70]; but it is usually very difficult to detect and correct for this kind of issue, since the detection would rely on identifying overlapping locations of the two devices over time. Furthermore, if the SIMs of the devices belonging to the same owner are linked to different operators, it is practically impossible to identify him or her as a single person, unless the nano-data from multiple MNOs are gathered together and processed jointly; only in this case, in fact, the similarities in the events observed for multiple devices would allow to reach the conclusion that they probably belong to the same individual. However, in the current scenario is assumed that this would not be allowed. In any case, as the use of MNO data in official statistics progresses, further studies will be able to quantify the impact of this error.

A second relevant source of over-coverage derives from the inclusion in the data of events referring to devices that should be filtered. An example, already mentioned in Section 6.2, are signals produced by IoT devices and machine-to-machine transmissions. In theory these cases should not affect the data because MNOs should be able to filter out such devices, thus eliminating the related events from the datasets before processing operations. However, ad hoc checks are planned to be developed within the pipeline to uncover the possible presence of such devices. Additionally, accidental roaming presents a unique form of over-coverage. This occurs when mobile devices near national borders unintentionally connect to a network in a neighbouring country, generating data records as if the user were in that foreign location. While, technically, the device is within the coverage area of the foreign network, the inclusion of these data points in statistical analyses can lead to overestimations. Particularly noteworthy are the cases of seamen and individuals working in maritime industries, who frequently experience accidental roaming due to the nature of their work, which involves crossing international waters and coming into proximity with multiple countries' networks. These individuals' mobile devices can connect to different terrestrial networks based on signal strength and inflate the related estimations. Furthermore, the activities of scammers and the operation of SIM card farms introduce additional complexities into the accurate assessment of network data. These actors often utilize large numbers of SIM cards simultaneously to conduct fraudulent activities or generate spam, creating a false impression of heightened network activity or an inflated number of unique users. Such practices not only pose security and fraud concerns but also skew the data used for official statistics and network planning, leading to over-coverage errors.

Eventually, it can be noted in the table in Section 6.2 that all the issues concerning coverage errors are relevant only for statistical purposes and not for MNO purposes. This can be a reason why statistical authorities should define alternative methods themselves to handle these issues. Indeed, the remedies lie outside the specific context of MNO data and can be found in the practices of statistical offices for similar situations: ad hoc surveys for under-coverage estimation, data integration, correction through weighting and calibration methods. In particular, the development of the methodologies for the integration of MNO data with not-MNO data in order to improve the quality of the statistical output is one of the objectives of the ESSnet MNO-MINDS research project, which hopefully will provide sound methods to solve or, at least, mitigate the effect of under-coverage on the accuracy of statistical results.

6.4.2 MISSING DATA

Besides under-coverage issues, there are other relevant non-observation errors in MNO data. Similarly to non-response in survey data and to missing data in the accessed administrative data source, in MNO data we can experience missing data, at the level of the entire event or for specific information (for example information

[70] To be more specific, the presence of multiple devices for a single owner leads to over-coverage in the sense that additional events are registered with respect to the person originating them. Technically, event data may be not considered over-covered per se (the events are counted correctly for the number of devices producing them, after all) but for the purposes of the statistical use of MNO data, generally, the presence of multiple devices per owner means an overestimation of the population of interest.

needed to assign a location to the event). Item missingness (absence), however, often makes the entire record not usable and it is then removed, resulting in missing data for the entire event. In this case, the error is frequently at the nano level and often the cause can be found in technical outages or other issues of the network. In the case of temporary data loss the difficulty is that such data usually cannot be recovered. But the impact of these accidents can be kept under control if the data flows (from the antennas to the MNO and from the MNO to the NSI) are regular during larger timeframes and an appropriate system of checks and warnings is in place, so that the operators are alerted when such circumstances occur. Indeed, this kind of errors is usually relevant also for the MNO purposes and they will solve the issue as soon as possible. For the purpose of the detection of these and other anomalies, the presence of multiple operators can be leveraged to compare the intermediate outputs and identify, for example, partially missing data for a specific operator. In any case, the missing data can have an impact on estimates that should be managed by the pipeline. How to handle the error can be different in different cases. For example, missing data for a complete region has effects similar to under-coverage errors and adjustment methods can be similar, with the advantage that information from the same region is available for other periods and can be exploited as auxiliary information for correction. A random set of missing events or missing data on network topology data can produce effects similar to measurement errors since the location of some events for involved devices can be inaccurate but the information on the existence of the device is not lost. In these cases, different strategies should be developed to correct estimations.

6.4.3 MEASUREMENT ERRORS

In the context of official statistics, a measurement error is defined as the difference between the recorded value that is collected through some acquisition tool and the true value that needs to be acquired. MNOs antennas and Telco network can be considered as the complex measurement tool that bring some inevitable measurement errors with them.

Coherently with their definition, measurement errors for MNO data are mainly originated at the level of event (nano) or cell, but when the error is in the variable that identifies the device, its impact is at micro level. An example of the latter case is when the same pseudonym is erroneously associated to different devices. In such cases, an error in a single variable propagates to all events related to the involved devices.

More commonly, simple syntactic checks are able to identify measurement errors due to the data being in the wrong format or out of the possible range. The impact of such cases is supposed to be limited but they should be monitored and warnings should be activated in case their amount becomes relevant, because they can be the alarm bell for issues in the network. In other cases, such errors are made up of faulty acquisitions of the event location. Following the logic of the pipeline, some semantic errors can be seen as an indication (or, more appropriately, as a consequence) of measurement errors: it is the case of the typical situation in which a device is seen moving from a location to another which would have been impossible to reach at a reasonable average speed within the observed timespan. In some circumstances this is due to the MNOs acquisition tools, while in other cases, however, this may happen due to a wrong assignment of the cell to the space which could be considered more similar to a processing error than a measurement error. Another specific type of measurement errors is 'ghost events' where incorrect domestic events are recorded in proximity to outbound events, significantly far from the actual location of the mobile device. Furthermore, operators may lease ranges of MCCMNC to other entities, leading to situations where the network code does not accurately reflect the actual country of the mobile activity.

6.4.4 MISCLASSIFICATION ERRORS

In statistics derived from traditional data sources, misclassification errors are related to errors in the frame from which the sample should be selected and concern errors in variables useful to contact the unit or to be used as auxiliary in sample design (e.g. to classify units in strata). Alternatively, misclassification errors are a kind of processing errors related to the wrong assignment of the units to the categories of a classification. For MNO data

we refer to such cases in which errors in event, topology or contextual data cause an erroneous classification of devices in relevant subgroups. Involving grouping of devices, as expected, these errors are identified mainly at micro or macro level. The issue can be connected to the lack of updated contextual data that should provide the classification items (e.g. the list of MCCMNC is not updated and devices are attributed to wrong operators and consequently countries, the administrative boundaries have changed or there are discrepancies between the classification adopted by the MNO and the NSI). These kinds of misclassification errors can have an impact also on geographical and temporal comparability of statistical output produced, and not only on their accuracy. A different misclassification error can be caused by the use of travel SIM cards by international travelers, often to avoid high roaming charges. It poses a challenge in accurately associating mobile activity with the correct geographic segments.

Besides the issues that can emerge from the pipeline, a relevant question for the production of statistical outputs based on MNO data is the lack of sociodemographic information related to device owners that could be useful as classification variables for statistical outputs. As for information on the market share of different MNOs or the level of under-coverage of the data for specific subpopulations, we should look for alternative methods to compensate for this lack of information that could be developed in other projects, such as the ESSnet MNO-MINDS.

6.5 INPUT QUALITY METHODS

In this section, the main methods used for the monitoring of the quality of the raw input data are detailed, with a focus, particularly on the checks involving network topology and event data. For each method the following information is provided:

- **Main objective**
- **Methodological overview -** brief description of the methodology (n.b. more detailed information about the methodology is available in the deliverables from Task 2)
- **Quality issues** providing the following information:
    - **Issue:** description of the quality issue and possibly the type of error associated
    - **Quality metrics -** a quantity or indicator that can detect if there is a deviation from normality
    - **Quality warnings -** alert, based on the quality metric, indicating that a process may not meet established quality standards.
    - **Quality actions -** the action that will be undertaken in the pipeline after receiving the 'quality warning'
    - **Mitigations actions:** mitigation actions that could be undertaken to prevent or reduce the error occurrence
    - **Impact on output quality**: possible impact on the quality of the output can be reported as well as suggestions on possible methods to evaluate such impact

Table 9: MNO network topology data cleaning – syntactic checks

MNO NETWORK TOPOLOGY DATA CLEANING – SYNTACTIC CHECKS (QM.TopSynt)						
Main objective						
The objective of this module is to remove erroneous entries and to produce corresponding syntactic quality metrics, performing syntactic checks on Network Topology Data.						
Methodological overview						
The method identifies records with missing values, out of range values and non-compliant with the requirements and remove them. Removed records by type of error are counted.						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Missing values	Count of cells with related error code	Warnings are raised if the error rate is over a threshold (absolute or over an average of a previous period); or if it is over the upper control limit defined by (average + X·SD).	Removal of entries with errors.	If the most recent topology data are missing too much information, previous updates could be used instead. If MNOs cannot provide information regarding the cell coverage plan, information to estimate the cell coverage should be provided instead.	Loss of topology data may have an impact on the identification and the localization of events.
2	Out of range values	Count of cells with related error code	Warnings are raised if the error rate is over a threshold (absolute or over an average of a previous period); or if it is over the upper control limit defined by (average + X·SD).	Removal of entries with errors.	If the most recent topology data are missing too much information, previous updates could be used instead. If MNOs cannot provide information regarding the cell coverage plan, information to estimate the cell coverage should be provided instead.	Loss of topology data may have an impact on the identification and the localization of events.
3	Non-compliance with requirements: wrong formats	Count of cells with error code related to unsupported data type	Warnings are raised if the error rate is over a threshold (absolute or over an average of a previous period); or if it is over the upper control limit defined by (average + X·SD).	Removal of entries with errors.	If the most recent topology data are missing too much information, previous updates could be used instead. If MNOs cannot provide information regarding the cell coverage plan, information to estimate the cell coverage should be provided instead.	Loss of topology data may have an impact on the identification and the localization of events.
4	Non-compliance with requirements: parsing failures	Count of cells with error code related to parsing error	Warnings are raised if the error rate is over a threshold (absolute or over an average of a previous period); or if it is over the upper control limit defined by (average + X·SD).	Removal of entries with errors.	If the most recent topology data are missing too much information, previous updates could be used instead. If MNOs cannot provide information regarding the cell coverage plan, information to estimate the cell coverage should be provided instead.	Loss of topology data may have an impact on the identification and the localization of events.

Table 10: MNO event data cleaning – syntactic checks

METHOD: MNO EVENT DATA CLEANING – SYNTACTIC CHECKS (QM.EvSynt)						
Main objective						
The objective of this method is to perform syntactic checks on the raw event data from the MNO. Data not matching the expected syntax are removed. Based on the removed records, quality metrics are created.						
Methodological overview						
The method focuses on the removal of entries containing invalid or null values for relevant fields. Rows with no location data are removed, as well as rows with coordinates that fall outside the bounding box. Rows are also removed if MCC or MNC codes are invalid or the timestamp is not in the correct format. Finally, duplicate rows are also removed.						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Missing values	Count of records with related error code. Metrics can be computed by date in aggregate terms or specified by user, by cell or by user and cell.	Warnings are raised if the error rate is above a threshold (absolute or above an average of a previous period); or if it is above the upper control limit defined by (average + X·SD).	Rows with missing values in mandatory fields are removed. This includes rows with no location data.	Data from other sources, in particular from other MNOs, could be used if a relevant size of data is missing or has been removed due to errors.	Loss of data on events may lead to undercoverage of devices or less information about them.
2	Non-compliance with requirements: wrong formats	Count of records with related error code. Metrics can be computed by date in aggregate terms or specified by user, by cell or by user and cell.	Warnings are raised if the error rate is above a threshold (absolute or above an average of a previous period); or if it is above the upper control limit defined by (average + X·SD).	Removal of entries with errors.	Data from other sources, in particular from other MNOs, could be used if a relevant size of data is missing or has been removed due to errors.	Loss of data on events may lead to undercoverage of devices or less information about them.
3	Out of range values	Count of records with related error code. Metrics can be computed by date in aggregate terms or specified by user, by cell or by user and cell.	Warnings are raised if the error rate is above a threshold (absolute or above an average of a previous period); or if it is above the upper control limit defined by (average + X·SD).	Removal of entries with errors.	Data from other sources, in particular from other MNOs, could be used if a relevant size of data is missing or has been removed due to errors.	Loss of data on events may lead to undercoverage of devices or less information about them.
4	Duplication	Count of records with related error code. Metrics can be computed by date in aggregate terms or specified by user, by cell or by user and cell.	Warnings are raised if the error rate is above a threshold (absolute or above an average of a previous period); or if it is above the upper control limit defined by (average + X·SD).	Removal of duplicate rows.		Correct removal of duplicate rows should not have an impact on intermediate and output quality.

Table 11: Event data cleaning at device level – semantic checks

METHOD: EVENT CLEANING AT DEVICE LEVEL – SEMANTIC CHECKS (QM.EvSem, QM.TopSem)						
Main objective						
The objective of the method is to perform checks to identify and flag semantically erroneous events of devices. The checks concern the validity of cell ids and the identification of illogical changes of location of devices, based on time and distance differences.						
Methodological overview						
For the assessment of cell ids, data objects are compared with network topology data and null or incorrect cell ids are flagged. For the illogical changes of location, certainly and probably incorrect locations are identified on the basis of a minimum distance threshold and a minimum speed threshold, and events are flagged accordingly. The proposed methodology should be able to handle different scenarios of incoherent locations concerning consecutive events that appear to be located too far away from each other. The different flagged error types are counted and stored in tables.						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Invalid cell id	Count of erroneous events	If the percentage of a specific type of error on the specific day is above the upper control limit, then display warning for the specific date. Upper control limit = average of percentages of errors over the lookback period + threshold * SD)	Erroneous events are flagged.	Flagged entries can be analysed in other modules to assess their possible usage in specific use cases.	The impact depends on whether the flagged entries can be used for specific use cases.
2	Illogical change of location based on the time and distance difference	Count of erroneous events	If the percentage of a specific type of error on the specific day is above the upper control limit, then display warning for the specific date. Upper control limit = average of percentages of errors over the lookback period + threshold * SD)	Erroneous events are flagged.	Flagged entries can be analysed in other modules to assess their possible usage in specific use cases.	The impact depends on whether the flagged entries can be used for specific use cases.

6.6 EXTENDING CONSOLIDATED QUALITY TOOLS TO MNO DATA

The previous sections are mainly devoted to analyse the quality of the MNO input data in terms of the possible impact on the accuracy of the estimates based on them. However, there could be other relevant quality issues related to input data quality, that cannot directly emerge from the analysis of the data in the RMP. In this paragraph some of the existing tools, that are already in use in official statistics to assess the quality of input data, will be applied to identify such relevant factors. They are aimed at administrative data sources that, as already mentioned, have some commonalities with MNO data; in particular, the fact that these are not generated for statistical purposes and the owner is not the statistical authority. Nonetheless, they also present many differences; therefore, explanations of the possible adaptations and extensions will be necessary. The main reference for the approach described is Daas et al. (2009)[71] and the following BLUE-ETS project. These tools identify three main hyperdimensions (Source, Metadata and Data) and some dimensions for each hyperdimension that can be used to investigate the quality of an input source also in terms of its usability for statistical production. We will try to use such hyperdimensions in the case of an MNO data source. The same hyperdimensions structure has been recognised as valid for big data in UNECE, 2014[72]. For the sake of precision, the analysis of hyperdimensions of Source and Metadata is more oriented to evaluate the usability of the data source for statistical purposes while the Data hyperdimension is more connected with quality assessment. However, as already mentioned, in this section we will focus mainly on dimensions related to aspects not previously considered and less connected with the accuracy of data, on which several issues have been already raised and analysed in previous sections of the present chapter, Thus, we will focus only on the Source and Metadata hyperdimensions. We will see that some of the lower-level dimensions are not applicable or meaningful for the input data of the pipeline since these data are not to be delivered to the NSIs. In such cases we will reconsider them in Section 7.3 related to the quality of the intermediate data delivered to the NSIs.

6.6.1 HYPERDIMENSION SOURCE

The Source hyperdimension includes five smaller dimensions: Supplier, Relevance, Privacy and security, Delivery and Procedures. We will not go into the details of Relevance, based on the assumption that MNO data are relevant for official statistics for multiple purposes or are even considered to improve the relevance of statistics produced. And neither in the details of Privacy and Security or Delivery, since MNO input data are not delivered to NSIs.

- **Supplier dimension**: this dimension investigates the available information on the data supplier and the characteristics of the interactions with them. Of course, partnerships between NSIs and MNOs are of utmost importance for the profitable and correct usage of mobile phone data. The importance of having a contact reference within the supplier organisation is stressed, in order to have a fruitful exchange of experiences and to obtain clarifications, if needed. The relationships with data providers are of utmost importance also to guarantee the continuity and the reliability of the data provision. The importance of the identification of a contact/focal point at the MNO, as well as at the NSI, for promoting the collaborative dialogue during the regular execution of the RMP has already been mentioned also in Chapter 5 Business process model.
- **Procedures dimension**: this dimension underlines the necessity to have transparent procedures in place in the exchange of data between organisations. Of course, such dimension was designed for the purposes of the delivery of traditional data sources (from an external organization to the NSI) and the situation with MNO event data is different. Still, we can identify the relevance of having standardized methods in place, as defined by the pipeline developed in this project, and encourage the MNOs to follow them. In addition, the need for transparency should be further emphasised in our case since the data are partially pre-processed by the MNOs,

[71] Daas P.J.H., Ossen S.J.L., Vis-Visschers R.J.W.M. and Arend-Toth J. (2009). Checklist for the Quality evaluation of AD Sources. Discussion paper 09042, Statistics Netherlands.

[72] Big Data Quality Framework - final- Jan08-2015 (3).pdf

The hyperdimension Source is, by construction, the least detailed of the three and it mainly contains qualitative assessment methods. Still, many indicators are proposed for each dimension. Here we present some of the indicators along with brief explanations on how they can be used for the assessment in the context of MNO data. This list is not meant to be exhaustive; the complete set of indicators can be found in the original reference.

Table 12: Examples of indicators and methods for the Source hyperdimension

DIMENSION	INDICATOR NAME	METHOD	NOTES
Supplier	Contact	Data source contact information	Having a contact reference within the MNO helps to solve issues in the introduction of MNO data in official statistics production.
Supplier	Contact	NSI contact person	For the same reasons and for a fruitful exchange of experiences, a fixed contact person within the NSI is important.
Relevance	Response burden	Effect of data source use on response burden	How can we expect that the response burden will be affected by the use of MNO data? This will vary for different use cases. Aspects to be analysed: will a survey be replaced/integrated with the use of MNO data? Will the size of the sample be reduced?
Procedures	Data generation (originally Data collection)	Familiarity with the way the data are generated	The normal generation process of input data is well known, but less clear is the situation in which the generation process leads to erroneous or missing data.
Procedures	Fall-back scenario	Dependency risk of NSI	This is a relevant indicator since the risk of a break in the agreements cannot be excluded. There is a need for assessment of the impact of an interruption in the data provisions from specific MNOs. Can the NSI replace those data with an agreement with other MNOs?

6.6.2 HYPERDIMENSION METADATA

As the name suggests, this hyperdimension deals with the information that accompanies the data and the aspects concerning the clarity of an input source. Four dimensions are included in this dimension: Clarity, Comparability, Unique keys and Data treatment. The last dimension (Data treatment) is especially relevant for NSIs in the MNO context since it investigates the treatment of the data by the source keeper.

When dealing with MNO data, there are multiple inputs and intermediate steps in which such inputs are processed. For simplicity, a main distinction that could be introduced is between the raw nanodata records, which are the first inputs for the operators, and the intermediate aggregated data, provided by the operators to the NSIs. Generally, the situation is more complex than the context to which the mentioned hyperdimensions framework is usually applied (i.e. administrative data sources). When applying the framework to new sources such as MNO data, any ambiguity concerning the specific data involved should be avoided. For the Metadata hyperdimension, the dimensions it includes can be applied either to the data processed by the operators or the data processed by the statistical offices. In the following bullet points the differences are mentioned, if any.

- **Clarity dimension**: similarly to the same name criterion of the output, this aspect concerns the availability of the information needed for a correct interpretation of the data. The complex nature of MNO data makes this dimension absolutely crucial for their correct usage. Within this dimension fall all the requirements concerning the formats of the data, the variables definitions, the ranges of expected variation, etc. Furthermore, the time interval to which the data refer is a concept that is usually included among the metadata, but for MNO data its presence is fundamental and it is often included within the data themselves. In the BPM it is suggested that MNOs provide the NSIs with a periodic quality report on source data that should complement the quality metrics and warnings produced by the RMP; this way, ensuring a high-level detail of the Clarity on raw input

data to the NSI. If applied to intermediate aggregated data, the information on the processing applied to the data should also be provided, making this dimension similar to the data treatment dimension.

- **Comparability dimension**: comparability concerns the similarity between the statistical definitions used by the NSI for units and variables and the concepts used within the origin source. In the context of MNO data, the differences can be significant if we look at the input sources. However, the same sources will undergo different transformations and some of these will be aimed at obtaining results for units and concepts that are proxies of the statistical ones. In general, comparisons and plausibility checks between the raw and intermediate data processed by different operators (if possible), may help with the detection of anomalies, as mentioned in Chapter 4 Applying and extending the ESS Common Quality Framework to the production of MNO-data based official statistics. In addition, we emphasise that comparability and clarity are two main drivers for the definition of a standard reference pipeline for the use of MNO data in the ESS; in a sense, these concepts transcend their specific application to input data and involve methodological, computational and process elements, as well.
- **Unique keys dimension**: this dimension is relevant for the data processed by the operators and it concerns, of course, the integration of multiple sources but in a different way than the usual integration with administrative sources. It cannot be expected that MNO nano or microdata could be easily integrated with existing statistical or administrative sources, especially due to privacy concerns. However, the possibility to integrate data from different MNOs would be highly facilitated if, for example, a synchronised pseudonymisation procedure could be applied, always respecting confidentiality requirements. Attention to unique keys is also relevant to the device identifiers, which have to be constant through different periods in order to make longitudinal analyses, unless more sophisticated technological solutions based on Privacy Enhancing Technologies are adopted[73]. For aggregate data, of course, the presence of unique keys is not particularly relevant. Nonetheless, at the microdata level the presence of correct cell identifiers allows for the integration with spatial data.
- **Data treatment dimension:** as mentioned above, this dimension explores the treatment of the data by the data provider, in this case the MNOs. This dimension and its indicators become extremely relevant for the aggregated data provided to the NSI. In order to be able to evaluate the overall quality of the data it is necessary to promote transparency and to ask MNOs to report on the procedures they apply to data to make them compatible with the pipeline requirements. Obviously, the application of an open and reproducible RMP would allow the NSI to know exactly the treatment performed by the MNO.

Table 13: Examples of indicators and methods for the Metadata hyperdimension

DIMENSION	INDICATOR NAME	METHOD	NOTES
Clarity	Time dimensions	Clarity score of the definition	For MNO data is not only necessary that the reference period is clearly defined, but each event record has to be accompanied by its validity date, which is part of the data. Due to the dynamic nature of the network, also the topology data should be accompanied by the information of the time period for which they are valid.
Clarity	Definition changes	Familiarity with changes occurred	Any changes in the data and deviations from the standardized methods have to be communicated to statistical authorities. This requirement should be included in formal agreements with MNOs
Comparability	Population unit definition comparison	Comparability with NSI definition	As already mentioned, the population and unit in MNO data are different from the statistical targets; however, the transformations that are applied to

[73] See, for example, the system prototyped by Eurostat in the project ESTAT ref. 2019-0232 at: https://cros.ec.europa.eu/estat-2019-0232

DIMENSION	INDICATOR NAME	METHOD	NOTES
			MNO data in the pipeline are intended to obtain proxies of the statistical concepts

6.7 CONCLUDING REMARKS

The quality assessment of input data sources is a crucial component in every quality assurance system, regardless of the kind of statistical process being analysed or the output data being produced. A good input quality is a necessary (but often not sufficient) condition to obtain a data product that fulfils predefined quality requirements. This chapter has explored the problems that MNO data may present when used as input information in a process designed to produce official statistics, and how some of these problems are different from what happens when dealing with traditional data sources. A major factor is that, from both a technical and a quality perspective, the concept of 'MNO data' comprises different subcategories of data, each presenting specific potential quality issues. This is one of the reasons why a bottom-up approach has been introduced in Section 6.2, allowing for the identification of issues emerging from different data object categories and aggregation levels. This approach also makes it easier to connect each issue to the modules in the pipeline in which they are dealt with. The detailed analysis of the issues as presented in this chapter, while still in progress and to be integrated with new information, constitutes the foundation of the quality assurance system for the pipeline presented in the deliverables from Task 2 and it is one of the main components of the general quality framework presented in this report.

From the low-level analysis of the multiple input issues, the next step has been the abstraction to the consolidated classification of non-sampling errors commonly adopted in official statistics. Indeed, the review carried out in Section 6.2 has allowed us to map and group the quality issues into the main non-sampling categories widely used, i.e. coverage, missingness, etc. Although the work is still in development,it is possible to identify some specificities. For example, in several cases, specific error types at nano level can propagate and transform into other types of error at the micro level and this could imply different mitigation actions depending on the point of the pipeline in which the error is handled.

Finally, in Section 6.6, one of the most used approaches for the assessment of the quality of administrative data sources has been investigated regarding its potential with respect to MNO data and the necessary adaptation in such a context. This can be useful, especially, for the consideration of some aspects that are at risk of being neglected when investigating the quality aspects of a new source, such as metadata and information on the data provider.

7 QUALITY ASSURANCE SYSTEM – THROUGHPUT QUALITY

7.1 INTRODUCTION

In the context of this report on the quality framework and business process model for official statistics derived from MNO data, quality assurance aspects associated with the throughput phase in MNO data processing serve as a relevant role. As part of a larger sequence that includes input data quality (Chapter 6), throughput quality (Chapter 7), and output quality (Chapter 8), this chapter provides an intermediary analysis essential for setting up an effective monitoring system for the quality of the process in the reference pipeline. The primary objective of Chapter 7 is to analyse and structure the quality measures applicable to the throughput phase of the production pipeline to produce official statistics based on MNO data. According to the proposal of ESSnet Big Data II, the throughput can be split into two main phases: the lower and the upper throughput. The lower throughput should represent the part of the process devoted to the transformation of non-statistical raw data into well-structured intermediate 'statistical' data and the upper layer in which the statistical data is used to produce the statistical outputs. In the reference scenario, the lower throughput corresponds roughly to the processing of MNO data carried out by the MNOs (i.e. the operational production stage at the MNO), while the upper throughput corresponds with the treatment carried out at the NSI level. Relevance is assumed by the intermediate data provided from MNOs to the NSIs. Consequently, it is considered relevant to divide the throughput process into three phases instead of the common two: lower throughput, quality of intermediate data, and upper throughput. By examining these stages, we aim to identify and address quality issues that can affect data accuracy and overall usability in official statistics.

The main objective of the Multi-MNO project regarding throughput quality issues is to provide an open and modular solution (methodological documentation and software) that is able to evolve as the proposed pipeline is increasingly used in production. A (non-exhaustive) list of potential quality issues of interest arising during the throughput phase is presented in Annex 2. From this list, in the scope of this project, a set of issues from the most relevant methods has been addressed by providing documentation on metrics, warnings, actions and impact (in the current chapter) and by implementing these quality 'rules' within the Multi-MNO software.

The current chapter is divided into the following three sections, each focusing on a distinct stage of throughput quality:

1. **Lower throughput quality**. This section addresses the initial processing conducted by MNOs in the reference pipeline, highlighting the primary quality issues that arise at this stage. The methods implemented in the reference pipeline can introduce errors that affect the output accuracy. Methods at this stage transform raw MNO data (nanodata) into aggregated data.
2. **Quality of intermediate data provided to statistical authorities**. Intermediate data is the output of the lower throughput stage. The quality of intermediate data is essential as it represents the primary input that statistical authorities receive for processing. This intermediate product serves as both the output of MNO initial processing and the input for NSIs, thus acting as a bridge between the two. Intermediate data can be subject to specific provision agreements, which define its required quality, accompanying metadata and usability standards.

3. **Upper Throughput Quality**. The third section focuses on the quality aspects related to the final processing phase conducted by NSIs, ensuring that data are accurately aggregated and transformed into statistical outputs. Here the intermediate data undergoes various transformation and integration stages to yield usable, relevant statistics. In this stage the statistical authority will also have the availability of data from different MNOs that can allow further quality checks. Methods of the upper throughput could cover the spatial projection of the data into convenient administrative zones, and include the integration of data from different MNOs, which, as described in Chapter 5, in the future, could also be carried out in a secure multi-party computation system for official statistics that is being developed and will be piloted in a parallel Eurostat project[74]. In addition, the upper throughput covers the estimation process to convert MNO aggregate data into target population statistics, which could include the integration of MNO data with non-MNO data with the aim of improving the quality of the statistical output. The detailed definition of these methods is beyond the scope of this project, as it is part of another project, the ESSnet MNO-MINDS research project. However, to provide a high-level view of the end-to-end process, this project presents an overview of quality aspects to consider in the upper throughput stage (see Section 7.4). Obviously, the final Statistical Disclosure Control (SDC) process before statistical output dissemination should be carried out, as is the case for traditional statistics.

Each time an issue is detected within the aforementioned phases, the problem may originate from the phase itself or from a prior process where the defined quality controls did not detect the issue. These errors may stem from input data or from the methods applied in the process (either due to the method's definition or its parameterisation). This chapter focuses on assessing potential issues related to the throughput process itself, but it is important to consider that actions to mitigate problems in this stage may derive from earlier steps or may be delegated to later steps. Within the throughput process, the main focus of issues' assessment is on the parameterisation of the defined methods (not considering methods' redefinition) and on the characteristics of the intermediate data.

[NOTE] The issues included in detail in this chapter are the ones planned to also integrate in the software. It may be the case that issues already defined here are not yet implemented in the current version of the software.

7.2 LOWER THROUGHPUT QUALITY

In this section, the lower throughput quality of the process is evaluated, covering the methods from the ingestion of the depurated/clean input data (input data quality issues are covered in Chapter 6) until the generation of the intermediate data computed by MNOs (intermediate data quality issues are covered in Section 7.3).

For quality evaluation purposes, methods have been classified into the following groups:

- Methods related to the estimation of device location
- Methods associated to daily processing
- Methods associated to mid-term processing
- Methods associated to long-term processing

For the most relevant methods of each group (the ones that can have a higher impact on the quality of the results), the following information is provided (similarly as for the input quality methods in Section 6.5):

- **Main objective**
- **Methodological overview -** brief description of the methodology. More detailed information about the methodology is available in deliverable D2.
- **Quality Issues** providing the following information:
    - **Issue:** description of the quality issue and possibly the type of error associated.
    - **Quality metrics -** a quantity or indicator that can detect if there is a deviation from normality

[74] See : JOCONDE | Eurostat CROS (europa.eu)

- **Quality warnings -** alert, based on the quality metric, indicating that a process may not meet established quality standards.
- **Quality actions -** the action that will be undertaken in the pipeline after receiving the 'quality warning'
- **Mitigations actions:** mitigation actions that could be undertaken to prevent or reduce the error occurrence.
- **Impact on output quality**: possible impact on the quality of the outputs.

The template adopted here is the same of Chapter 6, but it should be clarified that, since the methods described in Chapter 6 are aimed at detecting the errors in input data: the issue described arise in input data, while in this chapter the issues described are the ones potentially generated by the application of the method,

***[NOTE]** The final version of this deliverable may potentially cover additional methods based on future outcomes from Task 2 (e.g. methods related to tourism UCs)*

7.2.1 METHODS RELATED TO ESTIMATION OF DEVICE LOCATION

Location information from mobile devices is usually provided by the identifier of the cell to which the device is connected to. In order to determine the location of the device in the territory, it is needed to estimate the coverage area of each cell. The coverage area provides a spatial region containing all possible solutions for the location of the device. Errors in the estimation of these areas may lead to errors in the subsequent steps of the analytical process (e.g. errors in location assignment to municipalities which may distort final indicators by region, etc.).

The main method that estimates device location is 'Cell footprint estimation'. For this method, an analysis of quality issues is provided below.

Table 14: Quality in device location – cell footprint estimation method

CELL FOOTPRINT ESTIMATION						
Main objective						
Determine antenna's cell coverage areas providing signal strength estimates at grid level						
Methodological overview						
Based on the characteristics of the antenna (e.g. power, height, azimuth angle, etc.) signal strength values are estimated and discretized in a100x100 m. grid (INSPIRE grid) over the territory. The coverage area of each antenna is defined by a set of grid tiles. A grid tile belongs to the coverage area of an antenna if: (i) the signal strength value is above a certain threshold and (ii) if the signal strength value belongs to the top X values of signal strengths in that specific grid tile.						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Processing error: The algorithm does not assign any footprint (set of grid tiles) to a network cell	CF-M1 - Number of grid tiles per each cell	If CF-M1 is 0 for any cell, raise a warning and provide: (i) a table with a list of cells with this error and with the number of events associated to those cells. Cell_id | associated_events 214001214121245 | 67	If the warning is considered critical, the process stops; otherwise, the process continues with warnings. A critical warning is defined when the percentage of cells with this error is above X% (e.g. 5%) or the number of events	[1] Increase the limit of top X cells per grid tile in the configuration should increases the number of grid tiles per cell. [2] Reduction of signal strength pruning value in configuration should increases the number of grid tiles per cell	Loss of event data, since events associated to these cells are discarded. Depending on the number of events lost, the final results may be

CELL FOOTPRINT ESTIMATION				
	214002561481812 | 5	associated to these cells is above Y% (e.g. 1%)	Note that this mitigation actions may lead to an increment of computational/storage costs, look for a compromise solution	more or less affected.

7.2.2 METHODS RELATED TO DAILY PROCESSING

Daily processing methods generate a set of daily indicators that can directly be used as intermediate data (e.g. present population indicators) or contribute to the generation of mid-term indicators (e.g. mid-term permanence score). The daily process is the basis for all the statistical data to be generated, so errors in this step may affect all the statistical products to be generated in subsequent stages.

The main methods of the daily process are 'Daily Permanence Score' and 'Present Population'. For each of these methods, an analysis of quality issues is provided below.

Table 15: Quality in daily processing – Daily permanence score

DAILY PERMANENCE SCORE						
Main objective						
Determine the daily permanence of a device in the territory						
Methodological overview						
Taking as input a set of device events associated to the day under study, the method first classifies events in 'permanence' (the device remains stationary) and 'moves', based on speed criteria. For those events classified as 'permanence', the time the device remains in the same cell is computed (e.g., device 1 presents permanence in cell A from 10:00 to 12:45). The day is divided in time slots (e.g., 1 hour time slots). For each time slot, if the device presents permanence for more than half of the time slot, daily permanence score (DPS) is equal to 1, otherwise, is equal to 0. DPS is computed at grid tile from the INSPIRE grid 100x100m applying the transformation from cell ID to cell footprint. If the location of the device is unknown during the time slot, an 'unknown' tile is associated.						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Processing error: Unexpected number of devices with significant 'unknown' information	DPS-M1 – Percentage of devices for which the number of time slots with 'unknow' label is greater than X% (e.g. 50%)	If DPS-M1 is greater than Y% (e.g. 15%) raise a warning and provide DPS-M1.	The process continues with warnings	Check with the MNO if this warning is due to an error of the input data or if it is the expected quality of the data. Additionally, check parametrization on DPS regarding classification of events in permanencies/moves (if moves are overrepresented, potential missing of stays leading to more unknows)	Potential underestimate of the user's UE due to lack of event data along the day

Table 16: Quality daily processing – present population

PRESENT POPULATION						
Main objective						
Determine how many people is present in a specific area during a specific time instant						
Methodological overview						
For a given time instant, all devices with an active network connection within a defined temporal interval around this time instant are selected (for example, a 30-minute interval, 15 minutes before and after the target moment). From all the events recorded by each device during this period, the one closest to the target moment is chosen. Each event is associated with a network cell. Device counts are aggregated per cell to consolidate population volume at cell level. Subsequently, population presence is distributed per cell considering the cell footprint of each cell (as a set of 100x100 grid tiles with a probability distribution per tile) using an iterative Bayesian procedure.						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Undesirable low number of devices in specific time instant	PP-M1- Number of devices in a specific time instant	If PP-M1 is below X (e.g. 0.5 times the expected device number compared with previous period data) raise a warning providing PP-M1	The process continues with warnings	Increase the time gap in the software configuration to potentially capture more devices Note that this approach may lead to bigger sample but may also increase the location error when considering a longer observation period	Low number of devices may lead to an under-representation of the actual MNO devices present distribution in the territory

7.2.3 METHODS RELATED TO MID-TERM PROCESSING

Mid-term processing methods integrate outputs from daily processing methods to generate intermediate indicators that will be used in long-term processes.

The main method of the mid-term process is 'Mid-term permanence score'. For this method, an analysis of quality issues is provided below.

Table 17: Quality in mid-term processing – Mid-term permanence score

MID-TERM PERMANENCE SCORE						
Main objective						
Determine the mid-term permanence of a device based on the daily permanence scores						
Methodological overview						
The mid-term period (i.e. one month) is divided in day types (e.g. working days, weekends, etc.). Each day type is further divided into day periods (e.g. morning period, night period, etc.). For each day_type/day_period a set of metrics are computed based on daily permanence scores of the device, particularly: • **mps** (midterm permanence score): the result of adding up the daily permanence scores • **frequency:** absolute count of the number of days for which the daily permanence score was not null • **Regularity mean:** mean of the number of days between two consecutive non-null daily permanence scores • **Regularity std**: standard deviation of the number of days between two consecutive non-null daily permanence scores						
Quality issues						
#	**Issue**	**Metrics**	**Warnings**	**Actions**	**Mitigation**	**Impact**
1	Unexpected low value of 'frequency'	MPS-M1: flag if frequency below 'X' days in a specific month (e.g. 20 days)	if MPS-M1 raise a warning	The process raises a warning	Maintain information for further analysis	Underrepresentation of mid-term permanence score
1	Unexpected low value of 'mps'	MPS-M2: flag if "mps" below a threshold 'X' in a specific month	if MPS-M2 raise a warning	The process raises a warning	Maintain information for further analysis	Underrepresentation of mid-term permanence score

7.2.4 METHODS RELATED TO LONG-TERM PROCESSING

Long-term processing methods integrate outputs from mid-term processing methods to generate intermediate indicators (e.g. labels of UE at device level) or intermediate data (e.g. Usual Environment statistics for all devices).

The main method of the long-term process is the 'Usual Environment Labelling'. For this method, an analysis of quality issues is provided below.

Table 18: Quality in long-term processing – Usual Environment Labelling

USUAL ENVIRONMENT LABELLING
Main objective
Identify grid tiles that belong to the Usual Environment (UE) of the device and classify them in 'home', 'work' and 'other' (grid tiles that belong to the UE but are not classify as any other type)
Methodological overview
The method takes as main input the long-term permanence metrics per device. Based on these metrics, the method first identifies the 'rarely/discontinuously observed' devices for which information is not enough to determine UE of the device. For the rest of devices, UE is defined as the set of grid tiles with lps metric significantly higher than the rest of tiles. Apart from this process, grid tiles can be also labelled as 'home' or 'work' based on the values of lps metric considering different periods/days of analysis (e.g. considering the complete list of days for the whole day period, considering only night periods, considering only working days, etc.). At the end of the process, for some devices sufficiently observed, UE information is

USUAL ENVIRONMENT LABELLING

provided as a set of grid tiles with a label (ue, home or work). Additionally, the classification rule used for labelling is provided for quality analysis.

Quality issues

#	Issue	Metrics	Warnings	Actions	Mitigation	Impact
1	Unexpected number of tiles classified based on rule ue_1	UEL-M1- Number of tiles with assigned labels based on ue_1 rule	If UEL-M1 is above X raise a warning providing UEL-M1	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule
2	Unexpected number of tiles classified based on rule ue_2	UEL-M2 - Number of tiles with assigned labels based on ue_2 rule	If UEL-M2 is above X raise a warning providing UEL-M2	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule
3	Unexpected number of tiles classified based on rule h_1	UEL-M3- Number of tiles with assigned labels based on h_1 rule	If UEL-M3 is above X raise a warning providing UEL-M3	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule
4	Unexpected number of tiles classified based on rule h_2	UEL-M4- Number of tiles with assigned labels based on h_2 rule	If UEL-M4 is above X raise a warning providing UEL-M4	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule
5	Unexpected number of tiles classified based on rule h_3	UEL-M5- Number of tiles with assigned labels based on h_3 rule	If UEL-M5 is above X raise a warning providing UEL-M5	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule
6	Unexpected number of tiles classified based on rule w_1	UEL-M6- Number of tiles with assigned labels based on w_1 rule	If UEL-M6 is above X raise a warning providing UEL-M6	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule
7	Unexpected number of tiles classified based on rule w_2	UEL-M7- Number of tiles with assigned labels based on w_2 rule	If UEL-M7 is above X raise a warning providing UEL-M7	The process continues with warnings	Modifications of threshold parameters to modify classification rules	Quality of the results based on classification rule

USUAL ENVIRONMENT LABELLING						
8	Unexpected number of tiles without UE label	UEL-M8 - Number of tiles without UE label assigned	If UEL-M8 is above X raise a warning providing UEL-M8	The process continues with warnings	Provide the rules distribution for the labelled tiles and change the threshold parameters values	Quality of the results based on classification thresholds
9	Unexpected number of tiles without any location label	UL-M9 - Number of tiles without any location label assigned	If UEL-M9 is above X raise a warning providing UEL-M9	The process continues with warnings	Provide the rules distribution for the labelled tiles and change of threshold parameters values	Quality of the results based on classification thresholds
10	Unexpected behaviour when home location is not part of the UE	UEL-M10 - Number of tiles which are labelled as home, but are not part of UE	If UEL-M10 is above 0, raise a warning providing UEL-M10 and providing all the metrics values of the involved tiles	The process should be stopped	The available metrics should be analysed to identify the cause of the issue.	Inconsistency of results – it is expected that home location is part of the UE
11	Unexpected behaviour when work location is not part of the UE	UEL-M11 - Number of tiles which are labeled as work, but are not part of UE	If UEL-M11 is above 0, raise a warning providing UEL-M11 and providing all the metrics values of the involved tiles	The process should be stopped	The available metrics should be analysed to identify the cause of the issue.	Inconsistency of results – it is expected that work location is part of the UE

7.3 QUALITY OF INTERMEDIATE DATA PROVIDED TO STATISTICAL AUTHORITIES

In this section, the intermediate results generated by the MNOs by applying the RMP to the input data are considered. These intermediate data are received by the statistical authority under a set of provision agreements to be established with the MNOs. It should be noted that these provision agreements may vary between different MNOs (e.g. the frequency of delivery may differ based on technical or organisational conditions). Generally, these agreements should define the data format and content, delivery frequency (e.g. daily), the delay between the delivery date and the study date (e.g. a 7-day delay providing January 1 data on January 7), agreement duration, and the responsibilities of each party[75]. This section focuses on analysing aspects related to the quality of data provided by the MNOs.

The reference pipeline generates the following intermediate data:

\ Usual Environment
\ Present Population

[75] Please consider the template for agreement in Annex 2.

For each of the intermediate data sources, a quality table is provided containing a description of the data, contents of the data, and example of the data and a list of quality issues to consider when evaluating the data provided by the MNOs. For each quality issue, metrics, warnings and actions to be conducted are proposed. Other quality issues are listed in Annex 2.

Apart from quality issues, it is also proposed that for quality controls that MNOs complement the quality reports for source data proposed in Chapter 5 Business process model with some additional metadata on the delivery that can be relevant for the quality assessment such as the actual date of delivery, the planned date, general comments from the MNO about some relevant issues related to the generation of the results, classifications used for some variables, etc. Additionally, it is important to monitor whether the data received by the NSI is indeed the data intended to be provided by the MNO, to avoid transfer issues (e.g. part of the data is not provided for problems during the transfer of the data).

[NOTE] *The final version of this deliverable will contain additional intermediate data associated with the use cases that will be implemented in software codes: home location, internal migration, inbound tourism and outbound tourism.*

Table 19: Present population intermediate data

PRESENT POPULATION					
Description					
Number of devices at INSPIRE 100x100m level for a specific moment in time for the whole country of analysis					
Content					
• **Grid ID** (string - INSPIRE 100x100 format): identifier of the INSPIRE 100x100m grid tile • **Population** (float): total number of devices present in the grid tile for a specific moment in time • **Timestamp** (time - HH: MM: SS): time instant of the measurement • **Year** (integer - YYYY): year of the measurement • **Month** (integer - MM): month of the measurement • **Day** (integer - DD): day of the measurement					
Example					
grid id	**population**	**timestamp**	**year**	**month**	**day**
100mN4056000ES275300	156.3	12:05:03	2024	02	01

Quality issues

#	Issue	Metrics	Warnings	Actions
1	'Grid ID' field format error	M1 - Number of registers with format error	If M1 is greater than 0, raise a warning providing M1 and a list of erroneous unique IDs with their frequency of occurrence	Ask the MNO to review INSIPRE grid input data and software configuration
2	'Population' field format error	M2 - Number of registers with format error	If M2 is greater than 0, raise a warning providing M2 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review the software configuration
3	'timestamp' field format error	M3 - Number of registers with format error	If M3 is greater than 0, raise a warning providing M3 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review the software configuration
4	'year' field format error	M4 - Number of registers with format error	If M4 is greater than 0, raise a warning providing M4 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review Event Data input files and the software configuration

PRESENT POPULATION				
5	'month' field format error	M5 - Number of registers with format error	If M5 is greater than 0, raise a warning providing M5 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review Event Data input files and the software configuration
6	'day' field format error	M6 - Number of registers with format error	If M6 is greater than 0, raise a warning providing M6 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review Event Data input files and the software configuration

Table 20: Usual Environment intermediate data

USUAL ENVIRONMENT

Description

Number of devices at INSPIRE 100x100m level for a specific moment in time for the whole country of analysis that have usual environments in grid tiles

Content

- **Grid ID** (string - INSPIRE 100x100 format): identifier of the INSPIRE 100x100m grid tile
- **Weighted device count** (float): total number of devices with usual environment in a specific grid tile.
- **Label** (string): type of usual environment, classified as 'home', 'work' or 'ue'
- **Start date** (time – YYYY-MM-DD) initial date of the analysis of devices' Usual Environment
- **End date** (time – YYYY-MM-DD): final date of the analysis of devices' Usual Environment
- **Season** (string): name provided by the user to define the period of analysis

Example

grid id	Weighted device count	Label	Start date	End date	Season
100mN4056000ES275300	50.2	ue	2024-01-01	2024-06-01	winter
100mN4056000ES275300	155.2	home	2024-01-01	2024-06-01	winter

Quality issues

1	'Grid ID' field format error	M1 - Number of registers with format error	If M1 is greater than 0, raise a warning providing M1 and a list of erroneous unique IDs with their frequency of occurrence	Ask the MNO to review INSIPRE grid input data and software configuration
2	'Weighted device count' field format error	M2 - Number of registers with format error	If M2 is greater than 0, raise a warning providing M2 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review the software configuration
3	'Label' field format error	M3 - Number of registers with format error	If M3 is greater than 0, raise a warning providing M3 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review the software configuration
4	'start date' field format error	M4 - Number of registers with format error	If M4 is greater than 0, raise a warning providing M4 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review software configuration
5	'end date' field format error	M5 - Number of registers with format error	If M5 is greater than 0, raise a warning providing M5 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review software configuration

USUAL ENVIRONMENT				
6	'season' field format error	M6 - Number of registers with format error	If M6 is greater than 0, raise a warning providing M6 and a list of erroneous unique values with their frequency of occurrence	Ask the MNO to review software configuration

The simple validation checks proposed can be implemented in the RMP, but once the intermediate data from different MNOs, including the accompanying metadata (i.e. the quality report on source data), are received by the statistical authority, further plausibility checks can be applied directly by the statistical authority comparing the data from different MNOs. In general terms, if a quality issue arises from the data from one MNO, it can be checked if similar patterns are detectable also in other MNOs' data. If not, the cause of the issue should be in the specific MNO input data or the application of the pipeline (e.g. configuration parameters). Otherwise, the data produced by the different MNOs are probably highlighting some phenomena occurred that can be of interest and should be further investigated.

This type of comparisons and plausibility check can be carried out directly in the intermediate data received by the MNOs or in later stages of upper throughput, obviously before aggregating MULTI- MNO data.

In addition, going beyond the quality checks that can be applied directly to the data, as the intermediate data are the main object of the provision agreement between MNOs and NSIs, and the actual input received by statistical authorities for the production of statistical output, it is worth reconsidering the application of the hyperdimensions Source and Metadata, proposed for the quality of administrative data used for statistical purposes[76], and validated also by the UNECE big data framework[77]. In particular, for the hyperdimension Source we have to consider the Privacy and Delivery dimensions. However, privacy issues in the data transfer have already been taken into account in the description of the BPM in Chapter 5, where it is mentioned that in the future there could be a specific secure multi-party computation system that will receive and integrate the data from multiple MNOs. Concerning delivery, issues like costs of using the data source, frequency and punctuality of delivery and possible format of delivery should be considered. Nonetheless, all these issues should have already been taken into account in the definition of the provision agreement, while in the regular execution of the pipeline alignment with these will be only monitored (also thanks to the information in the quality report for source data).

Concerning metadata, the dimensions of clarity, comparability and data treatment are all very relevant. In particular, the documentation that accompanies the RMP already provides relevant metadata on the unit and variables provided. Also, the RMP provides an unambiguous description of the data treatment carried out by the MNOs.

It can be said that the adoption of the RMP allows for automatically fulfilling these quality requirements proposed for the metadata hyperdimension.

Concerning comparability, even if the definitions of units and variables do not coincide with the corresponding statistical concepts and further transformations should be applied by the NSI to try to achieve such correspondence, the adoption of a common RMP should ensure comparability of results throughout the ESS. However, a relevant factor for comparability is that the classifications adopted for some key variables, e.g. for administrative territorial units, MCC, MNC, etc., are the same for different MNOs. From this point of view, it is recommended that standard and shared classifications be used and that they are applied to the data from different MNOs directly as guided by the statistical authority which can identify incoherence in the applied codes.

[76] Daas P.J.H., Ossen S.J.L., Vis-Visschers R.J.W.M. and Arend-Toth J. (2009). Checklist for the Quality evaluation of AD Sources. Discussion paper 09042, Statistics Netherlands.

[77] Big Data Quality Framework - final- Jan08-2015 (3).pdf

7.4 UPPER THROUGHPUT QUALITY

The upper throughput quality is the final processing phase conducted by NSIs, during which it is ensured that aggregated intermediate data pre-processed by MNO are accurately transformed into statistical outputs. As mentioned in the introduction section of this chapter, the main objective of this project is to provide general guidance on quality aspects to be considered in this phase, without delving into specifics.

From a general perspective, upper throughput methods can be divided into four categories: (i) spatial projection, (ii) estimation, (iii) SDC, and (iv) multi-MNO data integration. For each of these groups, general aspects to consider when dealing with quality are provided below:

- **Spatial projection:** This method transforms the information from grid level (INSPIRE 100x100 level) to information at a convenient (administrative) zoning level. In this process of transformation, it is important to ensure internal consistency (e.g. if present population for the whole country at grid level sums up to X, once this information is converted to NUTS level, the sum is still X). In addition, it is important that the same administrative territorial boundaries are used for different MNOs. In this sense, it could be recommended that this activity is carried out by the NSI to avoid inconsistencies.
- **Estimation:** This method deals with the adjustments applied to the intermediate aggregates to correct, in particular, for coverage errors due to the discrepancies between the population of devices and the target statistical population (usually individuals). In practice, the effect of undercovercoverage and overcoverage errors identified in **Table 8** should be mitigated through this step. Adjustment methods can be based e.g. on the integration of MNO data with other statistical data. Additionally, other errors can be corrected with such methods that are the main focus of the ESSnet MNO-MINDS research project.
- **Multi-MNO data integration:** This method combines results from different MNOs. As already mentioned, this integration can be preceded by a set of checks on the coherence between the figures provided by different MNOs and can be a valuable input for quality evaluation. The statistical output produced using the data from the different MNOs and adjusted for non-sampling errors, through sound methodologies developed by the statistical authorities, will be disseminated to the public (after application of SDC) and the MNO provider of part of the data will have access to such results that could be an added value for them. Indeed, 'the final official statistics' produced and released publicly by statistical authorities may then serve as reference for calibrating the commercial analytics developed independently by MNOs and their partner companies specialised in mobile analytic services[78].
- **Application of SDC to final estimates:** As already mentioned in Annex 1, the statistical confidentiality and data protection procedures are crucial when dealing with MNO data: protection methodologies can be a complex issue and specific techniques might be required. The identification, design and development of statistical disclosure limitation methods are out of the scope of the Multi-MNO project. Nonetheless, another ESS project is working on a system for Multi-Party Secure Private Computing in Official Statistics in which intermediate MNO data could be processed safely. In the Multi-MNO project, data protection measures are limited to the build-in of the principles of 'data minimisation' and 'storage limitation' at methodological level into the RMP. In any case, the final statistical indicators will be subject to the application of traditional SDC procedures as with all the outputs produced by NSIs in the ESS.

[78] Ricciato F (2024) Quality for new data sources: Progress, challenges and directions for the European Statistical System, in 2nd WORKSHOP ON METHODOLOGIES FOR OFFICIAL STATISTICS. 6-7 DECEMBER 2023. Proceedings.

8 QUALITY OF OUTPUT

*[**Preliminary content**: This chapter will be developed for the final version of this deliverable.]*

Once the statistical output has been produced, it should be validated and its quality should be evaluated and reported. Validation can be carried out in different ways, being out of the scope of the present project to develop validation measures. However, the coherence of the results obtained will be compared with previous statistics produced from the same source. Furthermore, whenever possible, the coherence with other official statistics in the same domain will be considered. Naturally, the benchmark for validation should not have been already used in the estimation phase for compensating errors in the intermediate data from the MNOs.

Afterwards, the statistical output quality should be evaluated and this should be done following the traditional quality criteria in official statistics: relevance, accuracy and reliability, timeliness and punctuality, comparability and coherence, and accessibility and clarity (defined in Regulation (EC) No. 223/2009 on European Statistics).

While the methodology in the RMP is essentially focused on improving the accuracy of the statistical output based on MNO data (for compliance with official statistics' requirements), the other dimensions are also important for the output evaluation. Therefore, it should be verified if the use of MNO data can have an impact on them.

As a starting point for the evaluation of quality criteria, we take into account the ESS Quality and Performance Indicators (ESS QPIs), initially defined in 2014.[79] ESS QPIs are a standard set of indicators covering significant aspects of quality and performance in a standardised way. They have subsequently been incorporated in the Single Integrated Metadata Structure (SIMS), the ESS Standard for Quality Reporting and are described in the ESS Handbook for Quality and Metadata Reports[80].

The ESS QPIs are reported in the table below together with a preliminary evaluation of their applicability in the context of MNO data-based statistical output.

Table 21: ESS QPIs' applicability for MNO data-based statistical output

DIMENSION	QPI	APPLICABILITY TO MNO DATA BASED STATISTICS
Relevance	R1. Data completeness - rate	Applicable if the set of statistics to be produced is defined
Accuracy and reliability	A1. Sampling error - indicators	Not applicable
	A2. Over-coverage - rate	Applicable but not with the suggested formula
	A3. Common units - proportion	Not applicable
	A4. Unit non-response - rate	Not applicable
	A5. Item non-response - rate	Applicable as missing value rate in input data
	A6. Data revision - average size	Applicable is a revision policy is applied to the statistical output
	A7. Imputation - rate	Applicable if data have been imputed during the production of the statistical output
Timeliness and punctuality	TP1. Time lag - first results	Applicable if first results are disseminated

[79] See: https://ec.europa.eu/eurostat/documents/64157/4373903/02-ESS-Quality-and-performance-Indicators-2014.pdf/5c996003-b770-4a7c-9c2f-bf733e6b1f31

[80] See European Statistical System (ESS) Handbook for Quality and Metadata Reports — re-edition 2021 - Products Manuals and Guidelines - Eurostat (europa.eu)

DIMENSION	QPI	APPLICABILITY TO MNO DATA BASED STATISTICS
	TP2. Time lag - final results	Applicable
	TP3. Punctuality - delivery and publication	Applicable if dissemination or delivery date are announced
Comparability and Coherence	CC1. Asymmetry for mirror flows statistics - coefficient	Applicable for statistics related to mirror flows, e.g. tourism statistics
	CC2. Length of comparable time series	Applicable
Accessibility and Clarity	AC1. Data tables – consultations	Applicable
	AC2. Metadata - consultations	Applicable
	AC3. Metadata completeness - rate	Applicable, even if there could be the need of adapting the metadata standard

It can be noted that, for the majority of quality dimensions, the standard quality indicators are applicable and maintain the same meaning. On the contrary, the dimension with the majority of non-applicable quality indicators is accuracy. Indeed, the ESS QPIs defined for the accuracy dimension are mostly tailored for surveys and censuses and cannot provide a good evaluation of the accuracy of statistics based on MNO data. Other measures and methods should be identified. Possibly, as the other ESS QPIs, they should not be costly. Instead, they should be easy to obtain as a byproduct of the RMP and, at the same time, useful as 'alarm bell' of possible bias or lack of precision of the estimates.

It should be noted that quality metrics computed along the pipeline, with their corresponding quality warnings, are perfectly compliant with the mentioned characteristics. Thus, gathering the quality warnings and analysing them can be useful as an indirect accuracy measure of the output quality.

[In the final version of the deliverable, a proposal for a selection of the most relevant quality metrics and warnings to be analysed at the output stage will be reported.]

The computation of ESS QPIs can be a routine practice to associate simple quality measures to each statistical output release. However, statistical outputs based on MNO data need a more thorough and direct assessment of their accuracy to be accepted as Official Statistics. The methodology for such evaluation could be costly, similar to the traditional methods used to estimate the bias due to non-sampling errors on estimates produced through a sampling survey. For example, re-interviews on a subsample of respondents are needed to evaluate the bias due to measurement errors and post enumeration surveys are carried out to assess the coverage of censuses. Similar approaches could be recommended to be carried out only occasionally[81], in order to assess the accuracy of the statistical output based on MNO data, as in the auditing sampling approach proposed by Zhang, 2023.[82] Further developments are expected in this direction from the MNO-MINDS ESSnet project

The demand for or the focus on the evaluation of accuracy should not lead to disregarding the other quality dimensions. If relevance and timeliness are supposed to improve with the use of MNO data, attention should be paid to other dimensions.

First, coherence with other available relevant statistics that have been considered for validation purposes. Next, comparability over time, which includes as an inherent requirement the stability and continuity of MNO data transmission (also a guarantee). These characteristics take back to the input data characteristics and emphasise the importance of the agreements between the MNOs and the NSI. In addition, the use of standard concepts and methodology over time, which should be assured by the use of the RMP, sets a sound basis for obtaining comparable outputs.

[81] due to their costs

[82] See: https://www.ine.es/art/sjs/sjs_2023_01_05.pdf

Finally, clarity, which in the case of new data sources is perhaps more important than in traditional statistics. Indeed, transparency of the process should be assured to build and sustain public trust. From this point of view, the adoption of an open and reproducible pipeline based on open methodology should be considered a winning approach. Clarity is obviously connected to quality reporting associated to the statistical output. A first proposal for a tailored version of the ESS standard for quality reports (i.e. SIMS) for MNO data has been developed within the ESSnet Big Data II research project[83].

[In the final version of the deliverable, the ESSnet proposal on SIMS for MNO data will be reviewed and applied to the RMP. Furthermore, the impact that SIMS adaptation could have on the EHQMR will be considered.]

[83] See: ESSnet Big Data II
https://webgate.ec.europa.eu/fpfis/mwikis/essnetbigdata
https://ec.europa.eu/eurostat/cros/content/essnetbigdata_en
Work package K, Methodology and quality, Deliverable K6: Quality report template, Draft version, 28.2.2020

9 SOFTWARE QUALITY

9.1 INTRODUCTION

Software quality is the **degree to which a software product satisfies stated and implied needs when used under specific conditions** (see ISO/IEC 25010). The reference software is an open-source implementation of a processing pipeline that follows the methodological framework developed for processing MNO data, adhering to the requirements and specifications developed in Task 2 and Task 3 of this project. It provides a detailed and non-ambiguous description of the methods and algorithms used, ensuring both reproducibility and auditability. The goal of the reference software is to produce official statistics based on MNO data and ensure the same methodologies can be applied across multiple MNOs and countries. The software must allow for extensions and updates in future versions.

The software pipeline is not an industry-ready product with full functionality to handle all potential MNO data scenarios in official statistics. Instead, it is a *minimum viable product* designed to perform basic MNO data processing steps for a limited set of distinct statistical end products (use cases). These use cases are implemented and demonstrated within the project using real-world MNO data, with the expectation that the methodological framework and software design will remain flexible and adaptable to support additional use cases in future extensions and related projects.

\ STATED AND IMPLIED NEEDS OF THE REFERENCE SOFTWARE:

\ The software must be able to process standardised MNO data to generate statistical indicators that can be used for official statistics, adhering to the requirements and principles of statistical production, as well as privacy and data protection laws.
\ The software must ensure reproducibility and auditability of the data processing methods.
\ As the system is expected to handle large-scale data, scalability, including parallel (distributed) processing, should be built into the design and architecture of the software pipeline.
\ The pipeline should efficiently process large datasets in a timely manner but does not need to be performing with optimal resource utilisation.
\ The software must be developed as open source, with full documentation and code shared under open licenses (EUPL 1.2).
\ The pipeline needs to be highly modular and flexible, allowing for updates of individual components, the addition of new modules, and the incorporation of future methodological changes, performance optimisations, and new use cases without disrupting the entire system.
\ The software should have very comprehensive configuration possibilities to allow maximum parametrisation of methodological adjustments as well as support for maximum methodological sensitivity analysis.

\ SPECIFIC CONDITIONS FOR THE USE OF THE REFERENCE SOFTWARE:

\ The software will operate in the secure environment of the MNOs without external internet connection; all input data required to operate the software is assumed to be available within the secure environment.
\ The software must operate within the common infrastructure and IT environments of MNOs.
\ The software must be deployable, executable, manageable, and maintainable by standard IT system operators, with the aid of deployment and operation guidelines and with support from NSI statistical experts for configuring methodological parameters.
\ The execution of the software is regula,r with most commonly daily execution periods.

While the reference software is prepared for deployment and capable of calculating use case results with real MNO data, users may want or need to modify it for performance improvements, additional modules, or methodological adjustments. The real-life scenario of using the reference software is described in the following description.

\ DESCRIPTION OF THE GENERIC USAGE SCENARIO OF THE REFERENCE SOFTWARE:

- Open-source software and its documentation are openly available to be downloaded by intended users who are NSIs and MNOs.
- The software may need to be modified for optimisation or other purposes, or new modules may be developed for extending the functionality of the software. The modification of the software should follow the guidelines provided in this chapter.
- It should be tested with benchmark and synthetic data during the development (unit tests).
- The software is deployed on the secure infrastructure of one or more MNOs for testing with real data (testing environment).
- The software configuration parameters are modified by the users (based on the suggestions of NSI statisticians).
- Ongoing iterations of testing, modification and configuration are performed until the results are satisfactory.
- After testing is complete, the production version of the software is deployed with the final configuration parameters (production environment).
- Regular data updates of input data (MNO data).
- The software is regularly executed and produces regular results for selected use cases which are transferred to NSI.
- Monitoring of the quality of the results and feedback from the NSI to the MNO is performed during the regular execution.
- Modified software may be submitted to ESS for merging the modifications with reference software's master branch and, thus, becoming publicly available for other users.

9.2 OVERVIEW OF SOFTWARE QUALITY ASPECTS

ISO/IEC 25010:2011 – "Systems and software Quality Requirements and Evaluation for general software quality characteristics" is used as a guideline for describing the quality characteristics of the reference software developed in the project. The ISO/IEC 25010 standard is widely used in the software industry as it provides an internationally recognised framework for evaluating and improving software quality.

In the following sections, traditional characteristics are used as a starting point to scope the software quality aspects that are relevant for the reference software. Quality characteristics will be presented following a results-oriented approach reflecting how the quality of the software is supported by the process design stage and how the software reflects the needs of the potential specific users of the software (statistical community, NSIs, MNOs).

9.2.1 FUNCTIONAL SUITABILITY

This characteristic represents the degree to which a product or system provides functions that meet stated and implied needs when used under specified conditions.

***Status**: Relevant*

***Motivation:** The purpose of the reference software is to ensure that the algorithms strictly adhere to the described methodology, without deviation, when applied under specified conditions (e.g. processing MNO data with standardised input). The accuracy and reliability of the statistical output are contingent upon the software's ability to execute precisely as outlined in the methodology.*

1. FUNCTIONAL SUITABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Functional completeness: Degree to which the set of functions covers all the specified tasks and intended users' objectives.	*Relevant*	Functional completeness is directly related to the methodological requirements that the software must be able to perform. All methods have been implemented in the reference software.	The processing pipeline consists of the methodological description and software code that is the implementation of the methodologies (not more, not less). This principle should be followed in the future modifications of the software to ensure the functional completeness, i.e. actual algorithms cover all the methodological objectives. Task 2, Deliverable D2, Volume I - High-Level Pipeline Definition Task 4 Software Codes and documentation, particularly Component Requirements and Component Design Design and methodology, coding
Functional correctness: Degree to which a product or system provides accurate results when used by intended users.	*Relevant*	Functional correctness can be interpreted in a wider sense as the accuracy of the statistical output. The latter depends on: a) the methodology, b) the data processing algorithm, and c) input data quality. It is still challenging to assess the accuracy of statistics based on MNO data, as there are no comprehensive ground truth data for the majority of use cases, while ESS partners are working on developing methods to improve the accuracy (e.g. through the MNO-MINDS ESSnet project). However, those methodologies and data processing algorithms in the reference pipeline must be developed in the most logical manner, to avoid or reduce, as much as possible, the introduction of additional errors that could affect output accuracy.	When developing new methodologies and implementing them, during testing with real-world data, it is advisable to be able to compare the results with available benchmark data and adjust accordingly the methodology (and its implementation) to be able to state that such methodology represents the closest model to reality as possible. Future developments must ensure that the actual algorithms behave exactly the way that is described in the methodological descriptions. Design and methodology, testing.
Functional appropriateness: Degree to which the functions	*Relevant*	Given the appropriate input and methodological and technical configuration parameters, the software should	The specific tasks and objectives are presented in the methodological description of the pipeline, and the

1. FUNCTIONAL SUITABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
facilitate the accomplishment of specified tasks and objectives.		accomplish all required calculations and processing (tasks and objectives) of the MNO data.	software should follow the requirements (i.e. tasks and objectives). Task 4 Software Codes and documentation, particularly Component Requirements and Component Design Design and methodology, coding.

9.2.2 PERFORMANCE EFFICIENCY

This characteristic represents the degree to which a product performs its functions within specified time and throughput parameters and is efficient in the use of resources (such as CPU, memory, storage, network devices, energy, materials etc.) under specified conditions.

***Status**: Somewhat relevant*

***Motivation:** Functionality is the primary objective of the software, ensuring that it adheres exactly to the defined methodology, and behaves as an example of how the methodology is implemented. The software must operate within minimum acceptable performance parameters; for instance, it should be able to process one day of data in less than a day. This ensures the software remains usable and efficient without compromising its core functional objectives. While performance does not directly impact statistical outputs, the speed of the calculations, the computational requirements to the IT resources, do affect the timeliness and cost of the deployment of the software and should be taken into account when developing software that should process a large amount of data, as in the MNO data case*

2. PERFORMANCE EFFICIENCY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Time behaviour: Degree to which the response time and throughput rates of a product or system, when performing its functions, meet requirements.	*Relevant*	The current reference software is primarily designed to demonstrate the basic functionality of the MNO data processing methodology and algorithms, with less emphasis on achieving optimal performance. Therefore, time behaviour of the software is not optimal but meets requirements. The performance depends on the allocated computational resources, but there is much room to optimise individual modules. The current requirement for performance is the capability to process data with a minimum temporal scope of one single day.	It is expected that users need to improve the performance of the software in order to be able to process large amounts of MNO data efficiently within limited time period. The optimisation of the process should be done in parallel with the implementation of the methodological functions and, in some cases, the methodology may need adjustments or modifications for these reasons. Task 4 Software Codes and documentation, particularly General Requirements Requirement analysis, coding, testing, deployment
Resource utilisation: Degree to which the amounts and types of resources used by a product or system, when performing its functions, meet requirements.	*Somewhat relevant*	Due to the nature of the reference software, there are no requirements related to the computational resources. Nevertheless, when the reference software is intended to be used as a production component, such requirements will be needed.	Requirements on the computational resources must be introduced for the whole software. Requirement analysis, coding, testing, deployment
Capacity: Degree to which the maximum limits of a product or system parameter meet requirements.	*Somewhat relevant*	Due to the nature of the reference software, there are no requirements related to the computational resources. Nevertheless, when the reference software is intended to be used as a production component, such requirements will be needed.	Requirements on the computational resources must be introduced for the whole software. Requirement analysis, coding, testing, deployment

9.2.3 COMPATIBILITY

Degree to which a product, system or component can exchange information with other products, systems or components, and/or perform its required functions while sharing the same common environment and resources.

***Status**: Relevant*

***Motivation:** The software may use initial input data objects as common and shared resources with other systems, and output data objects may be shared with other systems. Nonetheless, the software does not require nor is meant to implement functional integration and compatibility with other systems. The software is implemented using PySpark programming language, which makes it compatible with the different deployment types of Spark clusters (Kubernetes, standalone, etc.) in different environments (on-premises, cloud). For the reference software, compatibility does not directly impact statistical outputs.*

3. COMPATIBILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Co-existence: Degree to which a product can perform its required functions efficiently while sharing a common environment and resources with other products, without detrimental impact on any other product.	*Relevant*	The software can share resources, but during the execution, the software may claim resources that will impact the performance of other products. The quantity of various resources (cluster-nodes, RAM, storage capacity) can be allocated by the MNO system operator.	Depending on the frequency of the execution of the software, and anticipated processing time, the software may be deployed in the dedicated infrastructure to ensure undisturbed performance of the software and other resources. Deployment, maintenance
Interoperability: Degree to which a system, product or component can exchange information with other products and mutually use the information that has been exchanged.	*Relevant*	By default, the software does not have integration modules to be able to exchange data with other resources. However, software interfaces (data objects) can be set up to provide information to other resources. This is especially valuable for quality metrics and quality warnings where it is suggested that the warnings are instantly relayed to some monitoring system. Also, the resulting output data should be automatically transmitted to NSI after the successful execution of the pipeline. However, such integration is not a part of the software. In addition, the software is implemented using PySpark, which makes it compatible with the different deployment types of Spark clusters (Kubernetes, standalone, etc.,) in different environments (e.g. on-premises, cloud).	It is recommended that new modules should include quality metrics and quality warnings that can be integrated with external components and allow for efficient monitoring of the pipeline. Design and methodology, coding

9.2.4 INTERACTION CAPABILITY

Degree to which a product or system can be interacted with by specified users to exchange information via the user interface to complete specific tasks in a variety of contexts of use.

***Status**: Somewhat relevant*

***Motivation:** The reference software is operated via command line and does not include graphical interface, therefore operating the software (including installation) requires skilled system operator to be able to deploy, operate and maintain the software with guidelines provided along with the software. The quality of operating the software does affect statistical outputs, so improving interaction by creating a user interface, or creating flexible and automated commands may increase the simplicity.*

4. INTERACTION CAPABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Appropriateness recognisability: Degree to which users can recognise whether a product or system is appropriate for their needs.	*Somewhat relevant*	As the software is publicly available, the description of the software should ensure recognition of its purpose and functionality.	
Learnability: Degree to which the functions of a product or system can be learnt to be used by specified users within a specified amount of time.	*Somewhat relevant*	Specialists who are responsible for deployment, operating and maintaining the software must be acquainted with the documentation. Depending on the role of the user (MNO system operator, NSI data engineer, NSI domain specialist, etc.) learning technical aspects of the software may take days to weeks.	The documentation of the software must be comprehensive, readable and easily understandable for the specific persons with specific skills. A set of competences and skills of MNO and NSI staff involved in the operational production process are introduced in Chapter 5 of this deliverable. Deployment, maintenance
Operability: Degree to which a product or system has attributes that make it easy to operate and control.	*Somewhat relevant*	This is a highly specialised software and should be developed targeting easiness of use as requirement. Therefore, it should not be designed in a complex manner.	The documentation of the software must be comprehensive, readable and easily understandable for the specific persons with specific skills. The reference software (and any of its future components) should be designed by highly skilled software architects that are able to translate the methodological details into a linear and simple and smooth codes execution. Design and methodology, coding
User error protection: Degree to which a system prevents users against operation errors.	*Somewhat relevant*	*[To be discussed]*	
User engagement: Degree to which a user interface presents functions and information	*Not relevant*	The software is meant to be operated by specialists with specific skills and does	

4. INTERACTION CAPABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
in an inviting and motivating manner encouraging continued interaction.		not include graphical user interface where potentially such elements play a role.	
Inclusivity: Degree to which a product or system can be used by people of various backgrounds (such as people of various ages, abilities, cultures, ethnicities, languages, genders, economic situations, etc.).	*Not relevant*	The software is meant to be operated by specialists with specific skills regardless of the background.	
User assistance: Degree to which a product can be used by people with the widest range of characteristics and capabilities to achieve specified goals in a specified context of use.	*Not relevant*	The software is meant to be operated by specialists with specific skills regardless of the physical or mental capabilities.	
Self-descriptiveness: Degree to which a product presents appropriate information, where needed by the user, to make its capabilities and use immediately obvious to the user without excessive interactions with a product or other resources (such as user documentation, help desks or other users).	*Somewhat relevant*	The reference software should be operated with the help of documentation, as it does not include graphical interface or any internal support mechanism for operating. There are only a limited number of people who would potentially use the software, and they should be capable of operating the software using OS tools.	Adding some helpful and supportive features (e.g. prompting for confirmation, questions, integration with dashboards to monitor quality metrics, etc.) may be simple and useful amendments. Deployment, maintenance

9.2.5 RELIABILITY

Degree to which a system, product or component performs specified functions under specified conditions for a specified period of time.

***Status**: Somewhat relevant*

***Motivation:** The reference software must operate within real-world data setting in a continuous manner to ensure the continuity of regular statistics production.*

5. RELIABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Faultlessness: Degree to which a system, product or component performs specified functions without fault under normal operation.	*Somewhat relevant*	The software has undergone unit testing, benchmark reference data and real-life MNO data tests. The faultlessness is not 100% guaranteed but has been tested without issues of such sort.	Testing of the modifications and new modules with regards to the potential failures – ensure that basic error handling and correction. Coding
Availability: Degree to which a system, product or component is operational and accessible when required for use.	*Somewhat relevant*	When deployed, the software is under the control of MNO and is operational at their disposal.	Deployment
Fault tolerance: Degree to which a system, product or component operates as intended despite the presence of hardware or software faults.	*Somewhat relevant*	As the software uses the Spark Framework, it is resilient and can recover from worker-nodes failures in a cluster.	Use of the same technology stack as other modules of the reference software to ensure the same level of performance regarding fault tolerance. Task 4 Software Codes and documentation, particularly Technology Stack. Coding
Recoverability: Degree to which, in the event of an interruption or a failure, a product or system can recover the data directly affected and re-establish the desired state of the system.	*Somewhat relevant*	*[To be discussed]*	Deployment

9.2.6 SECURITY

Degree to which a product or system defends against attack patterns by malicious acts and protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorisation.

***Status**: Relevant from the point of view of data protection and sensitive information protection*

***Motivation:** The software is meant to be deployed into a closed infrastructure environment of MNOs and should not have external access that would allow for any attacks, malicious acts, or access to private and sensitive data and information by external parties (outside MNO). Moreover, as the software processes sensitive data, the access to the software should be limited and controlled by MNO who is responsible for the data protection of its clients, as well as interested in keeping its sensitive business information secure. The software relies completely on the user access control of the infrastructure where the software has been installed. The deployment setup of the software should not affect the quality of the statistical output. However, security limitations may impact certain procedures, such as resolving data-related issues, and failure to address these could potentially affect the quality of the statistical output.*

6. SECURITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Confidentiality: Degree to which a product or system ensures that data are accessible only to those authorised to have access.	*Relevant from the point of view of data protection and sensitive information protection*	Due to MNOs' data security policies and/or personal data protection regulations, individual (non-aggregated) data will always remain within the MNO infrastructure and will never be exported to the NSI, thus access to the data is limited only to those authorised to have access.	Any modification of the software or its modules, and new modules should follow the existing data protection principles applied in the reference software (export only aggregated data, bottom-up one-way processing, access to any sensitive data for persons with non-disclosure agreements, etc.). Task 2, Deliverable D2, Volume I, privacy-by-design (aspects of privacy protection, and protection of sensitive information of MNO). Design and methodology, coding, deployment
Integrity: Degree to which a system, product or component ensures that the state of its system and data are protected from unauthorised modification or deletion either by malicious action or computer error.	*Somewhat relevant*	The software is deployed in a closed infrastructure environment of MNO, so access to the software and any activities related to operating the software correspond to the security level of the specific MNO infrastructure.	Deployment
Non-repudiation: Degree to which actions or events can be proven to have taken place so that the events or actions cannot be repudiated later.	*Not relevant*	Related to logging of the software.	Task 4 Software Codes and documentation, particularly Logging Design
Accountability: Degree to which the actions of an entity can be traced uniquely to the entity.	*Not relevant*	Related to logging of the software.	Task 4 Software Codes and documentation, particularly Logging Design
Authenticity: Degree to which the identity of a subject or resource can be proved to be the one claimed.	*Somewhat relevant*	The software is deployed in a closed infrastructure environment of MNO, so access to the software and any activities related to operating the software correspond to the security level of the specific MNO infrastructure. The identity	It is suggested to MNOs that they enable logging and monitoring of the activities of the users who access the software, in order to be able to trace back any suspicious activities to a specific user.

6. SECURITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
		of the subjects who access and operate the software are logged in the MNO system	Deployment
Resistance: Degree to which the product or system sustains operations while under attack from a malicious actor.	*Not relevant*	Protection methods for external attacks are not in the scope of the reference software. This type of security is handled by the MNOs infrastructure where the software is deployed.	

9.2.7 MAINTANABILITY

This characteristic represents the degree of effectiveness and efficiency with which a product or system can be modified to improve it, correct it or adapt it to changes in environment, and in requirements.

***Status**: Relevant*

***Motivation:** The reference software is a minimum viable product that is meant to be an example of the basic MNO data processing pipeline. It is meant to be modified in terms of the methodology, new modules, and performance aspects. The reference software is built as a modular software and should remain modular for any new modifications. It is important to keep the maintainability aspect of the software in future developments, especially if the future modifications (new modules, optimization) are meant to be merged with the master branch of the software.*

7. MAINTAINABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Modularity: Degree to which a system or computer program is composed of discrete components such that a change to one component has minimal impact on other components.	*Relevant*	The data processing flow within the framework is designed with a modular approach. Each functional unit is distinct and clearly specified, including input data objects, output data objects, data processing methods and quality controls. This modularity allows for easy improvement of specific functional units without extensive dependencies on other units, enhancing the flexibility and scalability of the framework.	Any modification and enhancement of the software should follow the modularity principle. Task 2 High-Level Requirements Task 4 Software Requirement Specification Design and methodology, coding.
Reusability: Degree to which a product can be used as an asset in more than one system, or in building other assets.	*Relevant*	The reference software is designed for reusability by multiple users (MNOs and NSIs in multiple countries) as separate instances. It does not, in any way, depend on the number of locations where it resides; it operates independently.	Any modification and enhancement of the software should not compromise the reusability of the software. Design and methodology, coding, deployment.
Analysability: Degree of effectiveness and efficiency with which it is possible to assess the impact on a product or system of an intended change to one or more of its parts, to diagnose a product for deficiencies or causes of failures, or to identify parts to be modified.	*Relevant*	Measurability is a requirement so that the functional performance could be objectively verified during testing or upon deployment. Logging, quality metrics and quality warnings are used for operational and functional performance respectively.	Any future developments should adhere to the continuous possibility of the software to be analysable through system logging and quality metrics and warnings. Task 4 Logging Design and Data Design (quality metrics, quality warnings), Software Requirement Specification Design and methodology, coding, deployment.
Modifiability: Degree to which a product or system can be effectively and efficiently modified without introducing defects or degrading existing product quality.	*Relevant*	Modularity enables the software to be modified without serious or irreversible effect on other components. The software is developed using open-source	It is highly recommended to follow the guidelines on modular development of the software in the future so that modularity and modifiability would remain intact qualities.

7. MAINTAINABILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
		technology and the source code of the software is available for third parties to modify any components.	Task 2 High-Level Requirements (evolvability) Design and methodology, coding, deployment.
Testability - Degree of effectiveness and efficiency with which test criteria can be established for a system, product or component and tests can be performed to determine whether those criteria have been met.	*Relevant*	The software is accompanied with a reference test data (benchmark reference data) for each software module. The purpose of such data is to provide possibility to validate the functional performance of the software, meaning that with specific input data, the specific outcome data must be achieved. Software can also be tested with real-life MNO data, as this is the purpose of the software. It does not matter what data the software processes as long as it follows the standard requirement of the input data and the configuration parameters correspond to the specificity of the date (e.g., geographical reference data).	Testing is an important part of the development phase, and it is important that any future development includes unit tests, tests with benchmark reference data, and also real-life MNO data before updates become available to other users. Task 4 Software Requirement Specification (testable) Task 5 Testing on real-world data Design and methodology, coding, deployment.

9.2.8 FLEXIBILITY

Degree to which a product can be adapted to changes in its requirements, contexts of use or system environment.

***Status**: Relevant*

***Motivation:** The reference software is designed for deployment within the MNO infrastructure, with an architecture that leverages Docker for flexibility across various deployment environments. The software's algorithms are built to accommodate changing requirements, while its modular design allows for easy integration of new methodologies. Most system environments used by MNOs support this type of deployment, ensuring broad compatibility and adaptability. It is recommended that any future modifications remain within the framework of such software development and deployment design in order to maintain flexibility, especially if the future modifications (new modules, optimisation) are meant to be merged with the master branch of the software.*

8. FLEXIBILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Adaptability: Degree to which a product or system can effectively and efficiently be adapted for or transferred to different hardware, software or other operational or usage environments.	*Somewhat relevant*	Docker technology is used for deployment of the software to isolate dependencies, acting like lightweight virtual machines with only the necessary libraries for running the software. Users only need Docker installed to execute the application. Additionally, Docker allows agile testing of different library versions by creating multiple containers with varied environments to verify software execution.	Any modification and enhancement of the software should be compatible and require Docker. Task 4 Infrastructure Design Task 5 Testing on real-world data Coding, deployment
Scalability: Degree to which a product can handle growing or shrinking workloads or to adapt its capacity to handle variability.	*Relevant*	The technology used for the reference software and architecture (including configuration design) allow for scalability of the software and distributed computing.	It is recommended to use existing technology stack of the reference software in order to comply with existing technological requirements that comply with scalability. Task 4 Configuration Design, Technology Stack Task 5 Testing on real-world data Coding, deployment
Installability: Degree of effectiveness and efficiency with which a product or system can be successfully installed and/or uninstalled in a specified environment.	*Relevant*	Docker technology is used for deployment of the software to isolate dependencies, acting like lightweight virtual machines with only the necessary libraries for running the software. Users only need Docker installed to execute the application. This means that the software can be installed on multiple different environments as long as they have Docker installed.	Any modification and enhancement of the software should be compatible and require Docker. Task 4 Infrastructure Design Task 5 Testing on real-world data Coding, deployment

8. FLEXIBILITY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE/SOFTWARE DEV. CYCLE
Replaceability: Degree to which a product can replace another specified software product for the same purpose in the same environment.	*Somewhat relevant*	Potentially, the reference software may replace or complement existing similar software products that MNOs use for processing their data for insights and statistics. Replacing those products is more of a business question. Technically, and from the software quality point of view, this is related to installability and deployment of the software itself. MNOs must probably adjust and modify the reference software to add functionality of the other products in order to compensate for the missing features of the reference software.	

9.2.9 SAFETY

This characteristic represents the degree to which a product under defined conditions to avoid a state in which human life, health, property, or the environment is endangered.

***Status**: Not relevant*

***Motivation:** The software does not include any functionality and external integration that could create conditions for endangering human life, health, property or environment.*

9. SAFETY

SUB-CHARACTERISTIC	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE /SOFTWARE DEV. CYCLE
Operational constraint: Degree to which a product or system constrains its operation to within safe parameters or states when encountering operational hazard.	*Nor relevant*	The software does not include any functionality and external integration that could create conditions for endangering human life, health, property or environment.	
Risk identification: Degree to which a product can identify a course of events or operations that can expose life, property or environment to unacceptable risk.	*Nor relevant*	The software does not include any functionality and external integration that could create conditions for endangering human life, health, property or environment.	
Fail safe: Degree to which a product can automatically place itself in a safe operating mode, or to revert to a safe condition in the event of a failure.	*Somewhat relevant*	Only relevant regarding some of the reliability sub-characteristics.	
Hazard warning: Degree to which a product or system provides warnings of unacceptable risks to operations or internal controls so that they can react in sufficient time to sustain safe operations.	*Nor relevant*	Software does not include any functionality and external integration that could create conditions for endangering human life, health, property or environment.	
Safe integration: Degree to which a product can maintain safety during and after integration with one or more components.	*Somewhat relevant*	Only relevant regarding some of the reliability sub-characteristics.	

9.3 FUTURE DEVELOPMENT AND INTEGRATION OF METHODOLOGICAL AND SOFTWARE IMPROVEMENTS

This chapter focuses on the key aspects of future development for the methodological pipeline and software, ensuring that the quality standards of the software pipeline are maintained or improved. Key practices from our project, particularly those related to the evolving methodology and software pipeline, should be clearly integrated into the new approach. While traditional quality characteristics remain important, the specific needs of our software pipeline require a focus on additional aspects of quality in both methodological and statistical development. These current practices will help shape the future evolution of the pipeline.

9.4 SOFTWARE DEVELOPMENT CYCLE

The future development of the software should continue to follow the established principles of the software development cycle, ensuring that the methodological aspects are fully integrated into each phase of the process. This approach is essential for maintaining key quality aspects. By adhering to these principles, the development process should remain structured and efficient, ensuring that the software evolves in line with methodological, technical and business objectives.

Each stage of the cycle can return to the previous or earlier stages with improvements requests (e.g. coding stage reveals that there are logical discrepancies in the methodology and methodology must be improved; testing may reveal performance issues, so the process must return to coding to correct; the whole steps may require change of requirements to correspond to reality, etc.). The iteration process continues until the resulting software meets the initial plan and requirements, and aligns with real-world conditions, including data and computational resource constraints.

The cycle itself should continue and iterate for each new modifications, and with versioning possibilities, these processes can be initiated in parallel (e.g. one team working on developing a new module and another team improving the performance of existing module).

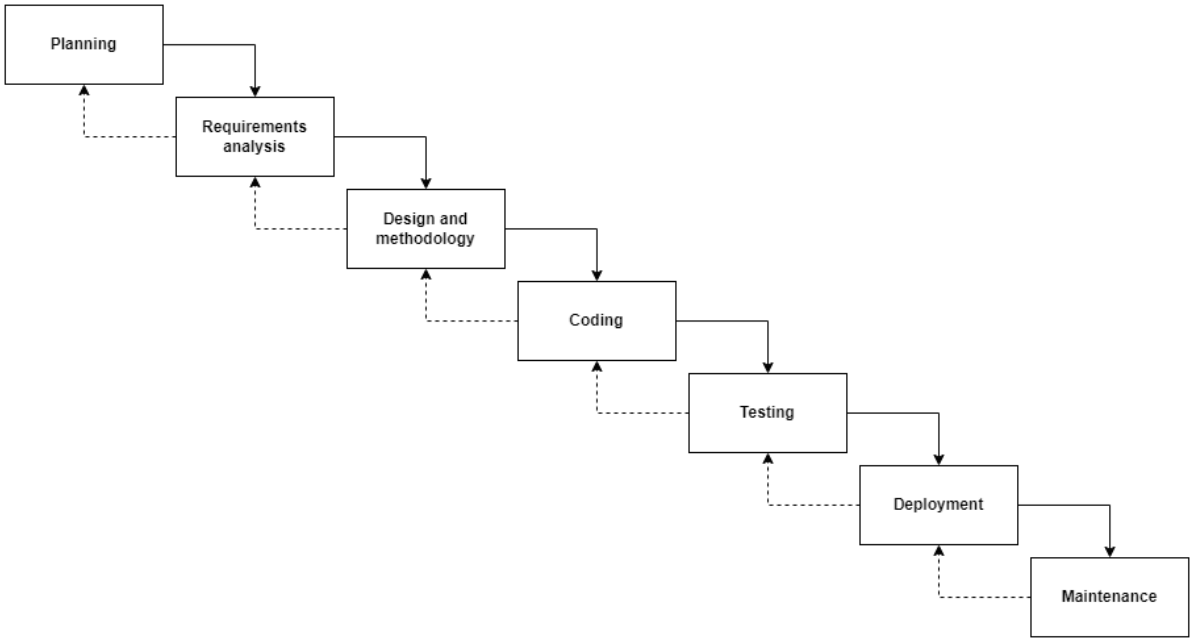

Figure 6: Software development cycle

The following software development cycle is practiced in the project:

PLANNING	
1. Defining the needs and the purpose	Identification of the purpose and needs of the development or improvement of the software.
REQUIREMENTS ANALYSIS	
2. Requirements	Identification of the additional functional requirements of the new modules, or functional or non-functional requirements of existing modules (e.g., to add new indicators of output of existing module, to improve the performance of existing module, etc.).
DESIGN AND METHODOLOGY	
3. Methodology definition	The methodology is defined by statistical experts and should include all components, such as input data, processing steps, output data, and any other relevant elements. The methodology must also align with and be implementable within the existing architecture and design of the software pipeline.
4. Methodological parametrisation	Any modification or new modules should include the wide options of changing methodological parameters. Enhancements must avoid hard-coded and non-flexible constants written in the algorithms. This ensures methodological flexibility and support for the methodological sensitivity analysis of the software.
5. Peer review and technical amendments	Methodology requirements' peer review and technical amendments from the perspective of data and software engineering and possible methodological and implementational clarity that are the basis for implementation by developers.
6. Documentation of the methodology	Documentation of the methodology must be amended to the main documentation of the pipeline. This may be updated later in case the methodology changes due to feedback from the implementation stage.
CODING	
7. Translation to software requirements	After the final review of the methodology, it is transformed into software requirements which are also reviewed by the methodological experts to ensure the correct translation of the methodology to the software specification.
8. Algorithm design and development	Design of the algorithm and software code by developers and data engineers. The development should be carried out by at least two developers at the time to ensure the best implementation model and code.
9. Unit testing	Unit tests are performed to verify the correctness of the code implemented as well as small case testing of the component to guarantee the functional validity.
10. Ongoing feedback	There is constant feedback between methodological experts and developers during implementation to resolve possible issues or for confirmation and clarification of any ambiguity.
11. Code review and integration	Once the methodology has been initially implemented into a software code by specified developer team, the code should be reviewed by other developers to avoid logical fallacies, performance issues, compliance with the methodology, compliance with the accepted software architecture and modular concept of the whole pipeline, output, and other potential issues.
12. Software requirements review by statistical experts	Software requirements' review by methodological experts to cross-check whether the planned algorithms follow the methodology.
13. Documentation of the software modules	Once the new methodology is implemented in the pipeline and the software, the proper software documentation must be amended to the main documentation of the software.
14. Code repository merge	The code is merged with the master repository of the software pipeline (local branch in case of external development). This stage may be done after the following testing stages are completed.
15. Deployment and operation documentation	Amendment of the documentation of the use guide for deployment (if applicable), operating and maintenance of the new modules of the software.
TESTING	

PLANNING	
16. Benchmark data testing	Testing with benchmark reference data ensures that the module's output, given specific inputs, aligns precisely with the requirements set by the methodology.
17. Testing with actual data	Testing with actual MNO data.
DEPLOYMENT	
18. Deployment	Deployment of the software pipeline should follow the guidelines of deployment and operations documentation. Any modification of the software should not alter the general deployment procedures.
MAINTENANCE	
19. Maintenance	Maintenance of the software pipeline should follow the guidelines of deployment and operations documentation. Any modification of the software should not alter the general maintenance and operating procedures.

In addition to the internal development cycle, the resulting pipeline and the software should be validated by external parties (e.g. other NSIs and MNOs of another country). In case there is an ambition to incorporate the updates of the software pipeline into the public master branch, the ESS as a central governing body of the software pipeline should review, validate, test and then merge the changes.

\ SOFTWARE MODULARITY

A modular design of a software pipeline is essential because it allows other developers to easily integrate and test new methodological variations, fostering collaboration and continuous improvement. By structuring data processing methodologies and software pipelines with clear, well-defined interfaces between modules, multiple alternative solutions can be tested independently. This flexibility not only makes it easier to expand the system but also ensures that updates or changes in one module do not disrupt the entire pipeline, enhancing both scalability and maintainability. Modularity itself serves different aspects of software quality like maintainability, flexibility, as well as interoperability.

Modularity with clear interfaces, input and output data allows the re-use of different data objects created by existing modules within the processing pipeline; for example, by using the Continuous Time Segmentation data object for multiple use cases. It is highly recommended that any future developments follow the modular design and integrate the new amendments as separate modules.

The following figure illustrates the data processing pipeline in which the new modules could be integrated/added following the existing modular design.

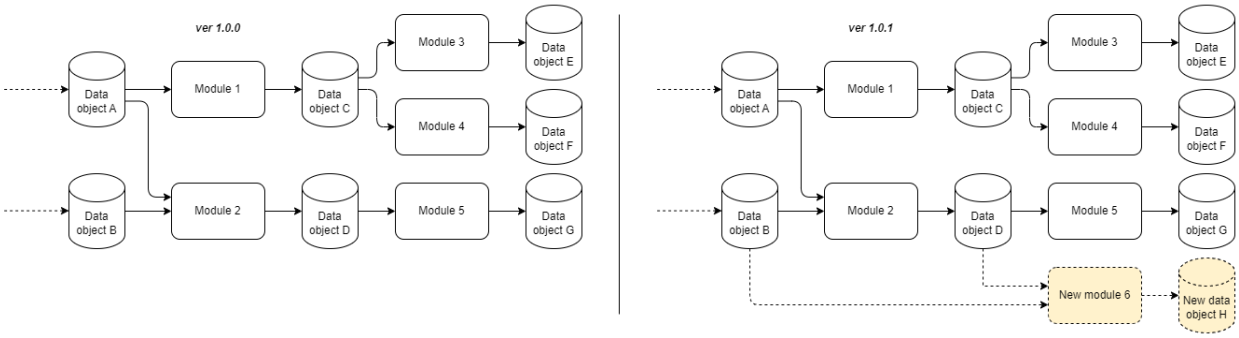

Figure 7: Data processing pipeline, modular design

A module must have a well-defined input data object, typically produced by a preceding module, a clearly described data transformation process outlined in the methodology, and a well-specified output data object. All of this should be accompanied by practical examples (tables and data scenarios). The module may also produce quality metrics data objects, which include metrics that characterize the resulting data and provide a basis for

assessing the quality of the results of the module (and the methodology) and a basis for generating quality warnings.

\ OPTIMISING PERFORMANCE, IMPROVING THE MODULES AND METHODOLOGY, CORRECTION OF EXISTING ERRORS OF THE PIPELINE MODULES OR METHODOLOGY

The current reference software is a minimum viable product designed primarily to demonstrate the basic functionality of the MNO data processing methodology and algorithms, with less emphasis on achieving optimal performance. Therefore, the future development of the software may include improving the performance and functionality of existing modules, as well as improving the overall software functionality and performance.

The improvement of existing modules may include changing the algorithms of the module, refactoring the processing language, computational logic, as well as other techniques. In some cases, the optimisation may affect or require the change of methodology due to various factors. In some cases, the ambition is to enhance and improve the methodology of specific modules. To keep the integrity of the software and to follow the principles of modular design, there are two general options to modifying of the software.

1. Creating new modules and new output data objects while keeping the existing modules intact and following the same or creating new methodology (option A from the following figure).
2. Modifying existing modules and using software versioning to keep track of the methodology, modules and output data objects (option B).

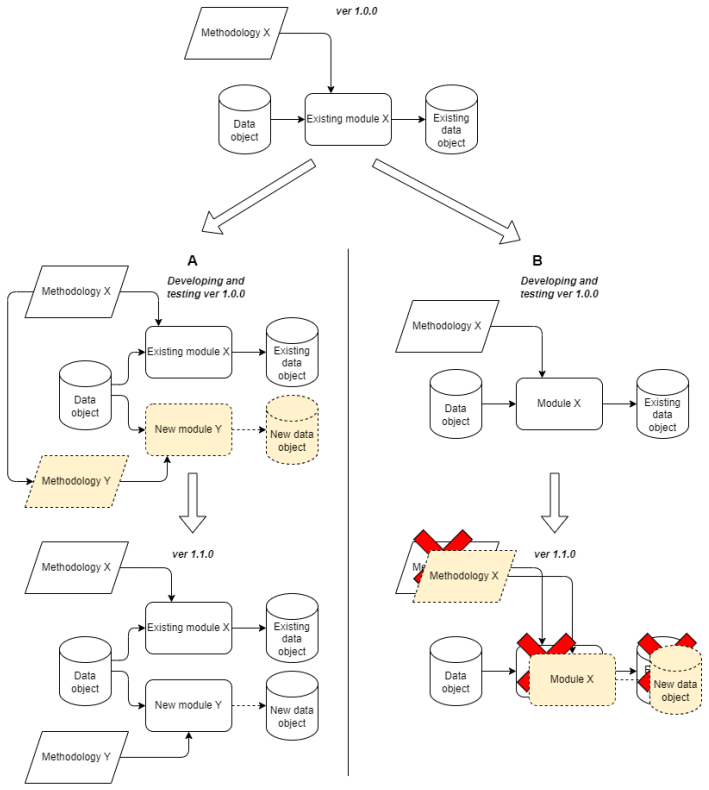

Figure 8: Options for modification of the software

Eventually, the governing body of the software pipeline should establish the specific guidelines on how to introduce changes and updates to the software pipeline which may include one or several of these options.

In any case, it is highly recommended that existing modules are not modified, but new modules and new output data objects are created that use existing data objects as input. This way, the existing and new modules that

potentially perform the same or very similar functions co-exist and can be run in parallel. This allows comparison of performance as well as comparison of the results of both modules. This also supports methodological sensitivity analysis of different methodologies.

Eventually, the original modules may be archived (removed from the pipeline software) and replaced by the new, improved and optimised modules. Any decision related to changes and updates to the software modules in the reference pipeline should be handled by a dedicated body within the ESS (e.g. a task force or working group mandated to govern the methodological framework and software pipeline on behalf of the whole ESS).

\ SUPPORT FOR THE METHODOLOGICAL SENSITIVITY ANALYSIS

Methodological sensitivity is the degree to which the results of the analysis of the data are affected by different methodological design choices for the same input data.[84] The possibility to run methodological sensitivity tests (along with parameter sensitivity tests) can be considered a quality aspect of the software. The modular design of the reference software and keeping the methodological parameters of the modules in a configuration of the software (separate configurations for separate modules) allow executing different modules or even the same modules with different configuration parameters. This makes it possible to compare and analyse results.

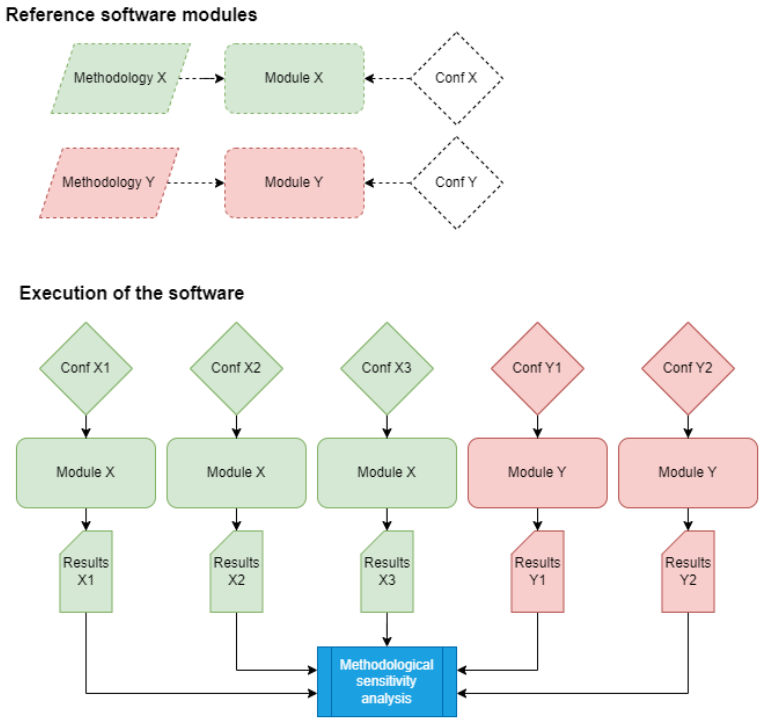

Figure 9: Graphical representation of the execution of different modules

\ BENCHMARK REFERENCE DATA

The open-source code must be accompanied by a thorough set of benchmark reference data serving multiple purposes.

The benchmark reference data, together with the corresponding benchmark configuration parameters, forms the cornerstone for organisations implementing the software pipeline to ensure that its initial 'default' setup processes data correctly, producing the expected intermediate data objects and results. By providing a reliable

[84] F. Ricciato, A reflection on methodological sensitivity, quality and transparency in the processing of new "big" data sources, Q2022 conference, Vilnius, June 2022. Available from https://doi.org/10.5281/zenodo.10246419

standard, the benchmark reference data allows organisations to verify that the software operates according to its intended design.

Another important role is the verification of methodological compliance by alternative implementations. Third-party developers may want to offer optimised or enhanced software implementations (possibly proprietary) that are functionally equivalent to the reference pipeline, i.e. provide the very same output results for the same input data. The methodological compliance of such alternative implementations can be checked by benchmarking intermediate data objects and final outputs against the reference input data.

The software is composed of interconnected modules where each module transforms input data objects into corresponding output data objects – subsequently, serving as inputs for the following module(s). The software developers can utilise the benchmark reference data to validate these transformations in their future implementations. By comparing the results of modified modules with the benchmark output data at each stage, developers can ensure their updates align with the pipeline's expected functionality and methodology. If methodological changes are introduced, this comparison also serves as a critical check to confirm that any resulting changes in outputs occur as anticipated and maintain consistency across the pipeline.

The original benchmark reference data is designed as raw input objects that are comprehensive enough to capture real-world scenarios and special cases for each pipeline module. When processed through the pipeline, these inputs generate benchmark output data at each stage (e.g. input data A for module 1 is transformed into output data object B, which serves as input for module 2 and is transformed into output object C, and so forth). This cascading structure ensures that benchmark outputs validate the accuracy of individual module transformations, while also supporting compatibility across the entire pipeline.

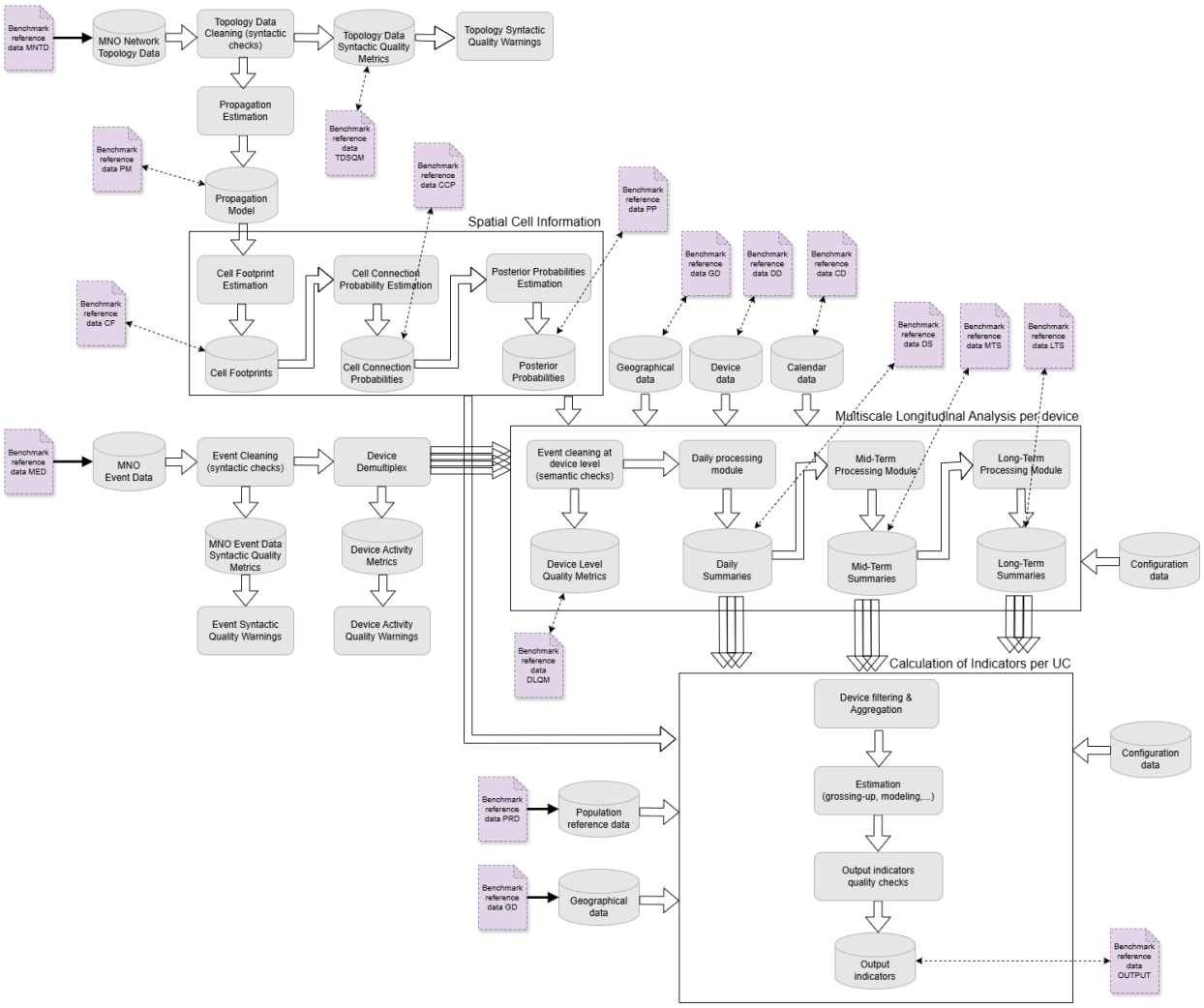

Figure 10: Illustration of benchmark reference data provided for each individual module

By establishing a clear and reliable framework for data transformation validation, the benchmark reference data empowers third-party developers to innovate confidently. Developers can test their modifications against the benchmarks, ensuring upstream and downstream compatibility and adherence to the pipeline's intended methodology. This approach fosters a collaborative environment for continuous improvement, enabling organisations and developers alike to enhance the software while preserving its robustness, accuracy, and scalability.

\ TESTING WITH REAL-WORLD MNO DATA

Any new major update of the software (except for minor bug fixes) should be preliminarily tested on multiple real-world MNO data before approval to the production stage. The purpose of the testing is to verify the functional completeness, performance efficiency, compatibility and all other quality aspects of the new software version. This is complementary to the testing of software modifications against the benchmark reference data.

The specifics of the testing carried out as part of the project (for the proposal for the standard software pipeline), along with general guidelines for the testing, are available as separate files. These can serve as inspiration for testing materials to be developed in the reference scenario.

\ VERSION CONTROL FOR THE DEVELOPMENT OF THE REFERENCE SOFTWARE

Semantic Versioning (SemVer) of the software is the most commonly used practice for numeration of different versions of evolution of the software. A typical version number looks like this: 1.2.3, where:

- MAJOR (1): Indicates significant changes that are not backward-compatible. These changes may introduce new features that alter the software's functionality in a way that requires other parts of the system or users to adapt.
- MINOR (2): Indicates new features or functionality that are backward-compatible. These changes add new capabilities without breaking existing functionality.
- PATCH (3): Indicates bug fixes, small improvements, or other minor changes that are backward-compatible and do not affect the software's features or API.

Example:

- 2.0.0: A major release with breaking changes.
- 2.1.0: A backward-compatible minor release with new features.
- 2.1.1: A patch release fixing bugs or making small improvements without new features or breaking changes.

There are other versioning alternatives; however for the sake of simplicity, SemVer is used as an example in this chapter. The actual versioning policy must be decided by ESS before the reference software becomes publicly available.

The central repository for the reference software uses Git, a distributed version control system, which enables sophisticated management of software versioning and development. As the software evolves, third parties may modify it within their own Git repositories (referred to as 'local branches'), typically originating from the latest version of the master branch. While versioning (numbering) in local branches should follow the same principles as the master branch, it is a manual process and subject to interpretation. This can lead to differences in how changes are classified, resulting in differing version numbers between local branches and the master.

Versioning individual modules is not recommended due to the complexity it introduces. Tracking separate versions for each module, along with their dependencies and compatibility with other modules, increases the risk of confusion and creates an additional burden on developers. Instead, it is recommended to version the software as a whole. Any small or large changes to any software component should result in an update to the overall version number, both in local branches and the master branch, ensuring consistency and clarity across the entire codebase.

For example, if an NSI further develops a local branch initiated from version 2.1.5 of the master branch and assigns next versions as 2.1.5 ➔ 3.0.0 ➔ 3.1.0 ➔ 3.1.1 ➔ 3.2.0 ➔ 4.0.0 ➔ 4.0.1 ➔ 4.1.0 ➔ 5.0.0 and decides to propose merging their branch with the master, the master version number, in case there have not been any modifications to the master branch would be 3.0.0 (and not 5.0.0). The decision of which version number to increase in the master branch (major, minor, patch) is up for the central governing body.

Merging the local branch with the master branch requires an initial merge of the master branch into the local branch (getting the latest updates), resolving potential conflicts, and only then can the local branch be merged into the master branch. The potential conflicts between the local branch and the master branch may require not just code-level resolutions, but also administrative decisions, including, for example, differentiating and naming modules, deciding on the version numbers, etc. For example, if in a local branch, a specific new use case module or statistical domain X has been developed, and similar module has been added to the master branch, the administrative decision may be to either a) keep two separate modules that have similar function, but are somewhat different, or combine two very similar modules into one; or b) renaming different modules according to the naming convention, etc. The modular design of the software allows for avoiding code-level conflicts (see the section on modularity and improving the software); this is because, ideally, the existing modules and codes

are not to be modified which allows for simple amendments to the code to the whole code repository (and not the modification of the existing code).

The master branch of the reference software code and documentation is centrally managed while allowing various third parties to download (check-out) and create their own branches of the software. Those branches can be developed as described previously. When a third party proposes the update of the master branch due to some substantial improvement (even if this is a patch-level improvement), the governing body of the software can allow for the merging if the procedure follows specific steps that ensure the integrity of the software. The following figure illustrates an example of versioning of the different local and master branches.

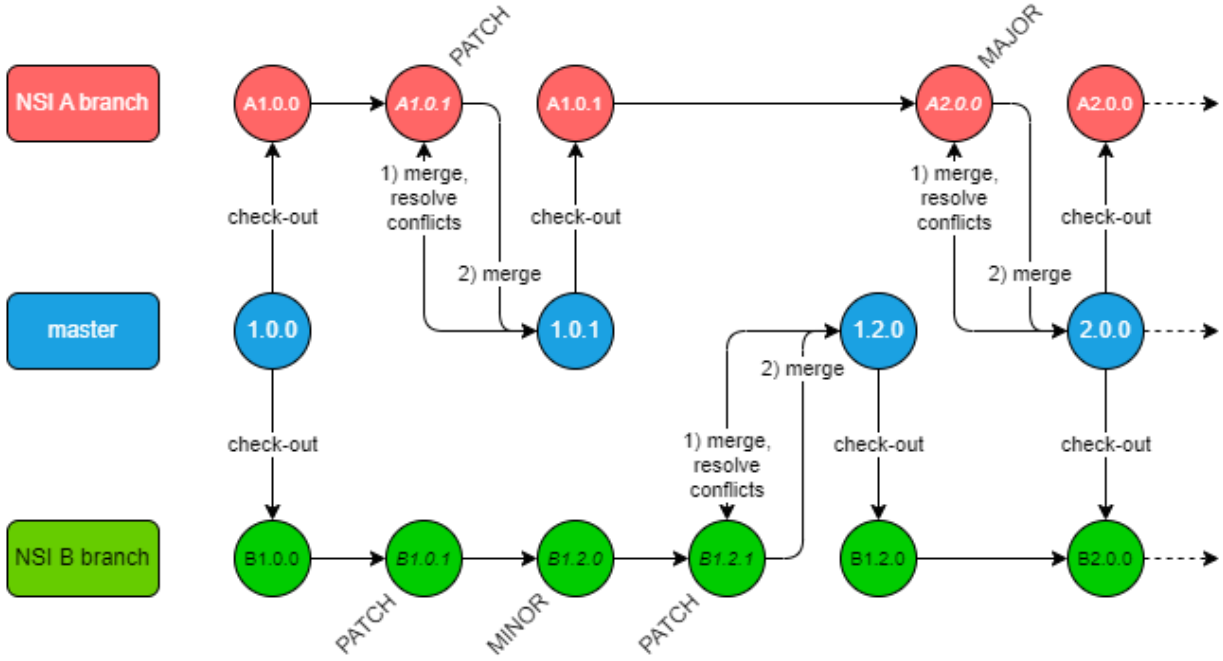

Figure 11: Software versioning options

In order to be able to compare the functionality and compatibility of the software between different versions, any and all merges to the master branch must include a change log that documents all changes that have been introduced to the software in incremental form. A properly updated change log is the source for tracking and understanding the differences between two versions.

\ MANAGEMENT OF THE SOFTWARE AND VERSION CONTROL FOR THE MASTER BRANCH

When governing an open-source software Git repository, both technical and administrative aspects are critical to ensuring smooth management of the open-source software.

From a technical perspective, the repository's structure and organization must be well-defined. This includes choosing a future branching and versioning strategy to track software releases. Code quality is maintained through guidelines and coding standards (including in-line comments, see Task 4), and a structured code review process, where pull requests are reviewed before merging into the master branch. Establishing coding standards ensures consistency and makes the review easier. Efficient issue and bug management is also essential, supported by a clear labelling system to prioritise and categorise future tasks. No code is without issues, even master branch, so maintaining a list of known issues is important. Reflecting the issues to developers improves transparency and planning to fix the issues (by the governing body or by other parties) and is a necessary component of maintaining the software repository.

Code documentation must be kept up to date; therefore, similarly to coding standards, documentation guidelines should also be proposed to developers. Contribution guidelines are important for onboarding new developers, while user documentation – such as README files and guidelines – should be accessible to both users and contributors. Security is also crucial, requiring proper access control to the repository, as well as regular checks for dependency vulnerabilities and adherence to best security practices. The nature of the reference software requires that contributions to the master branch are done by the governance body after a review process. Contributors and users may download (check-out) the software from the repository, but not merge to the master branch by themselves.

Administratively, managing the community around the repository is vital. A clearly defined governance model establishes how decisions are made, whether by a benevolent dictator, meritocratic processes or consensus. A code of conduct helps maintain a respectful and inclusive community. Ensuring clear and accessible onboarding for new contributors helps foster growth. Licensing is another critical area, where the project must have a clear open-source license (i.e. EUPL 1.2) that defines usage rights and contributions.

The decision-making process within the project needs to be transparent. A public project roadmap communicates long-term goals, while clear policies for merging pull requests and resolving conflicts (technical or administrative) keep the project running smoothly.

Release management is another key administrative responsibility. Establishing regular release cycles helps keep the community engaged and ensures steady progress. Maintaining a detailed changelog is also important, as it informs users about new features, fixes, and changes in each release.

Lastly, community engagement is essential for the health of an open-source software project. Regular communication through mailing lists, chat channels or social media helps keep users and contributors informed. Promoting the project through ESS channels, the project website, blog posts, conferences and talks can attract new contributors and maintain interest in the project.

In summary, both technical and administrative aspects must be carefully managed to ensure the success and longevity of an open-source Git repository. By balancing these responsibilities, project maintainers can create a sustainable and thriving open-source ecosystem.

ANNEX 1: ES COP AND ESS QAF: PRINCIPLES, INDICATORS AND METHODS OVERVIEW AND ANALYSIS

INTRODUCTION

The present Annex proposes a thorough review of the Principles, Indicators and Methods of the ES Code of Practice and ESS Quality Assurance Framework. It aims at:

- Establishing their relevance for the statistical production based on MNO data
- Identifying methods and tools that should be developed for statistics based on MNO data, in order to fulfil ESS CQF requirements
- Underlining which requirements could be satisfied through the outputs of the present project or other related projects implemented in parallel in the ESS
- Identifying what could be integrated into the ESS CQF to facilitate and reinforce the quality of Official Statistics based on MNO data (recommendations).

This analysis allows to identify relevant elements to be developed to complement the Reference Methodological Pipeline (RMP) with a comprehensive quality framework and, more generally, will provide suggestions for improving the current framework to better represent the quality issues arising from the use of MNO data.

The analysis follows a structured template, where, for each relevant ES CoP principle, an assessment of the relevance and specificity is provided, and in a cascade manner for the related indicators and QAF methods.

PRINCIPLE 1

PRINCIPLE 1. PROFESSIONAL INDEPENDENCE

Professional independence of statistical authorities from other policy, regulatory or administrative departments and bodies, as well as from private sector operators, ensures the credibility of European Statistics.

***Status**: General principle which also encompasses the use of MNO data in official statistics.*

***Motivation:** Professional independence of NSIs stands regardless of the nature of specific statistical processes or the origin of the source data. Besides, independence from private operators is already included in the principle. Nevertheless, the adoption of an open methodology developed by the ESS, such as the one implemented in the RMP, could limit the use of proprietary methods by the MNOs and improve transparency, safeguarding the independence of statistical authorities.*

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PRINCIPLE 1BIS.

PRINCIPLE 1BIS. COORDINATION AND COOPERATION

National Statistical Institutes and Eurostat ensure the coordination of all activities for the development, production and dissemination of European statistics at the level of the national statistical system and the European Statistical System, respectively. Statistical authorities actively cooperate within the partnership of the European Statistical System, so as to ensure the development, production and dissemination of European statistics.

***Status**: Coordination is a general principle which also encompasses the use of MNO data in official statistics. Cooperation is relevant for the use of MNO data in official statistics.*

***Motivation:** Coordination of the statistical system neither affects the production of statistics from MNO data, since MNOs do not belong to the national statistical systems, nor is affected by the use of MNO data in official statistics. However, it is worth noting that the adoption of the same RMP across the ESS is itself a strong form of coordination at European level.*
Cooperation is specified in the principle in regard to the partnership of the ESS; nonetheless, the principle could be extended as cooperation with MNOs as well.

Indicator 1bis.1: The National Statistical Institutes coordinate the statistical activities of all other national authorities that develop, produce and disseminate European statistics. They act in this regard as the sole contact point for Eurostat on statistical matters. Legislation and well defined and established procedures are in place for implementing the coordination role at both national and European levels.

General indicator on the coordination role of NSIs in national statistical systems.

Indicator 1bis.2: National guidelines to ensure quality in the development, production and dissemination of European statistics within the national statistical system are produced by the Heads of the National Statistical Institutes, where necessary; their implementation is monitored and reviewed.

General indicator which also encompasses the use of MNO data in official statistics. The guidelines mentioned in this indicator are addressed to the entities of the national statistical system.

***Recommendation**: Quality guidelines focused on how to implement quality assurance in the statistical production process, that could be specific for MNO data-based statistics, are mentioned in method 3 of indicator 4.1. Nevertheless, in order to stress the importance of such quality guidelines, an indicator recommending Quality Guidelines for MNOs and other data sources could also be integrated in this principle.*

Indicator 1bis.3: Statistical authorities continuously maintain and develop cooperation at various levels with each other and with the advisory bodies of the European Statistical System, as well as with the members of the European System of Central Banks, academic institutions and other international bodies, as appropriate.

***Recommendation**: The indicator could be strengthened (or a new one could be added) to promote cooperation and the establishment and maintenance of partnerships between statistical authorities and MNOs, or more generally with private holders of data.*

INSTITUTIONAL METHODS (INDICATOR 1BIS.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Cooperation within the European Statistical System. A policy supporting and promoting the participation of statistical authorities in relevant activities is in place. Instruments such as sponsorships, meetings, networks and conferences are in place to share knowledge and promote working together for improving official statistics, both on international and national levels. An exchange of staff with statistical authorities of other countries within the European Statistical System is encouraged.	*General method which also encompasses the use of MNO data in official statistics*	It refers to internal cooperation within the ESS. Besides cooperation with other EU NSIs, cooperation with other national authorities with experience in the use of MNO data should be fostered.	The current project, sponsored by Eurostat, which involves directly and indirectly other NSIs (e.g. through regular consultations with the ESS TF MNO), including partners in the ESSnet MNO-MINDS research project, can be considered an example of such cooperation. In the future, once the methodological and the quality assurance framework for MNO data-based statistics will be developed, its implementation and maintenance should be coordinated at the level of the ESS. A governance procedure should be established to maintain the methodological standard and the associated reference pipeline.
2. Policy on data sharing. The National Statistical Institute has a policy to share data with statistical authorities of other countries within the European Statistical System, in particular in areas of mutual interest such as flow and mirror statistics. The policy takes into account confidentiality and data protection requirements.	*General method which also encompasses the use of MNO data in official statistics*	It refers to internal cooperation within the ESS.	The confidentiality and data protection requirements defined in data sharing policies can be a reference to draw similar requirements for MNO data sharing.
3. Cooperation with the advisory bodies of the European Statistical System. Eurostat and the National Statistical Institutes follow-up on a regular basis recommendations from the advisory bodies of the European Statistical System, such as the European Statistical Governance Advisory Board (ESGAB) and the European Statistical Advisory Committee (ESAC).	*General method which also encompasses the use of MNO data in official statistics*	It refers to the cooperation with specific bodies (ESGAB and ESAC).	

INSTITUTIONAL METHODS (INDICATOR 1BIS.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Cooperation with the central banks. Regular meetings are held between the National Statistical Institute and the National Central Bank, and agreements or memoranda of understanding are concluded. At the European level, a Memorandum of Understanding between Eurostat and the European Central Bank/Directorate General for Statistics is implemented within the scope of the European Statistical Forum framework.	*General method which also encompasses the use of MNO data in official statistics*	It refers to the cooperation with specific institutions; however, the tool of MoU can be useful also for the cooperation with MNOs.	
5. Cooperation with scientific institutions. Instruments such as common statistical development projects, internships, doctoral positions or colloquia are used to maintain and develop cooperation between the statistical authorities and the relevant scientific institutions.	*General method which also encompasses the use of MNO data in official statistics*	It refers to the cooperation with specific institutions; however, the instruments described can be useful also for the cooperation with MNOs.	Under the umbrella of the current project, advancements are being presented in specific scientific fora (e.g. NetMob 2023, Q2024, etc.) to foster this cooperation. Improvements and contributions by the scientific community to the reference pipeline, which is presented as an open-source model, are also encouraged and represent an example of the cooperation recommended in this method.
6. Cooperation with international bodies. Instruments such as joint projects, working groups and colloquia are used to maintain and develop cooperation between the statistical authorities and international bodies.	*General method which also encompasses the use of MNO data in official statistics*	It refers to the cooperation with specific institutions; however, the instruments described can be useful also for the cooperation with MNOs.	
7. Promotion and support of innovation. The heads of the National Statistical Institutes, other statistical authorities and Eurostat promote/support innovation through cooperation and agreements with public institutions, private businesses, academic and research institutions,	*Relevant*	The terms 'private businesses' and 'technology innovators' could include MNOs as well; products derived from MNO data can be seen as an example of an important innovation.	A template for the agreement between statistical authorities and MNOs is proposed in Annex 2.

INSTITUTIONAL METHODS (INDICATOR 1BIS.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
government bodies and other technology innovators.			
8. Partnerships between statistical authorities. Joint projects are encouraged and in place, where possible, to reinforce partnerships among the National Statistical Systems and between the National Statistical Institutes and Eurostat, such as ESSnets, research, international cooperation projects.	*Relevant*	International research projects to facilitate the use and improve the quality of statistics based on MNO data are already in place and should be fostered. They can include MNO representatives for a fruitful exchange of knowledge.	The current project, sponsored by Eurostat, which involves directly and indirectly other NSIs (e.g. through regular consultation with TF MNO), including partners in the ESSnet MNO-MINDS research project, can be considered examples of such cooperation.

Recommendations:

An additional method specifically related to fostering cooperation and partnership between statistical authorities and MNOs (and other private data holders of relevant innovative data sources) could be added to provide further stimulus for the investment in the use of this data. The development of a common open reference methodological pipeline defined at the ESS level, involving NSIs and MNOs, represents a good example of such cooperation. In addition, publishing the pipeline that is developed as open-source and encouraging its reviewing and possible improvement can be considered an example of how to foster this cooperation. Finally, the adoption of the same RMP across the EU will foster coordination among NSIs in the ESS in a very concrete and effective way.

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PRINCIPLE 2

PRINCIPLE 2. MANDATE FOR DATA COLLECTION AND ACCESS TO DATA

Statistical authorities have a clear legal mandate to collect and access information from multiple data sources for European statistical purposes. Administrations, enterprises and households, and the public at large may be compelled by law to allow access to or deliver data for European statistical purposes at the request of statistical authorities.

***Status**: Highly relevant principle*

***Motivation:** Access to MNO data is a key aspect of the exchanges between NSIs and MNOs. 'Enterprise'" are already mentioned in the principle, but due to the special nature and sensitivity of MNO data, specific changes in legislation concerning access to MNO data are needed. The recent revision of Regulation (EC) No. 223/2009 on European Statistics (i.e. the European statistical law) provided the needed legislative support.*

Indicator 2.1: The mandate of the statistical authorities to collect and access information from multiple data sources for the development, production and dissemination of European Statistics is specified in law.

Highly relevant. Even if it is a general indicator which already also encompasses the use of MNO data in official statistics, the related methods are interesting to analyse.

INSTITUTIONAL METHODS (INDICATOR 2.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Mandate of statistical authorities. The mandate of the statistical authorities to collect and access information from multiple data sources, including administrative data, for European statistical purposes is set out in the national statistical law and/or in other relevant legislation.	*Relevant*	The recent revision of Regulation (EC) No. 223/2009 on European Statistics will help to facilitate the collection of MNO data by NSIs.	The method could be strengthened to explicitly include privately held data, i.e. '*The mandate of the statistical authorities to collect and access information from multiple data sources, including administrative data, for European statistical purposes is set out in the national statistical law and/or in other relevant legislation.* ***The legislation should also guarantee the conditions for access to privately held data*****.**
2. Availability of legislation. Relevant legislation regarding the mandate to collect data and access information is available through the statistical authorities' web page.	*General method which also encompasses the use of MNO data in official statistics*	Information about legislation regarding the mandate to collect data from MNOs should be published along with existing legislation.	
3. Justification of statistical needs. The need to collect and access data is justified on the basis of publicly available documents specifying regulatory, methodological, technological or administrative requirements.	*Relevant*	This method is particularly important to facilitate the access to MNO data for official statistics. If their relevance is properly justified in appropriate documents, from both a technical and institutional perspective, it represents a clear motivation to ensure the mandate to access them.	The recently published position paper (Eurostat, 2023)[85] includes a specific chapter on the relevance of the use of MNO data for the production of official statistics.

[85] Reusing mobile network operator data for official statistics: the case for a common methodological framework for the European Statistical System – 2023 edition - Eurostat (europa.eu)

PROCESS/OUTPUT METHODS (INDICATOR 2.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Procedures for data collection and access to data. Procedures are in place to manage data collection and access data from multiple data sources**.**	*Relevant*	A standard procedure or workflow to collect data from MNOs should be in place, and both the NSIs and the network operators should be expected to follow it.	A template for the agreements with MNOs, specifying the conditions for such data access, will be proposed in Annex 2. Besides the clear definition of the data that should be provided, elements like a secure environment for data access, privacy issues, storage of historical data should also be defined in the procedure. To better reflect the MNO data processing pipeline, the method could be strengthened to encompass also 'data processing' in addition to 'data collection'. This QAF method could be reformulated as '*Procedures for data collection**, data processing** and access to data. Procedures are in place to manage data collection, **data processing** and access data from multiple data sources'*. Alternatively, a new method could be added, dedicated to data sources requiring a non-negligible amount of processing at the data holder's premises.
5. Procedures for exploring data sources. Each statistical domain regularly explores possible new data sources, including privately held data sources, and assesses their feasibility and accessibility for producing statistics.	*Relevant*	Many statistical domains (e.g. population, tourism) could benefit from the use of MNO data. Therefore, the feasibility of their introduction into production processes should be assessed considering different purposes and domains.	

Indicator 2.2: The statistical authorities are allowed by law to access administrative data, promptly and free of charge, and use them for statistical purposes. They are involved from the beginning in the design, development and discontinuation of administrative records, in order to make them more suitable for statistical purposes.

Not relevant. It concerns administrative records.

Indicator 2.3: On the basis of a legal act, the statistical authorities may compel response to statistical surveys.

Not relevant. It concerns surveys.

Indicator 2.4: Access for statistical purposes to other data, such as privately held data, is facilitated, while ensuring statistical confidentiality and data protection.

Highly relevant. It covers the access to MNO data

***Recommendation**:*
*The indicator can be strengthened, since access to privately held data should not only be facilitated but guaranteed by law as in the case of administrative data, as it is now reflected in the revision of Regulation (EC) No. 223/2009 on European Statistics. In addition, the indicator could be extended to include a part similar to indicator 2.2., as follows: 'Indicator 2.4: **The statistical authorities are allowed by law to access** other data, such as privately held data, for statistical purposes, while ensuring statistical confidentiality and data protection. **Statistical authorities should collaborate with private data holders in order to facilitate the suitability of private data for statistical purposes**.*

INSTITUTIONAL METHODS (INDICATOR 2.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Agreements. Agreements with holders of other data, such as privately held data, are in place to ensure and facilitate access to these data. These agreements may set out the scope of the use of the data, sustainability of cooperation, frequency and timeline of data access/transmission/delivery, access/delivery mode, delivery of metadata, appropriate use of the data, possible compensation for the use of privately held data, statistical confidentiality and data protection.	*Highly relevant method*	Agreements with MNOs are crucial to ensure the smooth collection of MNO data. Such agreements are now facilitated by the revision of the European statistical law, which includes an obligation for private data holders to collaborate with statistical authorities and find a common agreement. These agreements should include: the expectations of NSIs in terms of delivery frequency, quality controls on the data, specific data formats, how data pre-processing carried out by MNO should be carried out, delivery of metadata, along with the necessary actions to ensure confidentiality.	A template for the agreements with MNOs, specifying the conditions for data access is proposed in Annex 2. Adopting a common and open RMP and quality framework provides the basis for building such agreements.
2. Partnerships. Partnerships between the statistical authorities and private companies, researchers and academia, the government, civil society organisations and others as appropriate, are in place to foster cooperation and to facilitate access to other data, such as privately held data.	*Relevant*	Partnerships with MNOs are already in place within the ESS and this method further fosters them. The recent amendment of the European statistical law further fosters such partnerships.	The current project is an example of positive cooperation between MNOs and statistical authorities. To facilitate the definition of such partnerships in the future, a template for the agreements with MNOs, specifying the conditions for data access, will be proposed in Annex 2. Adopting a common and open RMP and quality framework provides the basis for building such partnerships.
3. Awareness raising. The statistical authorities conduct meetings and other awareness-raising activities with holders of other data, such as privately held data, at both management and operational level, to explain issues such as the mission of official statistics, the mandate of the statistical authority, the reasons for the use of	*Relevant*	As with partnerships, activities with MNOs to exchange experiences and raise awareness are already being carried out within the ESS and this method further fosters them.	Preparatory meetings conducted with MNOs before their involvement in the present project can be considered as an implementation of the method.

INSTITUTIONAL METHODS (INDICATOR 2.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
privately held data, data protection legislation and their implementation by the authorities.			
4. Engagement. Senior management in the statistical authorities encourages the involvement of their peers at government level and key interest groups, such as business sector associations, in discussions with senior management of private data holders.	*Relevant*	Active involvement of the top management of NSIs is important to ensure that the interest of statistical offices in MNO data is backed by institutional commitment. Relevant telecommunication sector associations can be the key interest groups to be targeted.	
5. Guidelines. Guidelines for the cooperation of statistical authorities with holders of other data, such as privately held data, are in place and available to staff.	*Relevant*	Availability of specific guidelines for the cooperation with MNOs would be very useful.	Guidelines for cooperation should be tailored to country specific situations. Nonetheless, some indications can be derived from Chapter 5 and from the template for the agreements with MNOs in Annex 2.
6. Data scouting. Procedures are in place and resources available to identify possible new data sources.	*Relevant*	In the case of MNO data, procedures should focus on seeking cooperation with multiple MNOs, ensuring that the data collected is as complete as possible in terms of coverage at the national level. It is also important to monitor the evolution of MNO data so that possible future improvements (e.g. availability of more accurate location data thanks to triangulation, better data on subscribers' profiles, etc.) are rapidly identified (and possibly integrated into the proposed data processing pipeline).	In this perspective, an ad-hoc method could be formulated to encourage the involvement of different private data holders in the same sector to improve the coverage of the acquired data.
7. Access procedures. Procedures are in place to access other data, such as privately held data. They take into account limiting the burden for private data holders and avoiding interference with their business concepts.	*Relevant*	Such a procedure should be created to facilitate the use of MNO data in official statistics production.	The adoption of a common open RMP defined at the ESS level is strictly related to this method. A standardised procedure or pipeline to collect data

INSTITUTIONAL METHODS (INDICATOR 2.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
			from MNOs, with its software implementation, can ensure the quality of the incoming data, while limiting the burden and smoothing the workflow for all the involved organisations.
8. Free of charge access. Guidelines are in place on how to promote and encourage access to other data, such as privately held data, free of charge.	*Relevant*	As stated in the method, data should be obtained free of charge. However, the extraction and preprocessing activities that MNOs shall carry out in order to provide standardised aggregated data to statistical authorities can have relevant costs. Furthermore, the utilisation of cloud-based or physical server resources for data storage and computational tasks directly impacts business costs. This should be acknowledged by MNOs. The compensation of MNOs for their cooperation is an aspect that should be included in the agreements with them.	
9. Compensation for access. A procedure is in place to support sound decision-making on possible financial contributions or non-monetary compensation, such as methodological cooperation and training, to receive access rights to other data, such as privately held data.	*Relevant*	Since many MNOs are developing their own data monetisation products, methodological cooperation and awareness raising of the value of MNO data for public statistics can be particularly relevant for compensating MNOs and supplementing possible financial compensations.	.
10. Data protection procedures. Statistical confidentiality and data protection procedures with regard to other data, such as privately held data, are in place.	*Relevant*	Statistical confidentiality and data protection procedures are crucial when dealing with MNO data. Data protection methodologies can be a complex issue and specific techniques might be required.	The identification, design and development of statistical disclosure control methods are out of the scope of this project. In this project, data protection measures are limited to the

INSTITUTIONAL METHODS (INDICATOR 2.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
			incorporation of the principles of 'data minimisation' and 'storage limitation' at methodological level into the RMP. For the sake of the demonstrator scenario exclusively, a method for statistical disclosure control to be applied to the intermediate aggregated data from each single MNO before being combined in multi-MNO aggregates and accessed by the NSI, is detailed in Appendix I of Deliverable D2.2, Volume III. The corresponding software component is implemented in the software codes released in the context of Task 4.
11. Access management. Access to new data sources is centrally managed within the statistical authority. This could take the form of a virtual entity or central function at the level of the statistical authority.	*Relevant*	This concerns all categories of new data sources and is a suggestion for efficient internal NSI organisation. It is worth noting that such an entity/function in the NSIs needs specialised staff who understand the peculiarities of MNO data.	
12. Technical capacity. The statistical authorities have the technical capacity to access the data. All necessary technical safeguards are in place to guarantee secure access to and storage of the data.	*Relevant*	This method is particularly relevant in the case of MNO data, since the technical requirements to access the data include highly specialised aspects such as software, algorithms and an infrastructure that is shared with MNOs. The technical capacity of the NSIs should be improved accordingly, if necessary.	

Recommendation:

To facilitate the use of MNO data for official statistics, additional methods can be proposed taking inspiration from existing methods related to Indicator 2.2 on access to administrative data, also considering the favourable situation of the 'reference scenario' (see for further details the deliverables from Task 2). In particular, these methods could cover, for example:

- ⇨ Right to access MNO data (or more in general privately held data). The national statistical law and other relevant legislation shall establish the statistical authorities' right to access, for statistical purposes, MNO data (or, more generally, privately held data), while preserving data confidentiality and security (n.b. This is also covered in the methods of indicator 2.1. Nonetheless, since it is repeated for administrative data in method 1 of Indicator 2.2 it could be also included in Indicator 2.4).
- ⇨ Standardised metadata. Procedures are in place ensuring the regular provision of standardised metadata by the MNO (or, more generally, private data holders). (n.b. The standardisation of the pipeline also allows for the definition of a standardised set of metadata.)

A sensitive aspect of the use of MNO data for official statistics is the need of a continuous and collaborative dialogue with MNOs. A method suggested to facilitate this dialogue is:

- ⇨ An organisational structure aimed at maintaining relationships with MNOs (or, more generally, private data holders), which shall ensure fluent communication with new data sources providers.

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PRINCIPLE 3

PRINCIPLE 3. ADEQUACY OF RESOURCES

The resources available to statistical authorities are sufficient to meet European Statistics requirements

***Status**: Relevant*

***Motivation:** Adequacy of resources could be seen as a general principle that encompasses the use of MNO data for Official Statistics, but the specificity of processes based on MNO data suggests strengthening two main aspects: adequacy of the technical resources, meaning the adequacy of the infrastructure to collect and process the data coming from MNOs (after the off-premise processing procedures carried out by the MNOs themselves); and adequacy of the staff, who should have appropriate expertise in the field or be trained to such a purpose. In addition, as envisaged in the "Final Report of the High-Level Expert Group on facilitating the use of new data sources for official statistics" [86], a fair compensation for the costs incurred by private data holders for processing and providing data to statistical authorities can be agreed upon. These resources should be taken into account in the overall evaluation of adequate resources needed.*

Indicator 3.1: Human, financial and technical resources, adequate both in magnitude and in quality, are available to meet statistical needs

Relevant indicator which already encompasses the use of MNO data in official statistics in its formulation.

[86] https://ec.europa.eu/eurostat/web/products-statistical-reports/-/ks-ft-22-004

INSTITUTIONAL METHODS (INDICATOR 3.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Strategic planning. A strategic planning process is in place and takes into account needs for human, financial and IT resources.	*General method which also encompasses the use of MNO data in official statistics*	The strategic planning should take into account the specific needs to acquire and incorporate MNO data into production.	
2. Human resource policy. The statistical authorities have a human resource policy in place in order to ensure the availability of sufficient and highly-skilled staff. This policy includes procedures to recruit staff with relevant qualifications, allocate/reallocate resources, provisions on training, talent management, career development and staff motivation.	*Relevant*	The management of MNO data requires different skillsets and roles, from data scientists to telecommunication experts. Therefore, a human resource policy should plan not only around statisticians, but also include those other roles.	
3. Financial policy. The statistical authorities have a financial policy in place in order to ensure appropriate management and monitoring of financial resources. This policy includes budgetary procedures comprising the allocation and monitoring of budget, explanation of the roles and responsibilities of the actors, guidelines for budgetary reporting and outsourcing.	*General method which also encompasses the use of MNO data in official statistics*	The use of MNO data from a financial perspective should require the same care and the same policy approach as for other data sources. In particular, costs for compensation to MNOs, for establishing data access agreements and the need for specialised staff, etc. should be taken into account.	
4. IT policy. The statistical authorities have an IT policy in place in order to ensure an appropriate management of IT resources. This policy includes the availability, use and security of its computer systems, networks, and information resources. The IT policy and architecture are regularly reviewed and updated, when needed.	*Relevant*	In the context of a standardised IT policy within the NSIs, the use of MNO data may cause the need of some adjustments to develop an appropriate IT infrastructure for the processing of the data, due, for example, to their volume.	
5. Engagement of governance bodies. The statistical authorities regularly discuss resource issues with the relevant governance bodies.	*General method which also encompasses the use of MNO data in official statistics*	Once the resource needs have been defined by the statistical authority, taking into account the requirements for the use of MNO data, the discussion on resource aspects with governance bodies would not be specifically connected to the use of MNO data.	

INSTITUTIONAL METHODS (INDICATOR 3.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
6. Flexibility in allocation of resources. If possible, in the given administrative set-up, procedures are in place supporting decision-making on the flexible allocation of human, financial and IT resources in order to respond to changing needs and priorities.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is applicable also to processes based on MNO data. It could be noted that some specialised resources required for dealing with MNO data-based statistics may also be useful for addressing data products based on other new data sources. This can provide some flexibility in the allocation of resources.	
7. Monitoring of use of resources. Procedures are in place to regularly monitor the use of human, financial and technical resources (on the basis of relevant assessment procedures) and to report to senior management.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
8. Evaluation of adequacy of resources. Procedures are in place to regularly evaluate the adequacy of human, financial and IT resources	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data. In the case of MNO data, the resources needed by the MNO to process the data should also be considered.	An extension of the method could be considered to explicitly mention that the resources needed by the MNOs should also be included in the evaluation. *For example: "8. Evaluation of adequacy of resources. Procedures are in place to regularly evaluate the adequacy of human, financial and IT resources. **For privately held data sources, this evaluation should include the assessment of the resources needed by the data provider**."*
9. Risk management. Procedures are in place to regularly assess and mitigate financial and non-financial risks.	*Relevant*	Some relevant risks associated to the use of MNO data in official statistics are hereafter reported:	

INSTITUTIONAL METHODS (INDICATOR 3.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
		Technical risks: ⇨ Technical problems in the telecommunications network can hamper the quality of the raw data and have an impact on the quality of the resulting statistical products. ⇨ Changes in data formats/contents can required adaptations in the pipeline, so they are not properly anticipated, they can cause delays in the production of statistical outputs. **Financial risks**: ⇨ Increasing volume of data (e.g. due to increase temporal resolution, new data fields, etc.), while being beneficial for the quality of the statistical products, may have significant impact on data processing costs and, hence, on the compensations requested by MNOs. **Organisational risks**: ⇨ Changes in MNO staff/organisation may lead to lack of technical support. ⇨ MNOs may not allocate the right resources to collaborating with NSIs unless they have the proper incentives. ⇨ Since many MNOs have their own data monetisation products, they may feel that NSIs could impact negatively the market for such products, leading them to a less collaborative attitude.	

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
		Reputational risks: ⇨ If not properly communicated, the use of MNO data can raise concerns from citizens. **Data protection risks**: ⇨ If software components, cloud environment and similar IT infrastructure are not properly maintained and updated, security risks can arise.	
10. Job descriptions. Procedures are in place to ensure that job descriptions defining the tasks and necessary qualifications are available for all posts and are known to staff.	*Relevant*	The use of MNO data (or, more generally, of new data sources) can require job skills outside the scope of the traditional expertise needed for official statistics production. Therefore, specific attention should be paid to the description of such roles. In general terms, attention to the description of emerging jobs should be paid.	The method could be extended to underline that the procedures should also foresee a periodic update of the jobs description to take into account emerging jobs due to the use of new data sources. For example.*: 10. Job descriptions. Procedures are in place to ensure that job descriptions defining the tasks and necessary qualifications are available for all posts and are known to staff.* ***Considering that the expertise required to handle the new data sources can be outside the scope of traditional official statistics, job descriptions should be updated accordingly and take into account new jobs emerging from such innovations***. An overview of the job skills required to manage MNO data in statistical production are presented in Chapter 5.

INSTITUTIONAL METHODS (INDICATOR 3.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
11. Provision of training. Procedures are in place to plan and provide appropriate training to all staff to ensure adequate skills and competencies, as well as to regularly assess the adequateness and effectiveness of the training.	*General method which also encompasses the use of MNO data in official statistics*	The procedures mentioned in the method should be able to identify appropriate training also for the skills and competencies that will be needed with the increasing use of MNO data.	An overview of the job skills required to manage MNO data in statistical production are presented in Chapter 5.

***Indicator 3.2**: The scope, detail and cost of statistics are commensurate with needs.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 3.3:** Procedures exist to assess and justify demands for new statistics against their cost.*

General indicator which also encompasses the use of MNO data in official statistics. The cost-benefit analysis is particularly relevant for the decision to invest in the production of new statistics as the ones based on MNO data, since these entail significant costs associated to data processing (e.g. computing infrastructure). Nevertheless, existing procedures should not be changed for this specific case. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 3.4:** Procedures exist to assess the continuing need for all statistics, to see if any can be discontinued or curtailed to free up resources*

At the current stage, but also in the 'reference scenario' (see for further details the deliverables from Task 2), the indicator is not relevant, since we are still evaluating the possibility of producing official statistics based on MNO data. More in general, the existing procedures should apply also to MNO data-based statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Recommendation**: Additional considerations should be reflected for the cases, like the one of MNO data, in which the data provider is asked to carry out part of the data processing activities. Are the resources mentioned in Principle 3 (see above) also adequate to cover the technical and human resources needed within the MNOs for them to facilitate data provision to statistical authorities? This needs to be further discussed and can lead to an additional indicator. Guidelines and requirements should be provided by NSIs. For transparency, it would also be necessary for data sources to calculate their total costs.*

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PRINCIPLE 4

PRINCIPLE 4. COMMITMENT TO QUALITY

Statistical authorities are committed to quality. They systematically and regularly identify strengths and weaknesses to continuously improve process and output quality.

***Status**: Highly relevant*

***Motivation:** All aspects related to quality management (quality assurance, quality evaluation, quality improvement and so on) are relevant for traditional statistical processes as well as for MNO data-based processes. However, particular attention should be paid to the quality evaluation of statistics based on MNO data (and more in general on new data sources) because consolidated approaches may need to be adapted or extended. Indeed, while the general 'Commitment to quality' principle applies in the same way, procedures, methods and tools to assess and measure quality may differ for MNO data-based processes.*

Indicator 4.1: Quality policy is defined and made available to the public. An organisational structure and tools are in place to deal with quality management

While the availability of a quality policy and the existence of an organisational structure to deal with quality management are general aspects that encompass the use of MNO data without the need to be further specified, quality tools may need to be adapted, as suggested in the following related methods.

INSTITUTIONAL METHODS (INDICATOR 4.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. A quality policy / commitment statement. A quality policy / commitment statement sets out principles, practices and commitments related to quality in statistics, consistent with the goals set out in the Mission and Vision statements of the European Statistical System. The policy/statement is publicly available.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
2. An organisational structure for managing quality. There is a clear organisational structure for managing quality within the statistical authorities. Examples of such a structure are: • Quality Committee; • Quality Manager; • Centralised Quality Unit; • Other structures (e.g. members of staff trained to act as quality coaches).	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
3. Quality guidelines. Guidelines are defined on how to implement elements of quality assurance related to the statistical production process, comprising: • A description of the different phases of the statistical production process and links to relevant reference documentation for each phase, following the Generic Statistical Business Process Model (GSBPM) or any other equivalent process representation; • A description of the methods to assure the quality of each phase of the statistical production process.	*Highly relevant*	Specific guidelines regarding the use of MNO data in official statistics are needed.	The method in the QAF could be consolidated by specifying that ad-hoc quality guidelines for statistics based on MNO data (or, more generally, new data sources) shall be developed due to these peculiarities of the data. For example, *3. Quality guidelines. Guidelines are defined on how to implement elements of quality assurance related to the statistical production process, comprising:* • *A description of the different phases of the statistical production process and links to relevant reference documentation for each phase, following the Generic Statistical Business Process Model (GSBPM) or any other equivalent process representation;*

INSTITUTIONAL METHODS (INDICATOR 4.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
			• *A description of the methods to assure the quality of each phase of the statistical production process.* ***Due to the peculiarities of new data sources (e.g. MNO data), dedicated guidelines should be developed and include the aforementioned elements.*** The following chapters of this document can be considered a first nucleus of such quality guidelines, coherent with the proposed methodological framework defined in Task 2. Actually, Chapter 5 describes the business process model associated to the RMP and Chapter 6, Chapter 7 and Chapter 8 describe the methods to assure the quality of each phase of the statistical production process. In addition, the software developed in Task 4 will implement the quality controls identified.
4. Availability of quality guidelines. Quality guidelines are used and publicly available at least in a summary version.	*Relevant*	The method should be also applied to specific guidelines regarding the use of MNO data in official statistics, once available.	
5. An infrastructure for documentation. An infrastructure and resources are in place in order to maintain updated documentation on quality**.**	*Relevant*	The existing infrastructure for quality documentation could require updates/adaptations for processes using MNO data, e.g. to manage the documentation related to the quality of pre-processing made by MNO.	It should be considered that the open and reproducible RMP is also documented by the open-source software reference implementation. MNO data (such as, probably, other privately held data) are very granular, have high volumes and require complex methodologies to be processed. Thus,

INSTITUTIONAL METHODS (INDICATOR 4.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
			data processing needs to be automated as much as possible. This implies that methodologies are implemented in software and documented in formal languages 'as source-code'. This can be quite different from the current approach to quality documentation, but probably more and more frequent with the use of new data sources in official statistics. Therefore, a specific method can be integrated in the QAF for this issue.
6. Quality culture. A quality culture is spread in the organisation by means of regular training programmes supporting the implementation of the quality policy, training on the job, regular training courses, workshops and other initiatives.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also valid for processes based on MNO data.	
7. Risk management. Risk management is implemented in the organisation and is applied at different levels, for example: • Strategic level, i.e. the risks of not following the strategic values and goals; • European statistics Code of Practice level, i.e. the risks of not being compliant with the European statistics Code of Practice level as a whole or for specific principles; • Process, output and project level.	*Relevant*	MNO data pose specific risks that have to be addressed differently from other data sources, e.g. the risk of interruption of the flow of input data, due to lack of agreements or technical problems. These risks should be addressed at a strategic level other than an operational one.	*The method in the QAF could be integrated specifying that for statistics based on MNO data (or, more generally, new data sources) tailored risk management procedures shall be developed due to these peculiarities of the data. Some of the main risks to be faced are listed in QAF method 9 of Indicator 3.1. We propose the following formulation:* *7. Risk management. Risk management is implemented in the organisation and is applied at different levels, for example:* *• Strategic level, i.e. the risks of not following the strategic values and goals;* *• European statistics Code of Practice level, i.e. the risks of not being compliant with the European statistics*

INSTITUTIONAL METHODS (INDICATOR 4.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
			Code of Practice level as a whole or for specific principles; • *Process, output and project level.* ***New data sources pose specific risks, such as technical problems, interruption of data flows and so on. These risks may have a crucial impact on the process and should be addressed at a strategic level, rather than at the operational one. Risk management procedures tailored to the characteristics of these sources should be developed.***
8. Risk and quality management. Risk and quality management are closely coordinated.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also valid for processes based on MNO data.	
9. Availability of the European Statistics Code of Practice. The European statistics Code of Practice is prominently displayed on websites.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
10. References to the European Statistics Code of Practice. Where appropriate, the European Statistics Code of Practice is referred to in press releases that relate to disseminated statistics.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

Indicator 4.2: Procedures are in place to plan, monitor and improve the quality of the statistical processes, including the integration of data from multiple data sources.

Relevant for MNO data, particularly regarding the actions related to integration of multiple data sources.

INSTITUTIONAL METHODS (INDICATOR 4.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Methodological and technical support and general tools. Methodological and technical support and general tools are provided by specialised/dedicated units for implementing process quality monitoring, quality assurance and improvement plans.	*General method which also encompasses the use of MNO data in official statistics*	Specialised/dedicated units for methodological and technical support on the use of MNO for official statistics could also be foreseen. This is already covered by the present method.	As already mentioned, due to the peculiarities of MNO data (high granularity, high volume and complex methodologies to be processed), data processing needs to be automated, i.e. implemented in software and then 'brought into' data holders' premises. The software includes quality controls and, in this sense, can be considered a quality monitoring tool itself, automated, as far as possible, and integrated in the production system.
2. A culture of continuous improvement. A culture of continuous improvement is promoted and implemented, including: • Raising the awareness of staff about the importance and need to continuously improve the quality of statistical processes through training, seminars, communication etc.; • Systematic review and documentation of methodology and processes leading to improvement actions; • Systematic identification and exchange of good statistical practices; • Systematic monitoring, assessment and improvement of the quality of statistical processes, including the integration of data from multiple data sources.	*Relevant*	The culture of continuous quality improvement is highly relevant, from different perspectives, in the context of the introduction of MNO data for official statistics. First, processes that start using MNO data as input should be systematically subject to review and identification of improvement actions, even more than other processes since they are still in their infancy. Second, it is important to foster a culture that rewards attention to quality improvements from which official statistics can benefit thanks to their use. This could be achieved from appropriate training courses, seminars and events to raise awareness on the potential of MNO data. Third, MNO data itself evolves over the time and can offer higher quality information that statistical authorities should be ready to acquire and manage.	

INSTITUTIONAL METHODS (INDICATOR 4.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
3. Evaluating process quality. Processes such as quality audits, quality reviews or quality assessments are in place to evaluate the quality of the different phases of the statistical production process in accordance with the quality assurance and improvement plan.	*Relevant*	Quality evaluation could be especially important when a process starts to adopt MNO data sources. A focus on critical issues, with the identification of the phases in which they occurred, is useful in this regard. The evaluation can be more difficult since part of the process is out of the control of the Statistical Authority. Quality evaluation procedures like audits and quality reviews already in place in the statistical authority may need to be adapted.	The information derived from quality metrics and quality warnings implemented in the methods of the pipeline developed in the deliverables from Task 2 can be a valuable input for a quality evaluation procedure.

PROCESS/OUTPUT METHODS (INDICATOR 4.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. A quality assurance and improvement plan. A quality assurance and improvement plan or any other similar scheme is in place. It describes the working standards, formal obligations (such as laws and internal rules) and the set of quality control and improvement actions to prevent and monitor errors, to evaluate quality indicators, and to control as well as to improve quality at each phase of the statistical production process, including the integration of data from multiple data sources. The quality assurance and improvement plan is based on the quality guidelines or both documents are mutually consistent (depending on national circumstances). The quality assurance and improvement plan or any other similar scheme: • Takes user needs into account and checks the relevance of the statistical process; • Ensures effective technical and organisational design of the statistical production process; • Assures the quality of data collection, including the use of administrative data and other data sources; • Assures the quality of the integration of data from multiple data sources; • Assures the quality of data processing (coding, editing, imputation and estimation); • Ensures the systematic examination of possible trade-offs within quality; • Ensures that the information described above is accessible, for example in the quality reports, and comprehensible to users; • Ensures that reactions/feedback from users are regularly collected, assessed and acted upon where necessary; • Ensures the provision of suitable metadata to users to aid their understanding of quality; • Comprises any further quality assurance and improvement actions for different phases of the statistical process.	*Highly relevant*	All the elements described in the QAF method are applicable to statistical processes based on MNO data. Some changes or integrations may be needed, e.g. for the quality of data processing, assessment actions to evaluate the relevance of specific algorithms and software that is needed to process MNO data.	Chapters 6 to 8 in this document represent a quality assurance and improvement plan for the RMP.

PROCESS/OUTPUT METHODS (INDICATOR 4.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
5. Improve process quality. The results of quality evaluations are used at process level to improve processes and output quality. Monitoring the implementation of the improvement actions is regularly performed. Senior management is informed of the progress in order to decide on further actions.	*General method which also encompasses the use of MNO data in official statistics*	This method involves MNO data-based processes as well as other processes.	As statistical methodologies for MNO data need to be automated and implemented into software, 'software quality' should also be considered, i.e. How software can be designed collaboratively? How the software can be maintained? How the software would be reviewed and improved?, etc.

Recommendation:

For taking into account the peculiarity of MNO data where part of the processing is carried out by MNOs themselves, it is recommended to add a specific method, such as for example:

- ⇨ *Monitoring processes carried out by data holders. Procedures are in place to monitor the data processing carried out by data holders before delivering them to statistical authorities. For example, detailed documentation and agreed quality indicators are provided together with the data*

Such a method could apply also to administrative data provisions.

***Recommendation*:**

Having considered the specificities of monitoring the quality in an automated process, an additional method could be added to recommend the integration of quality monitoring modules in the software that implements the methodology, and a second additional one to introduce the issue of the management of software quality management and improvement. Chapter 9 will focus on recommendations for the maintenance of the software of the RMP.

Indicator 4.3: Output quality is regularly monitored, assessed with regard to possible trade-offs, and reported according to the quality criteria for European Statistics.

Output quality assessment for statistics based on MNO data is fundamental to understand whether these statistics comply with the quality requirements for official statistics. Nevertheless, these aspects are challenging, and in particular with regard to accuracy assessment. In any case, the indicator formulation is general and can cover the use of MNO data for official statistics, as well.

INSTITUTIONAL METHODS (INDICATOR 4.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Monitoring output quality. Procedures based on quality reporting are in place to internally monitor output quality. Results are analysed regularly and assessed with regard to possible trade-offs. Senior management is informed in order to decide on improvement actions.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data. However, statistical outputs from MNO data can be produced with a frequency that is unusual for statistical output and monitoring activities should rely on some sort of automatic quality warnings that are not used for other statistical products.	
2. Assessing output quality. Procedures are in place to assess output quality against the quality criteria for European Statistics. The assessment is aimed at quality improvement.	*Relevant*	Procedures to assess MNO data could be different from procedures to assess statistics based on survey data or administrative data, especially for accuracy and coherence quality criteria that are strictly related to source data and data processing quality.	The method could be consolidated by highlighting that assessing procedures can be different for statistics based on different data sources, which imply different concepts and methods. For example, *2. Assessing output quality. Procedures are in place to assess output quality against the quality criteria for European Statistics. The assessment is aimed at quality improvement.* ***Procedures that are required to assess statistics based on new data sources can be different from procedures used for survey data or administrative data and thus they should be developed accordingly.***
3. User satisfaction surveys. User satisfaction surveys or other methods monitoring user needs are implemented on a regular basis. Their main results are publicly available and incorporated, where useful, in quality reports.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data. However, as MNO data will enable the measurement of new phenomena that were not covered by 'traditional' statistics, continuous feedback from users will be particularly important to refine the	

INSTITUTIONAL METHODS (INDICATOR 4.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
		indicators that are computed and, progressively, converge towards those products that deliver the highest value for the end users.	

PROCESS/OUTPUT METHODS (INDICATOR 4.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. User-oriented quality reports. User-oriented quality reports are produced regularly and publicly available in accordance with the ESS standards for reference metadata and quality indicators, i.e. the Single Integrated Metadata Structure (SIMS).	*Relevant*	As already pointed out in the ESS Handbook for Metadata and Quality Reports (Eurostat, 2021)[87], relevant quality dimensions and quality indicators when using big data can be different from the traditional ones included in the SIMS structure. Nevertheless, it is fundamental to produce quality reports for these statistics. The ESSnet Big Data II has also proposed a customisation of SIMS for statistics based on MNO data. Such needs should be fulfilled by improving the current standard SIMS, while the QAF method could remain the same.	In Chapter 8 the proposal for adaptation of SIMS produced by the ESSnet Big Data II will be reviewed and integrated, whenever necessary and the related impact of SIMS customization on the EHQMR will be considered
5. Producer-oriented quality reports. Producer-oriented quality reports are produced regularly and disseminated as appropriate (periodicity to be determined, e.g. by the specific Regulation and the survey life cycle), in accordance with the ESS standards for reference metadata and quality indicators, i.e. Single Integrated Metadata Structure (SIMS). They are used for regular quality monitoring over time.	*Relevant*	See previous method.	

[87] European Statistical System (ESS) Handbook for Quality and Metadata Reports — re-edition 2021 - Products Manuals and Guidelines - Eurostat (europa.eu)

Indicator 4.4: There is a regular and thorough review of the key statistical outputs using also external experts where appropriate.

Relevant for MNO data and related processes, as quality review teams may need experts in this category of data and in IT, telecommunication and other fields.

INSTITUTIONAL METHODS (INDICATOR 4.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. A plan for implementing quality reviews. An appropriate plan for conducting regular quality reviews (through self-assessments, supported self-assessments, quality assessments, peer reviews or quality audits) is defined and implemented.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
2. Methodology for quality reviews. A methodology for quality reviews is in place and applied. It is revised according to needs.	*Relevant*	Some aspects of the quality review methodology could be consolidated or adapted to assess quality issues of MNO data usage.	
3. Organisational structure for quality reviews. An appropriate organisational structure for carrying out quality reviews is in place.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
4. Training of internal auditors. Internal quality reviewers/auditors are trained in statistical processing, quality, auditing techniques and behaviour.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
5. Reference documentation. Quality reviews use as reference documentation: • Quality policy; • Quality guidelines/quality assurance plan, or a similar scheme; • Producer-oriented quality reports and/or user-oriented quality reports; • Self-assessment questionnaires filled by producers; • Reports from reviews/assessments/audit interviews; • Questionnaires completed by respondents and/or users; • Any other user satisfaction study.	*Relevant*	The review of processes using MNO data could be consolidated or extended with the adoption of specific guidelines, e.g. adaptations of standard quality reporting templates, information on input data quality, additional questions in questionnaires.	Taking into account the impact that software can have on the quality of the statistical output based on MNO data, software documentation shall be added to the list of reference documentation in this method.

INSTITUTIONAL METHODS (INDICATOR 4.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
6. Action plans. The key findings of quality reviews are discussed with senior management and result in action plans.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
7. Feedback from users. Relevant feedback from different users provides input to action plans (making use of user satisfaction surveys or focus groups).	*Relevant*	Users' feedback on statistical products based on MNO data is particularly important. The potential of MNO data is related to the production of new information and the interest and satisfaction of users should be taken into account to improve the products.	
8. Deployment of external experts. External experts are deployed to review key statistical domains as appropriate.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
9. Benchmarking. Benchmarking on key statistical processes with other statistical authorities is carried out to identify good practices.	*Relevant*	Benchmarking for statistics based on MNO data can be also considered based on existing official statistics on the same or similar topic	

Recommendation:

The indicators of Principle 4 cover systematic process and output quality monitoring and assessment. Nonetheless, the systematic assessment of input quality is missing. An additional indicator on this issue could be proposed; this would be applicable not only to MNO data, but also to statistics based administrative data.

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PRINCIPLE 5

PRINCIPLE 5. STATISTICAL CONFIDENTIALITY AND DATA PROTECTION

The privacy of data providers, the confidentiality of the information they provide, its use only for statistical purposes and the security of data are absolutely guaranteed.

***Status**: Relevant*

***Motivation:** Strict compliance with European data confidentiality legislation should be ensured when using MNO data for statistical purposes. The adoption of common methodologies at EU level shall enable the definition of data protection measures directly at EU level. When it comes to very granular data for which statistics is a secondary use, resorting to supplementary protection measures based on Privacy-Enhancing Technologies (PET) should be encouraged, as in the Eurostat project exploring the feasibility of a Secure Private Computing solution for the privacy-preserving processing of pseudonymised MNO data.[88]More recent initiatives of Eurostat envisage the Steps Toward a Shared Infrastructure for Multi-Party Secure Private Computing in Official Statistics, for the targeted outcome of a 'Shared PET-Based Solution for the ESS'. Furthermore, the JOCONDE project is currently developing a prototype for a multi-party secure private computing system for processing confidential sets of micro-data across organisations in support of statistical innovation. Such a solution would allow the exploitation of private data provided by 'competing' data providers, as is the case with MNO data. The availability of MNO data from multiple MNOs within the same country is largely desirable to overcome the methodological and organisational issues related to one single MNO data provision (e.g. the coverage of the subscriber sub-population), as well as to avoid the risk of dependency and unequal position of the NSIs related to a single MNO. The strong business competitiveness of the MNO market, and the risks that individual and aggregated MNO data are exposed to many privacy risks, could be solved through the availability of PET technology for the exploitation of MNO data for Official Statistics purposes.*

Indicator 5.1: Statistical confidentiality is guaranteed in law.

General indicator which also encompasses the use of MNO data in official statistics.

[88] Project ESTAT.2019.0232 | Eurostat CROS (europa.eu)

INSTITUTIONAL METHODS (INDICATOR 5.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Legal provisions. Clear provisions are stated in the statistical law and/or in other relevant legislation (at European and national levels), guaranteeing statistical confidentiality and data protection.	*Highly relevant*	Any process for the production of official statistics based on MNO data should fulfill the statistical confidentiality and data protection requirements stated by law.	The specifications, including the prototype of a multi-party secure private computing system for processing confidential sets of micro-data across organisations in support of statistical innovation, developed in the JOCONDE project of Eurostat, will benefit from the analysis of critical points and legal issues of the system, including consultations with the European Data Protection Supervisor and the European Data Protection Board.

Indicator 5.2: *Staff sign legal confidentiality commitments on appointment.*

General indicator which reports a good practice not specifically related with the use of MNO data in official statistics.

Indicator 5.3: *Penalties are prescribed for any wilful breaches of statistical confidentiality.*

General indicator which also encompasses the use of MNO data in official statistics.

Indicator 5.4: *Guidelines and instructions are provided to staff on the protection of statistical confidentiality throughout the statistical processes. The confidentiality policy is made known to the public.*

Relevant indicator. It could be needed to customise guidelines and instructions on the protection of statistical confidentiality for the case of MNO data.

INSTITUTIONAL METHODS (INDICATOR 5.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Statistical confidentiality policy. A statistical confidentiality policy is publicly available. It sets out principles and commitments focused on statistical confidentiality that reinforce the trust of respondents, the general public and other stakeholders.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
2. Organisational structure on the protection of statistical confidentiality. An appropriate organisational structure is in place in the statistical authorities to ensure confidentiality and data protection. This structure aims at providing guidelines, recommending appropriate methodologies and periodically reviewing methods used for statistical confidentiality and data protection throughout the statistical processes.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
3. Guidance to staff. The statistical authorities prepare and provide staff with written instructions, guidelines and training in order to preserve and ensure statistical confidentiality and data protection throughout the statistical processes.	*Relevant*	Given the peculiarities of the process to produce statistics from MNO data, customised instructions, guidelines and specific training to identify potential risk situations, and how to handle them, may be needed.	Some general indications for the instructions are given in the description of the template of the agreement with MNO in Annex 2. *For example, (…) it should always be guaranteed that not only the confidentiality of mobile users' information, but also of the business sensitive data (is maintained).*
4. Methods for ensuring confidentiality. The ongoing research in the field of confidentiality is scrutinised on a regular basis. The methods in use are selected so as to counteract the trade-off between the risk of identification and the loss of information in an optimal way throughout the statistical processes.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data. Obviously, in our case, the trade-off is not only with the risk of identification, but also with the risk of revealing information that is business sensitive for the MNOs.	

INSTITUTIONAL METHODS (INDICATOR 5.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
5. Information to respondents regarding commitments to confidentiality. Respondents contacted during any kind of data collection are systematically informed that the statistical authorities fully commit themselves to data protection and statistical confidentiality, that the data are used for statistical purposes only and that individual data are not disclosed under any circumstances.	*Relevant*	Commitment to confidentiality should be included in the data provision agreements with MNOs.	A template for the agreement with MNOs is proposed in Annex 2.
6. Information to users regarding commitments to confidentiality. Users are informed that the statistical authorities fully commit themselves to data protection and statistical confidentiality, that the data are used for statistical purposes only, and that individual data are not disclosed under any circumstances.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

PROCESS / OUTPUT METHODS (INDICATOR 5.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
7. Statistical disclosure control methods. Provisions are in place to ensure that prior to the release of statistical information (aggregate data and microdata), statistical disclosure control methods are applied in order to secure statistical confidentiality.	*Relevant*	In our project, we differentiate between the location/sequence of the statistical disclosure control methods along the pipeline for the processing of MNO data by 'demonstrator' and 'reference' scenarios. It is thus very important to clearly establish when and who should apply these control methods.	
8. Output checking. Whenever access to microdata for research purposes takes place in a secure environment (e.g. remote access, safe centre, remote execution), all output is checked for disclosure before release. Procedures are in place to prevent the breach of statistical confidentiality.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

***Indicator 5.5**: The necessary regulatory, administrative, technical and organisational measures are in place to protect the security and integrity of statistical data and their transmission, in accordance with best practices, international standards, as well as European and national legislation.*

Relevant indicator. Also, the security and integrity of input data transmitted by MNO should be assured.

INSTITUTIONAL METHODS (INDICATOR 5.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Information security policy. An information security policy for the protection and security of confidential and sensitive data is in place throughout the statistical processes and is regularly updated. The policy covers the whole business, technical, administrative, and regulatory environment in which the statistical authorities operate. The policy is widely known and available to the staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
2. Security processes and measures. In line with the information security policy, the statistical authorities have appropriate physical and logical security measures and processes in place to check that data security is ensured throughout the statistical processes (including the storage, transmission and dissemination of the data) to prevent data breaches and violation of statistical confidentiality and integrity. These measures are selected in accordance with European and national legislation, the General Data Protection Regulation (GDPR), international standards, as well as best practices. All procedures are known and available to staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	The multiscale approach proposed in the pipeline takes into account GDPR requirements, trying to minimise the storage of confidential data in terms of amount and time. However, resorting to supplementary protection measures based on Privacy-Enhancing Technologies should be encouraged.
3. Information security audits. Regular and systematic security audits and penetration tests on the data security system of the statistical authorities are carried out. The audit evaluates every tool and safeguard that are in place to protect the security and the integrity of statistical data during their storage, transmission and dissemination.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
4. Secured storage of data. All statistical data is stored in secured environments that prevent access by unauthorised persons in accordance with confidentiality protocols, existing standards and best practices.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
5. Monitoring access to data. All access to data repositories and transmission channels is strictly monitored and recorded. Access rights are recorded and kept up-to-date to prevent unauthorised access.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
	General method which also encompasses the use of	The method reports a good practice that is also	

INSTITUTIONAL METHODS (INDICATOR 5.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
6. Treatment of identifiers. Names and addresses or other identifiers are deleted from data files as early as possible.	*MNO data in official statistics*	applicable to statistics based on MNO data.	
7. Information risk assessment. An information risk assessment procedure is set up. The security of the IT system is regularly evaluated and the relevant improvement actions are identified, implemented and followed up.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
8. Information security officer. Each statistical authority appoints an information security officer to manage the security of the organisation´s information systems. The information security officer: • Collaborates with information owners in the categorisation of systems with regard to security; • Promotes the continuous improvement of information security; • Performs risk analysis and sets up the security measures applicable to each system; • Supervises the implementation of security measures; • Promotes training, awareness and communication on security matters; • Coordinates the response to security incidents, etc.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data. In this case, a close collaboration with MNOs' security officers can be envisaged.	
9. Data protection impact assessment. In compliance with the data protection legislation, a data protection impact assessment is set up for some types of processing to assess its need and proportionality, and to help manage risks to the rights and freedoms of individuals.	*Relevant*	It is very important to carry out a data protection impact assessment in the case of MNO data use for official statistics. It could highlight that the advantage of using less aggregate data or storing them for more time can provide much more quality statistics with a very limited additional risk for data protection. It could be useful to prepare the assessment it in	

INSTITUTIONAL METHODS (INDICATOR 5.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
		collaboration with MNOs' data security departments/specialists.	

Recommendation:
*The indicator could be slightly modified as follows: 'Indicator 5.5: The necessary regulatory, administrative, technical and organisational measures are in place to protect the security and integrity of **input data**, statistical data and their transmission, in accordance with best practices, international standards, as well as European and national legislation.'*

***Indicator 5.6**: Strict protocols apply to external users accessing statistical microdata for research purposes.*

General indicator which also encompasses the use of MNO data in official statistics.

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PRINCIPLE 6

PRINCIPLE 6. IMPARTIALITY AND OBJECTIVITY

Statistical authorities develop, produce and disseminate European Statistics respecting scientific independence and in an objective, professional and transparent manner in which all users are treated equitably.

***Status**: General principle which also encompasses the use of MNO data in official statistics.*

***Motivation:** Impartiality and objectivity are characteristics that apply to all statistics produced within the European Statistical System, including products derived from MNO data, but this principle does not need specific requirements for this kind of processes. Similarly to the principle of professional independence, the adoption of an open reference pipeline, implementing a methodology developed by the ESS on strictly professional considerations and highly transparent, could contribute to the impartiality and objectivity of the produced outputs.*

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PRINCIPLE 7

PRINCIPLE 7. SOUND METHODOLOGY

Sound Methodology underpins quality statistics. This requires adequate tools, procedures and expertise.

***Status**: Relevant*

***Motivation:** Although the principle of sound methodology is valid for all kinds of statistical processes, it can be especially relevant for processes using MNO data. Given the fact that raw data are generated outside of the statistical authority control and that initial data processing is carried out outside the control of the NSI, greater attention to the applied methodologies is required, especially since such aspects may be new or outside the traditional expertise of the staff of the NSIs and new tools and procedures can be needed.*

Indicator 7.1: The overall methodological framework used for European Statistics follows European and other international standards, guidelines, and good practices, while constantly striving for innovation.

Relevant indicator. The use of MNO data in statistics represents one of the most relevant innovations of recent years. At the same time, the adoption of a common open RMP defined at the ESS level is aimed at standardising their use (i.e. streamlining the definition of a standard European methodological framework to promote and facilitate their use) and, consequently, accompanying them in crossing the ford from innovation to official statistics.

INSTITUTIONAL METHODS (INDICATOR 7.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. A summary methodological document. The methodological framework and the procedures for implementing statistical processes are integrated into a summary methodological document and periodically reviewed. The methodological document explains and details how European and other international standards are applied**.**	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
2. Availability of methodological guidelines, handbooks. Methodological guidelines are made publicly available if appropriate.	*Highly relevant*	Specific methodological guidelines regarding the use of MNO data in official statistics are needed.	The method in the QAF could be integrated by specifying that ad-hoc guidelines for statistics based on MNO data (or more generally new data sources) may need to be developed due to their peculiarities. For example, *2. Availability of methodological guidelines, handbooks. Methodological guidelines are made publicly available if appropriate.* ***Guidelines dedicated to the use of new data sources (e.g. MNO data) in official statistics should be developed due to their peculiarities.*** Deliverable D2 of the Multi-MNO project together with the outputs of the ESSnet MNO-MINDS can be considered a first nucleus of such guidelines.
3. Explanation of divergence from international recommendations. Divergence from existing European and international methodological recommendations are documented (explained and justified).	*General method which also encompasses the use of MNO data in official statistics*	At the moment, we are still defining the methodological recommendations for the MNO data statistical processing. However, the method should be taken into account for the future.	It is expected that the methodological guidelines developed by this project and the ESSnet MNO-MINDS will become in the future a set of methodological recommendations of reference for future developments.

INSTITUTIONAL METHODS (INDICATOR 7.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Striving for innovation. Statistical authorities actively encourage the exploration of new and innovative methods for statistics. They develop methodological work and supporting IT solutions to ensure the quality of statistics, especially when new and alternative data collection modes and sources are used as input.	*Relevant*	The exploration of new and innovative methods should continue to be fostered, for the sustained improvement of the quality of statistics produced.	The Multi-MNO project as well as the ESSnet MNO-MINDS are practical implementations of the method.
5. Innovative methods for collecting and processing data. Statistical authorities take initiatives and participate in the development of innovative methods for collecting and processing data including the integration of new and/or alternative data sources and geospatial data.	*Relevant*	See previous method.	
6. Statistical Services. The statistical authorities promote the adoption of statistical services under a common statistical reference architecture.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 7.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
7. Adoption of innovative methods. The impact on quality through the adoption of innovative methods is assessed in advance.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

***Indicator 7.2**: Procedures are in place to ensure that standard concepts, definitions, classifications and other types of standards are consistently applied throughout the statistical authority.*

Relevant indicator. One of the main challenges in the use of MNO data is to transform them to produce results that can be proxies of official statistics standard concepts, definitions and classifications. The distance from the results achievable with MNO data and standard concepts is considered one of the main limits for their use in current production; however, their informative potentialities should be considered to balance such a limit.

INSTITUTIONAL METHODS (INDICATOR 7.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Concepts, definitions, classifications and other types of standards. Concepts, definitions, classifications and other types of standards defined by the statistical authorities are applied consistently in accordance with European and/or national legislation and are documented.	*Relevant*	Concepts, definitions and classifications of MNO data are in general terms far from standard statistical ones. Methods applied to MNO data try to reduce this distance by introducing proxy concepts.	The deliverables from Task 2 introduce the main concepts and definitions. Some use cases proposed in these deliverables aim to derive results related to concepts that are proxies of statistical ones.
2. A methodological organisational structure. An organisational structure (e.g. a unit, net, committee) responsible for methodology is in place. Its tasks could include the design of statistical methods, the monitoring of their implementation, the validation of the results, and making available standard tools for the phases of the Generic Statistical Business Process Model (GSBPM).	*Relevant*	When part of the data processing is out of the control of the statistical authority, as it is the case for MNO data, such structure should also define methods to monitor the part of activities carried out by the data holder.	The indicator could be consolidated mentioning that, in the eventuality of data processing activities carried out by data providers themselves, these should also be monitored. A possible re-formulation is the following: *2. A methodological organisational structure. An organisational structure (e.g. a unit, net, committee) responsible for methodology is in place. Its tasks could include the design of statistical methods, the monitoring of their implementation, the validation of the results, and making available standard tools for the phases of the Generic Statistical Business Process Model (GSBPM).* ***In the case of data sources that are held and processed outside the control of the statistical authority, such structure should also identify the methods for monitoring the activities carried out by the data provider.*** The quality checks and warnings included in the pipeline, in the deliverables from Task 2, are also aimed to monitor the pipeline's correct implementation.

PROCESS/OUTPUT METHODS (INDICATOR 7.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
3. Views of experts and users. Statistical processes take into account the views of experts and users where appropriate.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	In the definition of the methodological and quality framework for statistics based on MNO data, the consultation of experts such as the project's Advisory Board is highly relevant to improve the deliverables produced.
4. Methodological documentation. Methodological documentation is elaborated for each statistical process and includes all pertinent information on concepts, methods, classifications and other types of standards, and is publicly available at least in a summary form following the ESS standard, i.e. Single Integrated Metadata Structure (SIMS).	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	The methods' description in the deliverables from Task 2 and their software implementation in Task 4 represent useful documentation of the pipeline. In addition, in Chapter 8 the proposal for the adaptation of SIMS produced by the ESSnet Big Data II will be reviewed and consolidated, whenever necessary.

Indicator 7.3: *The registers and frames used for European Statistics are regularly evaluated and adjusted if necessary in order to ensure high quality.*

Not relevant, it focuses on frames and registers.

Indicator 7.4: *Detailed concordance exists between national classifications systems and the corresponding European systems.*

Not relevant, it focuses on correspondence between national and European classifications

Indicator 7.5: *Graduates in the relevant academic disciplines are recruited.*

Recruitment of graduates in the relevant academic disciplines useful for treating MNO data should be considered. The indicator and the related QAF methods are general and already cover the use of MNO data in official statistics.

Indicator 7.6: *Statistical authorities implement a policy of continuous vocational training for their staff.*

Training programme should include disciplines useful for treating MNO data. The indicator and the related QAF methods are general and already cover the use of MNO data in official statistics.

Indicator 7.7*: Statistical authorities maintain and develop cooperation with the scientific community to improve methodology, the effectiveness of the methods implemented and to promote better tools when feasible.*

Relevant indicator. Considering the situation of MNO data use in statistical production, statistical authorities should maintain and develop cooperation not only with the scientific community, but also with private sector companies (MNOs and other companies with relevant experience in analysing MNO data).

Recommendation*:*

The indicator can be slightly modified. For example: 'Statistical authorities maintain and develop cooperation with the scientific community, including private sector relevant companies, to improve methodology, the effectiveness of the methods implemented and to promote better tools when feasible.'

INSTITUTIONAL METHODS (INDICATOR 7.7)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Collaboration with the scientific community. Collaboration is in place, for example through conferences, workshops, task forces, and training courses, with the scientific community to discuss methodological, IT and innovation developments.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	Under the framework of the Multi-MNO project, for example through the project's Advisory Board, there is an active dialogue and discussion on methodological, IT and innovation developments.
2. Comparative methodological studies. Comparative methodological studies are carried out with the scientific community to identify good practices.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
3. Collaboration with colleagues at international level. Staff collaborate on methodological issues with colleagues at international level.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	The Multi-MNO project and the ESSnet MNO-MINDS represent an implementation of the method (i.e. these are methodological research and/or service contracts involving several NSIs).
4. Participation and presentations at conferences. Regular participation and presentations at relevant national and international conferences (i.e. with attendance of academics/scientists and other professional experts) are encouraged for exchange of knowledge and experiences.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable also to statistics based on MNO data.	Under the framework of the Multi-MNO project, progresses and results have been presented at relevant conferences, such as NetMob 2023, Q2024 and CESS2024.
5. Organisation of conferences. National and international conferences, seminars, workshops, or similar events with the participation of the scientific community and other professional experts are organised by the statistical authorities. Participation of the statistical authorities is encouraged.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

PROCESS/OUTPUT METHOD (INDICATOR 7.7)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
6. External evaluation of methodology. Evaluations/assessments/audits of the methodologies used are requested from external experts (such as the scientific community) as appropriate.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	In the context of the Multi-MNO project, the project's Advisory Board members are requested to provide an evaluation of the methodologies proposed. In this way, the final results benefit from this early review.

Recommendation:

An additional method could be proposed on the cooperation with private sector companies with relevant experience in the treatment of particular type of data, e.g. MNO data.

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PRINCIPLE 8

PRINCIPLE 8. APPROPRIATE STATISTICAL PROCEDURES

Appropriate statistical procedures implemented throughout the statistical processes, underpin quality statistics.

***Status**: Relevant*

***Motivation:** As for the principle on sound methodology, the use of appropriate procedures can be relevant for processes shared with or carried out by MNOs. Obviously, for the procedures applied by the NSIs, this principle applies as usual, but it should also provide NSIs with the instruments to monitor and assess the quality of the processes carried out by MNOs*

Indicator 8.1: When European Statistics are based on administrative and other data, the definitions and concepts used for non-statistical purposes are a good approximation to those required for statistical purposes.

Relevant indicator. MNO data definitions and concepts are usually quite far from those required for statistical purposes. Transformations, statistical models and integration with not-MNO data are applied to achieve outputs that are statistical definitions and concepts good proxies. The high informative potentialities of MNO data make them worthy of this effort to use them in official statistics production

***Recommendation**: An integration of the indicator could be proposed to take it into consideration the issue described. For example: 'When European Statistics are based on administrative and other data, the definitions and concepts used for non-statistical purposes are a good approximation to those required for statistical purposes **or data can be properly processed to obtain the required approximation**'.*

INSTITUTIONAL METHODS (INDICATOR 8.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Responsibility for statistical processing of administrative and other data. The statistical authorities are responsible for the statistical processing of administrative and other data used for the development, production and dissemination of European Statistics.	*Relevant*	Even for MNO data, the responsibility for the production of statistical outputs remains with statistical authorities. However, it could be mentioned that part of the data processing could be off-premise and in such case it should be done according to the statistical authority's indications.	Extend the indicator clarifying that the statistical authority is still responsible, even if part of the data processing is carried out by the MNO (or another third party). For example: 1. *Responsibility for statistical processing of administrative and other data. The statistical authorities are responsible for the statistical processing of administrative and other data used for the development, production and dissemination of European Statistics.* ***In the case of privately held data sources, the statistical authority shall monitor and verify that the data processing conducted by the data holder (or another third party) meets all the quality requirements and indications provided by the authority itself.***
2. Distinction between statistical data, administrative data and other data processing. The processing of administrative or other data is clearly distinguished from statistical processing. The processing includes appropriate validation rules and specific procedures for controlling and assuring the quality of the data.	*Relevant*	The method makes already reference to 'other data', and includes, therefore, MNO data. Considering the peculiarities of such data it is deemed appropriate that input data validation is distinguished from statistical processing.	The distinction between lower and upper throughput that was introduced by the ESSnet Big data II and that we use in the present deliverable (see for further details Chapter 7) is coherent with the distinction between the processing of administrative or other data, and statistical processing.
3. Approximations of definitions and concepts. The definitions and concepts of administrative or other data are a good approximation to those required for statistical purposes. Administrative or other data holders are formally consulted about this issue.	*Relevant*	Formal consultation of MNOs should be always fostered. The pre-processed data they provide to statistical authorities should be accompanied by concepts and definitions used.	The involvement of MNOs in the adoption of a common open RMP defined at the ESS level implies they are consulted on several aspects including concepts and definitions. The requirement for formal consultation is included as a good practice proposed in Chapter 5.

PROCESS/OUTPUT METHODS (INDICATOR 8.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Processing of administrative or other data for statistical purposes. When administrative or other data are used for statistical purposes, data are processed specifically for their statistical use. This might imply deriving new variables, applying different validation and imputation rules, creating new data files, integrating data sources, calculating weights and new aggregates as well as specific quality checks.	*Relevant*	The method makes already reference to 'other data', including therefore MNO data.	The pipeline proposed in the deliverables from Task 2 includes all the steps recommended in the method.
5. Documentation of statistical, administrative and other data production processes. Appropriate documentation is in place describing the production processes for all types of data sources (statistical, administrative or other), taking into account their differences in terms of definitions, concepts, coverage, etc.	*Relevant*	The method makes already reference to 'other data', including therefore MNO data.	The description of the methods in the deliverables from Task 2, as well as the quality framework described in the present deliverable, along with the codes developed in Task 4 represent a comprehensive documentation of the MNO data and of the proposed production process.
6. Differences in concepts. Differences in concepts between statistical and other types of data (administrative and other data) used for statistical purposes are thoroughly studied, described and documented.	*Relevant*	The method makes already reference to 'other data', including therefore MNO data.	The differences between statistical concepts and MNO data concepts should be analysed and documented, as well as the transformations applied to MNO data to achieve proxies of statistical concepts. The deliverables from Task 2 define the concepts and definitions adopted in the project. The differences between MNO data and statistical data concepts and definitions are analysed in Chapter 6.
7. Measures to deal with differences in concepts. Measures are taken to deal with the differences in concepts between statistical and other types of	*Relevant*	The method makes already reference to 'other data', including therefore MNO data. The method refers to the	

PROCESS/OUTPUT METHODS (INDICATOR 8.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
data (administrative and other data) and described in quality reports as appropriate.		integration that we propose for the indicator.	

***Indicator 8.2**: In the case of statistical surveys, questionnaires are systematically tested prior to the data collection.*

Not relevant, it focuses on survey questionnaires.

***Indicator 8.3:** Statistical processes are routinely monitored and revised as required.*

Relevant indicator. Statistical processes based on MNO data should be routinely monitored and revised as the others but the methods to monitor and revise them could be different due to the fact that part of the process is out on statistical authority control and also considering their frequency. Given the peculiarities of MNO data, their processing as well as the monitoring should be automatised, i.e. implemented in software. Software quality should also be subject to monitoring and improvement.

INSTITUTIONAL METHODS (INDICATOR 8.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Organisational structure for guidelines, methodologies and examination of methods. An appropriate organisational structure is in place to provide guidelines, recommend appropriate methodologies, and periodically examine and revise as required the methods used for statistical processing.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
2. Reporting on methods to the public. The statistical authorities regularly report on the methods used in statistical processing. These reports are publicly available.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
3. Promotion and sharing of standards and best practices. Statistical standards and best practices of statistical processing are promoted and shared in order to improve the quality of statistics and to encourage the harmonisation of processes (e.g. within the National Statistical Institute, the National Statistical System or European Statistical System, etc.).	*Relevant*	Since the methodology for producing official statistics based on MNO data is still under development, it is very important to exchange on good practices and improve harmonisation. NSIs can also benefit from experiences shared by other institutions.	The method could be extended, underlining that the promotion and sharing of standards and best practices is particularly important when a new good practice or standard is developed for new data sources. For example: *3. Promotion and sharing of standards and best practices. Statistical standards and best practices of statistical processing are promoted and shared in order to improve the quality of statistics and to encourage the harmonisation of processes (e.g. within the National Statistical Institute, the National Statistical System or European Statistical System, etc.).* ***The promotion and sharing of standards and best practices is particularly important for new data sources.*** The aim of the Multi-MNO project is to produce a standard methodological process integrated with a quality framework that can be shared in the ESS to improve the quality of statistics based on MNO data.

INSTITUTIONAL METHODS (INDICATOR 8.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Metadata-driven. Statistical authorities promote the adoption of a metadata-driven development of processes.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 8.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
5. Design of statistical processes. The design of statistical processes based on data from surveys, administrative, multiple or other source is in compliance with good practices and standards.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
6. Renewal of sample designs. Sample designs are periodically renewed for recurrent surveys according to precision requirements.	*Not relevant*	The method refers to sample surveys.	
7. Procedures for designing, testing and updating questionnaires. Procedures for designing, testing and updating questionnaires are in place and in accordance with good practice and standards.	*Not relevant*	The method refers to survey questionnaires.	
8. Measurement of non-sampling errors. Non-sampling errors (coverage, measurement, processing, non-response errors as well as selection bias for administrative and other data sources and model assumption errors) are routinely monitored and the results used for process improvement.	*Relevant*	The error profile (type and relevance of non-sampling errors) in statistics based on MNO data can differ from those of surveys or statistics based on administrative data. It is important to identify the main error type in order to define corresponding measures and be able to monitor them.	The main sources of non-sampling errors in statistics based on MNO data will be identified and described in Chapters 6 to 8, together with proposed methods to identify them and to mitigate their effects, even if very often the mitigation activities will not be included in the RMP, but are expected to be developed in the ESSnet MNO-MINDS.
9. Assessment of sampling and estimation methods. Sampling errors are routinely measured to assess sampling and estimation methods.	*Not relevant*	The method refers to sample surveys.	
10. Assessment of data collection methods. Data collection methods and data collection designs are assessed regularly.	*Not relevant*	The method refers to data collection techniques.	
11. Provision of documents to respondents. Respondents are provided with all the necessary documents (i.e. letters,	*Not relevant*	The method refers to survey respondents.	

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
questionnaires, leaflets, especially in the case of self-administrated questionnaires and feedback if possible). These documents are reviewed regularly.			
12. Support to respondents. Respondents are supported in filling-in the questionnaires. Procedures are in place to answer respondents' requests and complaints and are easy to access.	*Not relevant*	The method refers to survey respondents.	
13. Training of interviewers. Training courses and workshops (including interviewing techniques) are provided for interviewers. For each survey, an interviewer manual/handbook exists and the accompanying interviewer procedures are implemented.	*Not relevant*	The method refers to interviewer training in surveys.	
14. A procedure to monitor data collection. Data collection is regularly monitored and optimised. This includes, among other elements, monitoring the mode of data collections, survey length, response rate, interviewer performance and administrative or other data transmissions.	*Not relevant*	The method refers to survey data collection.	
15. Procedures to follow-up non-response. Procedures are in place to follow-up non-response in order to improve response rates and manage non-response bias.	*Not relevant*	The method refers to survey data collection.	
16. Documentation and sharing of data coding methods. The data coding methods are documented and stored. These methods are shared with the relevant staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
17. Compliance of editing, imputation, and statistical disclosure control techniques with standards. Editing, imputation and statistical disclosure control techniques follow	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 8.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
methodological rules and good practices and are documented.			
18. Data integration. Procedures for data integration in the case of multisource statistics are in compliance with good practice and standards.	*Relevant*	Data integration is of high importance for the use of MNO data in official statistics. Integration with non-MNO data makes them usable and improves their quality.	Good practices and standards for data integration methods involving MNO data are expected as an output of the research project ESSnet MNO-MINDS.
19. Use of statistical models. When using statistical modelling, for example seasonal adjustment, the extent to which the assumptions are valid is assessed, as well as the impact on estimates.	*Relevant*	In the processing of MNO data, new methods are proposed which imply assumptions whose validity should be assessed.	Possible ways to assess the validity of assumptions will be proposed in Chapter 7.
20. Automated methods. Automated methods are promoted, monitored and revised if necessary.	*Relevant*	Due to the large volume of MNO data, their longitudinal character and the fact that some statistics may be produced on a daily basis, automated quality warnings and checks are particularly relevant for statistics based on MNO data.	The RMP mostly includes automated methods.
21. Process quality indicators. Process quality indicators are routinely calculated and monitored. Processes are revised accordingly.	*Relevant*	Due to the peculiarities of MNO data, specific quality indicators should be defined to monitor the processes and, part of them, should be requested to be calculated by MNOs themselves and provided to the statistical authorities.	In the deliverables from Task 2, several quality indicators (or metrics) are proposed to monitor the pipeline. Other measures will be defined in Chapters 6 to 8.
22. Process descriptions. Process descriptions are in place to document processes in accordance with Generic Statistical Business Process Model (GSBPM) or other relevant models in order to ensure the replicability of the process, the traceability of the data and the identification of improvement actions.	*Relevant*	Process documentation is even more necessary for MNO data since part of the process is out of the control of the statistical authority.	The business process for producing statistics based on MNO data are described in Chapter 5.

PROCESS/OUTPUT METHODS (INDICATOR 8.3)			
QAF METHOD	**RELEVANCE**	**COMMENT**	**RECOMMENDATION/REFERENCE**

Recommendation:
It is suggested to add two methods:

- *For the specific case in which part of the processing is not performed by the statistical authority, a method could be added to state that statistical authorities should provide the (private) data holder with the methodology to be applied on the data with clear indications on how to monitor the process (e.g. suggesting appropriate quality indicators and how to interpret them). This should be in the form of software code in the RMP*
- *While there are several methods related to monitoring data collection in the case of surveys, no methods are proposed for the assessment of the quality of input data. A method could be added to promote the systematic evaluation of input data (administrative and other data) through quality indicators.*

Indicator 8.4: Metadata related to statistical processes are managed throughout the statistical processes and disseminated, as appropriate.

Relevant indicator. Additional infrastructures to manage metadata related to MNO data could be necessary.

INSTITUTIONAL METHODS (INDICATOR 8.4)

QAF METHOD	REFERENCE	COMMENT	RECOMMENDATION/REFERENCE
1. Management of metadata. An organisational structure is in place to ensure that metadata is an integral part of all statistical processes. The management of metadata is effective at all phases of the process. The metadata include reference metadata (e.g. the Single Integrated Metadata Structure), structural metadata (concepts, classifications, structure of data etc.) and process metadata.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
2. Procedures to disseminate metadata. Clear, complete and up-to-date metadata are disseminated in accordance with ESS standards, i.e. the Single Integrated Metadata Structure (SIMS).	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	
3. Training courses for staff on metadata standards and quality reports. Training courses on the use of the metadata standards and quality reports are provided for the relevant staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to statistics based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 8.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Metadata on statistical processes. Clear, standardised and complete metadata is compiled and updated on the statistical processes in accordance with ESS standards, i.e. the Single Integrated Metadata Structure (SIMS).	*Relevant*	Clear, standardised and complete metadata should be compiled for MNO data-based processes. As already mentioned, the SIMS standard could potentially require customisation to better document this type of statistics.	As previously mentioned, a proposal on how to customise the SIMS structure for MNO data will be provided in Chapter 8.

***Indicator 8.5**: Revisions follow standard, well-established and transparent procedures*

General indicator which also encompasses the use of MNO data in official statistics.

***Indicator 8.6:** Agreements are made with holders of administrative and other data which set out their shared commitment to the use of these data for statistical purposes.*

Highly relevant. Formal agreements can be an effective tool to promote involvement and commitment of MNOs in the production of high-quality statistics

INSTITUTIONAL METHODS (INDICATOR 8.6)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Agreements with holders of administrative and other data. Agreements between the statistical authorities and the holders of administrative and other data are in place. When administrative and other data systems are developed or reviewed, such agreements facilitate that statistical needs are taken into account.	*Highly relevant method*	Several statistical authorities have already developed agreements with MNOs in their countries; guidelines and harmonisation for such agreements would be helpful.	The main elements of the agreements are proposed in Annex 2.
2. Guidance on new data sources. Guidance on how to identify and exploit the statistical potential of new data sources is provided to staff.	*Relevant*	The staff of statistical authorities should benefit of training in the management of the use of new data sources.	Capability development activities should accompany the introduction of the use of MNO data in statistical production.
3. Capabilities. The statistical authorities have the necessary capabilities and IT infrastructure to guarantee the safe storage and use of administrative and other data.	*Highly relevant method*	To be compliant with this method, the statistical authority should have the necessary capabilities and IT infrastructure to produce MNO data-based statistics.	Some requirements in terms of capabilities are described in Chapter 5.

PROCESS/OUTPUT METHODS (INDICATOR 8.6)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Documentation of administrative and other data. The data holder systematically provides the statistical authorities with documentation/metadata about the content of the administrative and other data as well as the production process of the data (e.g. a methodological document, concepts and definitions, and populations).	*Highly relevant method*	The availability of documentation about the content of MNO data, as well as the production process of the data is a prerequisite to assure the reproducibility.	The method could be integrated asking also quality measures related to the production process. For example: *4. Documentation of administrative and other data. The data holder systematically provides the statistical authorities with documentation/metadata about the content of the administrative and other data as well as the production process of the data (e.g. a methodological document, concepts and definitions,* ***quality measures related to the production of the data****, and populations).*

***Indicator 8.7**: Statistical authorities co-operate with holders of administrative and other data in assuring data quality.*

Highly relevant indicator. The topic of cooperation with MNOs has already been mentioned in other principles and indicators, but here is focused on and aimed at quality assurance.

INSTITUTIONAL METHODS (INDICATOR 8.7)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Informing the administrative or other data holder. Procedures are in place to ensure that the holders of administrative or other data are kept informed about how their data are used for statistical purposes and that they receive feedback on the quality of the data provided in view of further improvements. Staff in the statistical authorities are aware of these procedures.	*Highly relevant method*	Bi-directional communication with MNOs aiming at continuous quality improvement should be fostered by statistical authorities.	In Chapter 7, we introduce a subsection devoted to the assessment of quality of the pre-processed data provided by the MNOs to the NSIs. The results of such assessment should be shared with MNOs.
2. Quality requirements. The statistical authorities ensure that holders of administrative and other data are aware of the quality considerations and requirements for statistical production.	*Highly relevant method*	Projects like the present one are also aimed at raising awareness among MNOs on quality requirements for official statistics production.	When starting collaboration with an MNO, it is useful to organise a workshop to introduce the MNO' staff to quality requirements for official statistics.
3. Data correction policy. When statistical authorities detect incorrect data or quality problems in administrative or other data, they inform the holders of these data about the incorrect data or problems detected without violating the statistical confidentiality rules, with a view to improve future data sets. The data correction policy is made known to staff in the statistical authorities.	*Highly relevant method*	Errors, missing data, etc. can occur relatively frequently in the data provided by MNOs. A clear data correction policy should be defined. A collaborative dialogue with MNOs should allow the communication of errors detected to improve future data.	Collaborative dialogue between MNO and NSI is treated in Chapter 5.
4. Cooperation. Statistical authorities offer training courses and tools, such as guidelines, on quality control and quality assurance to the holders of administrative and other data.	*Highly relevant method*	In order to sensitise the MNOs, it is useful to organise workshops or training sessions to introduce them to quality assurance for official statistics.	

PROCESS/OUTPUT METHOD (INDICATOR 8.7)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
5. Continuous improvement. Procedures are in place to inform data holders of the incorrect data and quality issues that have been detected, without violating the statistical confidentiality rules. Staff in the statistical authorities are aware of the procedures.	*Relevant*	This is particularly important in the case of MNO data due to their longitudinal nature: we need procedures to detect, report and (when possible) fix these issues.	Collaborative dialogue between MNO and NSI is treated in Chapter 5.

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PRINCIPLE 9

PRINCIPLE 9. NON-EXCESSIVE BURDEN ON RESPONDENTS

The response burden is proportionate to the needs of the users and is not excessive for respondents. The statistical authorities monitor the response burden and sets targets for its reduction over time.

***Status**: Indirectly connected to the use of MNO data*

***Motivation**: The principle is not directly connected with the use of MNO data since device users are not bothered by data collection, but the use of MNO data for producing Official Statistics could, in the long term, lead to a reduction of burden on respondents. This is another positive aspect to be highlighted to promote their use. At the same time, we place a big burden on MNOs, ensuring 'non-excessive burden on MNOs' could be key to gaining their collaboration and commitment to doing their part in the best possible way.*

***Recommendation**: An additional indicator could be considered for this principle, aiming at containing response burden for private data holders*

Indicator 9.1: The range and detail of European Statistics demands is limited to what is absolutely necessary.

General indicator which also encompasses the use of MNO data in official statistics

***Indicator 9.2:** The response burden is spread as widely as possible over survey populations and monitored by the statistical authority.*

Not relevant. It is connected with burden due to surveys

***Indicator 9.3:** The data sought from businesses is, as far as possible, readily available from their accounts and electronic means are used where possible to facilitate its return.*

Not relevant. It concerns data collections from businesses related to their accounts.

***Indicator 9.4:** Administrative and other data sources are used whenever possible to avoid duplicating requests for data.*

Relevant indicator. MNO data could be used to replace, partially or entirely, sources that otherwise would require burden to respondents.

INSTITUTIONAL METHODS (INDICATOR 9.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Collaboration to increase the use of administrative and other data sources. Collaborative networks develop tools and methods to increase the use of administrative and other data sources.	*Relevant*	Other data are already mentioned in the method. Naturally, collaboration is needed when the holder of the data source is not the statistical authority.	The Multi-MNO project is an implementation of the collaboration promoted by this method.
2. Consideration of alternative data sources. Alternative data sources (including the availability and suitability of existing surveys and administrative data) are considered to optimise data collection.	*Relevant*	MNO data can be one of the alternative data sources.	
3. Guidance on data sources. Guidance, for example methodological advice and training, is available to staff on how to identify and exploit the statistical potential of administrative and other data sources and to how to ensure their quality.	*Relevant*	The methodology on the production of statistics based on MNO data is still not consolidated. However, the output of the present project could be a reference to design and implement trainings on this topic that are extremely needed by staff of statistical authorities.	One general recommendation could be to organise training sessions on the standard pipeline and its methods to spread the knowledge and promote its applications.
4. IT tools for the collection of administrative and other data. IT tools for the collection of administrative and other data to be used for statistical purpose are developed and implemented.	*Relevant*	Appropriate IT tools and interfaces are needed for the acquisition and processing of MNO data.	

Indicator 9.5: *Data sharing and data integration, while adhering to confidentiality and data protection requirements, are promoted to minimise response burden.*

Relevant indicator since integrating MNO data with other sources can be a way to reduce response burden.

INSTITUTIONAL METHODS (INDICATOR 9.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Agreements and tools for data sharing. Formal agreements and tools are in place for data sharing within the National and European Statistical Systems (e.g. web services and common data bases).	*Relevant*	Relevant initiatives regarding data sharing (partnerships with privately held data mainly) are ongoing also in other systems and organisations; see for example the World Bank initiative: https://datapartnership.org/	
2. Methods and tools for data integration. Methods (e.g. multisource approaches and matching techniques) and tools for data integration are in place in the statistical authorities.	*Relevant*	The feasibility and the potential of integrating MNO data with traditional sources and the methods and tools to do this are currently under research in the ESSnet MNO-MINDS.	
3. Sharing of data archives. When useful, data archives are shared within statistical authorities and in compliance with confidentiality policies.	*Relevant*	When useful, the data received from MNOs could be shared within authorities in compliance with confidentiality policies.	
4. Promoting register-based national statistical systems. The construction of a register-based national statistical system, making use of all available data, is promoted.	*Not related to MNO data*	The method is related to statistical registers.	
5. Key variables to be shared. In accordance with confidentiality rules, the statistical authorities define the key variables that need to be shared between statistical processes.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

***Indicator 9.6**: Statistical authorities promote measures that enable the linking of data sources in order to minimise response burden.*

Relevant indicator. Linking MNO data with other sources is being studied in the ESSnet MNO-MINDS. This could also minimise response burden.

INSTITUTIONAL METHODS (INDICATOR 9.6)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Guidelines, methods and tools for linking data. Guidelines, methods and tools are available in order to support the linking of data.	*Relevant*	Specific guidelines on the integration of MNO and non-MNO data could be developed.	The development of methods to integrate MNO and not-MNO data is one of the main objectives of ESSnet MNO-MINDS.
2. Key variables to be linked. The statistical authorities define the key variables that need to be linked between statistical processes.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 9.6)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
3. Assessment of quality of the linkage. When variables coming from different data sources are linked, an assessment is made of the quality of the data linkage.	*Relevant*	Quality assessment of integration and record linkage procedures, in particular, is a practice that can be planned for MNO data sources, as it is already carried out for other sources.	

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PRINCIPLE 10

PRINCIPLE 10. COST EFFECTIVENESS

Resources are used effectively.

***Status**: Relevant*

***Motivation:** The overall cost of collecting data from MNOs has to be investigated properly and it will be clearer as these sources become more integrated into statistical production. In terms of human resources, the absorption of MNO sources entails for the ESS the need to train the staff accordingly or even expanding the organisation's workforce; the need to adapt the current IT infrastructure; the need to build dedicated platforms to collect data from MNOs in a standardised way, and so on. According to the principle, the Statistical Authorities should guarantee that such additional resources are used effectively, e.g. to improve the quality of statistical results by improving their relevance or timeliness, or producing a reduction of other costs, e.g. for direct data collections. In addition, the use of the MNO data should be optimised: for some statistical products less frequent data or less granular data can be sufficient and can save resources.*

***Indicator 10.1:** Internal and independent external measures monitor the statistical authority's use of resources.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 10.2:** The productivity potential of information and communications technology is being optimised for the statistical processes.*

Relevant for MNO data. Further optimisation may be needed to manage them within statistical authorities' premises.

INSTITUTIONAL METHODS (INDICATOR 10.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Pooling of resources, investments and the identification of innovation/modernisation potential. Centralised IT and methodological units provide for the pooling of resources and investments and the identification of innovation/modernisation potential to optimise statistical processes.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
2. IT architecture and strategy. An IT architecture and strategy are in place and regularly updated.	*Relevant*	The design of an appropriate IT architecture and planning an adequate IT strategy are both crucial steps in the adoption of MNO data. The architecture and IT strategy in place may need updates to address the needs of MNO data management. On the other hand, MNOs should be flexible in adhering to technical requirements.	
3. Promote automated techniques. Policies, procedures and tools are in place to promote automated techniques for statistical processes, based on common standards (e. g. data capture, coding, validation, reporting etc.) and sharing of common statistical services.	*Relevant*	The promotion of automated techniques is crucial for the management of MNO data.	The Multi-MNO project will produce a common standard (the pipeline) which could be adopted by the statistical authorities. The software developed in Task 4 automatise the main part of the proposed standard.

PROCESS/OUTPUT METHODS (INDICATOR 10.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Automated processing techniques. Automated processing techniques are regularly reviewed and modernised.	*Relevant*	Small modifications in the algorithms used can have a considerable impact on statistical processes and statistical output, when using MNO data as input. The algorithms should be regularly reviewed and modernised.	In Chapter 9 this issue is considered.

***Indicator 10.3**: Proactive efforts are made to improve the statistical potential of administrative and other data sources and to limit recourse to direct surveys.*

Relevant for MNO data. While the use of administrative data is usually less costly than direct surveys, this is to be verified for the use of MNO data. However, improving their statistical potential would also make them more valuable.

INSTITUTIONAL METHODS (INDICATOR 10.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Meetings with holders of administrative and other data. Periodic meetings with holders of administrative and other data are held in order to discuss how to improve and increase the use of their data.	*Relevant*	Regular meetings with the MNOs are encouraged to promote agreements between parties, to anticipate future changes in technologies and to discuss improvements in the use of MNO data.	
2. Assessment of possible administrative and other data sources. An assessment of possible administrative and other data sources is carried out prior to launching a survey, in particular a newly designed one.	*Relevant*	The definition of potential use cases based on MNO data is currently ongoing; therefore, during this stage, collaboration with process and domain experts can help the organisations to find new ways to use MNO data, especially for integrating existing surveys and reducing the burden on respondents.	

PROCESS/OUTPUT METHODS (INDICATOR 10.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
3. Investigating the statistical potential of new data sources. Mechanisms are in place to investigate the availability of new data sources to enhance already existing statistical outputs.	*Relevant*	MNO data should be taken into account when investigating the availability of new data sources for existing statistical outputs. Other related data that can be considered include e.g. GPS information from MNOs apps that, if available, could be used for quality control.	
4. Data linking and integration methods. Data linking and integration methods are pro-actively pursued subject to data confidentiality and security considerations.	*Relevant*	The integration of MNO data with other sources is the foundation on which the potential of the new data could be exploited for statistical uses; confidentiality protection measures are paramount in that regard.	The ESSnet MNO-MINDS research project is focused on data linking and integration methods that can be used to improve the quality of statistics based on MNO data.
5. Quality indicators. Quality indicators are used to improve the methods for using administrative and other data for statistical purposes.	*Relevant*	The evaluation of MNO data with regard to the input, throughput and output phases will trigger the adaptation of existing standard quality indicators and the development of new ones.	In Chapters 6 to 8 quality indicators for MNO data will be proposed.

***Indicator 10.4**: Statistical authorities promote, share and implement standardised solutions that increase effectiveness and efficiency.*

Relevant for MNO data. The Multi-MNO project represents an implementation of the indicator.

***Recommendation**: Standardised solutions should facilitate reproducibility. This is relevant for all types of statistical processes, nonetheless particularly when part of the process is not carried out by the statistical authorities. The text of the indicator could be slightly modified to include reproducibility. For example:: 'Indicator 10.4: Statistical authorities promote, share and implement standardised solutions that increase effectiveness and efficiency **and facilitate reproducibility**'.*

INSTITUTIONAL METHODS (INDICATOR 10.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Standardisation programmes and procedures for statistical processes. Standardisation programmes and procedures are defined and implemented in the main phases of the statistical processes.	*Relevant*	The standardisation of specific phases of the statistical process and, in general, the adoption of a comprehensive pipeline for the use of MNO data can facilitate the use of such data in different contexts and for many use cases.	The RMP represents a standardised solution that will cover not only the main phases of the statistical process but also the preprocessing carried out by MNOs.
2. Strategy to adopt or develop standards. A strategy is in place to adopt or develop standards in various fields such as quality management, process modelling, software development, software tools, project management and document management.	*Relevant*	The definition of a strategy to adopt and develop standards is needed in order to introduce innovation in official statistical production.	The strategy outlined in the ESS TF MNO position paper (Eurostat, 2023) includes the development of a standard methodological and quality framework, a business process model and software tools to facilitate the use of MNO data in official statistics. These represent an implementation of this QAF method.
3. Sharing standardised solutions. Statistical authorities share and re-use existing standardised solutions (tools and methods) that increase the effectiveness and efficiency of statistical processes. They participate in joint projects, working groups or training courses on the development of such tools and methods to share development burden.	*Relevant*	The development of shareable standardised solutions is, recently, one of the main objectives in the international statistical system for reducing cost while continuing to assure quality. Standardisation should also be targeted for statistics based on new data sources.	The RMP represents a standardised solution that will be shared to improve effectiveness and efficiency.

PROCESS/OUTPUT METHODS (INDICATOR 10.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Standardisation. Actions are taken, based on an implementation plan, to move gradually towards or to comply with standardisation and are described in quality reports or other documentation.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

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PRINCIPLE 11

PRINCIPLE 11. RELEVANCE

European Statistics meet the needs of users.

***Status**: Relevant principle*

***Motivation:** The use of MNO data opens new scenarios and opportunities in terms of official statistics producers' capabilities to provide new information and satisfy existing information gaps. MNO data have the potential to enhance the current statistical production both in terms of a greater level of detail and exploration of new topics that were not considered before, due to a lack of available information. Obviously, indicator 9.1 on minimising the range and detail of European statistics to what is needed should always be respected.*

***Indicator 11.1:** Procedures are in place to consult users, to monitor the relevance and value of existing statistics in meeting their needs, and to consider and anticipate their emerging needs and priorities. Innovation is pursued to continuously improve statistical output.*

Relevant indicator. Users could be specifically consulted on themes regarding the use of MNO sources, such as their potential interest in innovative statistics that can be derived from MNO data, on their views on statistics based on MNO data, etc.

INSTITUTIONAL METHODS (INDICATOR 11.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Legislation on user consultation. The statistical laws (at European and national level) include an obligation to consult users on their needs for official statistics.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
2. Aim of user consultation. Feedback from user consultations is used to provide input for the preparation of the statistical work programme, identify emerging needs and priorities, improve the quality of statistical outputs, and monitor the value of statistics.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
3. User consultation procedures. Procedures and activities for the consultation of users on their needs are in place. For example, they consist in setting up user committees, holding regular meetings between key users and statistical authorities, consulting key users or other relevant stakeholders, calling on the skills of experts on specific issues or processing individual user requests and responses.	*Relevant*	Specific user consultations could be aimed at exploring the trust of the public towards the use of MNO data for official statistics or involving experts on such data. In general terms, user consultations should be promoted when new statistics or statistics based on new data sources and methods are going to be implemented.	The method should be integrated underlining that user consultation is particularly relevant when innovation is introduced in statistical production, also to gain trust and social validation. For example: *3. User consultation procedures. Procedures and activities for the consultation of users on their needs are in place. For example, they consist in setting up user committees, holding regular meetings between key users and statistical authorities, consulting key users or other relevant stakeholders, calling on the skills of experts on specific issues or processing individual user requests and responses.* ***User consultation is particularly relevant when innovation is introduced in statistical production, also to gain public trust and social validation.***

INSTITUTIONAL METHODS (INDICATOR 11.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Analysis of the use of statistics. Data on the use of statistics (for example, evaluation of downloads, subscribers of reports, web analytics, web scraping results) are analysed (for example, by statistical domain and by type of user) to improve statistical outputs.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
5. Relevance of statistical output. Procedures are in place to review statistical output on its relevance for users, including its use as a source for other processes, and the impact of its possible termination.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
6. Innovation. Innovative statistical methods and tools are developed and used to improve the relevance and value of statistical outputs.	*Relevant*	The use of MNO data can improve the relevance of the statistical outputs if they enable the production of data on additional variables or at more detailed levels. To this aim, appropriate statistical methods have to be developed and integrated with existing ones.	The innovative methods developed in the deliverables from Task 2 and also in the ESSnet MNO-MINDS are aimed at improving the relevance and value of statistical outputs by using MNO data.

PROCESS/OUTPUT METHODS (INDICATOR 11.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
7. Key users. A list of key users covering all relevant interest groups, their use of data and their un-met needs is regularly updated.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
8. Classification and user profiling. Classification and profiles of users for a given output are regularly updated and used for consultation purposes and to improve products and services.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
9. Quality indicator(s). Quality indicator(s) on relevance are regularly monitored and published in quality reports.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	The standard pipeline and the quality framework will be complemented by proposals for quality indicators to be used to monitor all the quality dimensions. For some aspects, the existing quality indicators will be sufficient, while in other cases, additional measures will be proposed.
10. Analysis and assessment of relevance. Quality indicator(s) on relevance are regularly analysed and assessed to improve the statistical process.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

***Indicator 11.2**: Priority needs are being met and reflected in the work programme.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 11.3:** User satisfaction is monitored on a regular basis and is systematically followed up.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

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PRINCIPLE 12

PRINCIPLE 12. ACCURACY AND RELIABILITY

European Statistics accurately and reliably portray reality.

***Status**: Relevant principle with regard to Accuracy. Reliability is a general principle that also encompasses statistical outputs based on MNO data.*

***Motivation:** As one of the main criteria of output quality, accuracy plays a fundamental role in all data products, including the ones derived from MNO data. The impact of the use of such data on accuracy is a matter of investigation. Indeed, as well known, accuracy of statistical output can be affected by input data quality and the errors that occur during the processing of such data. A great challenge is represented by the definition of sound methodologies and procedures to identify and evaluate the main types of errors affecting statistics produced based on MNO data. The impact of the use of such data on accuracy also depends on the purpose of their acquisition: in other words, the way an MNO data source can affect the accuracy of the final data can be dependent on whether it was collected as additional auxiliary information, as the primary source of information, or for the replacement of an existing source and so on. The impact on reliability, on the other hand, should be more limited, as this dimension concerns only the processes characterised by a revision policy which, in turn, should not be much affected by the origin of the data.*

Indicator 12.1: Source data, integrated data, intermediate results and statistical outputs are regularly assessed and validated.

Relevant for MNO data. The assessment of both source data and intermediate results requires specific interaction with the data holders since they carry out the initial processing steps.

INSTITUTIONAL METHODS (INDICATOR 12.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Assessment and validation systems. Systems for assessing and validating source data, integrated data, intermediate results and statistical outputs are in place.	*Relevant*	In order to produce official statistics based on MNO data, a specific set of checks and quality measures should be put in place to assess, especially, the source data and the intermediate outputs.	Quality checks and measures have been defined along the standard pipeline defined in the deliverables from Task 2. They are referred in Chapters 6 to 8 to assess the quality of source data, intermediate results and statistical outputs.
2. Assessment and validation guidelines. Guidelines for data quality assessment and validation are in place. They address accuracy and reliability issues.	*Relevant*	Specific quality guidelines for statistics based on MNO data are needed, taking into account accuracy issues.	As already mentioned in Principle 4, Chapters 5 to 10 of the present deliverable can be considered a first nucleus of quality guidelines for statistics based on MNO data, in which the accuracy issue will be discussed as well.

PROCESS/OUTPUT METHODS (INDICATOR 12.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
3. Assessment and validation procedures. Procedures to systematically assess data quality and validate data are in place**.**	*Relevant*	While such procedures are generally present in all statistical processes within the NSIs, for MNO data these need to be adapted and extended in order to capture, as well, the quality of the data processed out of the NSIs' premises.	The set of quality checks proposed in the pipeline defined in the deliverables from Task 2 are aimed to implement such systematic assessment. The measures defined in Task 2 are referred in Chapters 6 to 8 to evaluate quality of input throughput and output.
4. Comparison of intermediate results and outputs. Intermediate results and outputs are compared with other relevant sources of information in order to ensure validity.	*Relevant*	The intermediate results provided by MNOs to statistical authorities should be compared with non-MNO data, as a possible benchmark to ensure their validity.	Although the possible comparisons depend on the topic and on the availability of benchmark data, some examples related to the use cases proposed in Task 2 will be presented in Section 7.4.

Indicator 12.2: Sampling errors and non-sampling errors are measured and systematically documented according to the European standards.

Relevant for MNO data with regard to non-sampling errors.

INSTITUTIONAL METHODS (INDICATOR 12.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Guidelines and methods to measure and reduce errors. Guidelines on how to measure and reduce errors to an acceptable level are in place and known to staff.	*Relevant*	Errors in MNO data and the outputs derived from them should be studied and classified.	Specific methods to measure and limit the impact of errors on the statistical output should be developed. As already mentioned in Principle 4, Chapters 6 to 8 can be considered a first nucleus of quality guidelines for statistics based on MNO data. They will be focused on how to measure and reduce errors also referring to the quality checks proposed in the deliverables from Task 2, whenever relevant.

PROCESS/OUTPUT METHODS (INDICATOR 12.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
2. Quality indicator(s). Quality indicator(s) on accuracy and reliability are regularly monitored and published in quality reports.	*Relevant*	Specific quality indicators to assess the statistical outputs derived from MNO data may be needed. They should be integrated in quality reports.	The standard pipeline and the quality framework will be complemented by proposals for quality indicators to be used to monitor all the quality dimensions. Sometimes existing quality indicators will be sufficient, while in other cases additional measures will be proposed. The quality indicators on accuracy, which are actually requested in the ESS Standard for Quality Reports, are well tailored for surveys. Therefore, specific quality measures should be defined for the statistics based on MNO data. For example: *2. Quality indicator(s). Quality indicator(s) on accuracy and reliability are regularly monitored and published in quality reports.* ***Specific quality indicators to assess accuracy of outputs derived from new data sources (e.g. MNO data) should be defined and integrated in quality reports and other quality documentation.*** A first proposal of quality indicators aimed to assess accuracy will be included in Chapter 8 and some of them will be made available by the standard pipeline defined in the deliverables from Task 2 and implemented in the software codes developed in Task 4. Furthermore, refined accuracy quality measures are expected from the research carried out in the MNO-MINDS ESSnet.
3. Analysis and assessment of accuracy and reliability. Quality indicator(s) on accuracy and reliability are regularly analysed and assessed to improve the statistical process.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
4. Procedures for preventing and reducing errors. Procedures for preventing and reducing sampling and non-sampling errors to an acceptable level are in place: • The identification of the main sources of sampling and non-sampling errors (coverage,	*Relevant*	Appropriate methodologies should be developed for preventing and reducing the errors in the outputs derived from MNO data.	Chapters 6 to 8 will include the identification of main sources of non-sampling errors present in MNO input data or arising during data processing. They will also propose methods for their prevention and correction. Additional methods are expected from the research conducted in the MNO-MINDS ESSnet.

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
sample variability and selection bias, measurement, processing, non-response and model assumption errors) in statistical processes; • The quantification of sampling errors for key variables; the identification and evaluation, in quantitative or qualitative terms, of the potential bias and additional variance due to non-sampling errors; • The methods for the correction and adjustment of the errors as well as the analysis of differences between preliminary and revised estimates.			
5. Methods for improving accuracy. Methods for improving the accuracy of statistical data are developed according to methodological and precision requirements.	*Relevant*	The shortages of MNO data for producing official statistics estimates are well known (e.g. undercoverage errors, etc.). Methods to reduce bias due to these errors in statistical output should be developed.	In Chapters 6 to 8 the main issues will be discussed. In addition, MNO-MINDS ESSnet research project is expected to develop methods to mitigate such errors.

Indicator 12.3: Revisions are regularly analysed in order to improve source data, statistical processes and outputs.

Not relevant for MNO data. This indicator could become relevant in case the products derived from MNO data undergo periodic revisions and provisional data is published. In such case, all the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

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PRINCIPLE 13

PRINCIPLE 13. TIMELINESS AND PUNCTUALITY

European Statistics are released in a timely and punctual manner.

***Status**: Relevant with regard to timeliness. Punctuality is a general principle that encompasses also statistics based on MNO data.*

***Motivation:** The data supply flows from MNOs to statistical authorities can be quite different from the traditional survey data or from the acquisition of administrative sources that statistical offices are used to. Not only the nature of the data is different, but also the frequency of the flows could be. Depending on the needs of the statistical authority, it can be imagined that specific flows could be provided daily or weekly and, in any case, with greater continuity than traditional sources. Of course, this can have an impact on the timeliness of the final output that could materialise in an improvement of these specific dimensions, barring any risk of interruption of the data flows from the MNOs. The potential improvement of timeliness is one of the advantages that advocates for the use of MNO data. It can allow a better response from official statistics to crises, such as the COVID-19 pandemic, which highlighted the great need for nearly real-time statistics. However, one relevant point on this matter is the fact that, for some MNO data based statistical products, the limiting factor may be the availability of other non-MNO data used by the proposed pipeline.*

Indicator 13.1: Timeliness meets European and other international release standards.

Relevant indicator. The use of MNO data can help improve the timeliness of official statistics.

INSTITUTIONAL METHODS (INDICATOR 13.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Assessment and validation systems. Compliance with European and international standards. Statistical authorities comply with European and international standards on timeliness.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data. Standards on timeliness could be defined once the standard pipeline is deployed in production and regularly used.	
2. Publication of a release calendar. A release calendar is published covering all statistics for which timeliness standards are established within European and international regulations and agreements.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	
3. Divergences from timeliness targets. Divergences from European and international timeliness targets are regularly monitored and an action plan is developed if these targets are not met.	*General method which also encompasses the use of MNO data in official statistics*	Some potential delays in the case of MNO data-based statistics, can be related to data extraction (which are sometimes fixed a few days later), errors in MNO data, errors in data processing, errors in other input data, etc. However, these issues will be taken into account when fixing timeliness targets, which should also consider the timeliness of other data that will be combined with the MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 13.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Quality indicator(s). Quality indicator(s) on timeliness are regularly monitored and published in quality reports.	*Relevant*	Other than the standard indicators for the output, specific indicators on the timeliness of the input or certain phases of the process involving MNO data could be developed.	The standard pipeline and the quality framework will be complemented by proposals for quality indicators to be used to monitor all the quality dimensions. Sometimes existing quality indicators will be sufficient, while in other cases additional measures will be proposed. Concerning timeliness, indicators on the timeliness of the input and intermediate outputs can also be considered. It is deemed relevant to monitor the timeliness of input data since relatively short delays can indicate problems in the provision.
5. Analysis and assessment of timeliness. Quality indicator(s) on timeliness are regularly analysed and assessed to improve the statistical process**.**	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	

***Indicator 13.2**: A standard daily time for the release of European Statistics is made public.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 13.3:** The periodicity of statistics takes into account user requirements as much as possible.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 13.4**: Divergence from the dissemination time schedule is publicised in advance, explained and a new release date set.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

***Indicator 13.5**: Preliminary results of acceptable aggregate accuracy and reliability can be released when considered useful.*

General indicator which also encompasses the use of MNO data in official statistics. All the methods proposed in the QAF for this indicator can be applied without being further declined, specified or changed.

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PRINCIPLE 14

PRINCIPLE 14. COHERENCE AND COMPARABILITY

European Statistics are consistent internally, over time and comparable between regions and countries; it is possible to combine and make joint use of related data from different data sources.

***Status**: Relevant principle*

***Motivation:** Coherence and comparability are critical dimensions for the outputs produced from MNO data and, generally, from innovative data sources and so-called trusted smart statistics. Usually, these sources are not initially compliant with standard concepts, definitions and classifications used in official statistics and this increases the risk of lack of comparability and coherence of the results produced. To mitigate this risk, as already done with most innovative statistical processes, the first stage of production should be carried out in parallel with consolidated processes of the same domain in order to check the coherence between their respective outputs. Afterwards, considering the purpose of the statistical output based on MNO data, coherence with other sources and products should still be addressed, as well as the comparability of the data over time and space. For example, the addition of a MNO data source for integration or replacement purposes could imply a break in an existing time series, which should be investigated and documented.*

Indicator 14.1: Statistics are internally coherent and consistent (i.e. arithmetic and accounting identities observed).

Relevant for MNO data sources and outputs derived from them, as MNO data are always integrated with other sources, the consistency of the outputs must be verified.

INSTITUTIONAL METHODS (INDICATOR 14.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Procedures and guidelines to monitor internal coherence. Procedures and guidelines to monitor internal coherence are developed and monitoring is carried out in a systematic way. Where appropriate, guidelines should deal with consistency between microdata and aggregated data, between annual, quarterly and monthly data or other periodicity, between national and regional data, between domain statistics and National Accounts and within National Accounts, and with consistency in terms of relationships between related phenomena.	*Relevant*	Many aspects of coherence are relevant for outputs produced through MNO data, in particular, coherence between microdata and aggregate data and coherence between different domains	Specific guidelines may refer to the assessment of the coherence sub-categories mentioned in the comment. The different errors in input data or introduced by the data processing that could cause loss of internal coherence will be pointed out and methods to monitor them will be addressed in Chapters 6 to 8.

PROCESS/OUTPUT METHODS (INDICATOR 14.1)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
2. Procedures and guidelines to combine outputs from complementary data sources. Process specific procedures and guidelines ensure that outputs obtained from complementary data sources are combined so as to ensure internal coherence and consistency.	*Relevant*	In the context of MNO data, sources from different MNOs could be considered as complementary and therefore may need specific procedures for integration or to evaluate the coherence of different outputs produced from them.	Specific use cases in the deliverables from Task 2 deal with the combination of data from different MNOs. Guidelines on how to proceed with the combination of these data will be proposed in the corresponding methods.
3. Quality indicator(s). Quality indicator(s) on coherence are regularly monitored and published in quality reports.	*Relevant*	It can be relevant to the specific MNO context to determine if additional coherence indicators may be needed for MNO data products.	The standard pipeline and the quality framework will be equipped with proposals for quality indicators to be used to monitor all the quality dimensions. Sometimes existing quality indicators will be sufficient, while in other cases additional measures will be proposed.
4. Analysis and assessment of coherence. Quality indicator(s) on coherence are regularly analysed and assessed to improve the statistical process.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable also to processes based on MNO data.	

Indicator 14.2: Statistics are comparable over a reasonable period of time.

The use of MNO data in official statistics is in its infancy; there are no time series of statistics produced from MNO sources that would need a comparability evaluation. However, if past data are stored by the MNOs, it could be possible to produce comparable backwards time series, if needed. In the future, if statistics from MNO data are integrated into the official statistics production, longer time series may be available. In such a case, some of the following methods can be relevant for the MNO use and may need specific adjustments.

***Recommendation**: In this perspective, it should be considered that MNO data evolves over time and that the standard pipeline and the quality framework developed in the current project will also need to evolve. Some reflections on how to manage their maintenance should be done.*

INSTITUTIONAL METHODS (INDICATOR 14.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Identification of changes to concepts. Changes in concepts (classifications, definitions and target populations) in response to significant changes in reality, as well as their impact, are clearly identified/made visible, for example to facilitate the reconciliation of different statistical series.	*Relevant*	With MNO data, changes in concepts should be due in part to the technology evolution, e.g. the definition of the event reported in Call Detailed Records (CDR) is different from the event registered in signaling data. It is necessary to maintain an open dialogue with MNOs to be promptly informed and be able to evaluate the impact of changes on statistical results. Obviously, not only event data can change and have an impact on time series comparability, but also other data that are combined with MNO data to produce statistical outputs.	The agreements with MNOs should clarify that changes in concepts and definitions should be promptly communicated to statistical authorities.

PROCESS/OUTPUT METHODS (INDICATOR 14.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
2. Identification and measurement of changes in methods. Changes in methods are clearly identified and their impact measured to facilitate reconciliation.	*Relevant*	For processes using MNO data, changes in methods should include changes in software versions that imply different processing algorithms, which can have an impact on the final data and, therefore, on many dimensions (including comparability). There may be different reasons for this, from changes in the characteristics of the raw MNO data, to improvements in the data processing methodology.	The issue of the impact of software versioning on the quality of results is addressed in Chapter 9.
3. Publication and explanation of breaks in time series. Any breaks occurring in statistical series are highlighted together with their reasons, consequences and the methods for ensuring reconciliation over time. The explanations are publicly available. These methods can range from the most complete procedures (e.g. providing old series data linked to the new one) to the simplest (e. g, user's guidelines or recommendations for linking the different series).	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	
4. Quality indicator(s). Quality indicator(s) on comparability are regularly monitored and published in quality reports.	*Relevant*	The quality indicators on comparability required in the ESS Standard for Quality Reports are limited to the length of comparable time series and to the analysis of asymmetries for mirror flows statistics. While they maintain their relevance for statistics based on MNO data, further specific quality indicators can be considered.	The standard pipeline and the quality framework will be equipped with proposals for quality indicators to be used to monitor all the quality dimensions. Sometimes existing quality indicators will be sufficient while in other cases additional measures will be proposed. An analysis of possible causes of breaks in overtime comparability will be included in Chapter 8 with proposals of additional quality indicators, whenever needed. The

PROCESS/OUTPUT METHODS (INDICATOR 14.2)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
			issue of the comparability of input data will be discussed in Chapter 6.
5. Analysis and assessment of comparability. Quality indicator(s) on comparability are regularly analysed and assessed to improve the statistical process.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	

Indicator 14.3: Statistics are compiled on the basis of common standards with respect to scope, definitions, units and classifications in the different surveys and data sources.

Relevant for the MNO context, as the statistical domains that can use MNO data already follow such standards and statistics produced with the integration of MNO sources are expected to be compliant to definitions and classifications already in use.

INSTITUTIONAL METHODS (INDICATOR 14.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. A mechanism to promote coherence and consistency. A common repository of concepts or a mechanism to promote coherence and consistency is in place.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 14.3)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
2. Assessment of compliance with standards. Periodic assessments of compliance with standards on definitions, units and classifications are carried out and reflected in quality reporting.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	The definition of a standard pipeline is expected to represent, in the future, the standard to assure comparability of results
3. Explanation of deviations from standards. Deviations from standards on definitions, units or classifications are made public and the reasons for the deviations are explained, particularly in reference to European and international standards.	*Relevant*	Deviations from statistical definitions or international standards are expected in some cases when using MNO data. Furthermore, new concepts could be introduced in official statistics thanks to their adoption. In these cases, clear explanations should be provided to users.	The glossary included in the deliverables from Task 2 includes the definitions of the concepts adopted in the pipeline, with the explanation in case of deviation from standards.

Recommendation:

The methods could be integrated to propose a procedure for regular updates of standard concepts, definitions and classifications to reflect the opportunities offered by new data sources, as MNO data.

Indicator 14.4: Statistics from different data sources and with different periodicity are compared and reconciled.

Relevant indicator. Statistics based on MNO data need to be compared with other existing statistics to validate them

PROCESS/OUTPUT METHODS (INDICATOR 14.4)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Comparison of statistical output with related data. Statistical outputs are compared with other statistical or administrative data that provide similar information on the same domain/phenomenon.	*Relevant*	Since the production of statistics based on MNO data is still under development, the comparison of results with other available data is a mandatory step. Even in the future, when statistics based on MNO data are more consolidated, the validation with other available sources should be maintained.	Comparison with other available data is an output validation method currently used by statistical authorities In the case of new data sources it is even more important and challenging. The issue of output validation will be addressed in Chapters 7 and 8.
2. Identification and explanation of divergences. Divergences in the statistical outputs from different data sources are identified and the reasons clearly and publicly explained.	*Relevant*	When comparing MNO data with other data sources, the justified differences (e.g. due to different units or concept definitions) should be clearly and publicly explained.	The glossary included in the deliverables from Task 2 includes the definitions of the concepts adopted in the pipeline, with the explanation in case of deviation from standards.
3. Reconciliation of statistical outputs. Statistical outputs are reconciled whenever possible.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	

Indicator 14.5: Cross-national comparability of the data is ensured within the European Statistical System through periodical exchanges between the European Statistical System and other statistical systems. Methodological studies are carried out in close co-operation between the Member States and Eurostat.

Relevant for the use of MNO data in official statistics, as cross-national comparability may be harder to reach than for other categories of data products, since MNOs operate at a national level and the procedures that they have in place may be different within member states.

The present project includes multiple MNOs from different countries with the aim of developing also use cases involving flows and mirror statistics.

INSTITUTIONAL METHODS (INDICATOR 14.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Institutionalisation of assessments of comparability. Standard procedures agreed between National Statistical Institutes and Eurostat are in place for the regular assessment of comparability.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	The adoption of a standard pipeline should assure cross-national comparability and facilitate its regular assessment.
2. Collaboration in methodological studies. Methodological studies are conducted in collaboration among statistical authorities.	*Relevant*	For the MNO data context, methodological procedures may investigate the format of the data from different MNOs, the procedures that are in place, etc. Cooperation between statistical authorities of different EU countries can be important for this purpose; i.e. in order to achieve harmonisation and improve cross national comparability.	The Multi-MNO project and the ESSnet MNO MINDS represent examples of collaboration in methodological studies aimed at producing cross-national comparable statistical outputs based on MNO data.
3. Assessment by Eurostat on the comparability of data. Eurostat assesses the comparability of national data using the relevant metadata and quality reports that are requested from the national statistical authorities.	*General method that also encompasses the use of MNO data in official statistics*	The method reports a good practice that would be applicable to processes based on MNO data.	The adoption of a standard pipeline should assure cross-national comparability and facilitate its regular assessment by Eurostat.

PROCESS/OUTPUT METHODS (INDICATOR 14.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Analysis of asymmetries. An analysis of asymmetries is carried out where possible, and reports on mirror statistics among statistical authorities are publicly available.	*Relevant*	When using MNO data from different countries, mirror statistics can be produced and asymmetries may be analysed.	The participation of multiple MNOs from different countries in the current project allows us to carry out the analysis of asymmetries. It will be included for validation purposes in the relevant use cases (cross-border commuting, tourism statistics) developed in the deliverables from Task 2.
5. Analysis of mirror statistics. Discrepancies in mirror statistics are identified and corrected or described whenever possible.	*Relevant*	Obviously, if there are detected discrepancies in the MNO data from different countries, they should be corrected as much as possible.	The participation of multiple MNOs from different countries in the current project allows us to carry out the analysis of mirror statistics. It will be included for validation purposes in the relevant use cases (cross-border commuting, tourism statistics) developed in the deliverables from Task 2,

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PRINCIPLE 15

PRINCIPLE 15. ACCESSIBILITY AND CLARITY

European Statistics are presented in a clear and understandable form, released in a suitable and convenient manner, available and accessible on an impartial basis with supporting metadata and guidance.

***Status**: Relevant with regard to Clarity. Accessibility is a general principle that encompasses also statistics based on MNO data.*

***Motivation:** The accessibility and the clarity characteristics of the output usually stay the same regardless of the origin of the source the output was built from. However, clarity is particularly relevant in the case of MNO data: regarding the communication aspects, the new processes should be explained appropriately to the users to gain their trust and address possible concerns regarding the new data sources. Existing metadata standards could need adaptation and improvement to better document MNO data-based statistics.*

Indicator 15.1: Statistics and the corresponding metadata are presented, and archived, in a form that facilitates proper interpretation and meaningful comparisons.

General indicator which also encompasses the use of MNO data in official statistics.

Indicator 15.2: Dissemination services use modern information and communication technology, methods, platforms and open data standards.

General indicator which also encompasses the use of MNO data in official statistics.

Indicator 15.3: Custom-designed analyses are provided when feasible and the public is informed.

This is a general indicator which also encompasses the use of MNO data in official statistics. However, custom-designed outputs from MNO data could be provided once their presence in official statistics is more established, and at the same time custom requests, that result in specific use-cases, could be a way to experiment with new methods or statistical domains relevant for MNO data.

Indicator 15.4: Access to microdata is allowed for research purposes and is subject to specific rules or protocols.

This is a general indicator related to user access to microdata, it is not relevant for the MNO data neither in the demonstrator nor in the reference scenario since microdata are not going to be released to users. However, rules and protocols used to allow access to microdata to users could be taken into consideration in defining rules and protocols to allow statistical authorities access to MNO microdata

Indicator 15.5: Metadata related to outputs are managed and disseminated by the statistical authority according to the European standards.

Relevant for MNO data, as metadata standards may need some adjustments to cover the specificities of the involved processes.

INSTITUTIONAL METHODS (INDICATOR 15.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. Accordance of metadata with European Standards. The content, structure and dissemination of metadata are aligned with the ESS standards, i.e. the Single Integrated Metadata Structure (SIMS).	*Relevant*	As shown in other research projects, the SIMS standard could be enriched to contemplate the peculiarities of outputs that are derived from MNO data.	A proposal for such adjustments will be presented in Chapter 8
2. Procedures to update and publish metadata. Metadata is regularly updated. The updating procedures are clear and well-known to staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
3. Quality assurance for metadata. A procedure for the quality assurance of metadata is in place and communicated to staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
4. Training courses for staff on metadata. The statistical authorities offer training on metadata for their staff.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 15.5)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
5. Dissemination of metadata. All statistical outputs are disseminated together with the relevant metadata to enable a better understanding of the outputs. If metadata are disseminated separately from the statistical outputs, clear links are provided.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

Indicator 15.6: Users are kept informed about the methodology of statistical processes including the use and integration of administrative and other data.

This indicator clearly already encompasses also the use of MNO data and their integration with other sources.

Indicator 15.7: Users are kept informed about the quality of statistical outputs with respect to the quality criteria for European Statistics.

This indicator encompasses also the use of MNO data. Some specifications could be made about the information to be provided to users for MNO data.

INSTITUTIONAL METHODS (INDICATOR 15.7)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
1. ESS standards on quality reporting. User-oriented quality reports are based on ESS standards and guidelines for quality reporting. Quality reporting follows the ESS standard Single Integrated Metadata Structure (SIMS) on quality reporting as well as accompanying guidelines and handbooks.	*Relevant method*	As shown in other research projects, the SIMS standard could be enriched to contemplate the peculiarities of outputs that are derived from MNO data.	A proposal for such adjustments will be presented in Chapter 8
2. Central monitoring of publication of quality reports. The publication of quality reports is monitored centrally by a quality management unit.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	
3. Availability of quality reports. Quality reports are available on the websites of the statistical authorities.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is also applicable to processes based on MNO data.	

PROCESS/OUTPUT METHODS (INDICATOR 15.7)

QAF METHOD	RELEVANCE	COMMENT	RECOMMENDATION/REFERENCE
4. Publication of quality reports. Staff responsible for statistical processes regularly prepare and make publicly available user-oriented quality reports on the websites of the statistical authorities.	*General method which also encompasses the use of MNO data in official statistics*	The method reports a good practice that is applicable also to processes based on MNO data.	

Recommendation:

An investment on transparency and in communication is necessary to gain the trust of the users for statistics based on MNO data (or, more generally, on new data sources). An additional indicator on this aspect can be added to the principle.

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ANNEX 2: MNO AGREEMENT

INTRODUCTION

\ The parties and respective representatives
\ Object of the agreement
\ Duration or period of the agreement
\ How long are the clauses of the agreement valid after the termination of the agreement (i.e. does the NSI bear any rights or responsibilities regarding the data - input, intermediate and output - after the agreement has been terminated).

TECHNICAL DETAILS OF THE INPUT DATA PROVIDED BY MNO

\ Description of the input data provided by MNO:

- ⇨ Description of MNO network topology data or signal strength coverage areas or any other data format representing the geographic propagation of the cell network:
  - temporal resolution of the MNO network topology data (e.g. daily files, period files, etc.).
- ⇨ Description of MNO event data that includes the specific dimensions:
  - domestic, inbound roaming, outbound roaming
  - signalling data, CDR data, inclusive or exclusive description of specific events captured by MNO to be included in the input data provided by MNO
  - fields and data mapping of the columns of the data objects provided by the MNO (may be different for domestic, inbound roaming and outbound roaming)
  - mandatory and optional fields of the data
  - syntactic and semantic requirements of the input data.

\ Temporal scope of the data:

- ⇨ Start time of the data period
- ⇨ Specified or unspecified end time of the data period.

\ Geographic scope of the data:

- ⇨ Does the data cover the whole country or any specific region? If region, does that mean only events that happen in this region or data for all devices in the whole country who have been present in the specific region in a specific time frame?

\ Temporal resolution of the MNO event data:

- ⇨ Generic (as is - based on signalling data, there is no pre-specified resolution of the MNO events)
- ⇨ Specified as time precision (e.g. 1 second, 1 minute, 10 minutes, 1 hour, etc.).

\ Geographical resolution of MNO event data:

- ⇨ By default, related to MNO network topology data represented by network antenna ID (cell_ID)
- ⇨ May include geographical (GPS accuracy) coordinates for MNO-specific app-based events
- ⇨ May be generalised to specific precision (e.g. 1km2) - this precision is defined in MNO network topology data.

\ Frequency of the data updates (e.g. real-time data feed, 10-minutes updates, 1-hour updates, 12-hour updates, 24-hour/1-day updates, weekly updates, monthly updates, quarterly updates, yearly updates, etc.)

- Data update overlay period (e.g. in case of daily updates, is the data update temporally limited to all the data within the past 24 hours representing the date, or does it include a portion of overlapping historical data to take into account possible missing data from the previous data update - daily data update that happens every 24 hours may include data period of 48 hours)
- Data update time. When does the regular data update happen (e.g. for daily data updates, the data update for the previous date will happen at 02:00)?
- Metadata requirements for input data.

TECHNICAL DETAILS OF THE REFERENCE DATA PROVIDED BY NSO

- The list and description of the reference data needed to execute the data processing pipeline and who is responsible for preparing, QA and integrating the data to the pipeline.

PURPOSE OF THE DATA PROCESSING

- A clear definition for what use cases the data will be processed
- Limitations of the data (if any) regarding the introduction of new use cases (e.g. can it be automatically used for new use cases or does a separate agreement or procedure need to be agreed/signed for other use cases).

PROJECT MANAGEMENT PHASES

- If the cooperation consists of several phases, it may be set in the agreement:
  - ⇨ Implementation phase during which the infrastructure is being prepared, data processing software is being installed, initial input data is being extracted (by MNO, on MNO premises) and reference data is prepared and ready to be imported to the secure MNO infrastructure environment
  - ⇨ Initial test run with pre-specified historical data (e.g., first runs with 12 months of data)
  - ⇨ Setting up and maintenance of the continuously updatable system.

DATA PROCESSING PIPELINE

- Clear definition of what section or individual modules of the pipeline are executed in the MNO premises, including whether any statistical disclosure control elements are applied to protect the privacy of the users and sensitive MNO business information
- What data objects are transferred to the NSI
- What section or individual modules of the pipeline are executed in NSI's premises.

INFRASTRUCTURE REQUIREMENTS

- What are the infrastructure requirements needed for the execution, regular data processing and maintenance of the pipeline in MNO premises
- For how long does the infrastructure need to be supported and extended if necessary (e.g. every 2 years the infrastructure needs to be upgrades in terms of data storage size by X%, etc.).

ROLES AND RESPONSIBILITIES DURING IMPLEMENTATION AND OPERATIONAL PHASES

- Define all foreseeable roles and responsibilities of MNO
- Define all foreseeable roles and responsibilities of NSI.

DEFINE PROCEDURES FOR DATA AND PROCESSING PIPELINE ISSUES

- What are the foreseeable issues (e.g. data quality, missing data, late date, technical problems, communication problems etc.)
- What is the procedure when something with the data is identified as incorrect
- What are the roles and responsibilities
- What is the agreed time period within which the MNO must respond to the notification of the issue, for example:
  - ⇨ Confirm issue ticket received (e.g. 15 min)

- ⇨ Understand who is responsible for dealing with such issue (e.g. 2 hours)
- ⇨ Investigate the issue (e.g. 4 hours)
- ⇨ Report the essence of the issue (e.g. within 5 hours from reporting the issue)
- ⇨ Potentially correct the issue (e.g. 3 working days).

\ Proper data or processing quality violation review and steps to ensure such issues will not happen in the future.

DELETION OF THE INDIVIDUAL DEVICE INPUT AND INTERMEDIATE DATA

\ Description of the processes related to Deletion of the Individual Device Input and Intermediate Data.

PRINCIPLES AND APPLICATION OF PRIVACY PROTECTION OF THE DATA

\ Define what are the main principles of how individuals' data is protected during the whole pipeline
\ Data Protection principles applied by MNO (hashing, k-anonymity, etc.)
\ Data Protection principles applied by NSO (SDC, k-anonymity, grossing-up, etc.)
\ How are those data protection principles applied in the data processing pipeline.

PRINCIPLES AND APPLICATION OF SENSITIVE BUSINESS INFORMATION

\ Define the main principles related to how MNOs' sensitive business information is protected during the whole pipeline
\ How are those data protection principles applied in the data processing pipeline.

DATA BREACH PROCEDURES

\ What are the agreed procedures if sensitive data has been hacked or otherwise tampered with.

SUPPORT

\ What are the technical and data-related support procedures NSI personnel in implementation and operational phases (e.g. can the NSI's experts work with the MNO's experts inside MNO infrastructure to be able to set up the pipeline, or in case some data-related issues happen that require investigation on microdata level)?

FINANCIAL OBLIGATIONS

\ Who bears the responsibility of funding the activities in different phases of the project: the cost related to adding new infrastructure, new software license (if applicable), software maintenance and update, continuous operations, QA of each of the steps data processing, etc.
\ Is there a compensation mechanism for MNO to cover the direct and indirect costs related to providing the data?
\ Foreseeable future cover of the costs (e.g., expenditure plan foresees costs growing each year, who is going to fund this?).

FINANCIAL ACCOUNTABILITY

\ In case something happens (e.g. an increase in data volume requires additional cloud space), which requires a financial commitment, who, how, and for what scope is responsible (e.g., data breach, misuse of the data).

OWNERSHIP OF THE INPUT DATA, INTERMEDIATE DATA, OUTCOME DATA

\ A clear agreement on the ownership (authors) of the data objects in different stages of the processing pipeline
\ A clear agreement on who is allowed and to what extent to use the data for various purposes.

INTELLECTUAL PROPERTY (IP)

\ What IP components are being used in the processing pipeline (including processes integrated by MNO to facilitate the data feed), and how are they used in the project (describe specifically if any of the pipeline components may be used for other purposes outside the scope of the current agreement)

- Use of the trademarks of MNO (e.g., MNO requires, allows, forbids the use of their name as the data source, etc.)
- To what extent can MNO use the data processing pipeline software and the intermediate or final data objects for their internal and external purposes?

TERMINATION OF THE AGREEMENT

- Clear conditions for when the parties can deem the agreement terminated
- What are the conditions for the data (input, intermediate, output) after the termination of the agreement.

ANNEX 3: LIST OF THROUGHPUT QUALITY ISSUES

#	STAGE	GROUPS	METHOD/DATA	ISSUES	PROJECT SCOPE
1	**LOWER**	**DEVICE LOCATION**	**CELL FOOTPRINT ESTIMATION**	**The algorithm does not assign any footprint (set of grid tiles) to a network cell**	**Included**
2	LOWER	DEVICE LOCATION	CELL FOOTPRINT ESTIMATION	The algorithm assigns too many footprint grid tiles to the network cell	Proposed
3	LOWER	DEVICE LOCATION	CELL FOOTPRINT ESTIMATION	Coverage of the country is below threshold (proportion of all grids covering the land area not being part of at least some cell footprint)	Proposed
4	**LOWER**	**DAILY**	**DAILY PERMANENCE SCORE**	**Unexpected number of devices with significant 'unknown' information**	**Included**
5	**LOWER**	**DAILY**	**PRESENT POPULATION**	**Undesirable low number of devices in specific time instant**	**Included**
6	LOWER	DAILY	PRESENT POPULATION	Undesirable low number of grids with present population	Proposed
7	LOWER	DAILY	PRESENT POPULATION	One device cannot be in more than one location during the same time	Proposed
8	**LOWER**	**MID-TERM**	**MID-TERM PERMANENCE SCORE**	**Unexpected low value of 'frequency'**	**Included**
9	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule ue_1**	**Included**
10	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule ue_2**	**Included**
11	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule h_1**	**Included**
12	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule h_2**	**Included**
13	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule h_3**	**Included**
14	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule w_1**	**Included**

#	STAGE	GROUPS	METHOD/DATA	ISSUES	PROJECT SCOPE
15	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles classified based on rule w_2**	**Included**
16	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles without UE label**	**Included**
17	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected number of tiles without any location label**	**Included**
18	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected behaviour when home location is not part of the UE**	**Included**
19	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected behaviour when work location is not part of the UE**	**Included**
20	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected high volume of rarely observed devices based on device_fitler_1 rule**	**Included**
21	**LOWER**	**LONG-TERM**	**USUAL ENVIRONMENT LABELLING**	**Unexpected high volume of rarely observed devices based on device_fitler_2 rule**	**Included**
22	**INTERMEDIATE**	**UC**	**PRESENT POPULATION**	**Formatting of the data**	**Included**
23	INTERMEDIATE	UC	PRESENT POPULATION	Non-plausible population per grid tile	Proposed
24	INTERMEDIATE	UC	PRESENT POPULATION	Unexpected population volume at country level	Proposed
25	INTERMEDIATE	UC	PRESENT POPULATION	Stability of results over time	Proposed
26	**INTERMEDIATE**	**UC**	**USUAL ENVIRONMENT**	**Formatting of the data**	**Included**
27	INTERMEDIATE	UC	USUAL ENVIRONMENT	Unexpected Home location volume	Proposed
28	INTERMEDIATE	UC	USUAL ENVIRONMENT	Stability of results over time	Proposed
29	INTERMEDIATE	UC	USUAL ENVIRONMENT	Stability of results over time for home label	Proposed
30	INTERMEDIATE	UC	USUAL ENVIRONMENT	Stability of results over time for work label	Proposed