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IMPLICATIONS OF SOFTWARE DEVELOPMENT FOR R&D MEASUREMENT

COMPLEMENTARY GUIDANCE TO THE OECD FRASCATI MANUAL 2015 EDITION

TECHNICAL PAPER

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BETTER POLICIES FOR BETTER LIVES

Abstract

This OECD Technical Paper reflects on the growing importance of software development as input and outcome of Research and Development (R&D) activity. It provides conceptual and practical recommendations on how to apply Frascati Manual-consistent definitions and measurement guidelines to the specificities of software, including those of machine learning projects. It calls for national authorities to review their practices concerning both the measurement of the role of software in R&D and ensuring that software development activities are accurately accounted for in overall R&D measurement, consistently with guidance in the Frascati Manual and international practice.

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Note to Delegations:

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Foreword

A key challenge for OECD measurement standards in the rapidly shifting world of science, technology and innovation (STI) is keeping up with technical and societal developments such as the emergence and diffusion of Artificial Intelligence whilst ensuring the continuity of core measurement principles and comparability of statistical outputs over time and countries. Monitoring Research and development (R&D) is of major interest to policy makers due to the unique properties of the knowledge and solutions to challenges it contributes to generate.

Internationally recognised as the reference methodology for collecting and using R&D statistics, the OECD Frascati Manual is an essential tool for statisticians and science and innovation policy makers worldwide. It provides definitions of key concepts, classifications, and data collection and compiling guidelines for statistics on human and financial resources devoted to R&D and distinguish them from other activities. Its use transcends statistical applications, being a reference guide for policy makers, R&D managers and several other actors involved in the use of information on R&D for administrative and managerial purposes. First published in 1963, the Frascati Manual in its multiple editions is the result of work conducted by the Working Party of National Experts on Science and Technology Indicators (NESTI), the OECD body that brings together the organisations formally in charge of collecting these data, on behalf of the OECD Committee for Scientific and Technological Policy.

The growing ubiquity and importance of software as a general-purpose technology across all facets of economic and social activity is visible in the conduct and outcomes of R&D activity. Software is a key contributor to R&D efforts, while R&D activity may aim to produce new software as intermediary or final target. This report responds to the question of how R&D measurement practice accounts for the unique quantitative and qualitative features of software development and allows tracking this specific component. In doing so, it complements the recommendations contained OECD Frascati Manual's 2015 edition, which incorporated for the first time a comprehensive set of clear and implementable general R&D identification criteria. The guidance is primarily intended as input for the training of R&D statisticians and relationship management with respondents, but it is also relevant to a much wider group of potential users who rely on or are expected to provide accurate and reliable representations of R&D activity.

This report has been prepared by the NESTI Secretariat at the Science and Technology Policy Division in the OECD Directorate for Science, Technology and Innovation, drawing on extensive inputs from NESTI delegates and members of the OECD-NESTI informal expert network on R&D tax incentives. The latter group's workshop held in London in March 2019 hosted by the UK government provided the initial basis for mutual learning on guidance provided by countries on the eligibility of software development activities for R&D tax support and planted the seed for further work on this subject, connecting with ongoing measurement discussions at NESTI. Both groups provided the necessary drive and content to make this guidance possible. Special thanks are also owed to the NESTI Bureau as well as delegates and secretariat to the OECD working parties on Digital Economy Measurement and Analysis and National Accounts, respectively, who reviewed and provided feedback on the report.

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Executive Summary

The growing importance of software as a general-purpose technology across all facets of economic and social activity is visible in the conduct and outcomes of R&D activity. Software is a key contributor to R&D efforts, while R&D activity may aim to produce new software as intermediary or final target. How does R&D measurement practice effectively accounting for the unique quantitative and qualitative features of software development (SD) and allows tracking this specific component?

This document argues that software development has distinctive features that call for specific attention. R&D data compilers should consider using the full array of Frascati Manual recommendations and complementary guidance to statistically monitor the role of software in R&D, in view of its significance and fast pace of evolution. Furthermore, R&D definitions and measurement guidance need to be interpreted carefully in the presence of software development, adapting measurement instruments and approaches to ensure that core R&D definitions and classifications continue to be adequately interpreted by data providers and users.

This document responds to widespread requests specific guidance on the treatment of R&D, complementing the OECD Frascati Manual's 2015 edition, which incorporated for the first time a comprehensive set of clear and implementable general R&D identification criteria. It provides indicative guidelines on how to interpret these R&D definition criteria, discussing the cases of software development contributions towards R&D projects and the conditions for software development projects to be considered as R&D and their effective quantification. It also draws attention to the specificities of machine learning projects, other unique features of software development activity and software-related occupations that may be part of R&D personnel.

The guidance is primarily intended as input for the training of R&D statisticians and relationship management with respondents, a fundamental and unique aspect of R&D data collection, rather than elements calling for comprehensive inclusion in surveys. Questions on the volume of software R&D need not regularly feature in R&D surveys but should follow consistent approaches for international comparability. This report emphasises the importance of coordination with users of information on R&D for administrative purposes, given the many feedback loops between administrative and statistical reporting.

The following recommendations are spelled out throughout the document, supported and complemented by additional considerations and points for discussion.

> ***Recommendation 1.*** *Surveys should pay careful attention to ensuring that respondents have a sufficiently broad understanding of the tangible and intangible (intellectual property products) assets that the R&D capital expenditure cost question (or item) refers to, providing concrete explanations for the treatment of acquired software to be used for R&D, and ensuring that only the relevant R&D part of IPP acquisition by the company is recorded as R&D. This may be achieved through itemisation of the various capital asset categories.*
>
> ***Recommendation 2.*** *To collect information on the substantive software component of R&D activity, an ad hoc and non-exclusive approach is necessary. A model reference question for the business section is already available. This information does not need to be obtained on a frequent basis but can help provide both policy relevant information and inform survey practitioners about the need to provide industry specific examples of software R&D inclusions and exclusions.*

***Recommendation 3**. When considering reporting software development activities within broader R&D projects, respondents should be guided to:*

- *Make an accurate qualitative assessment of the entire project and its alignment with the five R&D criteria.*
- *Ensure that the software activity is a necessary and integral component of the R&D project.*
- *Ensure that the reported amounts for the software component are netted off software development or acquisition costs that do not directly contribute to R&D activity, including apportioning out costs of software assets that are expected to generate a revenue stream on their own.*

***Recommendation 4:** For a software development activity or project to be considered and quantified as R&D, it should meet the 5 Frascati definition criteria. Particular attention should be paid to assessing the requirements of novelty, creativity and uncertainty, which many software development projects do not necessarily satisfy in full or in part. R&D compilers and survey respondents should note that different prototypical phases in a software development project differ in their likely R&D characterisation, depending on the uncertainty that the phase's activities aim to resolve, the methods applied, the intent to generate significantly new knowledge that expands the state of the art in the area. Respondents should be encouraged to keep records that allow them to differentiate between eligible R&D and other activities that may be part of a software development activity or project. Respondents should be encouraged to make reasonable and prudent judgements.*

***Recommendation 5**: Since a significant part of the R&D workforce is effectively involved in software development activities, survey practitioners should re-assess whether and how software developers are referred as examples for inclusion and inclusion under the different categories of researchers and R&D technicians, using terms consistent with actual business or organisational practice.*

***Recommendation 6**: National R&D data compilers should equip themselves with custom guidance on software development for use in training their own teams and communication with target respondents. This should be consistent with the recommendations in this report and consider the specific features of the domestic landscape for R&D, including incentives and requirements for record keeping and administrative reporting. While such guidance may be conveyed judiciously and parsimoniously as notes and examples in survey questionnaires, its main value stems from its active use as tool for regular interaction in relationship management. R&D survey practitioners should be familiar with SD terminology and potential reporting biases, adapting their communications to prevent potential misunderstandings.*

***Recommendation 7**: R&D survey practitioners should exchange on guidance and recommendations with providers of related guidance for administrative purposes, such as R&D tax incentives, to ensure effective understanding of similarities and differences and gauge potential implications for their respective statistical and administrative purposes.*

Following the initial public consultation held from February to April 2025, this paper invites continued inputs from subject matter experts to help keep the guidance up to date with latest developments in the fields of R&D and software.

1 Introduction

The growing importance of software as a general-purpose technology across all facets of economic and social activity is particularly visible in the conduct and outcomes of R&D activity. Software stands high up in the list of products and activities that contribute to R&D efforts, while R&D activity may often have software as a primary target output. This begets the question of whether R&D measurement practice today is effectively accounting for the unique quantitative and qualitative features of software development. This document argues that there are distinctive features that call for both specific measurement of the role of software in R&D, following recommendations already in place and currently followed by few countries, and adapting measurement instruments and approaches to ensure that core R&D definitions and classifications continue to be adequately interpreted by data providers and users.

This document thus responds to widespread requests for a process leading to producing specific guidance on the treatment of R&D, complementing the OECD Frascati Manual's 2015 edition, which incorporated for the first time a comprehensive set of clear and implementable general R&D identification criteria. It provides guidelines on how to interpret these R&D definition criteria, and on the software related occupations within R&D personnel. It calls for additional inputs from subject matter experts, with the ultimate aim to arrive at consensus guidance. One important feature of this document is its emphasis on the importance of coordination with users of information on R&D for administrative purposes, given the many feedback loops between administrative and statistical reporting.

The document is structured as follows:

- Section 2 sets out basic concepts and reviews available approaches towards measuring the significance of software development for R&D statistics. The section recalls OECD guidance on identifying software-oriented R&D.
- Section 3 provides guidance on the assessment of R&D criteria available in the Frascati Manual 2015 edition in the context of software development activities, discussing the cases of software development contributions towards R&D projects, the conditions for software development projects to be considered as R&D and their effective quantification. This section draws attention to the specificities of machine learning projects and other unique features of software development activity.
- Section 4 spells out specificities of R&D personnel data reporting for individuals involved in software development.
- Section 5 concludes by spelling out two additional recommendations for action by NSO and keeps open the initial 2025 consultation questions for input from stakeholders in view of the rapidly changing nature of R&D and software development activities.

2 What is software development and does it matter for R&D measurement?

Relevance of software for R&D

The importance of software and ICT more broadly as a general-purpose technology (GPT) across all facets of economic and social activity is particularly visible in the both the conduct and outcomes of research and experimental development (R&D) activity:

- Software stands high up in the list of products and activities that contribute to R&D efforts, bought off-the-shelf or custom-developed within or outside a statistical unit,
- R&D activity may often have software as a primary target output, which might be on a standalone basis or designed to be embodied in specific types of other products (e.g. software for a motor vehicle).

The term **software** is typically used to refer to a collection of programmes or sets of implementable instructions and data that tell a computer how to perform specific tasks for defined information processing purposes.[1] This stands in contrast to **hardware**, the physical equipment on which computer-based systems are built, and which perform (execute) the work as set out by software code. Software instructions may change the state of a computer, by changing for example the values stored in a particular storage location in the computer system—an effect that is not directly observable to the user. Instructions may also invoke input or output operations, for example, displaying some text on a computer screen, causing changes that should be visible to users. This reflects the interconnection between the worlds of “atoms” (the physical world) and “bytes” (the virtual world of digital information) in which R&D and broader scientific, technology and innovation activities take place.

Software development (SD) can thus be viewed as the activity of conceiving, designing, developing, testing, deploying and maintaining software (potentially also decommissioning), the prototypical lifecycle phases of software are highly intertwined and iterative according to practitioners in the field. SD is a multifaceted activity that involves **professionals from various fields**, including software programmers, testers, documentation writers, graphic designers, user support specialists, marketers, and fundraisers, to name a few. It has a **scientific basis** in Computer science, which is the scientific study of computers and software, and an **applied technical engineering dimension** in Software engineering, which concerns the application of engineering principles to development and usage of software.

Developments in **Artificial intelligence** (AI) and machine learning in particular provide a salient example of the very high relevance of software for the conduct of R&D, enriching its underpinning methodologies to formulate and test research hypotheses and managing product and process development cycles. As noted by R&D World magazine[2], the transformational role of AI stems from its “ability to enhance decision-making processes” through “pattern recognition, predictive analytics, and data processing allows for the rapid identification and resolution of complex problems, […] increasing the speed of innovation and reducing time-to-market". AI systems leverage on increasing data resources and computational capabilities in ways that can assist domain experts in managing complexity, automatising routine tasks, and implementing predictive and creative-like tasks with different degrees of human involvement in ways that convey the impression of an underlying intelligence. As newly developed AI systems diffuse, this has created interest in developing specific methods to identify both the role of AI in R&D and innovation as an enabler whilst also monitoring what R&D and innovation efforts are specifically contributing to the development of AI capabilities.

Box 1. Definitions of Artificial Intelligence (AI)

While the objective of this note is not to propose concrete methods to measure the specific role of AI in R&D or formulate concrete definitions for measurement of AI in relation to R&D and innovation, it is relevant to flag existing major definitions of AI as a shaper of software development and note that this is area where definitions are constantly evolving.

The OECD Working Party on AI Governance revised in 2023 its definition of AI as follows:

> *"An AI system is a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and adaptiveness after deployment".* https://oecd.ai/en/wonk/definition

For the purposes of business ICT surveys, Eurostat defines AI by reference to concrete applications:

> *"Artificial intelligence refers to systems that use technologies such as: text mining, computer vision, speech recognition, natural language generation, machine learning, deep learning to gather and/or use data to predict, recommend or decide, with varying levels of autonomy, the best action to achieve specific goals."* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Artificial_intelligence_(AI)

The latest revision of the System of National Accounts adopts the following definition of AI:

> *"Artificial intelligence (AN11531ow1) refers to capabilities of a computer program, or system controlled by a computer program, of recognition, reasoning, communication, and prediction emulating human recognition, reasoning, and communication. Machine learning, in which data enables an artificial intelligence software program to learn to predict or classify from experience, is often used to develop or improve artificial intelligence programs, and artificial intelligence systems rely on a combination of software and data to generate their output. Furthermore, deep learning (a type of machine learning) enables some artificial intelligence programs to improve from experience while being used in production, whereas generative artificial intelligence creates new content. Although they perform tasks that normally require human intelligence, artificial intelligence programs often use data beyond a scale that humans could analyse".* https://unstats.un.org/unsd/nationalaccount/docs/2025_SNA_Pre-edit.pdf

Putting numbers on the importance of software in R&D: roles and information sources

There are multiple angles from which one can approach the measurement of software R&D using available guidance and reporting practice that has resulted in statistical data collected up to date:

- Acquisition of software assets used for R&D (part of capital expenditure for R&D).
- R&D performance by companies classified as part of the software (computer services[3]) industry (ISIC – by main activity of performer).

- R&D performance by companies reported to be oriented towards the economic activity of computer services (ISIC – by main industry of R&D orientation).
- Ad hoc requests of information on R&D performance relating to software more broadly.

Software and databases are categories of produced assets in the System of National Accounts (SNA). As a result, these are objects subject to capital formation because they are deemed to be able to produce benefits to their owners in the form of capital services over more than one accounting period. Measures of capital expenditures for R&D seek to reflect the component of R&D costs that is devoted to the formation of capital to be used for R&D in future years. The Frascati Manual recommends decomposing capital costs by type of assets as listed in the SNA.

This reporting practice is not yet widespread, but some examples can be reported for reference. In the cases of Sweden and the United States (see **Table 1**), recorded capital expenditure on computer software used for R&D is on the same order of magnitude if not on a par with capital expenditure for R&D devoted to machinery and equipment. US software capital expenditure represents 2.5% of BERD (16 out of a total of 634 USD billion in 2021). In the case of Sweden, the percentage is slightly lower at 1.7%.

Table 1. Software capital costs in business expenditure on R&D, Sweden and United States, 2021

	Sweden 2021 (SEK billion)	As % of BERD	United States, 2021 (USD)	As % of BERD
Total BERD	135.2	100	634.1	100
…Capital expenditure	10.1	7	52.8	8.3
…….Machinery and equipment	4.5	3.3	19.6	3.1
…….Software	2.3	1.7	16.2	2.5
…….Other IPP	2.8	2.1	5.7	0.9

Source: OECD analysis based on: Business enterprise sector’s expenditure for intramural R&D by industrial classification (NACE Rev. 2), type of cost, observations and every other year. PxWeb (scb.se) and Business Enterprise Research and Development (BERD) Survey 2021 | NSF - National Science Foundation

Recent experiences suggest that explicitly highlighting intangible assets as a category of capital used for R&D can lead to some significant statistical revisions in capital expenditure component of BERD. A possible reason is that respondents in companies may, by inertia, tend to focus R&D reporting on tangible assets.

> ***Recommendation 1.*** *Surveys should pay careful attention to ensuring that respondents have a sufficiently broad understanding of the tangible and intangible (intellectual property products) assets that the R&D capital expenditure cost question (or item) refers to, providing concrete explanations for the treatment of acquired software to be used for R&D, and ensuring that only the relevant R&D part of IPP acquisition by the company is recorded as R&D. This may be achieved through itemisation of the various capital asset categories.*

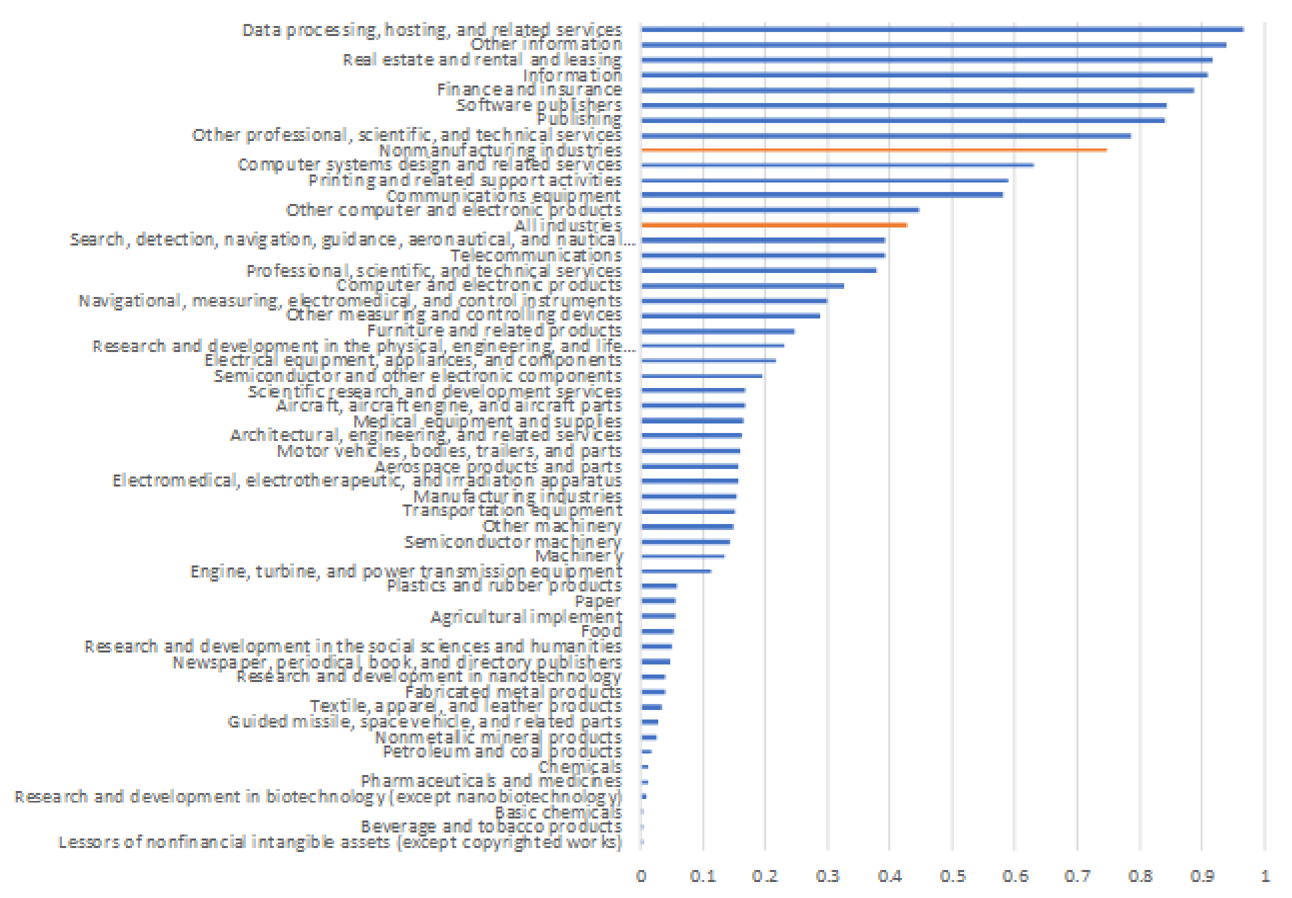
Statistical information on the relative importance of software in R&D is not easy to come by. In the business sector, **BERD statistics by main activity** do point to the growing importance of the ICT industry and computer services and software publishers within it. BERD statistics by **product or industry orientation** are less widely available, but also point in a similar direction. These statistics do however not necessary capture the importance of software development within the R&D activity of companies in other industries, especially when developed on "own account". Aircraft or car manufacturers or pharmaceutical companies may for example dedicate a significant share of their R&D resources to equipping themselves with software solutions that improve the performance of their products, accelerate new product and process development cycles, raise the efficiency and precision of their manufacturing tools, automatise tasks, etc… These will not be necessary captured by BERD breakdowns based on the institutional or functional classifications by economic activity using ISIC or national equivalent classifications.

Similar issues arise when attempting to use **R&D statistics broken down by field of R&D under the category of Computer and information sciences**, even in the case of the business sector where there is a rarely used classification for reporting. The combination of R&D domains in commercially oriented R&D activity makes it difficult to differentiate between mutually exclusive categories such as Computer science and Engineering domains (software engineering), or Med-Health science (bioinformatics), or even social sciences (computational social science).

In order to ascertain the true role of software development one would need to use ad hoc questions that do not impose mutual exclusivity across domains. As a result, there are few statistics available on the broader notion of **software-oriented R&D**. In the United States, which seeks out to measure software products or software embedded in other projects or products through an ad hoc question[4], nearly 43% of total R&D performed by business enterprises in 2021 was devoted to software products and embedded software technology focus area (**Figure 1**).

Figure 1. Software R&D intensity within US industries, 2021

Software R&D as a percentage of total business R&D



Source: OECD analysis of United States NCSES/NSF data, accessed from https://ncses.nsf.gov/pubs/nsf23351/table19

On the basis of this indicator, ICT industries are amongst the most software R&D intensive companies, but they are also accompanied by industries such as Real estate and Finance and insurance, as well as Other professional, scientific and technical services.[5]

> ***Recommendation 2.*** *In order to collect information on the substantive software component of R&D activity, an ad hoc and non-exclusive approach is necessary. A model reference question for the business section is already available. This information does not need to be obtained on a frequent basis but can help provide both policy relevant information and inform survey practitioners about the need to provide industry specific examples of software R&D inclusions and exclusions.*

Box 2. Recommended reference item for a question on software R&D

Please report how much of your company's R&D expenditure (INTRD_BERD) corresponds to work on new software (and database) development. [can also include examples and exclusions]

This category is singled out since software is a key policy priority for users of R&D data (also for National Accounts purposes).

Clarify that it is not any software development, but only software development that qualifies as R&D, i.e. R&D associated with software as an end-product, or software embedded in an end-product which meets the criteria for R&D [see FM 2.7]. The software and data being developed may be the ultimate target outcome and must aim for the properties listed in the R&D definition. Alternatively, the software developed may be instrumental to the pursued R&D project objectives and may therefore include routine components. However, it must be part of an R&D project that meets the definition's criteria. Software and data development costs can comprise labour, other current expenses and capital.

Source: Galindo-Rueda and López-Bassols (2022). Question item: INTBRK_SOFT

Implications for R&D measurement

As implied by the previous subsection, SD is not only important for R&D measurement as a specific additional object of measurement interest and potential priority, for which specific methods still need to be developed and standardised.

SD is also important as both a potential challenge and opportunity for maintaining and improving the quality of R&D statistical measurement, i.e. the "how" of R&D measurement. Addressing the **opportunity dimension of software for improved R&D measurement**, especially through the use of machine learning, is a very important matter for further development in separate work which is already embraced in aspects of NESTI work as new approaches are being developed, e.g. informing the use of qualitative data for producing quantitative indicators and implementing granular tagging and classification in R&D funding databases.

This document is principally concerned with **ensuring that SD is effectively dealt with by R&D data compilers to prevent R&D reporting misalignment and bias**. An increasing role of software in society can impact on measurement through changes in record keeping and data reporting practices through multiple channels. As the importance of SD increases, relatively small differences of appreciation as to whether and when SD is R&D can result in very large impacts on the overall validity and reliability of R&D statistics. As the OECD Frascati Manual 2015 edition approaches its 10th anniversary, it is possible to note that software is one of if not the main driver of stakeholder questions on clarification requirements to OECD.

SD is also a first-order issue for policy stakeholders seeking to target support to R&D, since as SD becomes relatively more important, more of their undirected support (e.g. through tax incentives) will ultimately support SD, over and above what it is explicitly directed to specific areas of SD. Their decisions on SD eligibility for support are informed to some extent by Frascati definitions but they are also compelled to provide ad hoc clarifications given the legal and financial stakes. These administrative guidelines, when introduced, may diverge across countries, and as a result, they may also push in different directions record keeping and reporting by statistical units.

Software development can be potentially mistakenly identified in many cases with the Frascati concept of experimental development (the D in R&D) when this is not necessarily the case. Indeed, experimental development is defined as systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes (OECD, 2015). The notion of experiment does not necessarily imply specific forms of laboratory-like experimentation but requires the existence of a procedure allowing to text scientific and technical hypotheses which cannot be known with certainty in advance and whose resolution generates new knowledge. This characterises a very concrete form of development activity.

Indeed, according to the Frascati Manual, for an activity to be classified as an R&D activity, five core criteria must be jointly satisfied: a) novelty; b) creativity; c) uncertainty; d) systematicity; e) transferability and/or reproducibility. This was a major methodological innovation in the 2015 Frascati Manual which codified into concrete points guidance that was provided implicitly in previous editions and by responsible national statistical organisations. The criteria have been referred to by users of manual as one of the most important contributions of the 2015 edition. Furthermore, this edition used the criteria to address several activities at the boundary of R&D. However, the amount of space that was devoted to the SD, a boundary activity for which the ensemble of R&D criteria does not necessarily apply, was constrained and arguably should have been expanded with the benefit of hindsight.

The remainder of this document aims to address this gap by kicking off a process of reflection and provision of concrete guidance on the application of the R&D criteria for identifying R&D in the presence of SD activities, complemented by additional guidance intended to ensure robust quantification in terms of expenditure and human resources.

3 Software development activities in R&D: guidance for accurate, internationally comparable measurement

Approaching the link between software development and R&D measurement

There are two major elements when identifying whether the resources devoted to a software development activity qualify for statistical measurement as R&D according to the guidance in the Frascati Manual.

- **Eligibility**: Is the software development activity R&D or part of R&D? (An issue covered in Chapter 2 on definitions in the Frascati Manual).
- **Unbiased and accurate measurement**: Which among the resources devoted to the SD activity relevant for R&D should be effectively counted as R&D? And how? (An issue pertaining to Chapters 4 and 5 of the Manual which deal with expenditures and human resources, respectively).

When discussing software development in R&D it can be useful to make the following distinction between two non-mutually exclusive scenarios that are contemplated in the Frascati Manual[6]:

- Software development as component of part of an R&D project.
- Software development as the target output of R&D.

These two scenarios may indeed overlap since an R&D project may both require acquiring or developing new software and aim to develop new software as key substantive goal. Separating between these two is however conceptually useful and is consistent with OECD statistical guidance and administrative guidance provided by many countries for the purposes of providing tax or other support for R&D.

Creation, development, acquisition or adaptation of software for the necessary and exclusive use within R&D projects

Software may be developed, acquired and used as inputs to R&D projects. When such a situation arises and the project does not necessarily have software as the objective, it can be helpful to consider the following steps in guiding respondents to statistical surveys.

Step 1. Is the overarching project an R&D project? Does it meet the 5 criteria?

From this perspective, the important issue to start with is to first assess whether the overarching activity is R&D or not, taking into account the full description of the project and its component parts. Assessing whether the five R&D definition criteria apply may however require some information about the different activities and plans. (a) novelty; b) creativity; c) uncertainty; d) systematicity; e) transferability and/or reproducibility.

Step 2. Are the SD activities measured within the R&D project necessary for R&D?

To be counted as part of R&D, the SD activity must be a necessary and integral component of a project that does qualify as R&D. The activity of software development, conducted internally or externally to the entity, does not necessarily have to fulfil on its own the R&D definition criterion in order to be considered a component of an R&D project. The SD activity may not be particularly novel, creative, etc… if viewed in isolation. This would apply for example to routine software development to ensure that a piece of lab equipment records the data necessary for a new experimental development project. The criteria should apply at the level of the project in which the software is developed. However, it is a requirement that the contributed SD activity must be necessary for the R&D project. This can be assessed by simply asking whether the project would be viable without the said SD activity, regardless of how it is procured.

Step 3. Are the full range of SD activities considered necessary for the project strictly for this R&D project? And if not, what part?

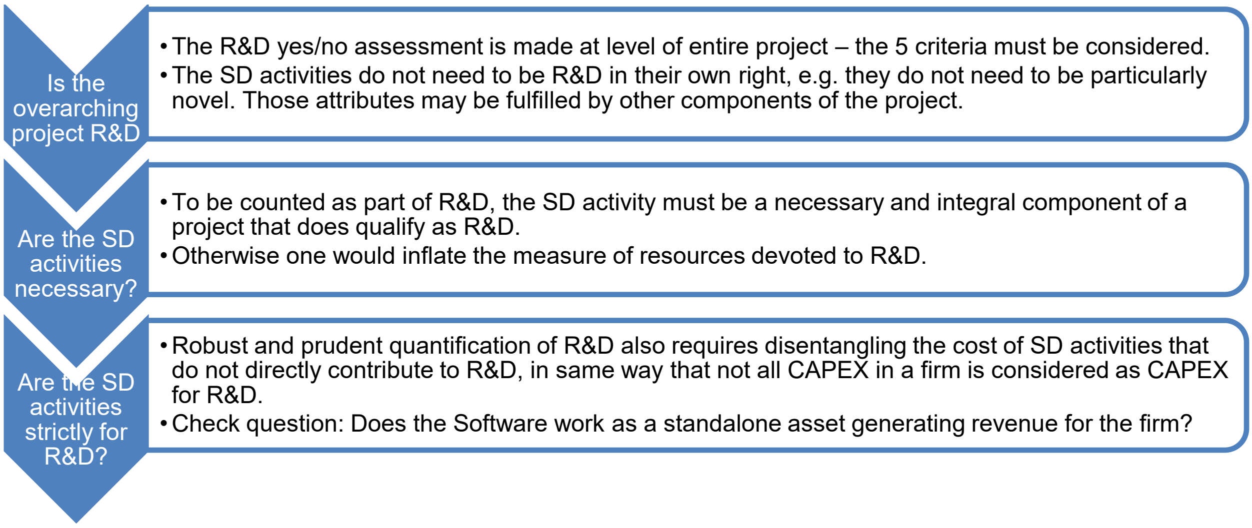
Prudent and unbiased measurement of effective resources devoted to R&D, consistency with software capital investment practices in the SNA, and alignment with practices for management of government support for R&D may be require that the software developed (or acquired) is **exclusively intended** for R&D or otherwise have its **costs/resources effectively apportioned across R&D and non-R&D purposes**.

If the SD work serves other purposes and/or represents a separately identifiable asset for the company, then there may be a presumption against counting those costs, at least in full, as part of the estimate of resources devoted to R&D and contributing to such an asset. Software development should in that case and principle be considered only for measurement of capital formation of software assets under the SNA framework for that asset class (Ker and Galindo-Rueda, 2017).

Beyond statistical measurement purposes, this third step is important in the case of administrative reporting of R&D for ensuring that public resources are only used to support R&D and minimise the risk they are used for other purposes. While companies may have projects positively (pre-)assessed as R&D projects, tax authorities may disagree on the effective volume of eligible R&D expenditures if they suspect a lack of necessity or exclusivity of software costs to the outcome of the eligible R&D project. In those cases, they will likely limit the extent of claimable R&D, possibly requiring additional information on apportioning costs. The UK tax authority (HMRC) refers, as an example where it would be appropriate to include in R&D an entire relative routine software activity, to the cost of developing data handling software needed (and exclusively intended) to record and monitor the results of R&D undertaken by a Life Science company (HMRC, 2016).

These three steps or questions, summed up in **Figure 2**, that arise in the context of statistical measurement also find parallels in related administrative use cases. These are used for example in the determination by national authorities of the eligibility for tax relief instruments or other subsidies and grants that seek to incentivise R&D expenditure. Sometimes, in the case of tax incentives, this assessment can be split across different organisations with distinct roles. As reported in the OECD INNOTAX platform[7], in some countries the judgement of research funding agencies or other accredited organisations is called in first to validate the description of the project as an eligible R&D project, and the tax agency assessing on an ex-post basis whether the amounts claimed for R&D for tax relief purposes are appropriate and justified. This suggests that there is scope of mutual learning between STI statistical and administrative communities that work with common concepts such as R&D.

Figure 2. Accounting for software development as a component part of an R&D project



Source: OECD own elaboration.

The following recommendation sums up the main conclusions of this subsection dealing with software activities, that while not necessarily R&D on their own right, might be components of R&D projects.

> ***Recommendation 3****. When considering reporting software development activities within broader R&D projects, respondents should be guided to:*
>
> - *Make an accurate qualitative assessment of the entire project and its alignment with the five R&D criteria.*
> - *Assure themselves that the software activity is a necessary and integral component of the R&D project.*
> - *Assure themselves that the reported amounts for the software component are netted off from software development or acquisition costs that do not directly contribute to R&D activity, including apportioning out costs of software assets that are expected to generate a revenue stream on their own.*

In conveying this guidance, another area of potential methodological synergy between statistical and administrative R&D monitoring concerns regulatory financial reporting requirements which are intended to protect investors by imposing disclosure of key business information. For example, article 730-10-50 in the Accounting Standards Codification (ASC) stipulates that "Disclosure shall be made in the financial statements of the total research and development costs charged to expense in each period for which an income statement is presented". It goes on to add that "Such disclosure shall include research and development costs incurred for a computer software product to be sold, leased, or otherwise marketed". The ASC is the source of the United States Generally Accepted Accounting Principles (GAAP) and it is maintained by the Financial Accounting Standards Board (FASB). ASC provides additional guidance on activities to be excluded and included from R&D which is highly comparable to Frascati Manual guidance.

Software as an intended product or goal of the R&D activity

This scenario helps put the focus on the specificities of SD and software as a product in its treatment as a self-standing R&D activity, when contrasted to the Frascati Manual definition's qualitative criteria and quantitative measurement guidance. The key question is whether the SD project qualifies as an R&D project in its own right. The Frascati Manual states that "for a software development project to be classified as R&D, its completion must be dependent on a scientific and/or technological advance, and the aim of the project must be the systematic resolution of a scientific and/or technological uncertainty" [§2.68]. This section aims to untangle the meaning of such guidance and attempt to provide more concrete examples that are relevant to the state of play of ICT and software today.

What is special about software?

As previously noted, the term development under SD is often equivalised with (experimental) development – i.e. the D in R&D. The terms 'research' and 'development' are frequently and, to some extent, also casually used in the software sector. **Care should be taken not to assume that a commercial project involving SD necessarily aligns with the definition of R&D.** The fast technical evolution of software and SD makes it difficult to provide guidance that is equally relevant to traditional and novel SD and withstands the test of time. Software, as with all information technology, is continually changing and developing with "well-established branches of software that continue to evolve (e.g. artificial intelligence, cloud or mobile computing), as well as new applications for software being developed (e.g. software robots, augmented reality and internet of things, and others yet to come)" (HMRC, 2016).

Another specificity of software as the outcome of R&D is the rather complex set of arrangements that define the ability of software developers and their companies to protect the intellectual property (IP) arising from their efforts. Software is *by default* covered by copyright protection, and it might also be considered protected by trade secrets, with the provisions applicable to both forms of protection. Patented inventions, which use criteria that are very close to those used for R&D, enable protection of functionality but their coverage of computer-implemented inventions differs across jurisdictions. In many, patent protection only applies to the systems in which software is embedded (not the computer programmes as such) and operates to produce a technical result, which is understood as a material effect (a "transformation of nature"). In that case, methods for controlling an industrial process, processing of data representing physical entities (temperature, size, shape etc.) and the internal functions of the computer are potentially patentable. The notion of technical character excludes, for example in the field of software used in finance, methods that relate behavioural aspects of the financial system. In more permissive regimes, there are still limits excluding claims to protect "abstract ideas" that computer programmes might embody if those are not focused onto concrete practical applications. For example, an algorithm may not be patentable but its application to rank webpages can be protected under such IP regimes.

SD is also quite distinctive in terms of its methodologies for managing uncertainty (one of the R&D definition's criteria) in comparison with other S&T domains. To execute tasks, software draws on information resources that can be re-used indefinitely, unlike patients treated with experimental drugs who cannot be treated again with alternative treatments. Likewise, code does not get destroyed when it malfunctions in the way that a new vehicle or aircraft prototype might do if they crash, so it can be repaired iteratively, i.e. over multiple loops. This implies that common modalities of SD are less linear[8] in nature that in other technology domains operating with "atoms" as opposed to "bytes", especially concerning the separation between experimental prototyping and products undergoing improvement and customisation. These features make software an appealing instrument of R&D but also complicate the task of setting clear boundaries and achieving precise quantification of the R&D dimension embedded in SD projects.

Additional dimensions of specificity for SD have to do with:

- the high degree of modularity present in software, as different bits of existing code can be integrated with each other to generate distinctive new code;
- the possibility to repurpose software across different industries with varying degrees of novelty and customisation efforts required;
- the scale and network dimensions of software-based business models built as digital platforms powering the direct or intermediated exchange of information and goods and services, which also results in different types of "actors";

- the degree of specialisation and division of labour that also gives rise to high levels of SD outsourcing, which can result in very substantive differences of appreciation and recording of the activity performed within or outside an institutional unit as R&D;
- the potential for automatisation brought about by AI developments, which contributes to redefining the role of researchers and R&D personnel in the definition and implementation of R&D tasks.

Assessing the R&D definition criteria

Ultimately, the five Frascati criteria must always apply for an SD project to be considered R&D. **Table 2** sets out the criteria and discusses how they apply to software in view of its specific features.

Table 2. Application of the Frascati definition criteria to software development

Frascati Manual R&D definition criteria	Substance of criterion	Considerations in the case of software development
Novelty (N)	SD needs to aim at new findings / knowledge, adding to the stock of knowledge in the industry	This is a first order consideration for assessing whether SD activity qualifies as R&D. A considerable amount of SD activity, that may indeed contribute to the innovation efforts of the firm, will not qualify as it will entail activities aiming to purely customise, imitate or reverse engineer software already in use in the industry.
Creativity (C)	SD needs to target based on original, not obvious, concepts and hypotheses	While software code is protected by copyright and this might qualify SD as "creative work", the FM definition has a higher standard of "creativity" , which goes beyond the notion of writing code for the first time. SD must pursue non-obvious software mechanisms and outputs even if those are novel to the industry. This criterion pursues ensuring that there is a substantive and non-trivial novelty dimension in SD.
Uncertainty (U)	SD needs to face and aim to address fundamental uncertainty.	The outcome at the outset of the SD project cannot be assumed as certain to be achieved for a given level of resources. The nature of the uncertainty also needs to be of a scientific or technical nature. Commercial and related uncertainty about the demand for the software and products it may be embedded in do not qualify.
Systematicity (S)	SD needs to be planned and budgeted for – e.g. R&D is conducted in a planned way, with records kept of both the process followed and the outcome	This criterion is a necessary condition for records to inform reporting and measurement. If SD is not planned and budgeted for it is difficult to assess the veracity of the N-C-U criteria. SD potentially meeting N-C-U would not be traceable or distinguishable from broader SD activities and would not be a suitable object of measurement. Non-linearity in SD methods e.g. through multiple iterative loops may present some significant challenges if record keeping in that context does not allow to establish a clear distinction between eligible R&D and other activities.
Transferability/ reproducibility (T)	An R&D project should result in outputs that may be transferred (allowing for the knowledge to be used as an asset).	Similar to criterion S, this is key for traceability and measurement, and treatment of R&D as a knowledge asset. SD output embedded as code is by definition transferable and reproducible by its owners so this may not represent a major challenge on its own. SD activity that may fail to achieve its objectives should likewise leave code and performance information that prevents repetition of previous errors.(NB. This criterion does not require that there is a plan for the external transfer of knowledge)

Source: OECD own elaboration, based on OECD (20215).

The criteria of novelty, creativity and uncertainty stand out as those potentially requiring considerable reflection by respondents and data compilers faced with ambiguities in the treatment of software development projects. These add to general reporting problems faced in the digital era (**Box 3**).

Box 3. Overcoming R&D reporting challenges in the digital era

While participation in R&D surveys is mandated in many countries by law, effective participation and unbiased reporting requires a voluntary form of effort and disclosure. Burdened with multiple reporting requirements, survey respondents often have limited incentives to pay attention to reporting guidelines, making the addition of notes, explanations and examples an insufficient strategy to ensure data quality.

One potential challenge for R&D statistics is a perceived potential growing unwillingness among respondents to differentiate between resources devoted to R&D and other technology-related development work. This may manifest itself into either a reluctance to respond to surveys or the amalgamation of all technology related work and its reporting as R&D. It is difficult to assess the full nature of the problem, as statistical secrecy prevents the collective assessment of reported data. Public disclosure requirements aiming to protect investors in publicly listed companies can be an additional source of information for some types of firms. Referring to data records that companies may hold for purposes such as benefiting from different forms of public support for R&D and innovation more broadly. It is important to understand in what ways those records may align or differ from Frascati concepts.

Software development specificities may be contributing to the reporting problem. For example, a major digital platform company like Amazon refuses to identify R&D in its financial reporting to the US Securities and Exchange Commission, arguing that its "business model encourages the simultaneous research, design, development, and maintenance of both new and existing products and services" and stating that "any dividing line between those costs described in ASC 730-10-55-1 and ASC 730-10-55-2 would be imprecise and inconsistent with our (Amazon's) approach to innovation" (1). While this example is not necessarily representative of confidential R&D statistical reporting or other administrative activities (Amazon does report in its published financial accounts unclaimed amounts of R&D tax credits), such statements are potentially revealing of an underlying challenge that R&D statistics compilers need to address and R&D measurement standards have to account for.

Furthermore, R&D practitioners may lack the expertise or contextual information to identify when over- or under-reporting errors may have a material impact on aggregate results. Potential signs of bias include sustained extraordinary levels of capital expenditures within R&D or, whenever they can match to innovation survey data, very small levels of innovation expenditures other than R&D. The regular informal interaction between experienced respondents and R&D compilers is critical since repeated interactions allow to build mutual trust and understanding over the discussion of concrete examples and resolve ambiguity. Staff turnover and, in cases, the infrequent conduct of surveys can disrupt continuity in data reporting and compilation roles on both sides. In the reporting by multinationals with potentially very large levels of R&D, it is particularly important to ensure an appropriate reporting baseline and fluid communication. For such reason, many National Statistical Organisations (NSOs) tend to entrust the entirety of MNE relationship management to a dedicated MNE reporting unit. The challenge with this approach is that the specialist MNE unit may often lack detailed specialist knowledge of R&D measurement guidelines. This may lead to misreporting, particularly in boundary areas like software development. Generic MNE relationship units should be effectively trained in R&D surveys concepts and methods and be prepared to identify signs of bias.

(1) Text extracted from correspondence between Amazon and SEC in 2016. Access in January 2025 from. https://www.sec.gov/Archives/edgar/data/1018724/000101872418000011/filename1.htm

Source: OECD own elaboration.

Advice on software development by tax authorities for R&D tax relief purposes

This section highlights elements of guidance provided by selected tax authorities with explicit, publicly available guidance on the eligibility of specific activities for R&D tax relief purposes within their respective national statutory frameworks. Whilst these do not necessarily match definitions and criteria developed for R&D statistical purposes, they share a great deal of common points and can shape what type of records companies may keep when reporting R&D for statistical purposes.

United Kingdom

The guidance provided by the UK Revenue and Customs (HMRC, 2016) is one of the few available comprehensive sources of guidance on R&D in software. The key features of this guidance were presented by HMRC officials at a workshop of the OECD informal network of experts on R&D tax incentives measurement and analysis held in London in 2019. Although intended for purposes very different to statistical reporting (i.e. linked to approval and auditing procedures), there are several potential lessons to be drawn from such guidance with a view to framing more specific Frascati guidelines in the future. This includes both the content of the guidance, which is highly relevant for R&D statistics, and in terms of process, since the HMRC guidance resulted from consultations held with a diverse set of stakeholders.

Table 3 sums up the HMRC guidance. It provides a framework for considering key R&D requirements in SD projects, associated questions that can be posed, and concrete guidance examples associated with each of those questions.

Table 3. Specific advice from UK tax authorities on software development and R&D

Requirement (tax purposes)	Examples of questions	Concrete guidance examples
Defined advance in science and technology - Demonstrate novelty and significance (creativity)	What is the baseline in technology that any advance sought is being measured against?	• A project involving customisation of existing software which materially affects underlying science or technology can be R&D and so can be collaborative work on commercial off the shelf (COTS) products, as long as the technological advance sought seeks to enable the modification of the product substantially beyond existing capabilities. • An advance or appreciable improvement can be identified is to measure and compare it relative to a comparable family (or category) of software that is viewed as representing the current state of overall capability in that area (e.g. Proprietary or open-source software frameworks).
	What was the gap in technological knowledge or capability which necessitated the commencement of the R&D project?	• Combining standard technologies, such as integrating platforms, can be R&D if a competent professional in the field can't readily deduce how the separate components should be combined to have the intended function (para 30). • The implementation of a novel algorithm that represents a significant increase in overall capability in software can also be R&D (para 23).
	What technological changes have been made in seeking a technological advance, or attempted advance?	• Must make appreciable improvement to an existing process, material, device, product or service through scientific or technological changes, so it can be used in a new or appreciably improved way
What are the scientific or technological uncertainties? (uncertainty)	What are the challenges? Are they strictly technical? What is the scientific or technological source of uncertainty?	• Uncertainty about the complexity of the entire system over and above that of its components is not sufficient. Must provide evidence that routine or established assembly methods would not be sufficient. • Developing new or improved data architectures that cannot be achieved with readily deducible solutions, e.g. pushing beyond the boundaries of existing readily available database engines. • Extending software frameworks (e.g. software development kits, or software libraries) beyond their original design, where knowledge how to extend these was not available or readily deducible at the time. • Attempting to partially or fully solve a technological uncertainty that is documented as a known subject of research by computer scientists (e.g. there are relevant and contemporaneous research papers on that specific S&T issue)
Project boundaries (quantification)	What part of an SD project is effectively R&D?	• Software development project(s) may need to be identified as smaller R&D projects within a larger commercial project. • Alternatively, it may also mean merging a number of separate workstreams that collectively serve to achieve the scientific or technological advance. The cycle of activities within a software R&D project can be a useful way of determining the types of activities that qualify.

Note: The points presented in this table effectively develop some but not all of the necessary R&D criteria depicted within Table 2.
Source: Adapted from HMRC(2016). https://www.gov.uk/hmrc-internal-manuals/corporate-intangibles-research-and-development-manual/cird81960

The HMRC guidance also provides a perspective on the most common features of an SD project along different stages that may be followed, not necessarily linearly, in the development of software. This provides additional clues on the specific issues arise at projects in such phases.

- Requirement gathering and planning.
  - Understanding user needs not included in general (e.g. analysis of commercial requirements), only technical requirement analysis.
  - Planning activities such as outlining, estimating and scheduling and planning for the R&D elements of the SD project is R&D.
- Analysis, design and development.
  - Cover only activities that aim to resolve S&T uncertainty.
- Testing.
  - To be included in an R&D project the purpose of the testing work should be to feed back into the development, not to validate that it definitely works properly once the technological uncertainties have been resolved.
  - Non-functional testing (of smaller units of code, system integration and security testing). In order to be considered as R&D, tests must not be purely confirmatory, e.g. regarding performance and security testing, but inform the assessment of a clear hypothesis.
  - Functional user acceptance. There is a general presumption of exclusion, esp. if the focus is on aesthetic look and feel issues. Work on functional user acceptance can be eligible if this formally feeds back into the development to resolve technical uncertainty.[9]
- Deployment.
  - There is a presumption that the S&T uncertainty has been resolved at this point. Only include if the nature of deployment brings additional elements of S&T uncertainty that formally feed back into the development.
- Maintenance
  - Maintenance and ‘fixes’ are presumed excluded. Only eligible if new problems emerge that may require R&D to recommence through the life-cycle stages of the software development.

Australia

Similarly to the UK experience, Australia’s Department of Industry, Science and Resources has recently issued specific guidance to help companies assess whether their software-related R&D is eligible for the domestic R&D Tax Incentive (Australian Government, 2024).

For example, Australia’s incentive defines R&D activities as “core” or “supporting”, two concepts developed for specific tax support purposes. The incentive excludes certain activities from being eligible as “core R&D”. Of relevance is the exclusion of the development, modification or customisation of computer software whose dominant purpose is the internal administration of the firm or its connected enterprises. The specific guidance further clarifies this exclusion for companies through practical examples, such as internal business applications like payroll and accounting, invoicing, ordering, quality control reports and information management, management information systems and enterprise resource planning.

While they may be excluded from constituting core R&D, activities may still qualify as “supporting R&D”. This distinction reflects considerations in section 3.2. that while an activity may not constitute R&D when taken in isolation, it may be essential in supporting an actual R&D project to attain its objectives. The specific guidance elaborates on this for software development activities, such as through a hypothetical example of a firm who customises software on a production line to facilitate an experiment in an eligible core R&D activity. The guidance explains that this directly relates to producing goods or services which is excluded from being a core R&D activity, however the activity may still be eligible as a supporting R&D

activity if the firm can show it conducted it for the dominant purpose of supporting an eligible core R&D activity.

US survey guidance on software development and R&D

Several countries, either by aiming to collect specific information or seeking to ensure consistent R&D reporting, provide detailed survey instructions on the reporting of software activity in R&D. One case in point is the US BERD survey (**Box 4**). It is important to ensure that countries are providing consistent guidance to survey respondents.

Box 4. US BERD survey exclusions and inclusions of software activity in R&D

R&D activity in software and Internet applications refers only to activities that have an element of uncertainty and that are intended to close knowledge gaps and meet scientific and technological needs. This item is reported in this survey regardless of the eventual user (internal or external).

- R&D activity in software includes software development or improvement activities that expand scientific or technological knowledge and construction of new theories and algorithms in the field of computer science.
- R&D activity in software excludes software development that does not depend on a scientific or technological advance, such as supporting or adapting existing systems, adding functionality to existing application programs, routine debugging of existing systems and software, creating new software based on known methods and applications, converting or translating existing software and software languages, and adapting a product to a specific client, unless knowledge that significantly improved the base program was added in that process.

Source: United States National Science Foundation. https://ncses.nsf.gov/surveys/business-enterprise-research-development/2021#technical-notes

Treatment of AI product development – machine learning projects

The case of machine learning (ML)-enabled AI may call for specific guidance in view of its several specificities and relative novelty. This document provides an initial reflection on such an endeavour by listing the different elements of ML according to available standards and practices, which are continuously evolving. For example, the Quality assurance methodology (CRISP-ML(Q)[10]), an industrial standard for building sustainable machine learning applications, presents each step in the ML life cycle. The text below provides some additional commentary on the scope for considering the R&D content of such activities in view of existing guidance.

- Planning
  - This phase is similar to other SD projects and similar considerations apply. Technical eligible elements will include whether an ML solution might solve a practical problem (which should be of technical nature to be R&D) or improve a current process and what are the specific technical uncertainties that will be faced. Planning issues of robustness and scalability will be within scope of R&D planning as long as they are technical in nature. In the case of ML projects, key tasks will include assessing data availability for model training in addition to other necessary human and material resources. Addressing legal constraints will be outside the scope, but it may be necessary to conduct genuine R&D to anticipate the impact of a ML application on society.

- Data preparation
  - Typical tasks entail data collection and labelling, cleaning, processing and management. It is important to identify which of these are specific for ML development with a view to apportioning resources allocated to data preparation, if at all possible. If data preparation also serves ongoing business needs such costs should be excluded. As in R&D in general, across all sectors, data preparation work is only R&D if it is an integral and exclusive part of an R&D project.
- Model engineering
  - In this phase, inquiries may be conducted to build an effective model architecture and define relevant model performance metrics. Although some practitioners may allude to this as "research", it will in most cases be at best an element of experimental development of, unless there is a separate project solely specialised on studying model features. Practitioners may in most cases refer to available model libraries for use in unique data resources.
  - Model engineering will lead to training and validating the model on the training and validation datasets, respectively. Codification is essential for tracking experiments, metadata, features, code changes, and machine learning pipelines. Further work will entail performing model compression and "ensembling" and interpreting the results by incorporating the input of domain knowledge experts.
- Model evaluation
  - This phase aims to determine whether the ML model is ready for production. The model will be tested on a test dataset and subject matter experts will be engaged to identify errors in the predictions. Testing for robustness on random and real-world data will help assess the model's performative ability to deliver value. Compliance checks will also be need with respect to industrial, ethical, and legal frameworks for AI solutions.
  - This phase presents some analogies with Phase 3 trials. Every process is recorded and versioned to maintain quality and reproducibility. The model evaluation will, by comparing results with planned success metrics, provide the basis upon which to decide whether to deploy the model or not. Evaluation tasks under this phase will be R&D depending on their necessity for the R&D dimension of the project and the nature of the uncertainty the evaluation resolves.
- Model deployment
  - In this phase, ML models are deployed onto a system that draws on real world inputs and produced intended outputs. This may be an existing system or one in ex-novo development. The deployment hardware needs to be tested against performance requirements and model performance in production needs to be tested to ensure user acceptability.
  - The deployment face presents challenges of R&D identification that are common to other forms of software development. Similar to the treatment of Phase IV clinical trials in the Frascati Manual, the fundamental issue is the nature of uncertainty resolution that applies in this stage.
- Monitoring and maintenance
  - As previously noted, the activities conducted under this phase have the strongest presumption against being counted as R&D, except when the ML cycle needs to be revamped entirely. The development of new AI systems for automatised monitoring and maintenance is a separate issue that should be dealt with as standalone SD projects.

Several challenges apply to the identification of R&D in ML projects in the face of accelerated adoption[11] and the presence of rapid technical change. The increasing automatization of ML development can result in the effective routinisation of the activities listed above, and potentially call into question the recording of ML projects or major components thereof as R&D. Measurement guidance requires additional cases and examples, like the one presented in **Box 5**.

Box 5. Australia's guidance on self-assessing machine learning activities for the R&D tax incentive

Australia's authorities provide a hypothetical case study laying out how entities using machine learning techniques can assess their activities for the R&D Tax Incentive program. The fictional case study depicts a company that provides digital tools to the agriculture sector using its expertise in predictive algorithm development and machine learning. As the company considers improving its current sensor-based irrigation decision support system (IDSS) with satellite imagery, it considers developing a machine learning model which accurately identifies which satellite imagery data and weather variables predict soil moisture.

The case study depicts a simplified project structure separating between a "preliminary research" and an "experiment" phase and illustrates what types of records the company would be expected to keep regarding decisions, activities and expenditures. The concept of experiment refers to iterations of training the algorithm on datasets with different selected variables and testing the resulting model for accuracy. The records should help the company decide at the end of the financial year which activities are eligible for the tax incentive, by assessing the following elements.

- Uncertainty about the outcome of applying a chosen machine learning training method at the outset of the project. Experts' reviews would not be able to anticipate which combination of variables would address the practical modelling challenges.
- Systematic progressions of work towards a conclusion on the project's hypothesis through experimentation, leading to logical conclusions from the analysis.
- The activity had the potential to generate new knowledge for improving IDSS.

In the guidance, the company self-assesses it can register the experiment as a core R&D activity as well as complementary activities solely or predominantly for the experiment as supporting R&D activities.

Source: OECD elaboration based on Australia's Government "Hypothetical Machine Learning case study". Accessed, January 2025, https://business.gov.au/grants-and-programs/research-and-development-tax-incentive/sector-guides-for-r-and-d-tax-incentive-applicants/software-development/hypothetical-machine-learning-case-study

The follow recommendation stems from the analysis of key features of software development projects and the guidance provided for statistical and administrative purposes.

> ***Recommendation 4:*** *For a software development activity or project to be considered and quantified as R&D, it should meet the 5 Frascati definition criteria. Particular attention should be paid to assessing the requirements of novelty, creativity and uncertainty, which many software development projects do not necessarily satisfy in full or in part. R&D compilers and survey respondents should note that different prototypical phases in a software development project lend themselves to a different R&D characterisation, depending on the nature of the uncertainty that the phase's activities aim to resolve, the methods applied, the intent to generate significantly new knowledge that expands the state of the art in the area. Respondents should be encouraged to keep records that allow them to differentiate between eligible R&D and other activities that may be part of the same software development activity or project. When this is possible, respondents should be encouraged to make reasonable and prudent judgements in their reporting.*

Additional R&D reporting and compilation challenges

R&D attribution when SD contributions are outsourced

The application of R&D criteria must take into account the business and open innovation models used by companies and in particular the outsourcing of SD activities in the context of R&D and SD projects. This also matters for the attribution of R&D (intramural) to the different actors involved. In the case of any software development activity (SDA) conducted by unit A for unit B, if B is outsourcing the SDA as input to an R&D project for which it is responsible, the purchase of such services may be:

- An external (extramural) purchase of R&D services by B, if the SDA conducted by A is a self-standing R&D project, meeting the R&D definition criteria. In that case, the cost of the SDA is intramural R&D for A and not B, even though it is on an accounting basis an R&D expense for B. Unit B may tend to overreport its intramural R&D while there is however an offsetting risk that unit A is not covered in surveys and contributes to total intramural R&D.
- Unit A conducts SDA activities which do not qualify on their own as R&D but are necessary for unit B's R&D project. This should be counted as either current (purchased services) or capital R&D expenditure depending on whether the purchased SD services build an asset for firm B that will be strictly used for R&D in the future. In this case, unit A should not report any intramural R&D performance of its own. However, the attribution to R&D of the cost of the asset resulting from the SDA should depend on whether and how much it might be used for non-R&D purposes.

Identifying specific actors in the population of R&D performers

In addition to this, additional efforts need to be paid to ensuring **adequate coverage in business registers of R&D performers operating in the area of software development**. As noted in OECD (2022), the very ongoing transformation of R&D activity and its apparent re-orientation towards work on developing new software that meets the definition of R&D may contribute to disruption in established sampling practices and weighting schema by industry and size bands.

- Industries traditionally considered to exhibit low R&D intensity and potentially sparsely sampled may at short notice witness the appearance of significant R&D investors through new software development, for example in the areas of agriculture, logistics and finance.
- The emergence of fast-growing start-ups in the area of software development and computer services may take time for registers to detect and reflect in baseline measures of probable R&D performers. These companies may swiftly move from one size band to another in the period spanning from detection to sampling and response gathering.
- Digital intermediary platforms (DIPs). OECD (2019) defines online platforms as “a digital service that facilitates interactions between two or more distinct but interdependent sets of users (whether firms or individuals) who interact through the service via the Internet”. From the perspective of National Accounts, DIPs have been defined more narrowly as “businesses that operate online interfaces that facilitate, for a fee, the direct interaction between multiple buyers and multiple sellers, without the platform taking economic ownership of the goods or rendering the services that are being sold/intermediated”. Online platforms have rather unique technical and economic features related to network, scale and scope effects, and allow them to operate with a relatively small mass of employees relative to turnover or other economic size metrics. Companies in these categories are among today's largest known R&D investors, operating across borders. Digital platforms are also in their own right major providers of services to R&D performers, who use their systems for highly advance data storage and computation purposes. They serve as technological building blocks on top of which innovators can develop complementary products/services.

Following previously introduced guidance; R&D data compilers should exercise care in ensuring that charges for the use of DIPs in their software development activities is not automatically assumed as R&D activity. The same applies to the costs incurred by DIPs in developing and maintaining the infrastructure. Claiming resources devoted to the launch of new infrastructure service offerings should carefully scrutinised against the core R&D criteria. This may require judicious apportionment efforts in terms of drawing a line between R&D and other innovation as well as the demarcation between R&D performance domestically and abroad. Given the size, economic significance and global reach of DIPs, compilers of R&D statistics should develop clear lines of communication with such companies.

The latest revision of the International Standard Industrial Classification includes a more informative category (group 631) “Computing infrastructure, data processing, hosting and related activities” to include activities such as cloud infrastructure and platform provision (Infrastructure as a Service - IaaS, Platform as a Service (PaaS)) and cloud computing (except software publishing and computer systems design) whether or not in combination with infrastructure provision, distributed ledger (blockchain) technology data processing activities and technical infrastructure provisioning services related to streaming.

R&D data compilers should also note that the growing and pervasive importance of general-purpose technologies such as software and AI also risks overstating the number of companies that declare to be doing R&D when in fact the reported activity might just relate to routine software development. This implies that one should treat indicative R&D markers included in generic surveys with great caution until they can be verified in a probabilistic or deterministic fashion.

4 Perspectives for the measurement of R&D personnel involved in software development

For the reasons previously noted, as it occurs with financial resources, human resources devoted to software development activities may be erroneously reported as contributing to R&D. For example, not all technicians or software developers are necessarily “R&D Technicians” in the sense of the Frascati definition for a category of R&D personnel.

However, conceptual and practical considerations apply in the case of measuring human resources devoted to R&D among those engaged in software development activities. There is a clear risk that expenditure and personnel statistics move in mutually inconsistent directions as a result of an increased role of SD in R&D. In the case of measurement of human resources for R&D, there is considerable awareness that surveys need to translate concepts and definitions to the realities of R&D today, since many of the terms that are used for reference and exchange among R&D survey practitioners are not easily understandable in particular by the business community across different industries. Without any additional context, the generic Frascati terms for R&D personnel functions evoke categories that are not necessarily the occupations and functions of a large part of R&D personnel today.

- The term **researcher** does not only comprise individuals in charge of research, but also those in charge of experimental development projects. This is particularly relevant for sectors where experimental development is the predominant form of internal R&D.
- The term **technician** (a category to which the manual adds “and equivalent staff”) does not only comprise individuals employed to look after technical equipment or do practical work in a laboratory, but is pertinent to all those skilled in tasks that are intrinsic to the implementation of R&D activities.
- The category of “**other supporting staff**” also includes skilled and qualified individuals involved in the facilitation of R&D activities, through tasks that represent a service to the R&D.

Some of the guidance gaps in the Frascati Manual were identified in the working paper on reference surveys for the business sector (Galindo-Rueda and Lopez-Bassols, 2022) as identified in the four leftmost columns of **Table 4** below.

Table 4. Guidance on the "translation" of R&D personnel terms to business language and software specificities

FM term for R&D personnel function	Generic problems/ issues	Proposed terminology for business reference survey	Extended clarifications (Some examples may be provided)	Software specificities
Researchers	In the business sector, most of researchers do not do research but actually take care of (experimental) development projects. The term is already absent from many business surveys. (	R&D managers and professionals [i.e. R&D planners and managers]	R&D managers, engineers, scientists, programmers, designers and other professionals with responsibility for the formulation, planning, and/or oversight of R&D programmes, projects or significant parts thereof. The presence of one of these individuals within the firm is necessary for the identification of R&D activity within the company.	Software engineers are likely to be among the leading researchers in several industries, particularly within computer services industries but also among the R&D IT departments Large IT companies are hiring scientists from Computer Science departments and there is a non negligible set of business personnel focused on research as opposed to experimental development.
Technicians and equivalent	The term is not aligned with reality that many individuals on this function are actually software programmers, etc…These are the professionals who get specialised elements of the R&D work done without being engaged on its design/ conception hence the functional focus is on implementation of R&D project tasks.	Scientific, engineering and technical personnel supporting R&D implementation [i.e. R&D project tasks implementers]	Other R&D engineers, technicians, scientists, programmers, designers and other equivalent personnel, in charge of implementing R&D project tasks of a scientific or technical nature under the guidance of, or as specified by R&D managers and professionals. Equivalent to "Assistant professional" category in ISCO.	Junior programmers and data scientists may play this role within R&D teams
Other supporting staff	No reference to R&D in the term. It therefore leaves considerable room for ambiguity.	Ancillary R&D support personnel	Personnel in charge of clerical and administrative tasks directly enabling internal and external R&D activities.	Potentially members of generic IT department providing IT services to R&D department, or those involved in securing access to/use of software and data from third parties. To the extent this is essential for an R&D project, there may be roles relating to ethics (e.g. AI software) and compliance.

Note: Beyond the business sector, the category of technicians and equivalent may also include
Source: OECD, adapted from Table 7.3. in Implementing the OECD Frascati Manual: Proposed reference items for business R&D surveys.

Surveys should provide the relevant cues for the respondents, most likely business contacts in charge of HR records, to be able to identify among their staff with their job categories those effectively qualifying R&D personnel, in particular under the two main R&D personnel categories:

- When it comes to **researchers**, the terms used should make it easy to recognise software engineers and data scientists that fulfil "researcher"-like roles. The personnel (including owners) in charge of experimental development projects with software as target output or substantive activity should not be missed out through the use of the Frascati Manual term of researcher.

- When it comes to **technicians and equivalent staff**, surveys should take into account the variety of specialised technical roles that implement the R&D activity and ensure adequate coverage of junior programmes and data scientists that do play such a role.
- Regarding **other supporting staff**, R&D projects may for example be internally charged for IT services for enabling the likes of data storage, processing, and security. The time of internal personnel in such roles may be charged in part or full to R&D projects. However, R&D records may fall short from showing personnel data and just limit themselves to internal financial transactions.

As in the case of measuring R&D expenditures, caution is required to ensure that the formal R&D criteria are met. There could be considerable misalignments and biases if R&D surveys were to induce respondents to list as R&D personnel all in house programmers working to code software and ensure that software products serve their intended purpose. As already mentioned, not all SD projects will meet the N-C- U criteria. Programmers and other personnel in software teams and companies are also involved with maintaining or making modifications to existing software. In terms of how programmers allocate their time, these activities may not be easy to disentangle from new software development that does qualify as R&D.

> ***Recommendation 5****: In view of the fact that a significant part of the R&D workforce is effectively involved in some form of software development activity, survey practitioners should re-assess whether and how software developers are referred as examples for inclusion and inclusion under the different categories of researchers and R&D technicians, using terms consistent with actual business or organisational practice.*

5 Concluding recommendations and invitation for ongoing feedback

Concluding recommendations

This report has provided insights and recommendations on measuring the contribution of software and related activities to R&D and ensuring the robust and accurate measurement of financial and human resources devoted to R&D in the presence of software development activities. Two additional implementation enabling recommendations are proposed as corollary to those:

> ***Recommendation 6****: National R&D data compilers should equip themselves with custom, specific guidance on software development for use in training their own teams and in written and oral communication with target respondents and their representatives. This guidance should be consistent both with the recommendations in this report and take into account the specific features of the domestic landscape for R&D, including incentives and requirements for record keeping and administrative reporting. While such guidance may be conveyed judiciously and parsimoniously as additional notes and examples in survey questionnaires, its main value stems from its active use as tool for regular interaction in relationship management. R&D survey practitioners should be familiar with SD terminology and potential reporting biases, adapting their communications to prevent potential misunderstandings.*
>
> ***Recommendation 7****: R&D survey practitioners should exchange on guidance and recommendations with providers of related guidance for administrative purposes, such as R&D tax incentives, in order to ensure effective understanding of similarities and differences and gauge potential implications for their respective statistical and administrative purposes.*

Request for ongoing feedback following the 2025 public consultation

Given the considerable feedback and examples obtained from different OECD formal bodies and expert groups in the preparatory stages, and also given the document's relevance to practitioners within businesses, business advisory specialists, professional bodies, standard setting organisations, and several others, it was decided for the first time in the history of NESTI to put a methodological guidance document for public consultation before its formal publication.

The public consultation was launched on February 14th. It was advertised on the OECD website, CSTP and NESTI community spaces, OECD STI newsletter, OECD civil society newsletter, and OECD NESTI secretariat LinkedIn accounts. Given the guidance strong focus on R&D data collection from business, the representatives of the Business Advisory Council (BIAC) at OECD were informed by the OECD Secretariat of the consultation. In parallel, a new webpage in the OECD website[12] was created to advertise and communicate the continuing development of the Frascati Manual, providing access to complementary material such as links to all previous editions of the manual, translations (official and not official) to different languages, and complementary guidance and methodological material. This public website announced and provided access to the consultation on R&D and software development, providing a link to a Microsoft Form with the consultation questions. There were four main questions:

- Does the guidance contained within this document provide a balanced and sufficient guide to assist in the application of Frascati Manual principles to software development to the reporting and compilation of data on R&D?
- Which points in this document you find more valuable and which ones are in your view in need for further elaboration?
- Please state a specific challenge(s) that in your view requires further elaboration in this guidance, describe it and spell out what in your view is the most appropriate approach for handling it in the of reporting R&D data?
- In your view, beyond any required complementary guidance, does the Frascati Manual 2015 edition provide appropriate general guidance for treating software development activities, or are there are elements within the Manual that need correcting to account for specific features of software development?

The public consultation resulted in 10 registered responses. All responses unanimously agreed that the guidance contained within the document provided a balanced and sufficient guide to assist in the application of Frascati Manual principles to software development to the reporting and compilation of R&D statistics. In line with the recommendations in this report, responses also anticipated that respondents and the business community at large, especially SMEs, would necessitate continuous assistance guidance from authorities and expected the pace of technological change to present new situations that would require explicit attention when providing record keeping and reporting guidance.

The responses also hinted at the importance of embedding the guidance on software development in data collection in the Higher Education sector. Several alluded to the case of free and open software, whose use does not represent an addition to estimates of resources devoted to R&D, but whose production, dissemination and curation may be an explicit or implicit element of R&D projects' funding and needs accounting for under the same principles indicated in the Frascati Manual and this report.

Comments on the measurement of R&D personnel echoed the points the report when it comes to software engineers and developers. These may be taken forward as part of the work of the Research and Innovation Careers Observatory that NESTI, a project conducted under the aegis of NESTI. Responses weighing on the continued relevance of the Frascati Manual were supportive of the existing principles but highlighted the potential need to update examples and language, for example by suggesting that references to "websites" could be replaced by "digital content".

Given the absence of requests for substantive edits or corrections, the declassified report has been released as an OECD Technical Paper as complementary guidance to the Frascati Manual within its dedicated webpage. Whilst for the time being NESTI does not envisage undertaking a wholesale revision of the Frascati Manual[13], its intention is to advance as much as possible in developing evidence and complementary guidance that helps address some of the most pressing issues within the framework of the guidelines available in the 2015 edition, so that when a revision is formally launched there is a considerable body of complementary guidance available that already benefits from consensus and evidence on its implementation.

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Endnotes

[1] The IEE defines software as "Computer programs, procedures, and possibly associated documentation and data pertaining to the operation of a computer system." (IEEE, 1990) According to the System of National Accounts, “Computer software consists of computer programs, program descriptions and supporting materials for both systems and applications software”. UN et al, (2008).

[2] See https://www.rdworldonline.com/ai-driven-research-and-development-a-paradigm-shift-in-innovation/ See also OECD(2023) for a specific view on the role of AI in science.

[3] Section J - Information and communication, Division: 62 - Computer programming, consultancy and related activities. https://unstats.un.org/unsd/classifications/Econ/Structure/Detail/EN/27/62

[4] The question states: 5-10 *What percentage of the amount reported in Question 5-2 was for software products or software embedded in other projects or products? See definitions in "Research and development activity in software" under guidance for Question 2-1. Include R&D in software for both packaged software that is sold/licensed to consumers as well as R&D in software for internet applications that generate revenue. This includes R&D in software developed specifically for an R&D project that has no alternative future use as well as R&D in software that is developed to be installed or run in other products sold by the company. Include the total cost of an R&D project with software applications in the calculation for this question, even if the project has other applications. This means that the percentages reported in Question 5-10 to 5-13 could sum to more than 100%.*

[5] Analysis by firm size shows there is no clear pattern of software R&D intensity by firm size alone, although assessing this would require looking at firm size differences within industries in order to avoid confounding effects.

[6] The Frascati Manual states that "In addition to the software that is part of an overall R&D project (to record and monitor its different stages, for instance), the R&D associated with software as an end product or software embedded in an end product could also be classified as R&D when the R&D criteria apply."

[7] See https://stip.oecd.org/innotax/.

[8] One of the most popular development models in modern software stems from agile methodology. This encourages teams to focus on continuous integration, collaboration and testing to develop products.

[9] Austrian Research Promotion Agency officials have suggested as an example for this exception work conducted in the context of an R&D project aiming to resolve access for excluded groups.

[10] See https://arxiv.org/pdf/2003.05155

[11] Furthermore, in order to reduce exposure to external risks, organisations may be enticed to develop their own models in pursuit of the so-called "algorithmic sovereignty", as opposed of adopting functionally equivalent and available "off the shelf" solutions. This may in in turn lead to an increase in the reporting of SD innovation expenditures that might not meet R&D novelty requirements.

[12] See https://www.oecd.org/en/about/projects/frascati-manual-development.html.

[13] The discussion on software and R&D can potentially open broader questions regarding the nature of scientific and technical uncertainty, the requirement that is present in the Frascati Manual, when confronted with intangible objects such as bytes and code, and with practical software applications that transform social systems in very concrete and often measurable ways. These are probably best left for discussion in fora like Blue Sky or potential future major updates of the manual.