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The Development of a New Approach for the Harmonized Multi-Sectoral and Multi-Country Cost Valuation of Services: The PECUNIA Reference Unit Cost (RUC) Templates

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Abstract

Background Increasing healthcare costs require evidence-based resource use allocation for which assessing costs rigorously and comparably is crucial. Harmonized cross-country costing methods for evaluating interventions from a societal perspective are lacking. This study presents the development process and content of the service costing templates developed as part of the European project PECUNIA.

Methods The six developmental steps towards technological readiness of the templates included (1) a common conceptual costing framework and review of methodological costing issues, (2) harmonization strategy formulation, (3) proof-of-concept with expert feedback, (4) piloting, (5) validation, and (6) demonstration in six European countries.

Results The PECUNIA Reference Unit Cost (RUC) Templates for service costing are three new self-completion tools to be used with secondary or primary data for top-down micro-costing or top-down gross-costing approaches. Complementary data collection and unit cost aggregation/weighting templates are available. The applications leading to the final versions including (4) piloting through calculation of 15-unit costs, (5) validation within a Health Technology Assessment framework, and (6) RUC calculations mostly based on secondary data demonstrated the templates' general feasibility, with feedback for improved usability incorporated and a supplementary user guide developed.

Conclusion The validated PECUNIA RUC Templates for multi-sectoral and multi-country service costing allow for harmonized RUC development while incorporating flexibility and transparency in the choice of costing approaches, data sources and magnitude of remaining heterogeneity. The templates are expected to significantly improve the quality, comparability and availability of unit costs for economic evaluations, and promote the transferability of service cost information across Europe.

1 Introduction

In an effort to support the sustainability of their healthcare systems, the European Union (EU) initiated the implementation of more consistent health-technology assessment (HTA) methods among its members [4], resulting in a regulation on HTA [5]. HTA is an evidence-based process assessing and comparing technologies, covering both the clinical (e.g. effectiveness) domain and additional non-clinical (e.g. economic) aspects [5]. However, cost and economic evaluations in HTA are still considered to be embedded in the context of the healthcare system and remain at national level according to the regulation, which ties the validity of the results to

individual countries [6]. The harmonization of the evaluation methods across member countries is thus an important step in the promotion of HTA by making results transferable and improving the efficiency of economic evaluations [7].

In a European survey, an important barrier to the uptake of HTA evidence according to HTA researchers and policy makers was insufficient quality of applied costing data [8]. Estimating costs in the course of an economic evaluation involves multiple steps, including the identification of relevant resource use, its measurement, and finally, the valuation of each unit of resource use [9] via unit costs. Unit costs, i.e. the average monetary value of unit of service use [10], are a key ingredients in economic evaluations, whose quality also depends on the quality of the cost assessment [11]. However, a universally accepted unit costing methodology does not

Extended author information available on the last page of the article

Key Points for Decision Makers

Cross-country and cross-sector standardization in unit costing methodology is essential for comparable high quality (multi-national) economic evaluations adopting the societal perspective.

The PECUNIA RUC Templates for service costing facilitate the standardized development of reference unit costs by completion based either on available secondary cost information or data primarily collected for costing purposes.

Their application allows the standardized, comparable and transparent valuation of services across sectors and countries.

Developed RUCs are collected and available in a PECUNIA RUC Compendium.

exist, neither for resource use in the healthcare sector nor for other sectors affected by the spill-over costs and effects of healthcare interventions [12]. Other sectors may include the education and (criminal) justice sectors and patient and family domain (e.g. informal care) [12], and estimating such spill-over costs is becoming increasingly important in light of the increasing adoption of the societal perspective in economic evaluations [13, 14]. While unit costs in the healthcare sector were found to be highly dependent on their calculation method (e.g. [13]), similar heterogeneities in costing methods also apply to other affected sectors [15]. As a consequence of methodological differences, unit cost estimates in economic evaluations are often not comparable across sectors, studies, and countries [16–18], potentially leading to non-optimal study conclusions.

Detailed guidelines and practical tools for standardized cross-sector and cross-country unit cost calculations are currently sparse [19], while insufficient quality of applied costing data was found to be an important barrier to the use of HTA evidence in a European survey [8]. In some countries, initiatives with readily available national-level unit cost estimates have been implemented which facilitate and standardize health economic evaluations, such as in the United Kingdom (UK) (e.g. [20–22]) and the Netherlands (e.g. [23–28]). These unit cost programmes typically adopt a country-specific methodology and mostly focus on resource use in the health and social care sectors [12]. In the absence of pre-developed unit costs, the Microsoft Access-based Preventonomics Unit Cost Calculator (PUCC) allows to generate unit costs for health and social care services and interventions in the UK [29]. However, this cost calculator does not incorporate a comprehensive cost data collection

approach, e.g. for primary data, and does not cover services outside the health and social care sectors.

The European research project PECUNIA's (2018–2021) aim was to address the aforementioned challenges in the generation of unit costs and “establish standardised costing assessment measures for optimised national healthcare provision in the European Union” [30]. This initiative is in line with the recommendation made by Frappier and colleagues to “reduce the significant bias process involved with costing” ([31], p. 598). In their view, an independent group with health economic and economic evaluation expertise should be mandated for the production of standard country-level unit costs accessible to national and international researchers and decision-makers [31].

PECUNIA included activities related to the harmonized costing of resource use in the health and social care, education, (criminal) justice and employment sectors and the patient, family and informal care domain. In parallel, four other activities aimed to harmonize the entire process involved in costing. These harmonization efforts aimed to address methodological issues related to the identification, definition and description (e.g. ambiguity of service content), measurement (e.g. units of analysis in questionnaires not aligned with the units of costing data) and valuation of resource use in all sectors.

For the health and social care sectors, first, a comprehensive international list of available services within health and social care for use in costing studies was developed [32, 33]. Second, the unambiguous definitions and descriptions of these services were established [33] using the Description and Evaluation of Services and Directories (DESDE) international coding system [34]. This step is relevant as services with the same name may carry out different activities in different healthcare systems. DESDE allows for a specification of services based on their activities (which is closely linked also to their costs) via codes as a common, standardized ‘language’ and was extended to sectors beyond health and social care in PECUNIA. Third, based on the list of services and their codes, questionnaire modules for assessing health and social care service use from patients in trial-based economic evaluations were designed for inclusion in the PECUNIA Resource Use Measurement (RUM) Instrument [35, 36]. Fourth, for harmonized resource use valuation of these services, multiple Microsoft Excel-based costing templates for Reference Unit Cost (RUC) calculations were developed (PECUNIA RUC Templates) and designed for use together with the PECUNIA RUM [37]. In the final phase of the project, the PECUNIA calculation templates were applied in selected European countries to estimate country-specific RUCs stored in an international, multi-sectoral electronic compendium (PECUNIA RUC Compendium) [2, 3].

This paper aims to present the methodological development process and the core content of the PECUNIA RUC

Templates for service costing, a new approach for the harmonized multi-sectoral and multi-country valuation of services. Specifically, we describe the development steps of the templates along the European Union's (EU) nine-stage Technology Readiness Levels (TRL) framework [38], including their expert assessment, piloting and application and validation for HTA across six European countries (Austria, AT; Germany, DE; Hungary, HU; the Netherlands, NL; United Kingdom, UK; Spain, ES). By outlining the foundation of the templates, this paper contributes to increasing the methodological transparency in unit cost development, currently often remaining a black box in practice [39]. Furthermore, an overview of the development steps involved may also be vital for countries, e.g. in low and middle-income contexts, which have yet to establish relevant costing instruments and systems.

2 Methods

The stepwise TRL development process of the PECUNIA RUC Templates for service costing (January 2018 to June 2021) is presented in Fig. 1. It depicts the progress ranging from observing the basic principles (TRL 1), formulating the concept of the templates (TRL 2), proofing the concept and seeking external expert feedback (TRL 3), validating the templates in a multi-country pilot study (TRL 4) to, finally, validating (TRL 5) and demonstrating (TRL 6) the templates in the relevant environments in six countries [38]. Implemented as part of the EU's Horizon 2020 work programme to outline the scope of its calls, the TRL framework provides a consistent and uniform point of reference for understanding the current degree of maturity of the templates [38] and consequently, what processes are still outstanding for their full 'readiness' [40].

2.1 TRL 1: New Costing Concept and Scoping Review

Methodologically, all PECUNIA RUC Templates were conceptualized on the basis of two main sources. First, the PECUNIA costing concept based on Donabedian's process of care [41] distinguishes between different types of costs impacts related to health and social care. These may include costs related to organisational inputs [i.e. services, such as general practitioner (GP) consultations and special education], personal inputs (i.e. time or money, such as informal care and out-of-pocket expenses), or outputs (i.e. tangible consequences, such as vandalism and household productivity) to avoid the potential problem of double-counting in economic evaluations. The PECUNIA RUC Templates follow this categorization with specific templates developed for service costing, the main focus of the current paper. Services were defined as follows: "At the micro-organisation level [a service] describes a combined and coordinated set of inputs (including structure, staff and organization) that can be provided to different user groups in a given sector (e.g. education) and under a common domain (e.g. child care), to improve the individual or population [health] status and/or functioning, or to attain a set of defined goals within a given sector" [42]. Unit costs were defined as the average monetary value of unit of service use (e.g. contact) [10]. The specification 'reference' unit cost (RUC) refers to the standardized methodology across sectors and across countries that was applied in the PECUNIA costing approach [27, 43].

Second, a scoping review (covering years 2008–2018, updated in 2021) was conducted [12, 44] to inform the development of the PECUNIA costing tools by generating an overview of the most relevant areas for harmonization in multi-sectoral and multi-national costing processes for health economic evaluations. Relevant literature from six PECUNIA partner countries (AT, DE, ES, HU, NL, UK) served as a basis to describe issues in costing that may impair the comparability of unit costing and may have to be addressed in the PECUNIA costing templates. Problematic

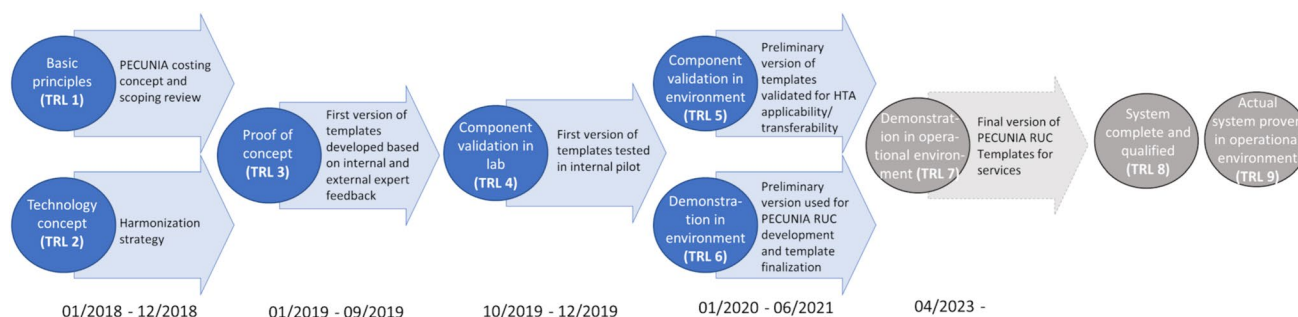


Fig. 1 Development steps of PECUNIA RUC Templates for services costing (2018–2021) along the Technology Readiness Levels (TRL) framework. HTA, health technology assessment; RUC, Reference Unit Cost

areas identified in the scoping review included double-counting of costs between sectors, intransparency in the costing approaches, differences in inclusion and handling of overheads costs or adjustment of unit costs for inflation [12, 44].

The scoping review, together with the DESDE coding system as adapted to PECUNIA [34], and earlier work steps in the PECUNIA project for the identification, definition and measurement of resource use [12, 33, 45], formed the basis for the proof-of-concept strategy development for the harmonized valuation of resource use (TRL 2).

2.2 TRL 2: Harmonization Strategy Formulation

Building on TRL 1, the PECUNIA work team responsible for resource use valuation developed the harmonization strategy for valuation, which included three aspects. First, it contained general suggestions for developing harmonized RUC Templates across resource use item categories from a reporting and formatting perspective and regarding their structure, i.e. the organisation of the templates in different modules. Second, it provided guidance on the harmonization of the PECUNIA RUC Templates content [12] by giving cross-sector and cross-country harmonized methodological recommendations, including

- (i) the compliance with fundamental economic and accounting concepts [46] and their transparent reporting [16] for a sound and replicable methodological foundation;
- (ii) the application of the long-run marginal opportunity cost principle [47] to reflect the full economic implications of the used resources by including, for example, overhead costs;
- (iii) the incorporation of different costing approaches (gross-costing/micro-costing) [7] to recognize their different appropriateness depending, for instance, on varying data availabilities.

Third, recommendations included the application of unified terminology and definitions. These terms and codes were developed within the new costing concept with RUCs now based on equivalence of services in terms of their activities rather than semantic interoperability [32] through application of the international DESDE coding framework [34] for PECUNIA.

2.3 TRL 3: Proof of Concept

The aim of TRL 3 was to demonstrate the general feasibility of the templates. The initial versions of the PECUNIA RUC Templates for service costing were developed at the Department of Health Economics (Center for Public Health)

at the Medical University of Vienna (MUV). The PECUNIA Group is a team of 38 international experts in the field of health economics, HTA costing, health services research and medicine from various European countries and health systems with different HTA systems. It was supported by an international Scientific Advisory Board (SAB) including representatives of policy makers, payers, providers and service users/carers. The SAB provided feedback throughout the different development stages in the course of multiple consortium meetings and exchanges.

International unit costing calculators and/or existing programmes (as of 2018–2019) served as illustrative examples in the development phase (e.g. [20–27, 48, 49]). In addition to the PECUNIA scoping review covering all sectors [12], the HealthBasket literature review [50] provided a comprehensive overview of relevant methodological issues regarding the valuation of health and social care services.

The focus of the PECUNIA costing templates was to enable harmonized and transparent RUC calculations that capture all relevant economic implications of the service delivery. Hence, in the templates, all relevant resources (e.g. staff, organisational overheads) to provide an average unit of the service were considered on the basis of the annual full costs of the service provision. In line with the full cost recovery theory [10], researchers should capture all relevant cost components including variable and fixed costs, or – if this is not possible – transparently document if data on any cost category (e.g. overheads) are missing. This approach potentially also allows for the development of average overhead rates (i.e. the presentation of overhead costs as a percentage of staff and other direct cost), which could be used for imputation when such direct information is unavailable for a comparable service.

For external feedback on the first version of the PECUNIA RUC Templates for services, two experts were consulted to explore the construct and content validity of the templates. First, a health economist at the London School of Economics and Political Science with longstanding experience in the unit cost development of health and social care services was taken counsel for peer feedback in an online meeting. Second, a cost accountant at the Vienna University of Economics and Business was contacted for a written methodological assessment from a cost accounting perspective against the purpose of the PECUNIA Service RUC Templates.

2.4 TRL 4: Piloting

As a first validation step, the initial versions of the PECUNIA RUC Templates for service costing were piloted in five PECUNIA countries (AT, DE, HU, NL, UK) for three services (GP consultation in a single practice/per contact; daycare centre for mentally-ill patients/per day; education

services provided in a special education school/per school day) in three sectors (health, social care, education) [37]. The choice of countries reflects different types of healthcare systems (e.g. tax-funded/social insurance-funded, different levels of costing guidance for economic evaluations, availability of unit cost catalogues). The services were selected from different sectors to represent important resource use items common in a health economic evaluation from a societal perspective and allowing for the potential application of all developed templates. The limitation to three services was due to the 3-month time frame of the piloting phase.

All templates were tested on the basis of available secondary national data (not older than 10 years) and/or by collecting primary data (i.e. cost data on an aggregated level) from individual service provider(s). As a follow-up step, feedback was sought to validate the data inputs and the costing templates, addressing their validity and feasibility (e.g. practicality, efficiency, acceptability [34]) based on oral or written feedback from the completing person(s) along the aforementioned dimensions.

For primary data, service providers filled out the data collection sheets, followed by a feedback round between the researcher and service provider. The costing templates were completed by the PECUNIA partners based on the service provider's data inputs. For secondary data, the costing templates were completed by the PECUNIA partners first and the calculated RUCs discussed with the relevant national data host (e.g. national statistics office) for feedback. The written feedback together with the completed costing templates were shared and discussed in a joint PECUNIA online meeting, and translated into relevant suggestions incorporated in the revised version of the templates.

2.5 TRL 5: Validation

In TRL 5, the PECUNIA RUC Templates were validated for feasibility and geographical transferability and applicability within an HTA framework in Spain (Spain was not involved in the original development). The PECUNIA RUC Templates for service costing were tested and used to estimate unit costs for eight services in three sectors (health, social care, education). The choice of services and sectors followed the principles outlined for the services selected for the piloting (TRL 4) and matched the selection of services in TRL 6.

The evaluation of the RUC templates involved (i) a usability assessment (based on System Usability Scale to assess the user experiences with the templates [51]); (ii) their transferability assessment (adapted from EURONHEED tool [52] addressing the identification, description, measurement and valuation aspects of the templates); and (iii) feasibility assessment (adapted from Bouwmans et al. [53] focusing on response rates, completion time and data completeness by an applicability test) including semi-structured interviews

with data providers. Furthermore, external validation steps of developed RUCs by comparison with existing estimates and focus group discussion with six Spanish experts on the relevant PECUNIA methods and tools were conducted [54].

2.6 TRL 6: Demonstration

In parallel to TRL 5, the PECUNIA partners applied the PECUNIA RUC Templates to develop RUCs for a core set of services in different sectors in their country [2], thereby further demonstrating the usability of the PECUNIA RUC Templates. The application included an external validation process of the RUCs via comparison with similar service unit costs, and feedback from experts, service or data providers. In total, 36 externally validated RUCs for five health and social care services (GP, dentist, help-line, daycare centre, nursing home) [2] and 16 RUCs for three services in the education sector (education services provided in a special education school, educational therapy provided in primary schools, educational therapy provided in secondary schools) [55] in six countries (AT, EN, DE, HU, NL, ES) were calculated. These RUCs together with their extensive meta-data were published in the PECUNIA RUC Compendium [2, 3]. Here, any deviations from the fully harmonized costing standards and reflecting the outcome of the external validation process are visible in the 'certainty index' included for each RUC as a three-level summary indicator. For instance, low certainty may stem from not fully fulfilling the PECUNIA costing standards and consideration as a doubtful unit cost estimate or no validation outcome available [2].

3 Results

3.1 TRL Key Findings

As the outcome of TRLs 1, 2 and 3 – i.e. the initial versions of the PECUNIA RUC Templates for service costing – separate Microsoft (2013) Excel-based worksheet templates were developed (in English) for top-down micro-costing and top-down gross-costing following a modular structure. To facilitate primary and/or secondary data collection, complementary data collection sheets, also organized in modules, were developed. For the harmonized summary of unit costs from multiple service providers into a single, aggregated RUC, an auxiliary RUC Aggregation/Weighting (RAW) data sheet was created.

In the external feedback loop conducted as part of TRL 3, the expert in unit costing methods concluded that after completion of the RUC development process, it would be crucial for the user to critically reflect on the calculated unit cost. Consequently, a respective note prompting the user to do so was included at the end of the costing templates.

The expert further stressed the importance of the planned country-level piloting and testing to identify challenges from an applied perspective. The second expert, a cost accountant, confirmed the validity of the structure of the templates and the appropriateness of the captured cost components including overhead costs based on an exemplary list. The allocation of overhead costs in the template based on the average principle was considered simple, yet correct, and the best choice for the given purpose, according to the expert. Finally, this expert speculated that the current opaqueness of unit cost estimates that motivated the PECUNIA project may not be accidental from a data provider's perspective, but in line with potential fears of benchmarking and competition.

In the pilot of the draft templates (TRL 4) in five PECUNIA countries, all PECUNIA partners managed to successfully complete the costing templates and develop 15 unit cost estimates [37]. However, in this calculation process, the original classification of funding types (public, private for-profit, private non-profit) collected as part of the service description module was not always clear to the individuals who completed the templates. Therefore, the funding categorization was revised in the final version of the templates to 'publicly funded (state-/social insurance)', 'privately funded' (funded through private expenditure, e.g. supplementary health insurance) and 'other' funding sources (e.g. donations). Furthermore, some service providers found it challenging to allocate direct and overhead costs in line with the data collection sheets. Hence, the homogeneity of the numerator and denominator in the data inputs (i.e. direct and overhead costs following identical definitions and including comparable cost components) was not always given in the pilot test, which hinders the calculation of an overhead rate. Especially in non-English speaking countries, the cost accounting language (in English) was perceived as difficult by some providers. Finally, to accommodate the availability of high-level cost data in practice, separate short-form versions of the top-down gross-costing templates focussing on the minimum unit cost calculation inputs and details were created.

The time needed for completion of the costing templates during the pilot phase (mean completion time: 39 min, ranging between 13 and 90 min) varied depending on data source of the RUC calculation: if based on secondary data, the mean time needed for completion of the unit cost template by the national PECUNIA partners was 54 min (15–90 min); if based on primary data, the mean time needed for completion of the data collection sheet by one service provider was 28 min (13–60 min) and the additional mean time needed for completion of the unit cost template by the national partners 18 min (13–30 min). For primary data collection, these estimates, however, exclude any additional time spent, e.g. on searching for service provider contacts and convincing them to provide data. Also, data collection from more than

one service provider multiplies the necessary efforts related to primary data collection.

In the Spanish validation study conducted as part of TRL 5, the PECUNIA RUC Templates for services were generally deemed feasible in practice, with data completeness depending on the type of data needed to estimate the cost. The respondents criticized the level of data detail required for the top-down micro-costing approach, supporting the necessity for the abovementioned short version of templates. Furthermore, the templates were found to be highly feasible when completed by health economists and HTA researchers, indicating the need for a user guide, especially for non-experts. Detailed findings of the Spanish validation study are available elsewhere [54].

In parallel to TRL 5, the draft templates were applied in the PECUNIA countries for RUC calculation (TRL 6) [2]. The majority of the RUCs calculated in 2021 were based on secondary data – a consequence of the onset of the coronavirus disease 2019 (COVID-19) pandemic that hindered primary data collection. The RUCs together with their extensive meta-data including the 'certainty index' were published in the PECUNIA RUC Compendium [2, 3].

Based on the experiences made in the demonstration phase, final revision efforts focused on further harmonization between all PECUNIA costing tools, including the addition of a new 'adjustment' module on inflation/currency conversion. This module automatically calculates an inflated RUC estimate following Turner et al. [56] when the necessary information (consumer price index, original year, reference year) is filled in. It also aids the researcher in converting the unit cost estimate to euros. A comprehensive user guide was developed to complement the templates.

3.2 Final Version of the PECUNIA RUC Templates for Services

The current system prototype PECUNIA RUC Templates for services are a Microsoft Excel® (2013)-based set of unit cost calculation tools using standardized and scientifically validated methods at TRL 6 for multi-sectoral and multi-country service costing in Europe. The templates are intended for self-completion by end-users seeking to develop comparable service unit costs across sectors and countries – RUCs – in any sector and any European country for health economic evaluations of health interventions.

The PECUNIA RUC Templates for service costing include the "SERVICE-1 top-down micro-costing template", the "SERVICE-2 top-down gross-costing template" and the "SERVICE-2 short form top-down gross-costing template" to calculate a RUC for a single provider/data source based on different costing approaches depending on data availability, data collection feasibility and the purpose of the costing exercise [7, 39]. Auxiliary data collection

sheets (“SERVICE-1 data collection sheet”, “SERVICE-2 data collection sheet”, “SERVICE-2 short data collection sheet”) mirror the required data inputs from primary data collected from service providers, secondary data provider, or a combination of both for completion by the data provider. The RUC Aggregation/Weighting (RAW) data sheet (“SERVICE RAW data sheet”) facilitates the harmonized aggregation and weighting of the data inputs collated in the service templates to transform one RUC from multiple sources to a representative RUC and documents its external validation process. A supplementary user guide with step-by-step instructions on how to use all PECUNIA RUC Templates including recommendations on data collection and aggregation is available [57]. Figure 2 illustrates the workflow for calculating a RUC with the PECUNIA RUC Templates for services, including the foreseen sharing of any developed RUC and non-confidential meta-data via the “PECUNIA RAW data sheet” for inclusion in the PECUNIA RUC Compendium.

An overview of the three PECUNIA RUC Templates for service costing is presented in Table 1. A full sample of the final “SERVICE-1 top-down micro-costing template” is available on Zenodo [1]. Each PECUNIA RUC Template for services is structured along the same core modules mainly resulting from the work as part of TRLs 2 and 3, varying in the level of detail within the seven modules (SERVICE-1

and SERVICE-2) or four modules (SERVICE-2 short). In the “SERVICE-1 top-down micro-costing template”, detailed resource use data are collated to calculate various RUCs of an average direct client contact (e.g. face-to-face at service provider location), for instance, a RUC per GP consultation in the physician’s practice. In the “SERVICE-2 top-down gross-costing”/“SERVICE-2 short” templates, more aggregated data are collated to calculate a RUC per average service unit (e.g. day, night) [7, 39], for instance, a RUC per day at a day-care centre. Descriptions of the modules included in the templates are provided in Table 2.

4 Discussion

The PECUNIA RUC Templates for services [1, 37, 57] are a novel one-stop toolbox covering all essential cost valuation steps from data collection to aggregation for harmonized unit cost calculation of service RUCs from the societal perspective and across countries. The templates introduce full transparency in the unit cost development by detailing the different relevant elements (e.g. unit cost year, sources, included cost components) in the calculation, which otherwise often remain a black box [16, 39]. Additionally, a comprehensive supplementary user guide with step-by-step instructions has been developed [57]. Potential end-users

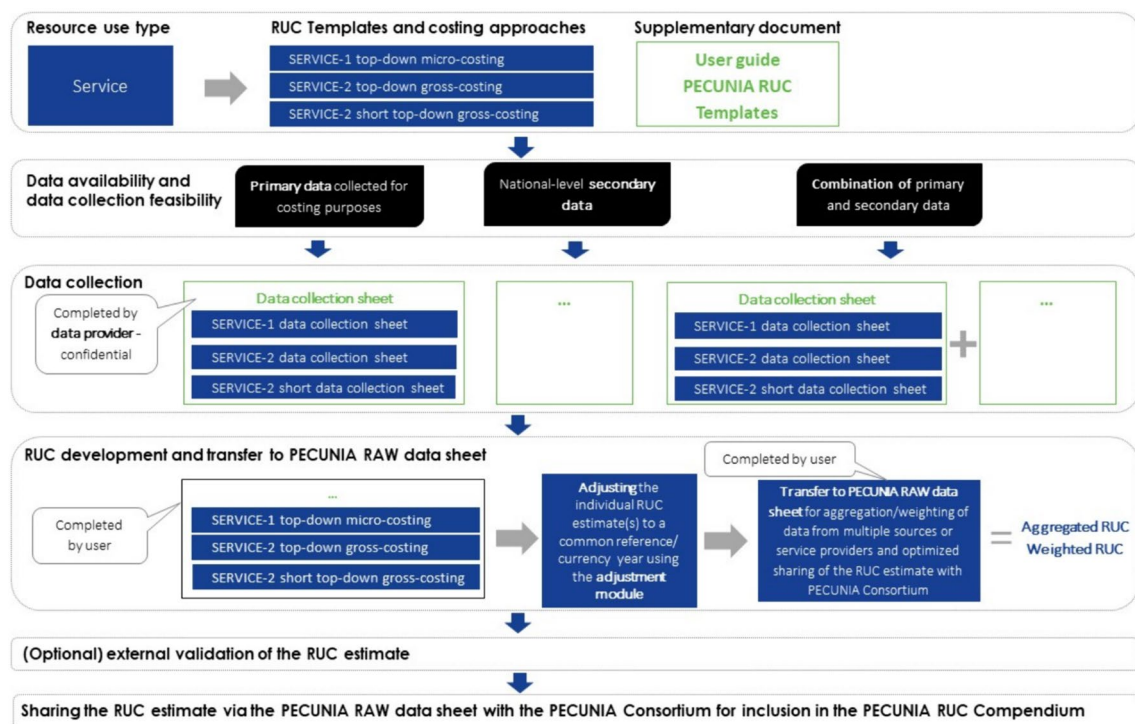


Fig. 2 PECUNIA Service Reference Unit Cost (RUC) calculation workflow process. RAW, Reference Unit Cost aggregation/weighting (RAW) data sheet

Table 1 Characteristics of the final PECUNIA Reference Unit Cost (RUC) Templates for service costing

RUC calculation based on: ⇒	SERVICE-1 template	SERVICE-2 template	SERVICE-2 short template*
Costing approach	Top-down micro-costing	Top-down gross-costing	
Unit of service use measurement	Direct client contact (e.g. consultation in minutes of face-to-face contact between the client and service provider, excluding non-face-to-face time)	Night, day, contact etc.	
Calculated unit cost	By setting: - Face-to-face contact at service provider location, excludes travel (by service provider) - Face-to-face contact at other location, includes travel (by service provider) - Face-to-face contact at client location, includes travel (by service provider) - Face-to-face contact at public location, includes travel - Via telephone contact - Online contact - Average of above	Per specified measurement unit (as above): e.g. night, day, contact	
Data sources for calculation	Secondary data and/or primary data		
Data collection sheet	“SERVICE-1 data collection sheet”	“SERVICE-2 data collection sheet”	“SERVICE-2 short data collection”
Number of template modules	7	7	4
Modules and cost components	<ul style="list-style-type: none"> - Basic characteristics of the resource (use) item including relevant information to specify a DESDE, ESCO or ICHI code (if available) (module 1) - Basic unit cost information (module 2) - Service team costs (direct costs), excluding administrative staff (module 3a) - Contact setting and direct client-related time for client resource use in minutes/hours: total for service (module 3b) - Other direct costs for service delivery not included elsewhere (module 4) - Overhead costs (including administrative staff costs) for service delivery: capital overheads (e.g. rental charges), non-capital overheads (e.g. management) (module 5) - Unit cost calculation inputs (totals) (module 6a/3a*) - Unit cost calculation results (module 6b/3b*) - Adjustment (module 7/4*) 		
Aggregation and external validation	“SERVICE RAW (RUC aggregation/weighting) data sheet” to aggregate estimates from multiple sources to calculate a single RUC; also for documentation of the external validation process		

DESDE, Description and Evaluation of Services and Directories; ESCO, European Skills, Competences, Qualifications and Occupations; ICHI, International Classification of Health Interventions

include researchers, health professionals, pharmaceutical industry and policy-makers. Following registration, the PECUNIA RUC Templates are free to use for non-commercial research purposes in healthcare and academic teaching activities [57], on the condition that any developed RUCs are shared with the research community via the PECUNIA RUC Compendium [2, 3]. Beyond the novelty of the final costing templates themselves, to the best of our knowledge, this is also the first study that explicitly followed the pre-defined

TRL steps in developing such tools and achieved harmonization across multiple costing tools including resource use measurement and valuation instruments.

Applications of the PECUNIA RUC Templates for service costing in practice as part of this research demonstrated that the methods are generally feasible and suitable for calculating RUCs but highlighted two main challenges in the harmonized RUC development. First, the differentiation between public and private for-profit and non-profit service

Table 2 Module content of the PECUNIA Reference Unit Cost (RUC) SERVICE-1, SERVICE-2 and SERVICE-2 short templates

Module description	Module no. in SERVICE-1, SERVICE-2 and SERVICE-2 short* template	Short description of the module's purpose
Basic characteristics of the resource (use) item	Module 1	This module collates basic characteristics of the service required for international comparability. It includes the specification of a DESDE, ESCO and ICHI code for the service. Using such typologies and classification systems such as DESDE allows for defining and describing the service based on the activities. The units of measurement of services and funding sources collated in Module 1 are aligned with the PECUNIA RUM instrument
Basic unit cost information	Module 2	This module compiles basic unit cost information on cost data inputs and sources relevant for the interpretation of the RUC (e.g. year, currency, country, details on data type and source)
Service team costs (direct costs), excluding administrative staff (to be included in module 5)	Module 3a	In the SERVICE-1 template, this module guides the user through the direct staff cost calculation (excluding administrative staff, which is covered separately in module 4) and develops a direct-to-indirect working time multipliers per professional groups (i.e. time spent directly working with clients versus any tasks related to service delivery not including direct client contact, e.g. preparatory activities). In the SERVICE-2 template, this module gathers data for the direct staff cost calculation (excluding administrative staff, which is covered separately in module 4), and data on direct to indirect working time is not collated
Contact setting and direct client-related time for client resource use in minutes/hours: total for service (SERVICE-1)/type of contact for client resource use (e.g. nights, days) (SERVICE-2)	Module 3b	In the SERVICE-1 template, this module collects costing information on direct client-related time for client resource use by various contact settings. In the SERVICE-2 template, this module collects the total number of client contacts as well as their measurement unit (e.g. nights, days)
Other direct costs for service delivery not included elsewhere	Module 4	This module gathers any other (annual) costs that are directly attributable to the service not included in modules 3a, 3b or 5, e.g. car and travel costs of the service provider and other direct costs
Overhead costs (including administrative staff costs) for service delivery	Module 5	This module assists the user in specifying the overhead costs. Overheads are a variety of costs indirectly related to the service delivery but not directly allocable, divided into the subcategories capital overheads (e.g. rental charges) and non-capital overheads (e.g. management). The user is requested to specify what elements of (overhead) costs are included
Unit cost calculation inputs (totals)	Module 6a/3a*	This module automatically summarizes the data needed to calculate the RUC entered in previous modules. As in the other modules, the user is asked to specify the included cost components for transparency
Unit cost calculation results	Module 6b/3b*	This module is completely automated and displays the developed RUC per average direct client contact based on the contact duration and direct-to-indirect time ratio specified in module 3b (SERVICE-1) or per average client contact (SERVICE-2/SERVICE-2 short)
Adjustment	Module 7/4*	This module allows to automatically calculate an inflated RUC estimate in Euros and aids the conversion from local currencies to euros (51)

DESDE, Description and Evaluation of Services and Directories; ESCO, European Skills, Competences, Qualifications and Occupations; ICHI, International Classification of Health Interventions

provision as in the preliminary version of the PECUNIA RUC Templates for services seemed not clear to the individuals completing the templates. At the same time, this information on public and private organisation funding is likely unknown to the individuals completing the PECUNIA RUM. To align the PECUNIA measurement (RUM) and valuation (RUC) tools, the final version of the templates therefore differentiates between publicly funded (state-/social insurance) services, privately funded services (e.g. out-of-pocket expenses) and other funding sources (e.g. donations). All services measured in the PECUNIA RUM may then be valued based on the applicable service funding in a country (e.g. RUC for a state-/social insurance-funded service, RUC for a privately funded service, or a representative weighted mixed RUC). Second, developing overhead rates that are transferable, for example, between services within the same sub-sector to allow for imputation of missing overheads may prove difficult in light of the different cost accounting standards applied in practice. The validity of such an overhead rate depends on the homogeneity of the numerator and denominator in the data inputs (i.e. direct and overhead costs following identical definitions and including comparable cost components), which may not always be given. The type of relevant (overhead) costs contributing to a service could differ, for example, also between countries.

The development process also highlighted issues that go beyond the templates themselves and are major hurdles to overcome in any unit cost calculation exercise. First, while the methodology implemented in the SERVICE data collection templates was considered as valid by costing experts, reservations about data protection issues and competitive reasons may prevent service providers from sharing their data, as also confirmed by the external cost accounting expert consulted for this study. This point further highlights why government mandates for costing and costing methodologies are indeed needed. Ultimately, the feasibility of the templates depends on data availability. Second, if secondary data of sufficient and transparent quality and timeliness, including all relevant cost components such as overheads, are available, unit cost calculations based on national-level data may be preferable due to their inherent representativeness and significantly lower workload on the researcher's part, especially if primary data from multiple service providers is needed. Reliance on secondary data, however, may have the downside of higher dependence on cooperation by national stakeholders, such as ministries, payers and statistical offices, to gain access to data, with the necessary level of detail, beyond the public domain.

5 Strengths and Limitations

The PECUNIA RUC Templates for services allow for the automated, step-by-step calculation of standardized RUCs, while providing flexibility in the choice of the costing approach and data sources and promoting transparency in the unit cost development process. Such a tool will also allow for more efficient future updating of calculated RUCs based on more up-to-date data, which is especially important in times of internationally fluctuating input costs (e.g. power, gas). With the incorporation of DESDE in the templates, the PECUNIA costing tools address the issue in international comparability of resource (use) items based on names, which is essential in cross-country comparisons [16]. The PECUNIA service RUC Templates are linked with the PECUNIA RUM [35], with the units of analysis (e.g. per day, per contact) matching between the instruments. This link will enable future patient-reported resource use measurement, e.g. in clinical trials, and valuation of services based on multiple coordinated tools, thereby filling a gap in the international health economics toolbox. Indeed, external health economists regarded the compatibility within the PECUNIA costing tools as one of the major strengths of the PECUNIA RUM [36].

The PECUNIA RUC Templates for service costing were developed in English language. While this should not be a main barrier for research use, it may pose language barriers with non-English speaking service providers. Future translations of the data collection sheets into national languages may therefore be necessary. Following – pre-planned – the TRL processes for the development and implementation processes of the templates was helpful in guiding and informing the necessary steps; further, having reached TRL 6 implies that the related technology is fully developed but not yet widely deployed. The PECUNIA RUC Templates have already been taken up by another research project (STREAMLINE – establishing a reference unit costs catalogue for the optimized evaluation and planning of mental healthcare in Vienna; 2023–2025) [58], which aims to further test the templates especially with regards to primary data collection and increase their TRL to level 7 through system prototype demonstration in an operational environment.

6 Conclusion

The PECUNIA RUC Templates for service costing allow for harmonized RUC development while incorporating flexibility and transparency in the choice of costing approaches, data sources and magnitude of remaining heterogeneity. The services for which RUCs are calculated can be defined and compared based on their activities using DESDE codes with

the relevant patient-reported resource use measured in the complementary PECUNIA RUM. Next steps in the template development may include the extension of the RUC calculation to other services, sectors, EU countries and regions in the world. Any future application of the templates will be a step towards closing the gaps in Europe's harmonized unit cost development.

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Ethics Approval Not applicable.

Consent to Participate Not applicable.

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via Zenodo [1]. Following registration, the PECUNIA RUC (Reference Unit Cost) Templates are free to use for non-commercial research, healthcare, and academic teaching activities [1] with the condition that the calculated RUCs are shared with the research community via the PECUNIA RUC Compendium [2, 3]. Anyone interested in using the PECUNIA RUC Templates commercially may contact the developers first.

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