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Answering Current Challenges of and Changes in Producing Official Time Use Statistics Using the Data Collection Platform MOTUS

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The modernization of the production of official statistics faces challenges related to technological developments, budget cuts, and growing privacy concerns. At the same time, there is a need for shareable and scalable platforms to support comparable data, leading to several online data collection strategies being rolled out. Time Use Surveys (TUS) are particularly affected by these challenges and needs as they (while producing rich data) are complex, time-intensive studies (because they include multiple tasks and are administered at the household level). This article introduces the Modular Online Time Use Survey (MOTUS) data collection platform and explains how it accommodates the challenges of and changes in the production of a TUS that is carried out in line with the Harmonized European Time Use Survey guidelines. It argues that MOTUS supports a shift in the methodological paradigm of conducting TUS by being timelier and more cost efficient, by lowering respondent burden, and by improving the reliability of the data collected. Importantly, the modular structure allows MOTUS to be easily deployed for various TUS configurations. Moreover, this versatile structure allows comparable, complex diary surveys (such as the household budget survey) to be performed on the same platform and with the same applications.

Key words: Time-use survey; data collection platform; cost efficiency; data quality, respondent burden.

1. Introduction

Today, National Statistical Institutes (NSIs) face challenges and changes in the way they produce official statistics (Radermacher 2020). On the one hand, technological developments create the opportunity for paradigm shifts in methodology (Ashofteh and Bravo 2021). On the other hand, modern societal changes and challenges create new user demands for high-quality data and statistics (Cai and Zhu 2015). Taken together with the budgetary restrictions in place, this results in a large pressure to shift to online data collection and to connect data collection environments with other data sources that bring valuable information to specific statistical domains (Ricciato et al. 2020). This digital transformation rapidly changes the context and needs, and it also leads to growing privacy and data security concerns and suspicion towards official statistics (Keusch et al. 2019; Ricciato et al. 2020). Amidst these challenges and changes, modernisation initiatives should

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be supported by trustable, shareable, and scalable processes considering "smart" ways to collect data (Bruno et al. 2022; Ricciato et al. 2019). These processes are assumed to lead to cost reductions for the statistical offices and to lower the respondent burden (Salemik et al. 2020). In addition, these processes must remain standardized for reasons of comparability, yet flexible and agile enough to meet (country) specific needs and allow statistics to be disseminated quickly. At the same time, these processes must not compromise on the quality and reliability of the collected data (Salgado et al. 2018; Stodden 2014).

At the European level, the European Statistical System (ESS), which is a partnership between Eurostat and the NSIs of the EU and EFTA countries, aims at enhancing the strengths (such as comparability) of harmonised statistical methods and reversing the trend of a gradual disintegration of the data collection process stemming from NSIs facing declining participation rates and increasing difficulties in organising data collections (and thereby jeopardizing the quality and reliability of the statistics). At the same time, the ESS foresees to jump on the bandwagon of the process of digitalisation, growing smartphone usage (Keusch et al. 2019) and the availability of 4G and 5G networks (Gohar and Nencioni 2021). New technologies should improve respondent responsiveness by using new tools, integrating new data flows by connecting data sources, and help NSIs become more efficient by defining data collection platforms. The goal is to better capture and disseminate the perspective of households (Carletto et al. 2022).

The Time Use Survey (TUS) is one of the European surveys that are substantially affected by the challenges of and changes in the way NSIs produce statistics, but at the same time would substantially benefit from new technological developments. Against that backdrop, this contribution aims to answer whether the Modular Online Time Use Survey (MOTUS) data collection platform is able to tackle these challenges and align with these changes. Official TUSs face numerous challenges, such as the need to replace the expensive and laborious paper-and-pencil method by a digitalized method with smart ways to reduce respondent burden amid the absence of updated guidelines to harmonize digitalized TUS across NSIs. Many of these challenges relate to the principles of the European Statistics Code of Practice (Eurostat 2018). The central question this contribution addresses is: can MOTUS improve on respondent burden (principle 9), cost efficiency (principle 10) and quality such as accuracy and reliability (principle 12), and timeliness and punctuality (principle 13) in producing official TUS statistics?

In answering this question, we consider respondent burden as a *perceived* burden, which results from low motivation, the complexity of the tasks at hand, and the challenging effort to complete the survey (Yan et al. 2019). Furthermore, we consider the timeliness, the accuracy and reliability of the (intermediate statistics production steps as well as the final) time use statistics as quality indicators. We assume that the accuracy and reliability of statistics can be gained by reducing human data entry errors, by reducing the respondent recall error, and by supporting respondents with real-time prompts during the data collection process. In what follows, we evaluate MOTUS in terms of expected improvements in costs, respondent burden, and quality compared to the current best practice of paper-and-pencil TUS for different phases of the GSBPM, Generic Statistical Business Process Model (Kuonen and Loison 2019).

2. Background

2.1. Time Use Surveys

A TUS collects data on daily life. They are a way to picture the "many interesting patterns of social life [that] are associated with the temporal distribution of human activities, with the regularities in their timing, duration, frequency, and sequential order" (Szalai 1972, 1). Respondents use a log or a time use diary of at least twenty-four consecutive hours to self-report their daily behaviour in a chronological and open-ended fashion on an activity-to-activity basis (Pronovost 1989; Robinson 1999). In the time use diary, respondents specify – for each new activity – the start and end time as well as some contextual information like the place of occurrence and the possible presence of others. This not only makes time use diaries capable of simultaneously collecting data on the duration, timing, tempo, and sequence of activities (Zerubavel 1982) but it also reduces respondent errors related to self-reporting of activities in daily life compared to other survey methods (Lavrakas 2008). Respondent errors related to understanding the concept (of the question asked) are reduced because respondents are not directly queried but use their own wording to describe their activities. However, insufficient detail in verbatim activity descriptions complicates posterior activity coding (Chenu 2004). Recall biases are reduced because respondents are asked to register their activities in close to real time, resulting in multiple registration moments per day. Other biases such as social desirability biases or confirmation biases are reduced because time diaries do not focus on a particular activity, activities chronologically follow each other (i.e., the ending time of one activity is the start time of the next activity), and activity durations are restricted to 24 hours a day (Te Braak et al. 2022b).

As TUS is a source for official statistics on which policymakers rely, and as it can further enhance the understanding of daily life, initiatives have been taken around the world to harmonize the production of time use data (Robinson and Godbey 1997). One of the most extensive harmonization processes was carried out by Eurostat and resulted in the guidelines on Harmonised European Time Use Surveys (HETUS) for these surveys conducted by NSIs (Eurostat (2020), referred to as "the guidelines" below). The guidelines (which include sample design harmonization and standardization, mode and methodology design, activity coding, data coding, weights, and metadata) have been used by nearly 20 European NSIs in two HETUS rounds between 1998 and 2015.

The TUSs are not merely a European matter. Since 2003, BLS, the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics 2023) collects yearly waves of the American Time Use Survey (ATUS) to support policy research related to household production, health and safety, and family and work-life balance. Similarly, and often with support of the International Labor Organization (ILO), numerous countries outside Europe use time use statistics to gain valuable insights on household production and gender (in)equality (United Nations 2016).

The major strength of TUSs is capturing detailed information of daily activities in a chronological and contextualised way. Yet this strength is also its weakness, both at the organisational "back office", as well as at the participation environment or "front office". From an organisational point of view, these surveys are costly, mainly due to postage, printing, and personnel costs resulting from multiple interviewer visits to the household

and data entry from paper time use diaries. Regarding the latter, the large number of offline manual operations increase the risk of errors. Additionally, fieldwork periods typically run for 12 months to capture seasonal variations. From the respondent point of view, the burden to complete such a survey is relatively high, because household members complete multiple questionnaires and keep track of their daily time use in paper time use diaries.

2.2. A HETUS Based TUS

To address the central question whether MOTUS can improve respondent burden, cost efficiency, accuracy and reliability, and timeliness and punctuality in producing official TUS statistics, we consider the guidelines to be the benchmark. As the HETUS is a household survey, sampling is carried out at the household level. The identified head of each participating household will complete a grid that records the relationships between all persons in the household (i.e., the household grid, see Eurostat 2020, 33) and a household questionnaire. Additionally, all eligible household members (i.e., aged ten and above) will complete an individual questionnaire. Currently, this is (most frequently) done via Computer Assistant Personal Interviews (CAPI), which implies an interviewer visit – at which the interviewer also leaves behind two paper time use diaries per eligible household member with the dates on which both time use diaries must be completed. One diary concerns a weekday, and one diary concerns a weekend day (the same two days for all household members). The interviewer might also leave behind a drop-off questionnaire, which is to be completed by all eligible household members after the time use diaries. At a prearranged date, the interviewer returns to check and collect the time use diaries and the drop-off questionnaire. At the NSIs, the paper time use diaries and drop-off questionnaires are entered into a database, often using parallel data entry to prevent input and coding errors.

3. Modular Online Time Use Survey

3.1. Introducing MOTUS

To counter the high costs of conducting TUSs and to lower the respondent burden, while maintaining reliable and quality output on daily life, scholars and NSIs started to experiment with conducting these surveys through web- and mobile applications (Bonke and Fallesen 2010; Fernee and Sonck 2013; Sonck and Fernee 2013; Sullivan et al. 2020), with the first applications coming into circulation around 2010. The first version of MOTUS was rolled out in 2012.

Figure 1 shows the platform architecture of MOTUS. The MOTUS data collection platform consists of a front office as well as a back office. The front office relates to the collection tool or application, with which the users can interact via a user interface (UI) and which delivers, through its functionalities, a user experience (UX). The MOTUS application is available as a web version for browsers (https://app.motusresearch.io) and in iOS and Android mobile versions for smartphones and tablets. The purpose of the application is to make it easier for the respondent to carry out all tasks of a (time use or other) survey.

The back office serves to build a survey, to facilitate data collection and monitoring, and to process the data. To this end, the back office, which is accessible via a web environment,

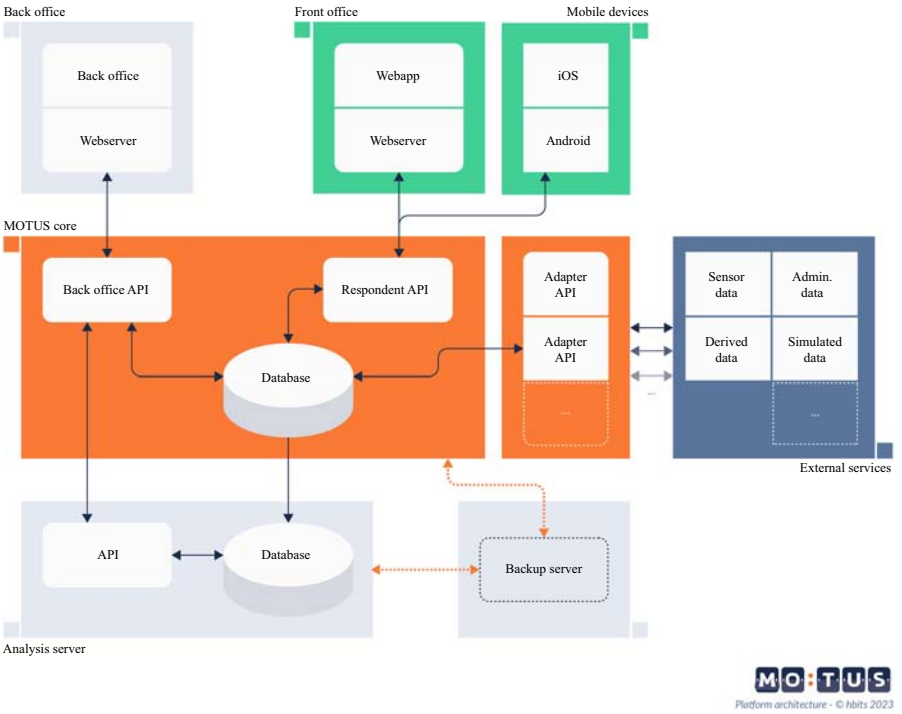

Fig. 1. Overview of the MOTUS platform architecture.

contains several *builders*. Both the front office and back office connect to the MOTUS core ("the core") through Application Programming Interfaces (APIs). The core holds the database with all information required to build a survey and collect data. A separate analysis server holds a replica of the database from the core and facilitates the processing of information in the back office. The back-up server is a replica of the core and analysis servers. Adapter APIs serve to adapt external information so that it can be processed in the core, thereby allowing the ingestion of, for example, passive data gathered via integrated sensors or connected devices, administrative/secondary data available via external data sources, or other processed data. For reasons of optimization, data security and privacy, these data are handled and organised in an anonymized way in stand-alone microservices. All input provided by the user is sent encrypted via an https communication to the server and is immediately propagated to all devices of the user via the respondent API. As a result, the MOTUS web and mobile applications can be used interchangeably.

3.2. Building TUS With MOTUS

To enhance the comparability of official TUSs in Europe, the design hereof in MOTUS is largely informed by the guidelines, which are regularly updated (Eurostat 2020). In the current situation, these guidelines provide a good starting point to include online applications and data collection platforms, while considering an online first approach which still ensures comparability with paper diaries (Vassilev et al. 2020). At the same

time, new applications and platforms and the options to implement smart solutions will produce possibilities that most likely impact the TUS design.

MOTUS supports building a HETUS guided TUS (see Subsection 2.2) and currently features nine builders – eight of which are relevant for a TUS, while the ninth builder offers future possibilities (see Subsection 4.1). All builders contribute in varying degrees to the lowering of the respondent burden, the cost reduction, the improvement of the accuracy and reliability of the data, and the increased timeliness and punctuality. Table 1 provides an overview of the builders in relation to the GSBPM build phase and the improvements that they bring in relation to current TUS practices.

3.2.1. Collection instruments

The *survey builder* serves to create online questionnaires based on all common question types with all common functionalities (e.g., answer-based routing, piping). This builder allows sharing previous questionnaires over studies. For a TUS the survey builder would be used to construct a household questionnaire, two individual questionnaires (i.e., one before and one after the time use diaries) and context questionnaires. Context questionnaires are linked to activities that are registered in the time use diary and can gauge where the activity took place (or what mode of transport used in case of travel), with whom the activity was undertaken, and if any information or communication technology was used during the activity. Obviously, online questionnaires are timelier and more punctual as well as more cost efficient because they (can) eliminate interview and data entry processes (as data are already digitized, which also eliminates human data entry errors). They also contribute to accuracy and reliability because conditions (e.g., mandatory questions) and restrictions (e.g., an answer cannot exceed a certain value) can be defined.

The *diary builder* sets up the time use diary. At the core of the time use diary is the Online Activity Classification List (OACL) that respondents use to register their daily life. The OACL is derived from the Activity Classification List (ACL) as described in the guidelines. In MOTUS, an OACL is created as a tree structure with up to three levels and as many activities or activity categories in any given level as needed. In MOTUS, a (different) context questionnaire (as created in the survey builder) can be attached to each specified activity. The diary builder contains a repository with previous OACLs for reuse.

The use of OACLs presents a major improvement. Firstly, it is cost-efficient because there is no need to assign actual activity codes to written, verbatim activities. MOTUS can present the OACL to the respondents as a collapsible tree structure, and/or as a searchable list, and/or as a list of favourites. The searchable list is very similar to the traditional verbal description, with the difference that respondents are shown the activities that match their description and thus code their description themselves. Since respondents do this straight away, this also improves the accuracy and reliability as well as timeliness and punctuality. For the searchable list to work, an unlimited number of search tags can be assigned to each of the activities at the most granular level of the tree structure in the diary builder. For the favourite list to work, respondents need to star activities. The different options of selecting activities in the time use diary are also likely to lower the respondent burden, accuracy and reliability as relevant response alternatives are suggested. To handle the situation when an activity cannot be found, OACLs might contain the option to describe activities in the respondents' own words. The search terms used, and the finally selected activity are stored in the background to

Table 1. Overview of the MOTUS builders in relation to the GSBPM build phase and improvements (by CoP principle) to TUS practices

Subphase	Supported phase	Builder	TUS elements	Improvement in CoP principles			
				Respondent burden	Cost efficiency	Timeliness & Punctuality	Accuracy & Reliability
3.1 Reuse or build collection instruments	4. Collect	Survey builder	– Household questionnaire – Individual questionnaires – Activity context questionnaires	–	•	•	○
		Diary builder	– Online Activity Classification List – Activity selection settings – Diary settings	•	•	•	•
		Grid builder	– Household members relationships – Eligibility criteria for participation	–	•	○	•
3.2 Reuse or build processing and analysis components	5. Process 6. Analyse	R builder	– Activation report (for reminders) – Finalisation report (for remuneration) – Quality and cleaning criteria – Dashboard progress report	–	•	•	•
3.3 Reuse or build dissemination components	7. Disseminate	R builder	– Data export	–	•	•	•
3.4 Configure workflow	4. Collect	Communication builder	– Communication content – Communication type	○	○	○	○
		Translation builder	– Set up multiple languages	○	–	–	○
		Invitation builder	– Manage respondent inflow	–	○	○	○
		Research builder	– Create workflow	○	•	•	•

progressively improve the efficiency of the search algorithm during the course of the survey. Secondly, paper-and-pencil questionnaires are limited regarding the context questions and these questions cannot vary per activity in the ACL. In contrast, OACLs can lower the respondent burden as (for instance) not all context questions need to be asked.

Next to the activity list, the diary builder also allows the survey manager to set a large array of time use diary parameters. These include the granularity of the time intervals (e.g., continuously or in whole minute intervals), the diary period and diary period calculation, the start and assignment of focus periods (i.e., the day or days for which the time use diary needs to be completed), and the (length of the) learning period. For a HETUS based TUS, the granularity would be set at ten-minute intervals, while the the focus days are a function of an algorithm that ensures an equal dispersion of starting days across the week and assigns one weekday and one weekend day to all eligible individuals of the household. Controlling the time use diary parameters brings a substantial improvement to accuracy and reliability. The major disadvantage of drop-off paper time use diaries is the lack of control over and insight in what happens between dropping off the diaries and collecting them (Te Braak et al. 2022a). The diary builder allows the survey manager to set, monitor, and adjust the time use diary during the fieldwork.

The *grid builder* is used when the unit of participation is not the individual but a group or, in this case, a household. In a TUS, the reference person of the household composes a household grid by adding household members, providing relevant information (e.g., at least date of birth), specifying relationships (e.g., mother-daughter, partners, siblings ...), and answering questions about household members less than ten years old (e.g., about day care arrangements). Based on this information, household members are checked for their eligibility (according to the criteria set out in the grid builder) to take part in the survey. If the reference person provides group members' email addresses, all group members who are eligible to participate will receive an invitation via email with their initially assigned personal credentials. An online household grid has the same cost and time benefits as online survey questionnaires.

In a HETUS based TUS, participation needs to be coordinated, because of synchronous time use diary registration by all household members. In MOTUS, this is achieved by all group members enter a virtual waiting room. Once all eligible members have entered the waiting room, a subsequent, synchronized task can be assigned. In other words, only when all eligible household members completed their previous task(s), they can proceed to the time use diary task. Optionally, the reference person can manually request the next task if waiting for other group members is deemed to be futile. The cost reductions are obvious because of the elimination of the interviewer and the fully automated process of completing the household grid, checking of eligibility, and distributing individual questionnaires and time diaries. This also improves accuracy and reliability as well as timeliness and punctuality. However, as the household grid still needs to be completed by the head of the household, the respondent burden is not decreased. Nevertheless, accuracy and reliability will improve if a waiting room is used because it allows the household members' time diaries to be truly synchronized; something which cannot be guaranteed (or even assessed) when the traditional method (dropping off paper-and-pencil time use diaries for pick-up at a later moment in time) is used.

3.2.2. Processing, analysis, and dissemination components

It is necessary to set up several processes (in addition to the collection instruments) that support the collection, the analysis, and the dissemination of the statistics. Many of the processing components are part of the MOTUS architecture (see Subsection 3.1), but some processes are built in the *R builder*.

Firstly, the R builder contains the `motusr` package which allows the creation of closing criteria settings or quality assessment of the time use diary. These thresholds or quality criteria relate to the amount of undefined time, the variance and number of different of activities logged, the prevalence of activities which start or end at the top of the hour, and the registration of certain activities, such as sleeping, eating, drinking, and travelling in case of changing locality (Juster 1986). Feedback on data quality can be presented to the respondent purely informatively via onscreen messages or lead to an explicit request to the respondent to adjust the registration in the diary as a requirement to proceed or end the time diary stage. The `motusr` package is currently under development and not yet listed on CRAN.

Secondly, the R builder periodically performs calculations on live data on the MOTUS server to check for changes and to update the outputs. These calculations feed into a dashboard that allows progress monitoring. Finally, the R builder facilitates the construction, labelling, and exporting of (including para- and metadata and Universally Unique Identifier (UUID) keys to merge different databases) in various formats.

In addition to making the fieldwork timelier and more cost efficient, the various automated processes outlined above also improve the accuracy and reliability of the data.

3.2.3. Configure workflow

The collection instruments and processes need to be brought together to form a workflow and are linked through communication. All communication is defined in the *communication builder* and, in the absence of an interviewer and except for initial postal invitations when an email address is not yet available, there are four ways of communicating throughout the data collection process: email, push messages, and static pages. Push messages include real-time prompts that remind respondents of their survey tasks and support respondents registration process by, for example, suggesting relevant response alternatives. This improves the accuracy and reliability. Additionally, if studies need to be conducted in multiple languages, all elements (i.e., collection instruments and communication) can be translated in the *translation builder*. The translation builder supports the xliff format (an XML variant) which allows translations to be done externally and imported into MOTUS. Furthermore, the *invitation builder* manages how respondents enter the workflow. There are different invitation strategies, ranging from voluntarily registering on the MOTUS webpage (possibly following advertising through various channels), via receiving a letter with login details, to uploading a list of potential respondents in advance. For a TUS that follows the guidelines, NSIs typically draw their sample from a national population register wherein no email address information is available. In this case, the invitation builder generates usernames and temporary passwords which are printed in the invitation letters that are send to the sampled households. Invitation letters contain both a QR-code and a fully written web link

directing respondents to the MOTUS website. Once respondents use the login credentials to participate, MOTUS will ask them to provide an email address for further communication throughout the survey.

While all the collection instruments and communications are created in their respective builders, the *research builder* sets up the overall collection process workflow. The workflow brings all instruments them together and places them in a linear order based on the different stages a respondent must go through to successfully participate in a survey. As these stages typically consist of tasks to be performed (collection instruments to be completed or communications to be read), they may also be referred to as "tasks".

Moving through stages is based on actions governed by conditions that are defined in the research builder. The conditions can be based on the completion of tasks or can be time based (e.g., sending a reminder after 24 hours of inactivity). Actions are communicated to the respondent by means of communications that are created in the communication builder. Additionally, communication criteria can be defined as a function of the progress within a stage.

For a TUS that follows the guidelines, the workflow is complex. It starts with sampling household members that will receive credentials to log in to MOTUS and complete the tasks of filling out a household questionnaire and composing the household grid. Thereafter, all eligible household members will be invited via email to carry out several tasks in MOTUS: completion of a first individual questionnaire, completion of two focus days in the time use diary, and completion of a second individual questionnaire. Actions involve numerous communications, for example, on what task needs to be completed next, reminders to complete certain tasks, or instructions on how to record an online time use diary.

To demonstrate how this works in practice, Figure 2 gives an example of a simplified workflow of a TUS that involves an individual pre-questionnaire and a two-day time use diary. Each box defines a stage and includes the title of the stage, a short description of the stage, and the option (for the survey manager) to edit or delete the stage. Within each stage, different actions are defined (the dark coloured bars), such as communicating, proceeding to the next task, or closing the survey participation for the respondent after a predefined period of inactivity.

The communication builder improves cost efficiency, timeliness and punctuality since communication is created online and sent to respondents through automated processes. Since the transmission of communications is conditional, it is tailored to the respondent and might increase the involvement of the respondent. In turn, this might lower their burden and therefore improve the accuracy and reliability of the data. The translation builder cannot alter the translation costs. The major advantage, though, is that respondents can easily switch between languages, which again might increase their involvement and lower their burden, especially in countries such as Belgium with multiple official languages. In a TUS, the initial invitation comes in the form of a paper letter, so the improvement provided by the invitation builder is limited at first. However, in case information is provided by the head of household, the eligible household members are invited via e-mail, which is cost and time efficient. Additionally, automated processes for assigning credentials and linking these to UUIDs leaves less room for error which improves accuracy and reliability.

The research builder improves current practices of TUS substantially because it allows building the complete workflow in an online environment and as a fully automated process. It enhances cost efficiency, timeliness and punctuality, while also improves the

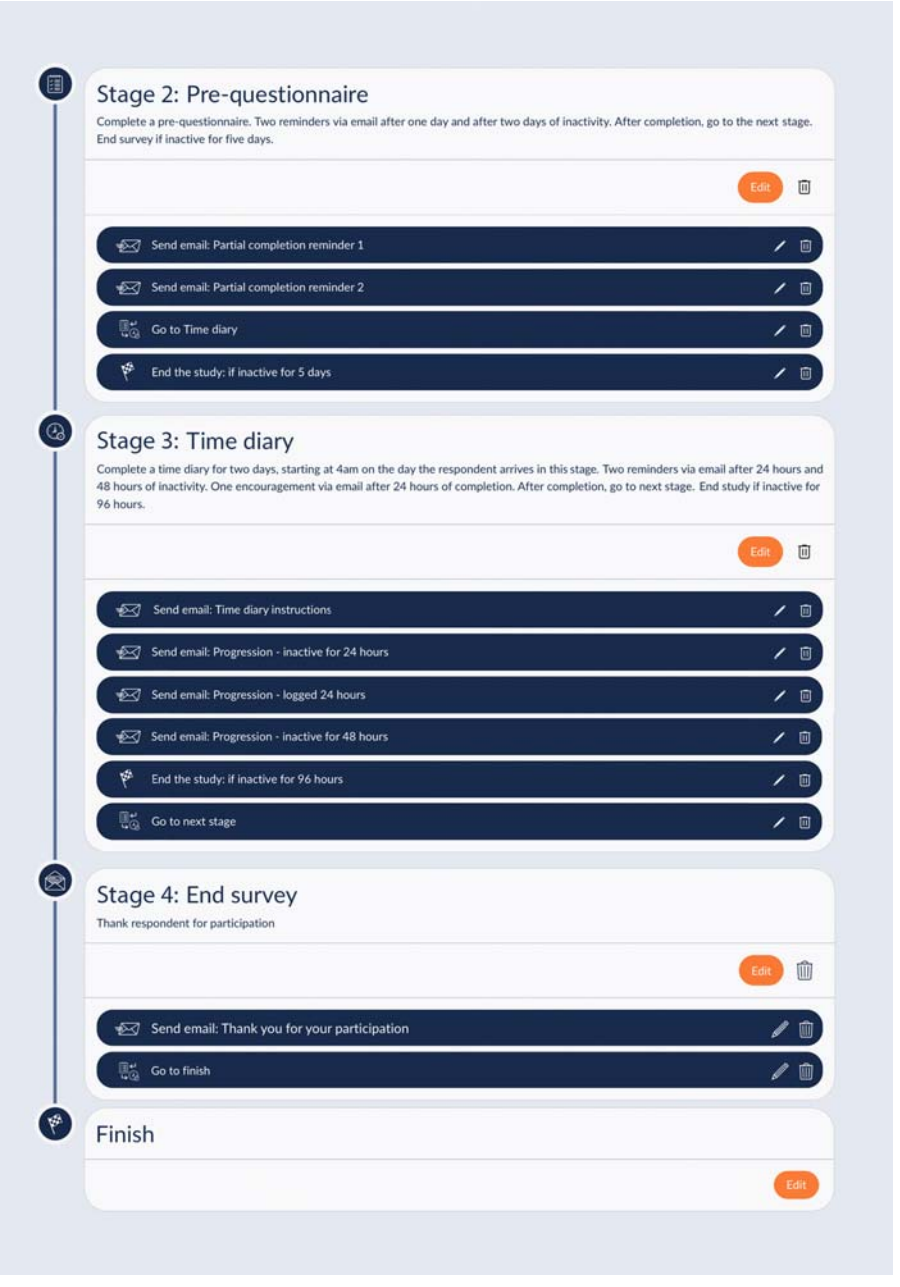

Fig. 2. Simplified workflow of a TUS on the MOTUS platform.
Note. Stage 1 (not pictured) involves the activation of the MOTUS account. The simplified workflow involves an individual pre-questionnaire (Stage 2) and a two-day time use diary (Stage 3).

accuracy and reliability of the data as it allows a more accurate and complete follow-up of respondents as they progress through the various stages. Although this closer follow-up cannot reduce the number of tasks involved, the communication between tasks might lower the respondent burden as it creates a sense of being supported.

3.3. The Generic Statistical Business Process Model

Building (or reusing) the designed collection instruments and processes is central to any statistical production process and part of the GSBPM. The GSBPM serves as a framework to describe and define the business processes involved to produce official statistics in a standardised way. It started as a joint effort of the United Nations Economic Commission for Europe (UNECE), Eurostat and the Organisation for Economic Cooperation and Development (OECD). The GSBPM is based on the business model of Statistics New Zealand (Kuonen and Loison 2019). Describing the business process of the production of official statistics using the GSBPM as the reference model allows NSIs to communicate these processes more easily.

The GSBPM is considered a non-linear process model and is aimed to apply to any data production (e.g., surveys, censuses, administrative registers). It serves as a reference model, which does not prevent NSIs from arriving at national versions of the GSBPM based on organisation-specific adaptations, combining phases, or a sequential reassessment to make it a linear process description (Ahmad and Koh 2011).

As shown in the first three columns of Table 1, each of the builders discussed above refers to one or more of the subphases of the build phase (i.e., GSBPM phase 3), while also supporting one or more other process phases (i.e., GSBPM phases 4 to 7). This highlights the non-linear sequence of the different phases of the GSBPM and the importance of iterative processes to support, evaluate and inform different phases and sub-phases.

4. Discussion

4.1. Wider Applications

The MOTUS applications (mobile and web) are not single purpose applications aimed at conducting a particular survey (or supporting a single area of statistics, such as time-use statistics). Instead, the MOTUS front office applications serve as a host for any survey that is defined in the back office. This modular capacity of MOTUS is based on the different builders that can be defined and put into a workflow for every different survey created in MOTUS. As such, MOTUS works particularly well for complex studies that are a sequence of multiples tasks (e.g., questionnaire and diary) or studies that link survey elements with data from other, external services (e.g., geolocation data). The Household Budget Survey (HBS) is an example of a complex survey with challenges comparable to those of the TUS. Like the TUS, it is also sampled at the household level and consists of recording data in a diary over time (in the the case of the HBS, this concerns purchases by household members over a period of at least 15 days). The HBS also includes completing a household grid and questionnaire. Given these major similarities and the modular approach of MOTUS, the project CRŒSS (Minnen et al. 2022) upgraded MOTUS to a platform that also can offer HBS studies. This was done by extending the diary builder, which can now also use the Classification of Individual Consumption by Purpose (COICOP) codes (instead of the ACL code used in a TUS). The adjustments achieved uniformity of the front office in the sense that the UI/UX is the same for TUS and HBS. This also holds for the back office. The MOTUS platform can now organize both a TUS and an HBS on the same platform and with the same applications. At the same time,

MOTUS uses container technology to make the platform available as an ESS platform. Each Docker container is a separate part of the MOTUS platform, as shown in Figure 1, with its software dependencies. How and where the containers are used is the responsibility of an NSI. It is recommended to use Kubernetes to deploy the containers on ISO/IEC 27001 certified infrastructure. This setup brings natural security barriers and also provides tools for scalability and high availability.

4.2. Smart Data Collection

Another future challenge of (digital) data collection concerns "smart" ways of collecting data, from which time use surveys could benefit (Zeni et al. 2020). "Smart" refers to data collection that combines passive or sensor data from personal smart devices (e.g., GPS, accelerometer) with active data explicitly provided by the respondent (e.g., responses to queries). Here, "passive" refers to the respondent not actively providing input (Ricciato et al. 2020).

MOTUS interprets the "smart" concept in a very broad sense, noting that data collection can be smart not only in the way it uses or processes already available data, but also be smart in the way it supports respondents to participate in surveys. MOTUS therefore continues to develop and add builders with new possibilities to the back office. One such builder is the *event builder*. Events follow the if-this-than-that (ITTT) approach and are thus triggers that are pulled if a certain condition is met. These conditions and the actions they initiate are defined in the event builder and are available from microservices that collect sensor data and are connected by an adapter API to communicate with MOTUS. These events can on the one hand ask the respondents to perform a specific action (e.g., answering a short questionnaire), or on the other hand show tentative entries in the respondents' diary, which they can commit and as such can reduce the registration burden and increase the quality of the registration. For example, if the GPS coordinates correspond with respondents' working address, working activities might be suggested in their time use diary.

The inclusion of smart data requires a data collection platform that is able to communicate with different other environments or standalone microservices (Ricciato et al. 2020). As shown in Figure 1, the MOTUS platform architecture allows these external smart data sources to communicate with the core via so-called adapter APIs. An example is the connection to the GeoService that collects geolocation data points from the respondents' smartphones. Particularly in complex studies such as TUS and HBS, the inclusion of sensor data, or administrative data in line with the Only Once Principle (OOP), should result in increased response rates, lower time investments of respondents as data providers, a further reduction of survey costs, and an increase in the accuracy and reliability of the data.

4.3. Para- and Metadata

The wealth of para- and metadata captured by MOTUS can provide insights into a lot of processes that have remained hidden from view in the traditional paper-and-pencil TUSs. For example, who actually completes the time use diaries? Each household members by themself? Or one person for all? We can only guess how this might have affected the intra-household correlation of the time use diary registration. Similarly, when were time diaries completed? Throughout the day? At the end of the day? Or just before the interviewer

came to pick up the diaries? Again, we can only guess how this might have affected the reliability of the time use diary registration in the past. Furthermore, if respondents drop out during the fieldwork, all information prior to drop-out remains available in the database of the server running the survey. Unless the respondents exercise their rights as defined in the General Data Protection Regulation (http://data.europa.eu/eli/reg/2016/679/2016-05-04) to delete all stored information. This might be useful to evaluate the dropout. On the negative side, it is yet to become known what all this will bring to light in terms of accuracy and reliability. On the positive side, at least then we know – and may be able to compensate for it.

4.4. Communication

One of the future challenges of online research, and especially with surveys like TUSs, are the multiple and complex tasks respondents must complete. The absence of face-to-face contact puts substantial pressure on online communication and gives rise to questions such as how much to communicate, by which means and in which wordings – and whether the communication should be differentiated by background characteristics. Options for respondents to switch on or off optional communication, such as reminders, suggestions, tips and tricks and select preferred media channels (e.g., email, text message, on screen notifications) could further tailor the user experience to the respondent and increase the feeling of being supported and decrease the potential challenging effort to complete the survey (Yan et al. 2019).

4.5. Conclusion

TUSs have a history of collecting data that can produce reliable and widely applicable statistics and indicators. However, the implementation of a (HETUS based) TUS is based on a complex sequence of household and individual level questionnaires and time use diaries on two different days of the week. A paper-and-pencil version comes with high postal and printing costs and with substantial cost and time investments in multiple interventions from interviewers and coders. These surveys also imply a relative high participation burden and thus a risk for accuracy and reliability. The modernization of TUSs, driven by current and future technological developments, involves more than just translating the current paper and pen-based version into a digital format. It requires a shift in the methodological paradigm of doing these surveys and an overhaul of the business processes for producing official time use statistics.

This contribution introduced MOTUS not only as an online TUS, but as a provider for the collection of these surveys by breaking down all elements of conducting an online TUS into modular builders that are congruent with and supportive to several subphases of the GSBPM. It showed that MOTUS stands for a modern approach to surveys in general and to complex surveys (such as the TUS and the HBS) in particular. The MOTUS builders inform the design phase, enable the build phase, and facilitate the collect, process, analyse, and disseminate phases of the GSBPM. It also showed that MOTUS makes it possible for modern, online data collections to provide a partial answer to recent challenges by lowering the respondent burden, by being more cost efficient, and by providing timelier, more punctual, more accurate and more reliability official statistics. MOTUS has already

partly proven itself in the past for TUS both for a population sampled TUS (see Minnen et al. 2014) and for several target sampled TUSs (see, for example, Te Braak et al. 2022a). Future challenges include further applications and use of MOTUS for TUS and other surveys in different statistical domains (e.g., the HBS – for which first steps have been taken as described in Subsection 4.1 above) and collecting feedback for adjustments and improvements. These applications and subsequent evaluations will continue to cement and expand the potential of MOTUS to meet current challenges of and changes in producing official statistics based on complex surveys.

5. References

Ahmad, N., and S.-H. Koh. 2011. *Incorporating estimates of household production of non-market services into international comparisons of material well-being. UNECE Working Paper* No. 42. STD/DOC(2011)7. DOI: https://doi.org/10.1787/5kg3h0jgk87g-en.

Ashofteh, A., and J.M. Bravo. 2021. "Data science training for official statistics: A new scientific paradigm of information and knowledge development in national statistical systems." *Statistical Journal of the IAOS* 37(3): 771–789. DOI: https://doi.org/10.3233/SJI-210841.

Bonke, J., and P. Fallesen. 2010. "The impact of incentives and interview methods on response quantity and quality in diary-and booklet-based surveys." *Survey Research Methods* 4(2): 91–101. DOI: https://doi.org/10.18148/srm/2010.v4i2.3614.

Bruno, M., F. Inglese, and G. Ruocco. 2022. "Trusted Smart Surveys: Architectural and Methodological Challenges Related to New Data Sources." In *Studies in Theoretical and Applied Statistics*, edited by N. Salvati, C. Perna, S. Marchetti,and R. Chambers, Springer Proceedings in Mathematics & Statistics, 406. DOI: https://doi.org/10.1007/978-3-031-16609-9_31.

Cai, L, and Y. Zhu. 2015. "The challenges of data quality and data quality assessment in the big data era." *Data science journal* 14. DOI: http://doi.org/10.5334/dsj-2015-002.

Carletto, C., H. Chen, T. Kilic, and F. Perucci. 2022. "Positioning household surveys for the next decade." *Statistical Journal of the IAOS* 38(3): 923–946. DOI: https://10.3233/SJI-220042.

Chenu, A. 2004. "Prendre la mesure du travail." In *Pour une histoire des sciences sociales. Hommage à Pierre Bourdieu*, edited by J. Heilbron, R. Lenoir and G.D. Sapiro: 281–304. Paris: Fayard.

Eurostat. 2018. Eurostat, *European statistics code of practice: for the national statistical authorities and Eurostat (EU statistical authority).* Luxembourg: Publications Office of the European Union. DOI: https://doi.org/10.2785/798269:

Eurostat. 2020. *Harmonised European Time Use Surveys (HETUS) – 2018 guidelines – Re-edition*. Luxembourg: Publications Office of the European Union. DOI: https://doi.org/10.2785/926903.

Fernee, H., and N. Sonck. 2013. "Is everyone able to use a smartphone in survey research?" *Survey Practice* 6(4): 2884. DOI: https://doi.org/10.29115/SP-2013-0020.

Gohar, A., and G. Nencioni. 2021. "The role of 5G technologies in a smart city: The case for intelligent transportation system." *Sustainability* 13(9): 5188. DOI: https://doi.org/10.3390/su13095188.

Juster, F.T. 1986. "Response errors in the measurement of time use." *Journal of the American Statistical Association* 81(394): 390–402. DOI: https://doi.org/10.1080/01621459.1986.10478283.

Keusch, F., B. Struminskaya, C. Antoun, M.P. Couper, and F. Kreuter. 2019. "Willingness to participate in passive mobile data collection." *Public Opinion Quarterly* 83 (S1): 210–235. DOI: https://doi.org/10.1093/poq/nfz007.

Kuonen, D., and B. Loison. 2019. "Production processes of official statistics and analytics processes augmented by trusted smart statistics: Friends or foes?" *Statistical Journal of the IAOS* 35(4): 615–622. DOI: https://doi.org/10.3233/SJI-190530.

Lavrakas, P.J. 2008. *Encyclopedia of survey research methods*. Sage Publications.

Minnen, J., I. Glorieux, T.P. van Tienoven, S. Daniels, D. Weenas, J. Deyaert, S. van den Bogaert, and S. Rymenants 2014. "Modular Online Time Use Survey (MOTUS)-Translating an existing method in the 21st century." *Electronic International Journal of Time Use Research* 11(1): 73–93. DOI: https://dx.doi.org/10.13085/eIJTUR.11.1.73-93.

Minnen, J., J. Olsen, and K. Sabbe. 2022. *CRŒSS: Establishing a Cross-domain data collection platform for the ESS (European Statistical System)*. Brussels and Bonn: Statistics Belgium, Destatis, hbits CV and Vrije Universiteit Brussel. Available at: https://torvub.be/torwebdat/publications/t2023_13.pdf.

Pronovost, G. 1989. "The sociology of time." *Sociologie Contemporaine (La)* 37(3): 1–124.

Radermacher, W.J. 2020. *Official Statistics 4.0. Verified Facts for People in the 21st Century*. Cham, Switzerland: Springer. DOI: https://doi.org/10.1007/978-3-030-31492-7.

Ricciato, F., A. Wirthmann, K. Giannakouris, and M. Skaliotis. 2019. "Trusted smart statistics: Motivations and principles." *Statistical Journal of the IAOS* 35(4): 589–603. DOI: https://doi.org/10.3233/SJI-190584.

Ricciato, F., A. Wirthmann, and M. Hahn. 2020. "Trusted Smart Statistics: How new data will change official statistics." *Data and Policy* 2. DOI: https://doi.org/10.1017/dap.2020.7.

Robinson, J.p. 1999. "The time diary method. Structure and uses." In *Time use research in the social sciences*, edited by W.E. Pentland, A.S. Harvey, M.P. Lawton, and M.A. McColl: 47–89. New York: Kluwer Academic/Plenum Publishers. DOI: https://doi.org/10.1007/0-306-47155-8_3.

Robinson, J.P., and G. Godbey. 1997. *Time for life: The surprising ways Americans use their time*. Pennsylvania: Penn State Press.

Salemink, I., S. Dufour, and M. van der Steen. 2020. "A vision on future advanced data collection." *Statistical Journal of the IAOS* 36 (3): 685–699. DOI: https://10.3233/SJI-200658.

Salgado, D., M.E. Esteban, M. Novás, S. Sadaña, and L. Sanguiao. 2018. "Data Organisation and Process Design Based on Functional Modularity for a Standard Production Process." *Journal of Official Statistics* 34(4): 811–833. DOI: https://doi.org/10.2478/jos-2018-0041.

Sonck, N., and H. Fernee. 2013. *Using smartphones in survey research: a multifunctional tool.* The Hague: The Netherlands Institute for Social Research.

Stodden, V. 2014. "The reproducible research movement in statistics." *Statistical Journal of the IAOS* 30(2): 91–93. DOI: https://doi.org/10.3233/SJI-140818.

Sullivan, O., J. Gershuny, A. Sevilla, P. Walthery, and M. Vega-Rapun. 2020. "Time use diary design for our times-an overview, presenting a Click-and-Drag Diary Instrument

(CaDDI) for online application." *Journal of Time Use Research* 10. DOI: https://doi.org/10.32797/jtur-2020-1.

Szalai, A. 1972. *The use of time: Daily activities of urban and suburban populations in twelve countries*. The Hague: Mouton.

Te Braak, P., F. van Droogenbroeck, J. Minnen, T.P. van Tienoven, and I. Glorieux. 2022a. "Teachers' working time from time-use data: Consequences of the invalidity of survey questions for teachers, researchers, and policy.? *Teaching and Teacher Education* 109: 103536. DOI: https://doi.org/10.1016/j.tate.2021.103536.

Te Braak, P., T.P. van Tienoven, J. Minnen, and I. Glorieux. 2022b. "Bias in estimated working hours in time use diary research: The effect of cyclical work time patterns on postponing designated registration days.? *Time and Society* 31(4): 508–534. DOI: https://doi.org/10.1177/0961463X221111948.

United Nations. 2016. *Integrating a Gender Perspective into Statistics*. *Studies in Methods, Series F No. 111*. New York: United Nations Publication. Available at: https://unstats.un.org/unsd/demographic-social/Standards-and-Methods/files/Handbooks/gender/Integrating-a-Gender-Perspective-into-Statistics-E.pdf.

U.S. Bureau of Labor Statistics. 2023. *American Time Use Survey User's Guide. Understanding ATUS 2003 to 2023*. Available at: https://www.bls.gov/tus/atususersguide.pdf.

Vassilev, G., W. King, S. Wallace, and J. White. 2020. *Modernization of the Production of Time-use Statistics.* UK: UK Office for National Statistics. https://unstats.un.org/unsd/-statcom/53rd-session/documents/BG-3h-Modernization_UN_EG_TUS2021_FINAL_-SENT_rev-E.pdf.

Yan, T., S. Fricker and S. Tsai. 2019. "Response burden: What is it and what predicts it?" In *Advances in Questionnaire Design, Development, Evaluation and Testing*, edited by P. Beatty, D. Collins, L. Kaye, J.L. Padilla, G. Willis and A. Wilmot: 193–212. New Jersey: John Wiley & Sons. DOI: https://doi.org/10.1002/9781119263685.

Zeni, M., I. Bison, F. Reis, B. Gauckler, and F. Giunchiglia. 2020. "Improving Time Use Measurement with Personal Big Data Collection – The Experience of the European Big Data Hackathon 2019." *Journal of Official Statistics* 37(2): 341–365. DOI: https://doi.org/10.2478/jos-2021-0015.

Zerubavel, E. 1982. *Hidden rhythms: Schedules and calendars in social life*. Chicago: The University of Chicago Press.

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