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Costing Healthcare Services Using Time-Driven Activity-Based Costing

A Simple Step-By-Step Guide for Data Collection and Analysis

LUMBWE CHOLA · RYAN McBAIN · Y-LING CHI

Abstract

Cost information is essential for priority setting and optimized resource allocation in the healthcare sector, especially in low- and middle-income countries (LMICs) where resource constraints and opportunity costs are significant. In recent years, a costing approach labelled time-driven activity-based costing (TDABC) has gained prominence, as a means for more closely estimating unit costs. TDABC is a process-based micro-costing methodology that adopts a patient perspective to identify resources that are allocated over the course of service provision, mapping each step of a patient journey. Unlike other activity-based costing methods, TDABC includes the recording of the amount of time that resources are utilized for each activity. The manuscript is developed as a step-by-step guide for researchers, students and policy makers intending to undertake TDABC. While there are many academic resources explaining the theory and steps to conduct TDABC, in this paper, we provide easily accessible descriptions of methods for collecting data, tools that can be adapted to diverse research questions and settings, as well as practical data collection "tips" we learned from applying approaches on the ground.

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Costing Healthcare Services Using Time-Driven Activity-Based Costing: A Simple Step-By-Step Guide for Data Collection and Analysis

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1. Introduction

Cost information is essential for priority setting and optimized resource allocation in the healthcare sector; *e.g.,* through the use of cost-effectiveness analyses. This is especially important in low- and middle-income countries (LMICs) where resource constraints are significant and opportunity costs are high. While numerous health care innovations have come to fruition in the past decade, remarkably less attention has been given to costing (1). For several decades, analysts have pointed to substantial variation in costing methods and their applications (2), making comparisons across settings and interventions difficult (3). This is because adequately capturing costs in the healthcare sector is time-consuming and resource-intensive—due to the complex and widely varying delivery of services. Analysts often undertake costing exercises for different purposes and thus have different requirements and the scope of the costs included.

Time-driven activity-based costing (TDABC)

Let's imagine that you work in a ministry of health and have been asked to allocate funds to expand access to active tuberculosis services (to the TB programme). There are different costing methods that could be used for this purpose: at the most general level, top-down and bottom-up approaches are often used in healthcare. To answer the ministry's query, we *'simply'* need a cost estimate per patient per year in terms of clinical visits, tests, medications, and related services. If using a bottom-up approach, it would involve knowing what type of resources are required to provide the service and to be able to attribute quantities and costs to each of those resources.

BOX 1. Why is it hard to cost care?

- Treating a patient involves a large number of resources: from the construction of a facility, to the associated personnel, supplies, medication, IT systems, and electricity that go into services
- Patients with different conditions will take different paths through the system, and therefore use different sets of resources
- Patients with different conditions share resources such as physical space and equipment
- Patients with the same condition may also take different paths through the system
- Patients with the same condition may have comorbidities such that they are receiving care for multiple conditions at the same time
- In many LMICs, funding and provision of healthcare is fragmented

Source: Adapted from Kaplan and Porter (2011).

In recent years, time-driven activity-based costing (TDABC) has gained prominence, as a means for more closely estimating unit costs. TDABC is a *process-based micro-costing methodology that utilizes process maps* (4). Unlike 'traditional' ABC, TDABC uses a patient perspective to identify resources that

are allocated over the course of service provision, with a specific emphasis on the amount of time that resources are utilized for each activity during a patient's visit.

TDABC requires a large quantity of information. In some ways, TDABC is like a jigsaw puzzle: to get a complete and accurate picture, the analyst will need to bring together many pieces, of different shapes, and put them together in the correct combination. Some of the pieces will be about **the what** (the activity that the patient undergoes), **the who** (health staff involved in completing the activity), **the when** (duration of time), **the where** (the location in which activities occur) and **the frequency** (how often activities occur over a defined period of time) (4). Missing any pieces means you won't get the full picture or will need to make assumptions. Additionally, collecting information 'in the wrong shape' may then require adjustments. Unlike some other types of costing methods, TDABC routinely entails primary data collection and, as a result, the development of data collection tools and surveys. There are no standardized templates for TDABC that can support analysts new to this method. Moreover, much of the TDABC literature pertains to high-income settings and there is a gap of resources for LMIC analysts.

There have been many resources developed over the years that have proved useful for researchers to understand the intricacies of costing health interventions (see Box 3 for list of introductory costing resources). However, one of the major limitations with these resources is that they are not developed *for analysts working on data collection*, and therefore fall short when it comes to showing exactly how data are to be collected and analysed. We aim to make a contribution to the literature by showing analysts in LMICs who are interested in TDABC how they can undertake such exercises.

In this manuscript, we provide easily accessible descriptions of methods for collecting data, tools that can be adapted to diverse research questions and settings, as well as practical data collection 'tips' we learned from applying approaches on the ground. The manuscript is developed as a step-by-step guide for researchers, students and policy makers intending to undertake TDABC. It builds on the experiences of the authors, which have been mainly gathered while costing HIV service delivery in LMIC settings.

BOX 2. Manuscript aim and objectives

Manuscript Aim: To improve application of TDABC in LMICs, recognizing the challenges and constraints specific to low resource settings.

Objectives: To make information available to analysts, researchers, managers, and policymakers that will help them understand how to implement TDABC, by demonstrating how to implement a TDABC study and describing useful tools for anyone intending to do this exercise.

We acknowledge that our experience is not entirely generalizable and that the tools featured in this resource will need to be adapted: Our tools were used to cost HIV services in health facilities (hospital or clinic) and therefore may have to be adapted to be applied to other types of services (*e.g.,* diabetes care) or settings (e.g., community or outreach services), or to reflect a particular country's health system. However, we hope that the featured materials constitute a strong starting point for adaptation. Finally, the 'tips' featured in this manuscript are learned through piloting and recalibrating our approaches to data collection and analysis. However, they have not been 'scientifically tested' and should only be used as advice when planning.

2. Time-driven activity-based costing: A quick explainer

What are the main costing approaches?

There are several approaches to healthcare costing, which can be broadly categorized as follows (5)(6):

TABLE 1. Classifications of costing approaches

		Level and Type of Data Collected	
		Expenditure data collected at organisational level (e.g., cost centre)	Resource use data collected for each patient and then multiplied by the unit cost
Level of identification of resource use items	Highly detailed resource use items are identified	Top-down micro-costing	Bottom-up micro-costing
	Aggregate resource use items are identified	Top-down gross-costing	Bottom-up gross-costing

Source: Spacirova et al. (2020), adapted from Tan et al. (2009).

This is a pragmatic classification that looks at costing methods from two dimensions: how resources are allocated to generate a unit cost (top down or bottom-up) and the granularity of the information on resource use (gross vs micro). It is worth noting that this terminology is not used consistently across the literature and there are hybrid versions using a mix of approaches. For more extensive discussion of the different costing methods, please see the GHCC reference case (listed in Box 3).

Gross costing is typically employed using expenditure aggregates and follows a top-down approach. Micro-costing, on the other hand, disaggregates a service into a series of inputs consumed to produce a service. Top-down or bottom-up refers to the way in which resources are allocated to the unit cost; with top-down approaches 'dividing' the overall cost into a number of outputs to calculate unit costs; bottom-up costing measures input quantities at the level of clients or activities (3).

BOX 3. Useful resources on costing

- Time-Driven Activity-Based Costing, by Kaplan and Anderson (2004)
- Time-driven activity-based costing in health care: a systematic review of the literature, by Keel, Savage, Rafiq and Mazzocato (2017)
- Rethinking the Cost of Healthcare in Low-Resource Settings, by McBain et al. (2016)
- Reference Case for Estimating the Costs of Global Heath Services and Interventions, by Vassall et al. (2017)
- A general framework for classifying costing methods for economic evaluation of health care, by Spacirova, Garcia, Rovira and Epstein (2020)
- Costing guidelines for HIV prevention strategies, by UNAIDS (2000)

What is TDABC?

TDABC is a method of micro-costing which was first presented by Kaplan and Anderson (7). Unlike previous versions of activity-based costing, TDABC employs a time estimate for the utilization of each resource to allocate costs to services (8). Before we discuss the steps involved in TDABC, we introduce the definitions for two central concepts of the approach: the capacity cost rate (CCR) and time and motion study discussed in Box 4.

BOX 4. Two key parameters

Capacity cost rate (CCR): the CCR is defined as "the cost of resources divided by the practical capacity of those resources" (9). It is expressed in the form of "currency per minute". As we will see, calculating the CCR involves making an inventory of all the resources (buildings, personnel, medical goods and equipment) that are directly or indirectly employed towards caring for a patient. All components of the capacity have to be *expressed in time,* including medical equipment—for which an expected life span will need to be estimated. The capacity expressed in time will be divided by the cost of each resource to calculate the capacity cost rate.

Time and motion study: Using process maps, the process of caring for a patient will be broken down into discrete and sequential steps. Time and motion studies measure the duration that patients or providers spend on each of the steps. Note that the perspective for TDABC is the patient perspective (unlike other types of time and motion studies).

Steps to TDABC

There are typically seven steps involved in conducting TDABC. We have divided those between the **data collection processes** (first four steps) and **data analysis** processes (the last three). We will follow those steps for the remaining of the manuscript.

TABLE 2. Steps to TDABC

Data Collection
1. Define the service under consideration
2. Define the care delivery value chain, i.e. chart all key activities performed within the entire care cycle
3. Develop process maps that include each activity in patient care delivery, and incorporate all direct and indirect resources
4. Obtain time estimates for each process, i.e. obtain time estimates for all activities and resources used—with the exception of consumables that are not shared across patients
Data Analysis
5. Estimate the cost of supplying patient care resources, i.e. the cost of all direct and indirect resources involved in care delivery
6. Estimate the capacity of each resource and calculate CCRs
7. Calculate the total cost of patient care

Source: Keel et al. (9), adapted from Kaplan et al.

Do I need to apply this method?

You may consider asking yourself the following questions when thinking about which method to use for your costing exercise:

- *Why are you undertaking this costing exercise?*

TDABC will produce detailed data and information on resource use for healthcare planners and providers. Beyond the cost estimates, the exhaustive mapping of resources based on observed patient journeys could yield valuable insights, as discussed in our section 'Applications of TDABC'. For instance, the use of process maps and time and motion studies will allow stakeholders to identify potential inefficiencies such as redundant steps or long waiting times. If there is demand for this type of evidence in addition to the costing estimates, this could be an argument for investing resources into implementing the approach.

- *Do you have the possibility to collect primary data?*

If you are working on a project where your main data source is secondary data, then using a gross costing top-down approach may be more appropriate.

- *How much time and resources do you have to do this costing exercise?*

As mentioned above, TDABC has important resource implications. While it is arguably more practical than activity-based costing (and therefore less resource intensive), it still requires you to commit resources towards developing protocols, data collection tools, data collection efforts, and analysis. Planning ahead for teams of data collectors and supervisors is essential. As is typical of any primary data collection exercise, the size of the study will determine the amount of time and resources

required. Nevertheless, any primary data collection exercise is demanding and this should be seriously considered when planning the study.

- *How complex is the service under consideration?*

Because of its reliance on process maps, TDABC will follow patients throughout the production of a service and—as a result—may provide better insight compared to other types of costing approaches for more complex interventions, such as those occurring across different locations and involving multiple processes.

Challenges and limitations of the approach

- Estimation of capacity may be setting specific so will need understanding of both supply and demand side constraints.
- Very resource intensive to collect sufficient process map data to generate robust estimates
- It is complex to convert qualitative process maps, the times attached to them to resource valuation, in particular need significant setting specific understandings of when and why patient pathways were structured in a particular way, how they may be streamline and any potential unintended consequences of this.

3. Collecting data

Throughout these sections, we will use one example—highlighted in pale gold boxes such as this one—to help illustrate the application of methods. It is not a real-life example.

In this section, we will go into the details of the first four steps of TDABC data collection (Table 2). Data collection should be planned carefully to ensure that the right information is collected. This requires an understanding of the study objectives and how they translate into the project work plan; as well as ensuring that logistical arrangements are in place to facilitate data collection.

Practical tips: Conceptualising the service provision ahead of the data collection

The analyst must first understand how an intervention is situated and structured in a facility before embarking on the costing exercise. Often times, the way that a health facility organises itself to deliver a service or intervention determines the amount of resources that are utilized. Analysts must remember that the costing process is primarily one of identification of resources, and therefore must determine how these resources are organized to meet the needs of the facility.

Step 1. Define the service under consideration

In any costing exercise, a key first step is to define the intervention being evaluated. Describing the intervention in detail will allow an analyst to have an idea of the extent of the costing exercise, and to anticipate the types of services that are typically important for the delivery of the intervention. This allows the analyst to know the 'boundaries' of an intervention and what additional services could be considered in the costing exercise or will need to be excluded. Analysts can refer to the template for defining the scope of a costing exercise presented in the costing guidelines for syphilis screening (10).

The service under consideration is antiretroviral therapy for stable patients under differentiated care guidelines. Stable patients have a reduced clinical pathway: they only have 2 visits with a clinician per year, have an additional 2 pick-ups for a three-month course of antiretroviral drugs (ARVs) at the pharmacy and 1 viral load test per year. In our facilities, those services are all provided at a clinic level. We exclude 'treatment of opportunistic infection' from the costing exercise, given their rare occurrence in stable patients.

Step 2. Define the care delivery value chain

This step involves the identification of services that a patient receives when they visit a facility to access health services. In most instances, care to patients will be given at designated wards or departments such as an HIV/AIDS centre, with a defined care pathway. However, patients might also receive services from other departments. For example, a tuberculosis (TB) test could be administered in a separate TB centre. All the services that a patient is likely to receive should be listed beforehand. This will allow the analyst to isolate services that are important to a particular treatment—for instance, if interested in HIV care, only services that add value to HIV care should be considered during data collection.

ART is provided at different levels of care, but for our study we focus on clinics and out-patient services in hospital settings. Across a year, patients visit: (i) clinicians, (ii) laboratory services, (iii) pharmacies. Depending on the setting, clinical visits are either streamlined with other services or provided in separate wards. Laboratory services are always situated within the clinics or hospital, but may be in different locations from the visits. The analyst should also remember to include general locations such as reception or waiting rooms.

Step 3. Develop process map

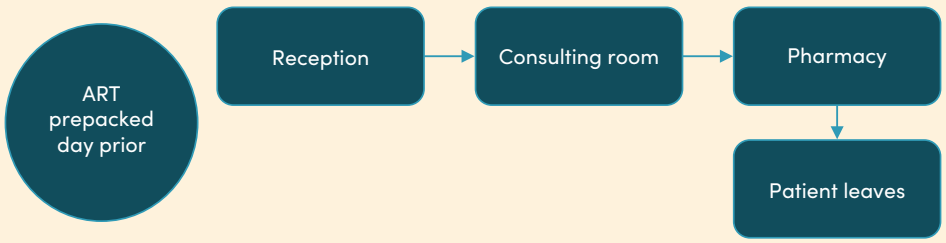
Once all the services that patients receive are listed, process maps to establish the care pathways must be developed. The process map is basically a patient flow chart that shows how patients move through the facility when receiving a particular service—from arrival to exit. Health facilities often organise themselves to provide care in the most efficient way and move patients along to the extent that available resources including personnel and space are optimised, although this is not always the case.

It is always a good idea to draw the process map as a diagram depicting the various steps in the care pathway. This is important because it gives clarity not only on where each step occurs but the direction of the patient flow and the sequence in which services are given. In some facilities, for example, two different types of services may occur at one step of the pathway (e.g., the reception area can also be used for triage), and at times patients may be required to return to a certain step. This can get confusing if not displayed diagrammatically. Conversely, two patients that seem to present for the same services may follow a different pathway, based on their clinical needs. In this case, you will have to 'resolve' any differences between observed patients.

The first step is to draw a simple process map, as shown in the figures below. We show different process maps for stable patients visiting the clinic for ART, based on the type of visits they require.

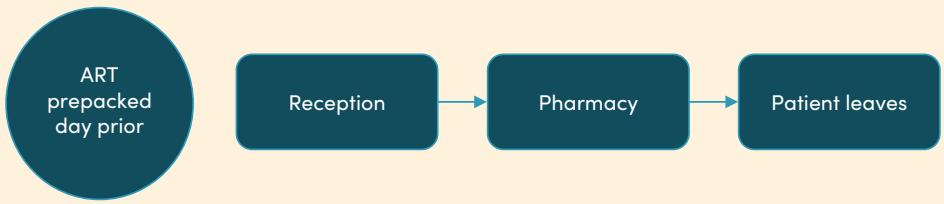
The first process map shows the flow of patient for a six-month clinical visit (Figure 1). It is worth noting that the process map starts before the patient arrives, as the ART is prepacked based on the appointments. Typically, facilities will have a reception area where patients are received and directed to a particular service. From there, patients will go for an initial assessment or triage where vitals are taken, then to a waiting room and a consultation room. Before the patient leaves, they will go to the pharmacy with prescriptions to pick-up their ARVs. The process map tracks this flow of patients. The below process map may be extended to include laboratory services once a year (for a viral load test).

FIGURE 1. Process map for six-month clinical visit



We also draw a process map for ART pick-ups (Figure 2), which patients do every three months and which does not include a clinical visit.

FIGURE 2. Process map for ART pick-ups



The data collector must ensure that the process map is correct. As a result, following direct observation, you should seek confirmation from knowledgeable health facility staff.

A guide that can be used for process mapping is provided in Appendix 1. With this tool, the data collector lists all the steps in the care pathway from 1 to 'n' in the order in which they occur. Make sure to get the correct names of each step.

Note that sometimes a facility may have differing pathways for different groups of patients. In our example, ART is provided to all patients registered following a positive HIV test. However, stable patients have a different clinical pathway compared to new patients, unstable patients, or paediatric patients. Depending on how the service is defined, you may want to make process maps for each patient and ensure that your data collection process observes a sufficient number of patients across all the identified categories. Various sampling techniques can be used to ensure that a representative sample of patients is drawn (11).

Practical tips: Process mapping

- Processes and treatment pathways may differ from one facility to another, even if they are of a similar level. Therefore, if collecting data in more than one facility, the process mapping will have to be repeated at each facility visited.
- Sometimes, health facilities will have the patient flowchart (process map) already drawn out and placed somewhere in the health facility, which can be used as a reference.
- Do not forget to include general services at the facility level: your focus is to track patients from the moment they arrive at the facility to the moment they leave. This means waiting rooms will be a feature of your process maps.

Inventory of resources

Once the process mapping is completed and all the steps of the patient pathway are listed, the enumerator should make an inventory of all of the resources that are used to provide these services at each step. An example of an inventory tool is provided in Appendix 2. Information will be gathered on all resources, including the personnel providing services at each step, the equipment, and medical devices. An often-overlooked category of resources is furniture, which will also need to be documented.

The inventory process described below should be done for each step of the pathway. For example, Figure 1 has three processes or steps: 1) Reception, 2) Consulting room, 3) Pharmacy. Each of these steps are conducted in a separate room (or area) and there are people (or personnel) involved and they use resources, which will be recorded by the enumerators.

We present our inventory of resources for the consultation room. We start by measuring the space area of the room. Because it is small and has a considerable amount of furniture, we use a tape measure to do so.

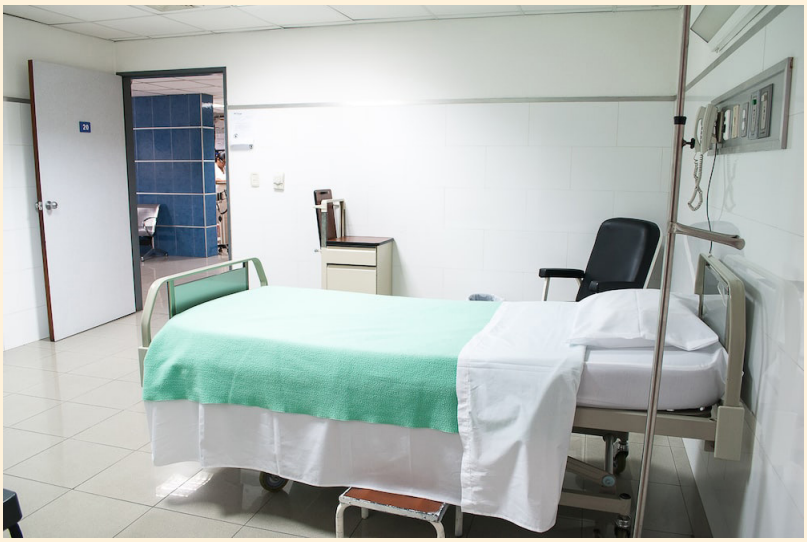


Photo courtesy of Martha Dominguez de Gouveia (unsplash).

The consultation room is attended by a clinical officer only. The room has the following equipment: mechanical bed, armchair, stepping stool, filing cabinet, phone system, trash bin.

a. Space or building surface area

Information on the space and its floor area where services are offered should be collected in order to estimate building costs. Data collectors will measure the squared metres of space used to provide a service and record this in the data collection tool. If the building floor plan is available (usually displayed at the facility), this can be consulted; otherwise, the space must be measured manually. Table 3 is a simple table that can help record the information.

TABLE 3. Inventory of spaces

No.	Name of Place	Funded by	Square Metres
1			
2			
3			
4			

Measurements can be done in several ways and should be as accurate as possible. Data collectors can use 1) measuring tape, 2) a measurement app on a mobile smart phone or tablet, or 3) the pace out method with a natural stride.

To measure the floor area, one must first take the length (L) and the width (W) and multiply them together.

If using the pacing method, the data collector will walk the length of the room and count the steps that it takes to get from one end to another. For this method, one step (or stride) is approximately a meter. If, for example, it takes ten steps to walk the length of a room, then that distance can be estimated at ten metres. If the width of that room is five metres, then the area of the room is:

Area = Length x Width
= 10m x 5m
= 50m^2

Practical tips

- Some methods for measuring space may be less appropriate depending on the space: for instance, if the room is small and contains a large amount of furniture, then using a natural stride is not recommended. Conversely, if the room is very large, then using a tape measure is not recommended.
- One method should be employed consistently across all rooms.
- Other ways to measure space include a) a laser measurement tool if available or b) a floorplan, a ruler and a scale to turn a centimetre into x meters or c) a print-out from Google Earth, and knowledge of how many floors each building of relevance has.

b. Collect information on the people or personnel involved in each step

Data should be collected on all the staff involved, including non-medical staff (e.g., security guard or receptionist), at each step. It is important that the name of the process and step are clearly labelled on the data collection tool. An ID for the employee (name is not usually collected, in order to protect study participants' identities), their job title and where funding for any remuneration is obtained (e.g., paid by the government, donor or other funding agencies) is recorded in the tool. The latter is important when differentiating between economic and financial costs to reflect the purpose of a costing study.

Data on salaries and wages of staff is typically not available at the facility and this should thus not be the focus of data collection at this stage. Such data will typically be documented by their employer, whether it is the government or another entity (e.g., an NGO). A simple table similar to Table 4 can be created to record this.

TABLE 4. Inventory of personnel

No.	Process	ID of Personnel	Job Title	Funded by
1				
2				
3				
4				
5				

When all individuals have been found and listed, interviews can be conducted to gather more information on how staff spend their time performing various tasks. Some of those questions will help you calculate the CCR (e.g., on working time, lunch break time). You may consider the following questions:

- How many people have the same role as you at this facility? _____
- How many people in this role are typically working at the same time? _____
- Can you briefly describe what you do during this step? _____
- On average, how long do you spend doing this activity for an average patient? _____ min
- How many hours a day do you spend performing this activity? _____ hours
- What percentage of the time is someone in your role engaged in this activity? _____%
- How many days a week do you work? _____
- What are your working hours on an average day? _____
- What are your working hours on weekends (if working weekends)? _____
- Do you have a (lunch) break during the day? _____ If yes, how long? _____

c. Collect information on the resources in the space where the step takes place

The name of the place at which each step occurs is recorded, together with the resources available there. Resources will include equipment, medical devices, and furniture. Record the number and type of each item, providing a good description of the type, make and condition. Once again, the funding source of all resources should be recorded (e.g., whether government or donor). You should conduct the inventory only once, for items that are presently functional.

TABLE 5. Listing of equipment, implements and furniture

No.	Items	Description	Funded by
1			
2			
3			
4			
5			

Examples of equipment typically found in a health facility include computers and laptops, scales, blood pressure machines or cuffs, thermometer stands, bassinettes, linen receivers, bedside screen or curtains, oxygen cylinders. Furniture can include hospital beds, chairs, tables, metal cabinets, fridge, freezer, benches, operation stool, food trolleys, steriliser baskets. Medical devices include catheter, thermometer, infusion pump, surgical sutures, scalpel, blood glucose metre, pulse oximeter, stethoscope. The analyst must also estimate the useful life years of all equipment, furniture, and other capital items (such as buildings) that are purchased in one year but used over time in the provision of services. These data are important for annualizing capital items and ultimately estimating the capacity cost rate.

Practical tips

- Most facilities will have an inventory list of all furniture, equipment, and devices available in each room or area. If this list is available, the data collector should take note of the listed items and confirm that everything is in place.
- Quite often, movable equipment and devices will be shared between 'spaces' or departments, for example, a scale used at step one is the same one used at step four. Data collectors should take note of this and ask knowledgeable personnel how often and for how long a particular 'shared' resource is used at each step. During data analysis, such 'shared' resources can be allocated to a particular step or department.

d. Collection of information on shared resources and indirect costs

Usually, an intervention is located in one area of a health facility and will occupy a section or space in the facility. For example, HIV/AIDS interventions usually take place in the HIV/ART department, and the office space will be on the same floor or building. Within this department, there may be several units, e.g., for paediatric HIV, adult HIV, PMTCT.

If the costing survey is focused on only one unit (e.g., adult ART) or does not cover the entire facility, there may be shared resources between the unit being covered in the survey and the rest of the facility, which will not be accounted for by the process map since this tool records the resources for a particular intervention.

Typically, "indirect costs" include all resources that benefit patients in an *indirect* rather than *direct* manner. Thus, while clinical staff such as nurses or doctors and pharmacists meet directly with patients (a "direct" cost), others such as administrative staff, janitors, security guards and other personnel do not (an "indirect" cost). Likewise, while specific machines may be used to process a blood sample (a "direct" cost), heat, electricity, air conditioning, internet and other utilities are not specifically used for an individual service. Shared costs can be assigned to a particular programme using an allocation factor. For example, if a building is being shared, the analyst can allocate costs based on floor space used (12).

The facility under consideration offers eight different services, and HIV services are mainstreamed with general care.

We identify the following shared resources across all the services: in addition to water, electricity and internet; we also note the use of a security service during the day and night, cleaning service and technicians on site to conduct small repairs and maintenance. A mini-van is owned and used by the facility to pick up deliveries so we also include the value of the van, its maintenance and fuel as part of the overheads. Part of those expenses are recorded by the facility accounts, although some may be donated or paid for by the ministry.

In addition, the facility management team employs three persons for finances, reporting, general management and human resources. Information on the average gross remuneration for this staff is collected from the Ministry of Health rather than from facility accounts.

Practical tips: Calculating indirects

- At the beginning of the process mapping, the enumerators can gain knowledge on those indirects by observation and speaking to facility staff.
- Indirects are typically more challenging to obtain if the facility is larger, as it would require investigating all the shared functions of the facility. Some facilities may have estimates at hand. If this is the case, ensure you understand what they cover and what they do not; assumptions should be made to ensure they are comprehensive.

Step 4. Conduct a time and motion study

The time and motion study (TMS) is linked to the process mapping and involves the observation of the time that it takes health personnel to provide services to patients at each step of the clinical pathway. For an example analysis in Microsoft Excel, see this instruction manual developed by Ryan McBain.[1] Below we describe the steps one should take when preparing and undertaking a time and motion study.

a. Identification and recruitment of patients

The first step in the time and motion study is to identify and recruit patients to be followed through the care pathway. Consent should always be obtained before recruiting patients into the sample.

The number of patients to be recruited should be determined beforehand. If available, the patient register could be used as a sampling frame. In some instances, patients attending HIV care are pre-booked and come to the facility on appointment, making it easier to sample prior to data collection. If a patient register is not available and there is no order to when patients present to the facility,

1 The author of the spreadsheet has agreed to sharing from his personal drive.

recruitment can be done as and when patients arrive. In both instances, a random sampling method should ideally be adopted.

Systematic sampling is ideal, where patients are selected at regular intervals from the sampling frame (patient register) or as they arrive at the facility. The intervals are chosen to ensure an adequate sample size. If a sample size *n* is required from a population of size *x*, every x/*n*th patient will be selected from the frame. For example, if a sample size of 100 is desired from a population of 1,000, every 1000/100 = 10th patient will be selected from the sampling frame. You may also pay attention to the time and the day of the week you are observing: some may be busier than others so spreading your sample across different times is advisable to get TMS results that are most representative of an average day.

It is also important that the sample is as representative as possible of the patient population, therefore stratification can be done by sex or patient category.

Practical tips: Sampling patients

- One of the first steps would be to discuss with staff at the facility how appointments are made and being recorded. Asking for a patient register will allow identification of patients' categories much easier, especially if you need to sample a minimum number across different patient categories.
- If a patient register is not available (or there is no system of appointment), you can gain insights to understand what the pattern seems to be for different types of patients. Using our example again, there may be differentiated clinic days for stable or unstable patients. Stable patients, whose consultations are much shorter, may tend to come much earlier in the day before work if the clinic opens early. Discussing those patterns with staff could be helpful.
- Also discuss with facility staff what they think the 'average' time spent at the facility by a client from entrance to exit is. If you are doing direct observation (as per one of the below options), then this can help you decide on how many patients you can sample as it would influence how many patients you are able to observe.

b. Observing patient time

Once patients have been recruited and have consented, they are followed up to record the amount of time that it takes to receive services at each step of the pathway using the process maps which you have developed earlier. For example in Figure 1, patients start the process at the reception (step 1) and exit the facility after visiting the pharmacy.

Following of patients through the patient pathway can be difficult and there are several ways to do the time and motion study, depending on the circumstances and available data collection resources:

- Observation (enumerator): The enumerator could be stationed at a location which makes it possible to observe the entire process map. This is possible when the facility has organized the care pathway in a small space and the process map follows a linear pattern with steps occurring in sequence, one after the other.
- Time stamps (with the help of facility staff): Facility workers stationed at each step of the pathway can be recruited to collect data. In this instance, the facility staff must be trained on how to record the time they spend with patients. Care must be taken to create minimal disruption to workflow. Alternatively, the staff can be given a clock and record what the time is when they first encounter the patient. Any gaps in between two recorded times can be inferred as waiting times.
- Patient diaries: Patients can be given a sheet where they record the time spent at each step of the pathway as they receive services.

The time sheet used to collect data on time is provided in Appendix 3.

Time can be recorded using a stopwatch or a clock. If using a stopwatch, data collectors should ensure that the actual amount of time observed is recorded and not rounded off. If a process takes 5 minutes and 30 seconds, this will be recorded as the actual time taken and not 5 minutes. Enumeration can be done for a full day or until the required number of patients for the day is achieved. Timing of data commencement is also important. In some facilities, patients come very early to queue up before the facility opens.

Practical tips: Observing patient time—direct observation, time stamps or patient diaries?

Different methods have advantages and drawbacks:

- Observation: This method can be time consuming and there is a large probability of errors in recording and observation if the enumerator is observing more than one patient. If observing only one patient, then this method will result in a low number of observed patients.
- Time stamp: This would allow to draw information from a large number of observations. However, it will require training of healthcare facility staff and it may be less popular because it imposes constraints of staff. Moreover, errors may occur, for instance if the patient forgets to hand in the time sheets or the facility staff write down incorrect times. You may want to budget for such errors, as much as 20%.
- Diaries: This may be prone to error or reporting bias and will require extensive patient training. An enumerator should be posted to collect the diaries at the exit.

c. Observation of staff time

An important aspect of the time and motion study is the observation of staff time. This is because the allocation of staff time to different activities is important to calculate the CCR and also because some activities relating to patients may be conducted before or after the patient visit (see our example on the clinical visit starting with ART packed the day before). At least one staff member can be enumerated at each step of the process map. This should ideally be the person that is usually at this place (or in charge). Start observing them from the time they start work and record all times including breaks. Health workers could also be requested to keep a diary where they record the time on specific activities.

TABLE 6. Sample staff time sheet

Step	Name of Process	Staff Job Title	Service Time (in Hours)		Break (in Hours)	
			Hours	Minutes	Hours	Minutes
Step 1						
Step 2						
Step 3						
Step 4						

Data collection can be done on one day to get a cross-sectional estimate, or over several days or a period to get a representative sample of times. The decision on this will obviously depend on the availability of time and resources. This exercise can be quite demanding and resource-intensive. An alternative would be to monitor staff time for a select number of patients, inclusive of preparatory time (if relevant, before seeing the patient) and post-processing time (if relevant, after seeing the patient). For example, a clinician might review a patient's medical chart prior to seeing her/him, and write up a consultation note and do EMR entry after seeing the patient.

The TMS needs to take place in one day in the facility. We decide on working with facility staff to use the time stamp system, given the limited time. We choose a mid-week day to ensure that the data collection, after discussing with facility staff is as close to a 'neutral day' as possible.

Prior to the TMS day, we ask who the personnel will be in each step of the process map and ensure that they are trained about the process. Two enumerators will be deployed over that day to support both patients (and obtain their consent) and facility staff. They will also be checking the first time stamp sheets collected in the morning to see if the data was properly recorded. An additional investment is the purchase of a number of clocks or watches (preferably digital), which will be provided to each staff identified through the process map.

Time sheets are printed in bright colour paper to ensure that either the patient or the clinician remembers/sees them and the print should be large to ensure that the clinician or client can read it easily. We estimate that one in ten time sheets will be lost or incorrectly filled, so it is decided that 4 patients per hour will be recruited, for an estimated total of 28 sheets in the entire day.

4. Data analysis

Data can be organised and analysed using Microsoft Excel. To execute the analysis, the unit cost of a service can be broken down into costs of personnel, equipment, space, drugs and indirect costs. The data analysis is done in the following three steps:

Step 5. Estimate the cost of supplying patient resource

This step involves estimating numerators—the cost of a resource, which is typically defined over a period of time. For example, for personnel, salaries and benefits are often defined annually (e.g., $20,000 per year). This is also true for the cost of equipment and space: the cost of building and maintaining a consultation room in a health centre may translate to $200 per year, once one has accounted for depreciation. Consumables such as medicines are slightly different because these are usually only available for one-time use, in which case the unit cost of the item would be the appropriate numerator.

Step 6. Calculate the capacity cost rate

As noted earlier, this is one of the most important components of the approach. The goal of this step is to calculate the unit cost, which is generated by combining numerators and denominators. Specifically, the cost of the resource (numerator) is divided by the amount of time that resource is available to be utilized for patients (denominator). The goal is to generate a unit cost (dollars/min) for each resource in the cycle of care: personnel, equipment, space and indirects.

In the case of personnel, a clinician's salary and benefits (e.g., $20,000 per year) is divided by the number of minutes that this individual is available for delivering patient care over the defined period (e.g., 100,800 minutes) for a standardized rate (e.g., $0.20 per minute). The number of minutes that the clinician is involved in delivering care is the total working time, minus the lunch break, other breaks that may be routinely taken throughout the day, including waiting times in between patients and other aspects of non-clinical care (logged in your staff time sheet). In academic institutions, the amount of time the clinician devotes toward teaching and research is subtracted.

For equipment, the cost of the machine is divided by the number of minutes the machine is available for utilization, taking into account the number of tests the machine performs.

Non-consumables are accounted for separately since they have no denominator.

Step 7. Calculate the total cost of patient care

Once all the calculations have been made for capacity cost rates, the total cost of patient care can be generated in a very simple manner: namely, by multiplying unit costs for each resource by the duration of time the resource is utilized. This is done for all categories of costs that are expressed in

dollars/minute (or other monetary unit). For example, if a provider sees a patient for a 5-minute visit and their capacity cost rate is $0.20 per minute, the cost of provider time associated with the visit would be $0.20 per minute * 5 minutes = $1.00.

The costs of all personnel, equipment, and space are then aggregated to estimate the total cost of patient care. This can be compared with reimbursement prices to ensure that there is a positive margin for these are aligned. Too low reimbursement is not sustainable, too high reimbursement is inefficient and averts money from elsewhere where more value can be generated i.e. this would mean that other things cannot be funded.

Two additional considerations should be mentioned. First, as noted above, for consumables, one would not be utilizing a capacity cost rate. Instead, the multiplication would account for the unit cost of the consumable (e.g., $0.10 per tablet) and the number of units expended (e.g., 30 tablets taken once per day): $0.10 per tablet * 30 tablets = $3.00. It is worth noting that some studies might also include wastage or expiry.

Second, indirects can be a difficult aspect of resource consumption to estimate and factor into your final value for the total cost of patient care. One approach to addressing indirect costs is to generate a capacity cost rate by summing all indirect costs for an entire year at the facility level and then dividing this cost by the (estimated) total number of patient minutes spent at a facility by all patients over the year.

For example, if one were to add up all "indirect" personnel, utilities, common space, and the like, the cost may come out to $100,000 per year. If 20,000 patients were seen over the course of the year and, based on your process maps, you estimate the average duration of time spent at the facility (inclusive of wait time) is 120 minutes per patient, then the indirect capacity cost rate would be: $100,000/(20,000*120)=$0.04 per minute.

5. Applications of TDABC

As noted in the Introduction, TDABC has several unique features that make it an robust choice for conducting cost analysis. Below, we discuss six potential applications.

1. Identify actual costs for providing services, which are often unknown

At the most fundamental level, TDABC is intended to provide accurate information on the cost of services. Compared to other methods that often rely on questionable assumptions, this approach is based on the direct observation of the actual resources consumed by patients throughout the care delivery process. The capacity cost rate also represents a single, standardized metric underpinning calculations in your cost estimation exercise. Most often, such costing estimates are used at the

decision-making and resource allocation level for the following exercises: budgeting, resource planning and mapping, budget impact calculations (e.g., in the case of expansion of coverage).

2. Account for rapid changes in service delivery, recognizing that one-time cost data become dated

The TDABC framework is easy to update based on revisions in the care delivery process: one only needs to modify process maps to reflect revised care pathways, gather additional time estimates (if relevant), and revisit capacity cost rates as well as other background changes that may have occurred—for example, in overhead or a change in clinical guideline (e.g., additional services added to the pathways). Because of the disaggregated nature of TDABC's method, the estimates could serve as an ongoing apparatus for tracking resource consumption and modifications in clinical care over time to keep up-to-date cost data.

3. Inform decision making for more financially sustainable and effective services via routine collection of service delivery costs

With a stronger understanding of cost drivers in your healthcare system, you have the opportunity to reflect on the existing system's strengths and weaknesses. The process mapping component of TDABC provides a foundation for your clinical leadership to ask questions like:

- Which steps in the care delivery process are being skipped, and how often?
- Are appropriate labs and medicines being ordered and prescribed? Why or why not?
- Are the correct providers involved in each step? Could it be equally done by someone less qualified (i.e. taskshifting)
- How long are providers spending with patients, and is this an appropriate amount of time?
- Are some patients receiving more care than others, and if so what types of patients are these? Does it reflect need or user demand?

4. Drive efficiencies through improved delivery of service

A related contribution of TDABC is the potential to identify opportunities for greater efficiency. By efficiency, we broadly refer the outputs generated by each dollar invested in the health system. On the one hand, greater efficiency could be achieved by focusing on greater standardization of care delivery processes—which may result from a comparison of expected versus observed care pathways for patients. On the other hand, greater efficiency could be achieved by dedicating greater resources to patients with higher levels of need and a more streamlined set of resources for those with lower levels of need: for example, in a differentiated care system. Using the capacity cost rates collected for each type of provider, physical space, equipment and the like, individuals with TDABC information can also construct hypothetical scenarios for remodelled care delivery and project cost estimates for this.

5. Inform the development of broader national strategic plans and increase local capacity

When TDABC is conducted across multiple clinics within a district or country, it presents a possibility to compare cost estimates at a broader level. For example, administrative heads can examine: whether capacity cost rates diverge significantly (for the same personnel) across facilities and geographies; whether the care processes themselves diverge significantly (for the same service) across facilities and geographies; and whether the cost of care—and by extension, dedicated resources—diverge significantly across facilities and geographies. These inputs can, in turn, guide policymakers in the development of strategic plans that may seek to standardize care delivery, promote more equitable resource allocation, and determine future budgets in areas that TDABC concludes are under-invested.

6. Allow for more effective provider payment rate setting

In public and private healthcare settings where payment rates are determined based on a fee-for-service structure or through an alternative payment model such as capitation in which there is risk adjustment, payment to providers is (typically) dictated by the average cost of a medical service. However, when the average cost of a medical service is unknown, these payments may be too large (creating an incentive for health systems to provide more of the service, thereby maximizing profits) or else too small (creating an incentive for health systems to withhold the service, undermining quality of care). TDABC provides an evidence-based cost estimate for determining payment in the public sector as well as negotiations for reimbursement from insurers in the private sector.

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Appendices

Appendix 1. Process mapping guide

INTRODUCTION: Thank you for your participation. Please describe all the steps that happen for a patient when they come for HIV treatment—all the way from the point of registration to the point of discharge. Let's go one step at a time, in order.

Step 1: _____

Step 2: _____

Step 3: _____

Step 4: _____

Step 5: _____

Step 6: _____

Step 7: _____

Step 8: _____

Step 9: _____

Step 10: _____

Note: The treatment pathways are different for different patients. Repeat this for Unstable patients; Stable patients 3mo visit; Stable patients 6mo visit.

Appendix 2. Inventory of resources

For each of the steps listed in the patient flow above, document the staff who work in a particular place and the resources used when providing services (furniture, equipment, computers, etc.

Part A: The People

Who from the staff is involved in this step?

Probe: Is there anyone else normally involved? Are there any variations in staff?

No.	Process	ID of Staff	Job Title	Funded by	How Many People Have the Same Role as You at this Facility?	How Many People in this Role are Typically Working at the Same Time?	Can You Briefly Describe What You Do During this Step?	On Average, How Long Do You Spend Doing this Activity for an Average Patient? (in minutes)	How Many Hours a Day Do You Spend Performing this Activity?	Do You have a (Lunch) Break During the Day?	If Yes, How Long?	What Percentage of the Time is Someone in Your Role Engaged in this Activity?	How Many Days a Week Do You Work?	What are Your Working Hours on an Average Day?
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

Part B: The Place

Where does this step take place?

(Probe: Is there any other place that this Step sometimes takes place?)

List all the equipment in this place

No.	Items	Description	Funded by
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

List all the medical devices used

No.	Items	Description	Funded by
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

List all the furniture

No.	Items	Description	Funded by
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Part C: Building surface area

Measure the surface area of the rooms where services are provided (in square metres).

No.	Name of Place	Funded by	Floor Space (m^2)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Appendix 3. Patient time sheet

Step	Name of Process	Service Time (in minutes)		Waiting Time (in minutes)	
		Minutes	Seconds	Minutes	Seconds
Step 1					
Step 2					
Step 3					
Step 4					
Step 5					
Step 6					
Step 7					
Step 8					
Step 9					
Step 10					