A feasibility study using time-driven activity-based costing as a management tool for provider cost estimation: Lessons from the National TB Control Program in Zimbabwe in 2018

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Abstract

**Background** Insufficient cost data and limited capacity constrains understanding of true required resources for TB control. This study using time-drive activity-based costing documented service delivery processes, mapped resources that are required to sustain and identified areas to optimise efficiency in delivery of TB services was conducted in Zimbabwe.

**Methods** A multi-disciplinary team applied time-driven activity-based costing (TDABC) to develop process maps and measure the cost of clinical pathways used for Drug Susceptible TB (DS-TB) at urban polyclinics, rural district and provincial hospitals, and community based targeted screening for TB (Tas4TB). The team performed interviews and observations to collect data on the time taken by health care worker-patient pairs at every stage of the treatment pathway. The personnel's practical capacity and capacity cost rates were calculated on 5 cost domains. An MS Excel model was used to calculate diagnostic and treatment costs.

**Findings** Twenty-five stages were identified in the TB care pathway across all health facilities except for community targeted screening for TB. Variations existed in health care professionals providing services between facilities for client registration, vital signs, treatment follow-up, medicines dispensing and sample processing.

The average cost per patient for the entire DS-TB care was USD324 with diagnosis costing USD69 and treatment costing USD255. The average cost for diagnosis and treatment was higher in clinics than in hospitals (USD392 versus USD256). Nurses in clinics were 1.6 time more expensive than in hospitals. The main cost drivers were human resources (USD130) and laboratory (USD119). Diagnostic cost in Tas4TB was twice that of health facility setting (USD153 vs USD69), with major cost drivers being demand creation (USD89) and sputum specimen transportation (USD5 vs USD3).

**Conclusion** We concluded that TDABC can be used as a costing and management tool in a low resource setting. Results from this study were used to identify areas of innovative improvements in the NTP under public health programme settings. Re-engineering laboratory testing processes and synchronising TB treatment follow-up with antiretroviral treatments could achieve significant cost savings in Zimbabwe.

**Background**

In 2018, Zimbabwe had an estimated Tuberculosis (TB) incidence rate of 210/100,000 population, more than the global average of 130/100,000, and was among the 14 countries with a triple-burden of TB, Tuberculosis/Human immunodeficiency virus (TB/HIV), and multi-drug resistant TB (MDR-TB) [1]. The country had a high TB and HIV co-infection rate of 62% and a treatment coverage of 83% [2]. With nearly one-fifth of undetected TB cases acting as *foci* for community transmission, innovative TB case finding approaches remain an urgent priority.
Despite high-level political commitment to raise USD15 billion annually for the global TB response, only USD6.9 billion was available from both domestic and international donors in 2018 [3,4]. In the Zimbabwe context, poor economic performance led to a funding shortfall of more than USD67 million (69%) for meeting the National Tuberculosis Programme (NTP) Strategy Funding requirement for 2017-2020. Contrasting the funding shortfall with Zimbabwe’s achievement of relatively high treatment coverage of more than 80%, donors were concerned about the robustness of the costing for NTP’s 2017-2020 strategy. There is limited true cost data for delivery of TB services leading to incorrect projections and optimisation of resources. This triggered a desire to better measure and understand TB program costs, identify areas that needed improvement in implementation, and guide resource allocation. We applied time driven activity-based costing (TDABC) to calculate the costs of actual healthcare resources consumed as a patient moves along a care process [5, 6, 7]. This bottom-up approach, which has had limited application to date in low-income settings, contrasts with the top-down volume-based cost allocation methods used previously in most health settings. This paper illustrates the feasibility of applying TDABC in a low-income setting for costing the care pathway for DS-TB. The study was approved by the Medical Research Council of Zimbabwe (MRCZ/A/2393).

**Methods**

**Program Set-up**

The DS-TB care pathway started with a presumptive TB patient’s initial contact with the health facility and their confirmation as a TB case, through to successful treatment completion. A molecular test using Cepheid GeneXpert was used for the initial diagnosis of all presumptive TB cases. Smear microscopy was used only for treatment monitoring. Out of the more than 1000 health facilities in Zimbabwe, there were 125 GeneXpert machines available in 2018. A private courier or motorised Environmental Health Technicians (EHTs) were being used to transport sputum sample from facilities without Xpert machines. A medical officer used chest X-rays for bacteriologically negative but clinically unwell patients to either confirm TB diagnosis or discharge the patient.

Since 2017, Zimbabwe had been using chest X-rays, as a more sensitive initial TB screening tool (Tas4TB) compared to symptoms assessment alone for screening hard-to-reach and high burden populations. Tas4TB was introduced initially in 21 high-burden but low notifying districts. In 2018, Zimbabwe introduced bi-directional screening for diabetes and TB. In this study, facility based TB diagnosis and treatment, was defined as the standard of care.

The treatment regimen for DS-TB consisted of rifampicin (R), isoniazid (H), pyrazinamide (Z) and ethambutol (E) for two (2) months, followed by RH for four (4) months (2RHZE/4RH). Confirmed TB patients were required to visit the health facility once every two weeks to collect medicines and assess treatment efficacy. At 2-3 months, 5 and 6 months, repeat sputum specimens were collected as part of treatment monitoring and to confirm cure.

**Study Sites**
We purposively sampled nine (9) health facilities (study sites), considering disease burden and level of care managed by either the Ministry of Health and Child Care (MoHCC) or the Ministry of Local Government. Two provincial hospitals (Chinhoyi and Gwanda), two district hospitals (Maphisa and Banket), four urban polyclinics (Rutsanana, Dzivarasekwa, Mzilikazi and Princess Margaret) and one Tas4TB mobile clinic were selected for the study.

**Costing Approach and Implementation**

A multidisciplinary team from NTP, University of Zimbabwe, College of Health Sciences, (UZCHS), Price Waterhouse Coopers Advisory Services (PWC), Harvard Business School (HBS) and the Global Fund (GF) conducted the study using TDABC. Capacity building was achieved through training of national partners on TBABC, joint development of process maps and tools, and pilot testing facilitated by GF and HBS.

Process maps for TB care pathways were developed iteratively using a combination of diagnostic algorithms, observations of workflows at the facilities and discussions with health care workers. Diagnostic maps captured the care pathway processes from the time a patient presented with signs and symptoms to confirmation of TB. Treatment maps captured the patient care pathway processes from notification of a confirmed TB case to completion of recommended treatment, which is, 6 months for DS-TB. Tas4TB maps described the process from site identification, demand creation, TB symptom screen using a WHO symptom screening tool, digital chest X-ray, Xpert MTB/Rif tests for presumptive cases, and treatment initiation in communities.

We observed health care workers providing TB care services at different TB care pathway stages, and documented the personnel type performing the task and the time taken per stage as described by Kaplan and Porter [7]. Time taken by health care workers at each stage was multiplied by the capacity cost rate (CCR), across five cost categories namely human resource (HR), medicines, equipment, laboratory supplies, and space (building). The sixth cost domain, overheads related to program coordination by the NTP Unit within MoHCC, was assumed to be constant with minimal variation over time. The CCR, the cost per minute of each resource, was derived by dividing the cost of supplying a service by the resource's annual practical capacity. Two parameters were used to calculate the total cost per TB patient: cost of resources used across the six cost domains, and the time required to perform an activity in the care cycle.

Practical capacity calculation for personnel was based on five working days per week for each health care worker adjusted to exclude days used for vacation, continuing professional development, sick leave and health breaks. The team estimated number of minutes available each day of each personnel type, and multiplied this quantity by number of working days per year to obtain the total minutes available per year per person. Each personnel’s CCR was calculated by dividing the annual cost of employing that person (salary plus benefits) by that person’s practical capacity (total minutes available per year). Salary data for each cadre of health care worker was obtained from the HR Departments in the MoHCC and Local Government Authorities.
A similar method was used to calculate the CCRs for equipment and space. We assumed an equipment utilization of 85% with 15% down time for repairs, maintenance, and scheduled calibrations. Cost of equipment was based on most recent procurement data supported by government or donors and useful life of equipment. Useful life of equipment was estimated as 10 years for X-ray machines and vans; five years for GeneXpert, full blood count, chemistry and audiometer, and seven years for the digital X-ray machines. We measured square metres within a health facility dedicated to delivering TB care and time taken to provide TB services. In case of shared space, estimates were used. Cost of space was based on replacement cost per square metre, useful life (depreciation), plus annual operating expenses as defined in the MoHCC guidelines and costing of the National Health Strategy (NHS), 2015-2020. Costs of utilities (water and electricity supply), medicines, including anti-TB medicines, laboratory supplies, and other consumables were collected from the facilities and the NTP at central level.

Time taken for activities at each step of the process map was averaged to calculate the provider unit cost per patient by facility type. The final calculated provider unit costs per patient, measured in United States Dollars (USD), were aggregated by cost domain and facility. Using the cost of diagnosis and treatment of one TB patient per facility, we estimated the total cost per facility using routinely reported facility data for 2017. This assessed cost variation by facility.

Data Collection and Management

The study was conducted from August 2018 to January 2019. Project team trained registered nurses, at each facility providing TB care, as research assistants (RA) to collect data. The RAs were assigned to facilities away from their usual workstations to minimise bias. Training and supervision of data collection were provided by the central team of experts from the NTP, UZCHS, PwC, HBS and GF. Data collection tools were pre-tested in non-participating facilities and adjusted accordingly before field work. The tools were programmed and uploaded into REDCap (Research Electronic Data Capture; https://projectredcap.org/software/), a data collection, transmittal and storage open source software. Data were transmitted electronically to the central level where the study biostatistician provided data quality checks and appropriate feedback to the RAs.

Study participants

Health care workers (HCWs) and facility managers were interviewed as key informants. Each HCW-patient pair was observed during diagnosis, care, and treatment to collect information on time and resources used step by step. We observed 3 to 7 HCW-patient pairs to reach saturation and get an optimal average time for each stage. Informed consent was obtained from all research participants including patients.

Results

Six hundred and seventy (670) observations for health care worker-patient pairs were conducted across nine sites. We interviewed 116 key informants.
Availability of TB services by facility

All four hospitals had capacity to offer chest X-ray, Xpert MTB/Rif/Ultra, full blood count, and chemistry services. One urban clinic, Dzivarasekwa, had a GeneXpert machine. The three clinics without GeneXpert machines transported sputum specimen to nearest GeneXpert sites. All facilities had microscopy services for treatment monitoring. Facilities with no X-ray, chemistry and full blood count services referred patients to hospitals offering the services. Hospitals provided entire cascade of care from diagnosis, treatment follow-up, to treatment outcomes evaluation. Integrated TB/HIV services were available in all sites (Table 1). The Tas4TB used a mobile van equipped with chest X-ray machines for TB screening. Clients who were positive on chest x-ray and symptom screen, had sputum collected and referred to nearest facility with GeneXpert machine.

Diagnosis, treatment and care pathways for DSTB

Twenty-five stages were identified from the process maps for care pathway. These were relatively similar across facilities except for Tas4TB (Figure 1-5). Community Tas4TB included demand creation stage and excluded treatment follow-up. All TB confirmed cases diagnosed through Tas4TB were linked to a nearest facility for treatment follow up.

Variations existed in health care professionals providing services at each stage between facilities for registration, vital signs, treatment follow-up, medicines dispensing and sample processing (Tables 2a, 2b and 3). Five facilities used nurse aides, and four facilities used nurses for vital signs. Diabetes Mellitus (DM) and HIV testing were embedded in the diagnosis stage care cycle. Sample transportation in Harare City was sub-contracted to a private courier whilst the rest was carried out by EHTs. After treatment initiation, DSTB patients were reviewed by the nurse once every two weeks for 6 months during scheduled appointments for drug pick up, review of treatment and adverse drug events monitoring. The last treatment monitoring follow-up review was done by medical officers to assess treatment outcome status.

Average time spent on each stage

Sample processing and transportation and HIV testing required the longest average times for health care workers (Table 4 and 5). Tas4TB, used in remote locations far from GeneXpert sites, had longer sample transportation (75 minutes) than district hospitals (69 minutes) and clinics (55 minutes). The recording and reporting of data, as well as treatment initiation took much longer in Tas4TB than in standard of care (10 vs 4 and 16 vs 4 respectively). First consultation during diagnosis phase was longer in clinics compared to both Tas4TB and hospitals (8 vs 2 vs 6) respectively. There were no significant variations in time taken by presence of co-morbidities or gender across all the stages and DM testing. The average time for HIV testing was high in district hospitals compared to both urban clinics and hospitals. Efficiencies were realized for patients with known comorbid conditions (such as HIV) since they did not need separate counselling and testing sessions for those conditions.
The longest time for recording and reporting was observed for Tas4TB compared to the other three settings (10 minutes vs 3 minutes). Tas4TB, a new concept in Zimbabwe, used a recording and reporting tool with 66 variables that took longer to complete.

**Space capacity cost rate, Zimbabwe TDABC, 2018**

The consulting rooms for hospitals had higher space CCR compared to clinics. Tas4TB had the lowest space CCR of all facilities. Capacity cost rate for GeneXpert was USD0·05 and USD0·19 for chest X-ray. The most expensive equipment per patient was the TB mobile van, with a CCR of USD0·57 (Tables 1 and 6), given the added fuel and vehicle costs.

Capacity cost rates for waiting area, laboratory, and pharmacy were the highest across all facilities (Table 6). Chinhoyi Hospital had the highest CCR for waiting area (USD0·98), pharmacy (USD0·105) and laboratory (USD0·145). The waiting area CCR for Dzivarasekwa clinic was similar to that of Maphisa and Banket district hospitals, USD0·05. In other clinics, some TB care activities were being provided in the same space, for example, waiting area and first consulting rooms.

**The Cost of Care for DS-TB**

The average cost per patient of the entire care pathway was USD324 for all facilities (Tables 7 and 8). The average cost was higher in clinics (USD392) compared to hospitals (USD256). The cost for hospitals ranged from USD239 to USD272 while clinics ranged from USD335 to USD489. Mzilikazi and Princess Margaret clinics had costs of over USD400, due to high unit cost for sample transportation and HIV testing.

The diagnostic cost was USD69 and treatment cost was USD255 per patient. Treatment cost ranged from USD181 to USD387 per patient. The average diagnostic and treatment costs per patient were 1·2 and 1·7 times higher in clinics than in hospitals average cost of HIV testing per patient was higher in clinics (USD7) compared to hospitals (USD3), due to the type of HCW. Sample processing cost per patient during treatment stage was higher compared to diagnosis stage (USD84 versus USD19). These high costs were driven by repeat tests during treatment follow-up visits.

On average and across all facilities, the major cost drivers were HR (40%) and laboratory (37%) (Table 8). Cost of diagnosis and treatment of TB was higher in urban clinics compared to hospitals due to variation in cost of labour. The HR costs were lower in hospitals USD56 vs USD204 compared to clinics. Laboratory costs were higher in hospitals USD127 vs USD111 in clinics since most of the laboratory work was hospital based. Nurses working in urban polyclinics were paid more, contributing to the higher costs of providing TB services at clinics compared to hospitals (average USD0·46 vs USD0·08 per minute). Medical officers from urban clinics were expensive compared to district and provincial hospitals average (USD0·50 vs USD0·16). The overall cost of treatment was pushed up by the number of follow-up visits to facilities (of up to six) made by patients. Half of the visits are only to collect the next two weeks of refills, with no clinical assessment beside vitals.
The costs of targeted active TB screening

The diagnosis cost for TaS4TB was twice that of standard of care, USD153 vs USD69. Major cost drivers were demand creation, chest X-ray and sample transportation to nearest diagnostic facility (USD89, USD33 and USD19 respectively (Table 7)). Demand creation which precedes TaS4TB screening involves senior level health care workers from national and provincial levels.

Discussion

This study demonstrated that TDABC can be used as a management tool for understanding services’ organisation, mapping resources and cost in a public health program and identifying opportunities for improvement. Key success enablers were a strong orientation at the onset of the programme, joint development of protocol and tools, and use of nurses familiar with the TB processes. Zimbabwe uses the primary health care concept which relies on the availability of well-trained HCWs at the lowest level of care to manage the most common diseases affecting the local population [8]. Nurses in Zimbabwe are trained to manage commonly occurring diseases, including TB. Additionally, the collaboration between local partners, GF and the HBS team built local capacity for implementation.

We observed minimal variations in the workflow for treating TB and related comorbid conditions, HIV and diabetes. Lessons drawn from this study, therefore, can be applied to the rest of centres that provide TB services. The urban polyclinics had limited capacity in diagnosing, yet the volume of patients on treatment was similar to hospitals [9].

Treatment cost at urban polyclinics was more expensive than at district and provincial hospitals. Some of this difference was due to the higher compensation paid to HCWs in polyclinics, which were supported by the Ministry of Local Government, compared to the HCWs in hospitals, supported by the MoHCC. Despite donor funded retention allowances for rural hospitals, those HCW salaries were still lower than in urban polyclinics. The skill-mix also varied between clinics and hospitals. Higher paid nurses provided TB/HIV counselling care in urban polyclinics while lower paid lay counsellors provided these services at hospitals. Hospital staff generally operated at the top of their license, with nurses delivering direct patient care and lower-paid staff performing less-skilled roles. Nurses at clinics, however, performed multiple functions because of staffing gaps caused by the inadequate funding for many clinics. Third, hospitals mainly diagnosed TB patients and then referred them to clinics for treatment and follow up. Clinic TB diagnostic costs were 1·2 times higher than at hospitals because of the high specimen transport costs. HIV testing cost was also higher in clinics than hospitals, likely due to task shifting. Hospitals used lay personnel for HIV testing services while nurses performed HIV testing at clinics.

Ongoing treatment at clinics involved many steps, including two weekly treatment follow-ups, recording and reporting, specimen transportation costs, laboratory monitoring of treatment response, and medicines pick up. Zimbabwe could reduce costs by shifting to monthly follow-up visits, a frequency already used for antiretroviral therapy (ART) for HIV patients, and with treatment outcomes comparable to other low- and middle-income countries (LMICs) [10].
The NTP could also study the cost-saving benefits from eliminating repeat sputum microscopy tests at the 5th and 6th monthly visits. These studies would assess quality of care, misclassification errors of cured into treatment completed and proportion of missed multidrug resistant TB cases post-treatment. The cost data from this study was used for the 2020-2024 national strategic plan, using the TB/HIV Impact Measure and Estimates (TIME) modelling tool.

Cost of confirmation at Tas4TB was 2.2 times more than standard of care due to sample transportation costs and demand creation. Since Tas4TB was a new concept, opportunities to improve its efficiency are possible. For example, reorganising the Tas4TB workflow and reassigning of responsibilities from national level to district health care workers, especially for demand creation, would lower total costs. Embedding a molecular diagnostic equipment in the van used for Tas4TB would also lower costs. Optimising screening by Tas4TB is critical because studies from Zimbabwe and other countries have shown that targeting high risk groups increases access and reduces TB incidence [11-12].

An inherent limitation of the study, due to it being the first to use TDABC to measure the cost of TB treatment, was the inability to compare and learn from treatment processes and costs in other low-to-medium income countries.

Our study results provided data to inform possible policy changes and cost reductions. The cost of laboratory (diagnostic) services could be reduced by redeploying GeneXpert machines to reduce transport costs and improve access of TB diagnostic services to patients. This would require a thorough mapping exercise to assess the current reach of GeneXpert machines. In addition, to increasing access to patients and reducing cost of transport, this policy change could lead to a net increase in capabilities (or resources) and decrease processing time at each facility. Another improvement would be to batch samples across TB diagnosis as well as other disease programmes to optimize shared costs. The number of patients’ follow-up visits during treatment phase can be reduced from 12 to 6 visits, by customizing drug-refill frequencies to patient risk characteristics. This would reduce provider costs and increase patient compliance by removing repetitive process steps with limited added value to treatment outcomes.

Conclusion

The study has shown that it is feasible to apply and embed TDABC in limited resources settings as a management tool for analysing and costing care processes in public health programs. The results identified processes that require re-engineering and dimensions of domestic funding landscape that are not visible in the NSPs such as contributions through the Zimbabwe Ministry of Local Government. Alignment of drug refills for co-infected TB/HIV patients can reduce both provider and patient cost.

List Of Abbreviations

ART: antiretroviral therapy
Declarations

Ethics approval and consent to participate

The study was approved by the Medical Research Council of Zimbabwe (MRCZ/A/2393). Written consent was sought from both patients and health workers before commencement of observations.

Consent for Publications

This is not applicable because there is no personal information that has been provided in the manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

BNS, CS, SC, LM, AB, RSK substantively contributed to conceptualization of the study. BNS, SC, LM, RSK, KB, PD, JC, CS, TM, TMap, SS, CT, AM, EA, MN, EW made substantial contribution to the study design, methodology and development of tools. TM, TMas, MD, SS, TMap, JC, AM, CT, BNS, SC made substantial contribution to data acquisition, curation and data analysis. All authors contributed to interpretation. JC, BNS, CS, SC, LM, AB, AM, CT, RSK, KB, PD, TM, TMap, SS, AM, EW contributed to drafting of the manuscript and revisions.

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