

District overview of travel time to ART facilities: Blantyre

Kevin Lam, Jeffrey W. Eaton, Stone Mbiriya, Brown Chiwandira, Tiwonge Chimpanzule, Thokozani Kalua, Rose Nyirenda, Andreas Jahn. *Department of HIV and AIDS, Ministry of Health, Government of Malawi; MRC Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London*

Version: 05 March 2022; Correspondence to: Andreas Jahn (ajahn@hivmw.org)

Objectives

- Map the estimated prevalence and number of people living with HIV (PLHIV) by approximately 1 km grid cells.
- Estimate the travel time to the nearest ART facility for PLHIV in Malawi.
- Identify optimal locations for additional facilities with ART service to reach PLHIV with long travel times to existing ART facilities (>60, 90, or 120 minutes).

Interactive results are available at: https://mrc-ide.github.io/mwi-hiv/ART_facilities/index.html.

HIV prevalence and PLHIV estimates

Figure 2 illustrates estimates for spatial HIV prevalence for adults aged 15–49 years. Figure 3 shows the estimated number of PLHIV (all ages), and the locations of health facilities with ART services (labelled with A) and without current ART services (labelled with F).

Table 1: Summary estimates for Blantyre, September 2020.

Total PLHIV (all ages)	36,418 (32,349–40,752)
HIV prevalence, age 15–49 years	11.2% (10.0%–12.5%)
Total patients receiving ART	155,150
Average walking time to nearest ART (minutes)	34 (33–35)
Number PLHIV > 60 minutes walking time	4,203 (3,645–4,797)
Percentage PLHIV > 60 minutes walking time	11.6% (10.8%–12.4%)

Table 2: Traditional authorities with the lowest and highest estimated number of PLHIV, 15-49 Prevalence, and average walking time, respectively.

	Lowest TA	Largest TA
PLHIV	TA Makata: 1,416 (1,141–1,732)	TA Kapeni: 9,280 (7,976–10,785)
15-49 Prevalence	TA Kunthembwe: 8.2% (6.3%–10.5%)	TA Machinjiri: 14.4% (12.1%–17.1%)
Average Walking Time	TA Somba: 26 min (25–27 min)	TA Kunthembwe: 47 min (44–49 min)

Travel time to existing ART facilities

In Blantyre, there are 22 ART facilities that had at least 1 patient in September 2020. The median number of ART patients per facility was 749. The list of *active ART facilities* is in Table 4. Private not-for-profit facilities have been excluded from the analysis. Figure 4 shows the modelled travel times to the nearest active ART facility. The average walking time to the nearest facility for residents in each traditional authority are in (Figure 5).

- The estimated average walking time for PLHIV to the closest ART facility across Blantyre is 34 minutes (33-35 min).
- The shortest estimated average walking time to the closest ART facility is in TA Somba (26 minutes (25-27 min)).
- The longest estimated average walking time to the closest ART facility is in TA Kunthembwe (47 minutes (44-49 min)).

An estimated 11.6% (10.8%–12.4%) of PLHIV reside more than 60 minutes walking time to their nearest ART facility, compared to 12.4% of the total population. This decreases to 0.9% (0.7%–1.1%) of PLHIV and 1.3% of the total population residing more than 90 minutes walking time to their nearest ART facility. More details are provided in Table 3.

Table 3: Estimated PLHIV and population not reached at different thresholds

Threshold (minutes)	Population not reached	As % of total population	PLHIV not reached	As % of total estimated PLHIV
45	139,849	29.5%	10,272 (9,014–11,657)	28.3% (26.8%–29.7%)
60	58,757	12.4%	4,203 (3,645–4,797)	11.6% (10.8%–12.4%)
90	6,233	1.3%	321 (254–404)	0.9% (0.7%–1.1%)
120	1,414	0.3%	64 (43–88)	0.2% (0.1%–0.2%)

Proposed facilities for new ART services

A list of 6 *non-ART facilities* were considered to identify existing health facility locations for expanding ART services, listed in Table 5. Figure 6 shows the number of PLHIV in grid cells where the estimated travel time is longer than 60 minutes and candidate new ART facilities.

- The TA with the largest number of PLHIV residing more than 60 minutes from their closest ART facility is TA Kapeni (851 PLHIV (665-1058) with walking time > 60 minutes).
- The facility that can reach the most PLHIV residing outside 60 minutes travel time is **TEDZANI**, **TEDZANI**, with 107 PLHIV (77, 77-142, 142) reached.

Limitations

There are several important limitations to this analysis:

- Travel time surfaces and catchments may not optimally reflect typical routine travel or movement patterns, for example for work or other activities.
- Results do not represent uncertainty in the 1km gridded maps of PLHIV arising from uncertainty about the gridded populations.
- There are discrepancies in the gridded HIV prevalence estimates from the Bayesian geostatistical model and the Naomi estimates for some districts which should be further reviewed, especially neighbouring urban and rural districts.
- Geographic locations of some health facilities are discrepant between multiple data sources and need to be confirmed.
- The physical infrastructure and suitability of candidate health facilities for supporting an ART service is unknown.
- Optimisation analysis for locations for new facilities has not considered overcrowding, wait times, or other barriers to access at existing facilities. It could be more optimal to expand services in some geographically dense locations to address barriers to access.

Summary figures and maps

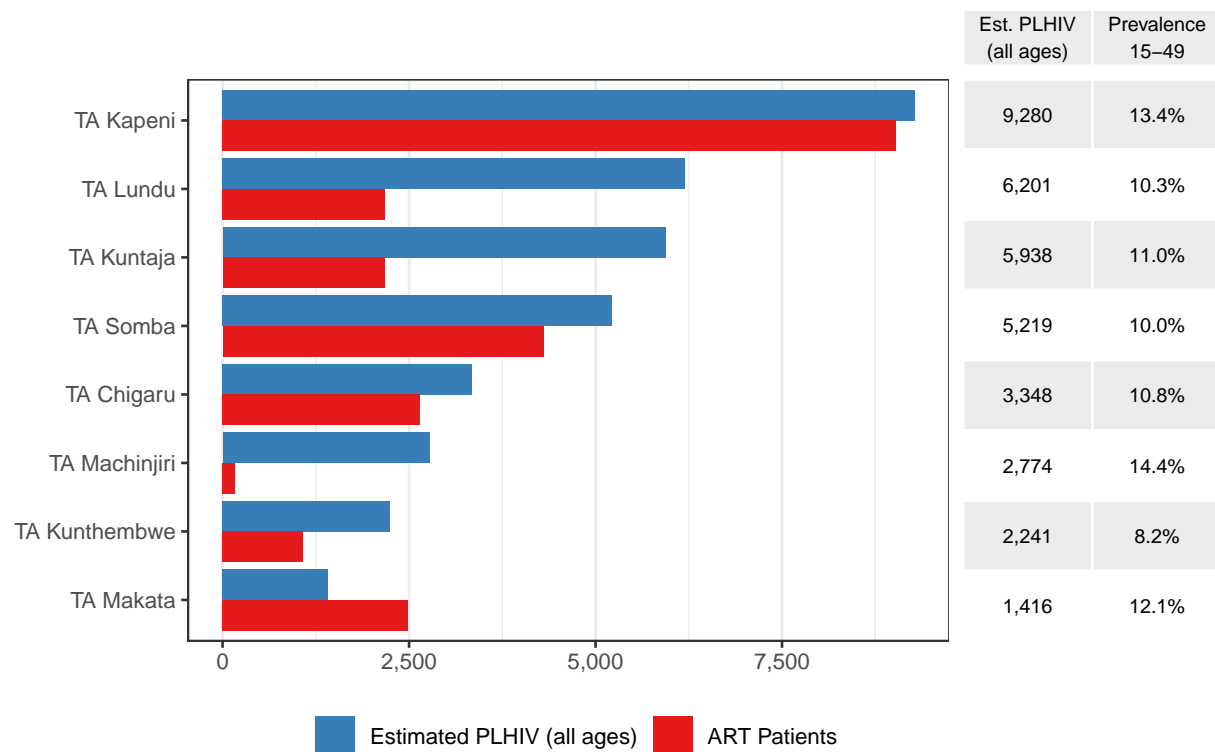


Figure 1: Number registered ART clients within each TA and estimated number of PLHIV within the TA. The right table indicates the estimated 15-49 HIV prevalence.

HIV prevalence in ages 15-49

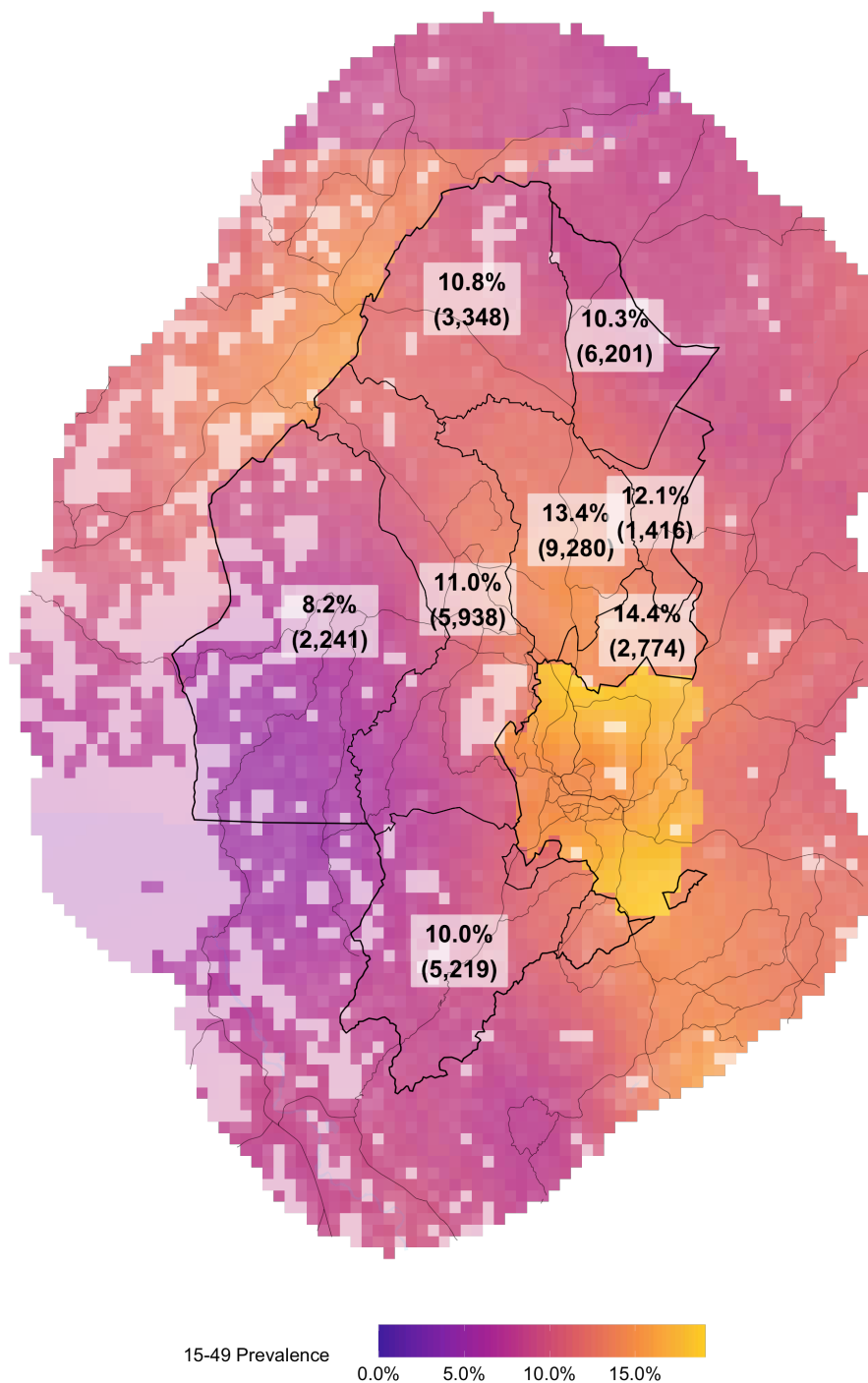


Figure 2: Estimated spatial HIV prevalence. Percentages correspond to TA level 15-49 HIV prevalence and numbers in brackets indicate the estimated number of PLHIV overall.

Estimated number of PLHIV at 1km square

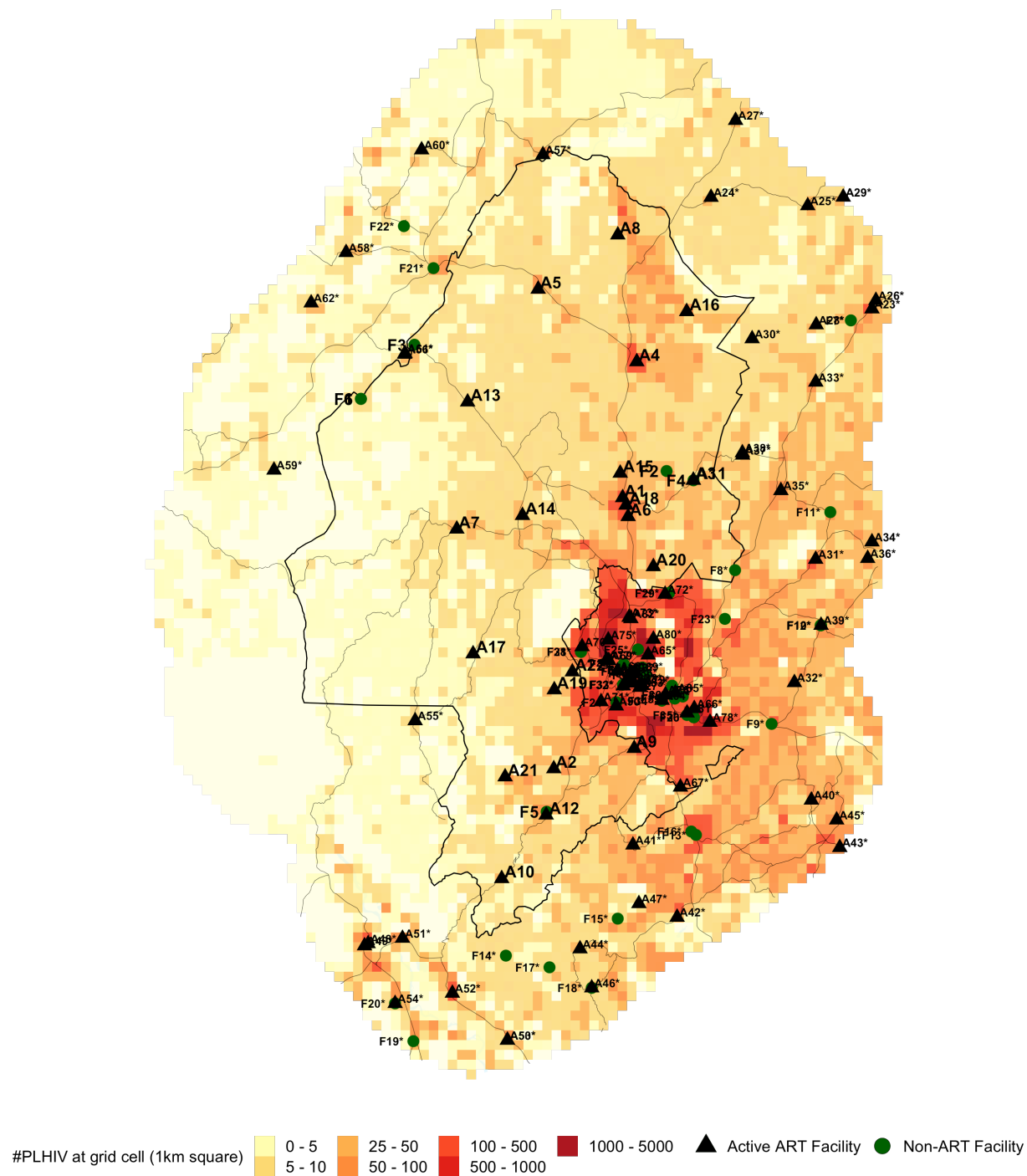


Figure 3: Estimated number of PLHIV on a 1km square.

Table 4: List of active ART facilities that had at least 1 registered ART patient in September 2020. The column "ART" indicates how many ART patients are registered at the ART facility. Facilities outside the district boundaries that may be accessible to residents within the district are marked with "*".

ID	District	TA	Name	Type	Authority	Long.	Lat.	ART
A1	Blantyre	TA Kapeni	Mlambe Mission Hosp.	District hospital	CHAM	35.02	-15.64	6690
A2	Blantyre	TA Somba	Mpemba HC	Health centre	Government	34.96	-15.87	1910
A3	Blantyre	TA Makata	Makhetha Clinic	Dispensary	Government	35.08	-15.63	1729
A4	Blantyre	TA Lundu	Lirangwe HC	Health centre	Government	35.03	-15.53	1714
A5	Blantyre	TA Chigaru	Mdeka HC	Health centre	Government	34.94	-15.47	1588
A6	Blantyre	TA Kapeni	Kadidi HC	Health centre	Government	35.02	-15.66	1412
A7	Blantyre	TA Kunthembwe	Chikowa HC	Health centre	Government	34.87	-15.67	1078
A8	Blantyre	TA Chigaru	Lundu HC	Health centre	Government	35.01	-15.42	1057
A9	Blantyre	TA Somba	Soche Mat.	Special	Government	35.03	-15.86	789
A10	Blantyre	TA Somba	Madziabango HC	Health centre	Government	34.91	-15.97	761
A11	Blantyre	TA Makata	Makata HC Lunzu	Health centre	Government	35.08	-15.63	760
A12	Blantyre	TA Somba	St Vincent HC Chadzunda	Health post	CHAM	34.95	-15.91	738
A13	Blantyre	TA Kuntaja	Dziwe HC	Health centre	Government	34.88	-15.56	733
A14	Blantyre	TA Kuntaja	Chileka SDA HC	Health centre	CHAM	34.93	-15.66	690
A15	Blantyre	TA Kapeni	Kapeni Dream Centre	Health centre	NGO	35.02	-15.62	483
A16	Blantyre	TA Lundu	Namikoko HC	Dispensary	Government	35.07	-15.49	466
A17	Blantyre	TA Kuntaja	Chimembe HC	Health centre	Government	34.89	-15.78	453
A18	Blantyre	TA Kapeni	BLM Lunzu	Special	NGO	35.02	-15.65	446
A19	Blantyre	TA Kuntaja	Pensulo HC	Health centre	Government	34.96	-15.81	262
A20	Blantyre	TA Machinjiri	AMECCA Chilaweni HC	Health centre	Government	35.04	-15.70	170
A21	Blantyre	TA Somba	Mpingo Mat.	Health centre	Government	34.91	-15.88	104
A22	Blantyre	TA Kuntaja	Sanjika Clinic	Dispensary	Government	34.97	-15.79	32
A23*	Zomba	TA Mlumbe	Thondwe HC	Health centre	Government	35.24	-15.48	1878
A24*	Zomba	TA Mlumbe	Chipini HC	Health centre	CHAM	35.10	-15.39	1667
A25*	Zomba	TA Mlumbe	Chingale HC	Health centre	Government	35.18	-15.40	933
A26*	Zomba	TA Mlumbe	Namikango HC	Health centre	CHAM	35.24	-15.48	898
A27*	Zomba	TA Mlumbe	Chilipa HC Zomba	Health centre	CHAM	35.12	-15.32	665
A28*	Zomba	TA Mlumbe	Mwandama HC	Health centre	Government	35.19	-15.50	484
A29*	Zomba	TA Mlumbe	Changalume Barracks Clinic	Special	Other	35.21	-15.39	385
A30*	Zomba	TA Mlumbe	Maera HC	Health centre	Government	35.13	-15.51	256
A31*	Chiradzulu	Chiradzulu Boma	Chiradzulu District Hosp.	District hospital	Government	35.19	-15.70	6637
A32*	Chiradzulu	TA Likoswe	St Joseph Mission Hospital Nguludi	District hospital	CHAM	35.17	-15.80	4204
A33*	Chiradzulu	TA Mpama	Namadzi HC	Health centre	Government	35.19	-15.55	2934
A34*	Chiradzulu	TA Kadewere	Chileka HC Blantyre	Health centre	Government	35.24	-15.68	2686
A35*	Chiradzulu	TA Mpama	Mbulumbuzi HC	Health centre	Government	35.16	-15.64	2680
A36*	Chiradzulu	TA Kadewere	Ndunde HC	Health centre	Government	35.23	-15.70	2390
A37*	Chiradzulu	TA Chitera	Chimvu HC	Health post	Government	35.12	-15.61	1169
A38*	Chiradzulu	TA Chitera	Chitera HC	Health centre	Government	35.12	-15.61	1076
A39*	Chiradzulu	STA Onga	PIM HC	Health centre	CHAM	35.19	-15.75	236
A40*	Thyolo	TA Chimaliro	Mikolongwe HC	Health centre	Government	35.18	-15.90	2393
A41*	Thyolo	TA Bvumbwe	Makungwa HC	Health centre	Government	35.03	-15.94	1811
A42*	Thyolo	TA Bvumbwe	Thunga HC	Health centre	Private	35.07	-16.00	1636
A43*	Thyolo	TA Chimaliro	Chisoka HC	Health centre	Government	35.21	-15.94	1512
A44*	Thyolo	TA Thomas	Thomasi HC	Health centre	CHAM	34.98	-16.03	821
A45*	Thyolo	TA Chimaliro	Chingazi HC	Health centre	CHAM	35.21	-15.92	648
A46*	Thyolo	TA Mphuka	Didi HC	Health centre	Government	34.99	-16.06	569

A47*	Thyolo	TA Bvumbwe	Amalika HC	Health post	Government	35.03	-15.99	138
A48*	Chikwawa	Chikwawa Boma	Chikwawa District Hosp.	District hospital	Government	34.79	-16.02	6504
A49*	Chikwawa	Chikwawa Boma	Makhwira HC	Health centre	Government	34.79	-16.03	2383
A50*	Chikwawa	TA Makhwira	Mapelera HC	Health centre	Government	34.92	-16.11	1051
A51*	Chikwawa	TA Mlilima	Bereu HP	Health post	Government	34.82	-16.02	835
A52*	Chikwawa	TA Katunga	Mfera HC	Health centre	Government	34.87	-16.07	794
A53*	Chikwawa	TA Makhwira	Mangulenje HC	Health centre	Private	34.92	-16.11	560
A54*	Chikwawa	TA Katunga	Kasitu HC	Health centre	Government	34.82	-16.07	363
A55*	Chikwawa	TA Kasisi	Chavala HC	Health centre	Government	34.83	-15.83	236
A56*	Neno	TA Symon Likongwe	Zalewa PIH	Special	NGO	34.83	-15.52	1554
A57*	Neno	TA Symon Likongwe	Matope HC	Health centre	CHAM	34.95	-15.35	893
A58*	Neno	TA Symon Likongwe	Lisungwi Community Hosp.	Health centre	Government	34.77	-15.44	852
A59*	Neno	TA Mlauli	Chifunga HC	Health centre	Government	34.71	-15.62	606
A60*	Neno	TA Symon Likongwe	Midzemba HC	Health centre	Government	34.84	-15.35	424
A61*	Neno	TA Symon Likongwe	Nkula HC	Health centre	CHAM	34.83	-15.52	292
A62*	Neno	TA Symon Likongwe	Luwani HC	Health centre	Government	34.74	-15.48	176
A63*	Blantyre City	Soche East Ward	Queen Elizabeth Central Hosp.	Central hospital	Government	35.02	-15.80	15053
A64*	Blantyre City	Limbe Central Ward	Limbe HC	Health centre	Government	35.05	-15.82	7758
A65*	Blantyre City	Ndirande Matope Ward	Ndirande HC	Health centre	Government	35.04	-15.78	6254
A66*	Blantyre City	Bangwe Mthandizi Ward	Bangwe HC	Health centre	Government	35.08	-15.82	6030
A67*	Blantyre City	Chigumula Ward	Bvumbwe Research HC	Health centre	Government	35.07	-15.89	5391
A68*	Blantyre City	Blantyre City Centre Ward	Blantyre Dream Project	Special	NGO	35.01	-15.79	4770
A69*	Blantyre City	Mbayani Ward	MACRO Blantyre	Special	NGO	35.01	-15.78	4435
A70*	Blantyre City	Chilomoni Ward	Chilomoni HC	Health centre	Government	34.98	-15.77	4257
A71*	Blantyre City	Blantyre South Ward	Zingwangwa HC	Health centre	Government	35.00	-15.82	3524
A72*	Blantyre City	South Lunzu Ward	South Lunzu HC	Health centre	Government	35.05	-15.73	2974
A73*	Blantyre City	Michiru Ward	Chirimba HC	Health centre	Government	35.02	-15.75	2236
A74*	Blantyre City	Soche East Ward	Gateway Clinic	Dispensary	Government	35.02	-15.80	1545
A75*	Blantyre City	Mbayani Ward	Mbayani HC	Health centre	Government	35.00	-15.77	1330
A76*	Blantyre City	Limbe Central Ward	MASM Medi Clinic Limbe	Special	Private	35.06	-15.81	1324
A77*	Blantyre City	Mbayani Ward	Blantyre Adventist Hosp.	District hospital	CHAM	35.00	-15.78	1228
A78*	Blantyre City	Namiyango Ward	Umunthu Foundation Clinic	Special	NGO	35.09	-15.84	953
A79*	Blantyre City	Soche East Ward	Blantyre City Assembly Clinic	Special	Government	35.03	-15.80	855
A80*	Blantyre City	Ndirande Makata Ward	Malabada HC	Health centre	CHAM	35.04	-15.76	635
A81*	Blantyre City	Bangwe Mthandizi Ward	Bangwe Madina HC	Health centre	CHAM	35.07	-15.83	593
A82*	Blantyre City	South Lunzu Ward	MACRO Chirimba	Special	NGO	35.02	-15.75	343
A83*	Blantyre City	Soche East Ward	Chichiri Prison Clinic	Health centre	Government	35.03	-15.81	337
A84*	Blantyre City	Limbe Central Ward	Kanjedza Police Clinic	Dispensary	Other	35.06	-15.81	259
A85*	Blantyre City	Limbe Central Ward	Soche Adventist HC	Health centre	CHAM	35.06	-15.81	225

A86*	Blantyre City	Namalimwe Ward	Pace Clinic	Special	Private	35.02	-15.80	211
A87*	Blantyre City	Namalimwe Ward	Chichiri ESCOM Clinic	Special	Private	35.02	-15.79	172
A88*	Blantyre City	Soche East Ward	Polytechnic Blantyre	Special	Other	35.03	-15.80	90
A89*	Blantyre City	Namalimwe Ward	Lafarge Cement Clinic	Special	Private	35.03	-15.79	74
A90*	Blantyre City	Soche West Ward	Nancholi Youth Organisation Clinic	Special	NGO	35.01	-15.82	

Table 5: List of non-ART facilities considered in the analysis. The column "PLHIV" indicates the number of PLHIV that currently need more than 60 minutes to walk to the closest ART facility but less than 60 minutes to the listed health facility in the table. Facilities outside the district boundaries that may be accessible to residents within the district are marked with "*".

ID	District	TA	Name	Type	Authority	Long.	Lat.	PLHIV	95% CI
F1	Blantyre	TA Kunthembwe	TEDZANI	Dispensary	Company	34.79	-15.56	107	(77-142)
F2	Blantyre	TA Kapeni	Aquid Lifeline Project	Clinic	NGO	35.06	-15.62	73	(53-96)
F3	Blantyre	TA Kuntaja	Blantyre Water Board - Walker'	Clinic	Company	34.83	-15.51	38	(28-51)
F4	Blantyre	TA Makata	Makata Dispensary Ndirande	Health Centre	Government	35.08	-15.63	0	(0-0)
F5	Blantyre	TA Somba	St Vincent HC	Health Centre	CHAM	34.95	-15.91	0	(0-0)
F6	Blantyre	TA Kunthembwe	TEDZANI	Dispensary	Company	34.79	-15.56	107	(77-142)
F7*	Zomba	TA Mlumbe	Thondwe Pastoral Centre	Health Centre	CHAM	35.22	-15.49	0	(0-0)
F8*	Chiradzulu	TA Mpama	NJULI	Health Post	Government	35.12	-15.71	1791	(1451-2191)
F9*	Chiradzulu	TA Likoswe	Malavi Disp.	Dispensary	Government	35.15	-15.84	3	(2-4)
F10*	Chiradzulu	STA Onga	Providence Industrial Mission HC	Health Centre	CHAM	35.19	-15.75	0	(0-0)
F11*	Chiradzulu	TA Kadewere	Mwanje DAPP Clinic	Special	NGO	35.20	-15.66	0	(0-0)
F12*	Chiradzulu	STA Onga	P.I.M HC	Special	Government	35.19	-15.75	0	(0-0)
F13*	Thyolo	TA Bvumbwe	BLM Bvumbwe	Special	NGO	35.08	-15.93	1407	(1106-1747)
F14*	Thyolo	TA Thomas	THABWANI	Health Post	Government	34.91	-16.03	276	(206-358)
F15*	Thyolo	TA Thomas	Chithebe HC	Health Centre	Government	35.01	-16.00	87	(64-117)
F16*	Thyolo	TA Bvumbwe	Bvumbwe HC	Health Centre	Government	35.08	-15.93	1320	(1036-1635)
F17*	Thyolo	TA Thomas	PUTENI	Health Post	Government	34.95	-16.04	85	(63-111)
F18*	Thyolo	TA Mphuka	Dzimbiri HP	Health Post	Government	34.99	-16.06	0	(0-0)
F19*	Chikwawa	TA Maseya	HOPE VILLAGE	Dispensary	NGO	34.83	-16.11	119	(76-168)
F20*	Chikwawa	TA Katunga	Kasinthula Disp.	Dispensary	Government	34.82	-16.07	0	(0-0)
F21*	Neno	TA Symon Likongwe	Zalewa DAPP VCT Station	Clinic	NGO	34.85	-15.45	821	(588-1082)
F22*	Neno	TA Symon Likongwe	Mota-Engil Clinic - Mkwinda Ca	Clinic	Company	34.82	-15.41	628	(448-827)
F23*	Blantyre City	Mapanga Ward	Amitofo Care Centre	Clinic	NGO	35.11	-15.75	1852	(1483-2287)
F24*	Blantyre City	Soche West Ward	BLM Zingwangwa	Special	NGO	35.01	-15.82	0	(0-0)
F25*	Blantyre City	Ndirande Gamulani Ward	BLM Ndirande	Special	NGO	35.03	-15.77	0	(0-0)
F26*	Blantyre City	Bangwe Mthandizi Ward	BLM Midima	Special	NGO	35.08	-15.83	0	(0-0)
F27*	Blantyre City	Limbe Central Ward	Unilever South East Company Clinic	Special	Private	35.06	-15.80	0	(0-0)
F28*	Blantyre City	Blantyre City Centre Ward	BLM Chilomoni	Special	NGO	34.98	-15.78	0	(0-0)
F29*	Blantyre City	South Lunzu Ward	Sos Childrens Village Blantyre	Health Centre	NGO	35.06	-15.73	0	(0-0)

F30*	Blantyre City	Bangwe Mthandizi Ward	BLM Bangwe	Special	NGO	35.08	-15.83	0	(0-0)
F31*	Blantyre City	Blantyre City Centre Ward	BLM Chilomoni	Special	Government	34.98	-15.78	0	(0-0)
F32*	Blantyre City	Soche East Ward	Beit trust Cure International	Other Hospital	CHAM	35.02	-15.80	0	(0-0)
F33*	Blantyre City	Soche East Ward	Kachere Rehabilitation Centre	Other Hospital	NGO	35.02	-15.80	0	(0-0)
F34*	Blantyre City	Limbe Central Ward	Limbe Home Based Care Centre	Clinic	NGO	35.05	-15.82	0	(0-0)
F35*	Blantyre City	Bangwe Mthandizi Ward	Madinah Social Services Clinic	Clinic	NGO	35.07	-15.83	0	(0-0)
F36*	Blantyre City	Bangwe Mthandizi Ward	Auction Holdings Clinic	Clinic	Company	35.06	-15.81	0	(0-0)
F37*	Blantyre City	Ndirande Matope Ward	Blantyre Water Board - Mudi	Clinic	Company	35.04	-15.80	0	(0-0)
F38*	Blantyre City	Namalimwe Ward	Carlsberg Brewery Malawi Ltd.	Clinic	Company	35.03	-15.79	0	(0-0)
F39*	Blantyre City	Bangwe Mthandizi Ward	Central East African Railways	Clinic	Company	35.06	-15.82	0	(0-0)
F40*	Blantyre City	Namalimwe Ward	David Whitehead	Clinic	Company	35.03	-15.79	0	(0-0)
F41*	Blantyre City	Namalimwe Ward	Henred Fruehauf Clinic	Clinic	Company	35.03	-15.79	0	(0-0)
F42*	Blantyre City	Bangwe Mthandizi Ward	Limbe Leaf Tobacco Clinic	Clinic	Company	35.07	-15.81	0	(0-0)
F43*	Blantyre City	Namalimwe Ward	Portland	Clinic	Company	35.03	-15.79	0	(0-0)
F44*	Blantyre City	Namalimwe Ward	PVHO	Clinic	Government	35.02	-15.79	0	(0-0)

Travel Times to Closest ART Facilities

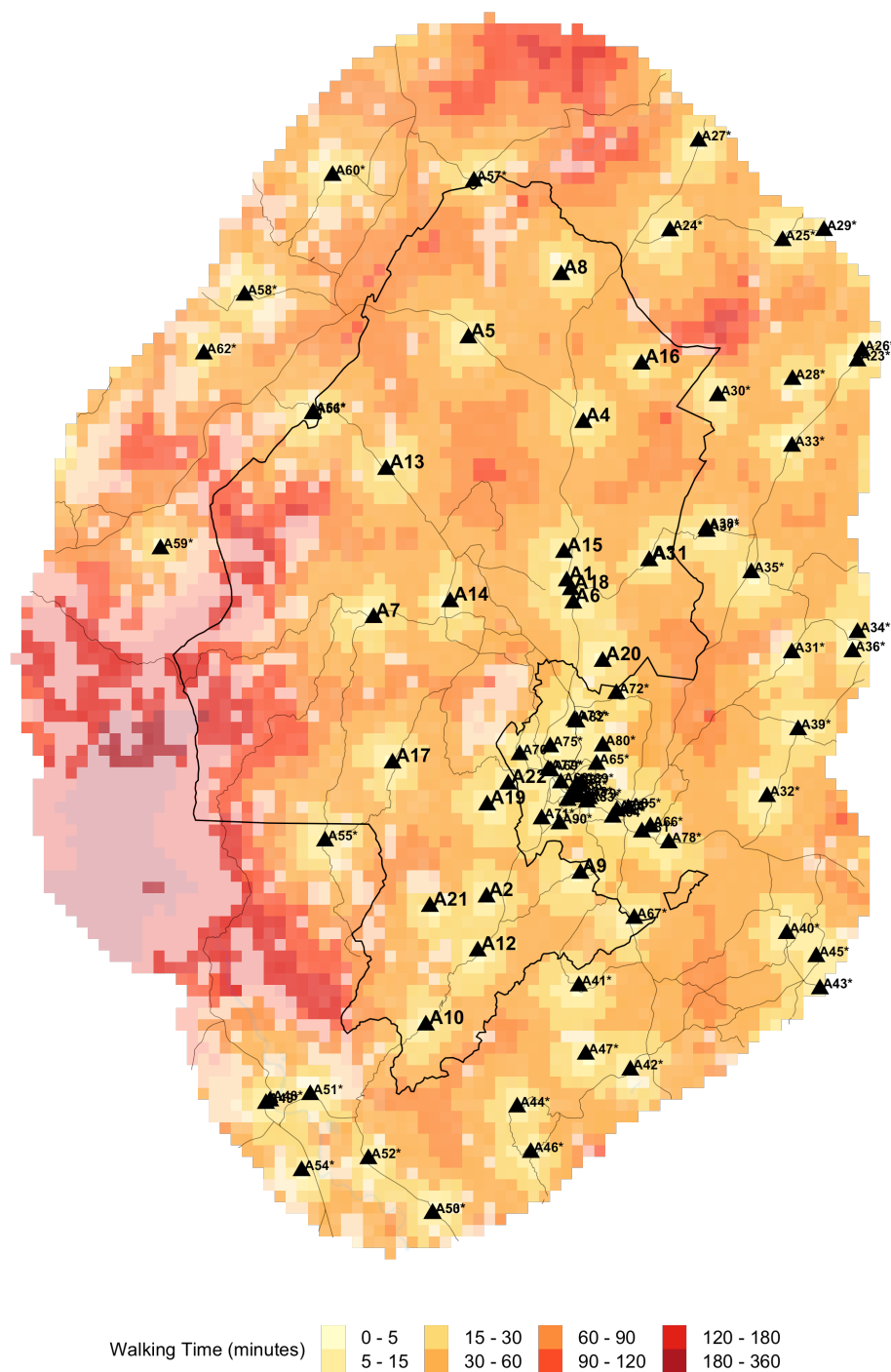


Figure 4: Estimated travel times to the closest ART facility. Travel times were calculated using data on road infrastructure, types of terrain and land elevation.

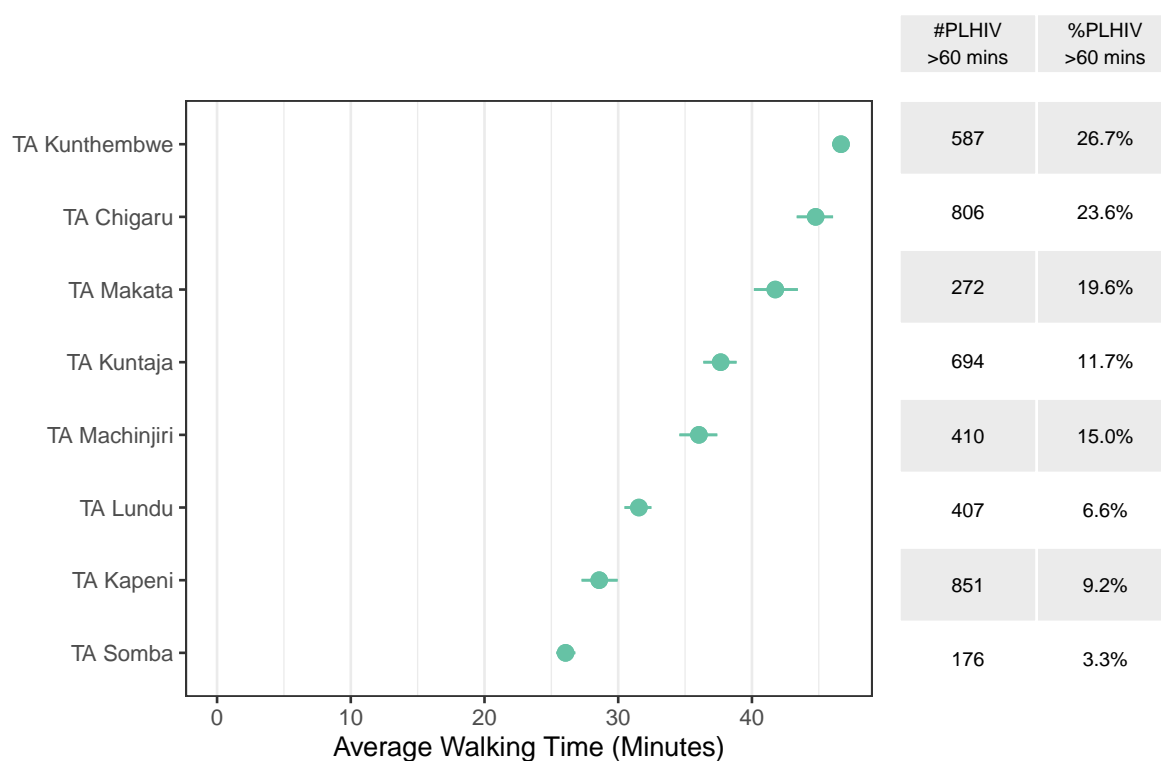


Figure 5: Estimated average walking time to the closest ART facility, weighted by the estimated number of PLHIV within the traditional authority. The right table indicates estimated number and proportion of PLHIV that need more than 60 minutes to travel to the closest ART facility, respectively.

Areas outside 60 minutes travel

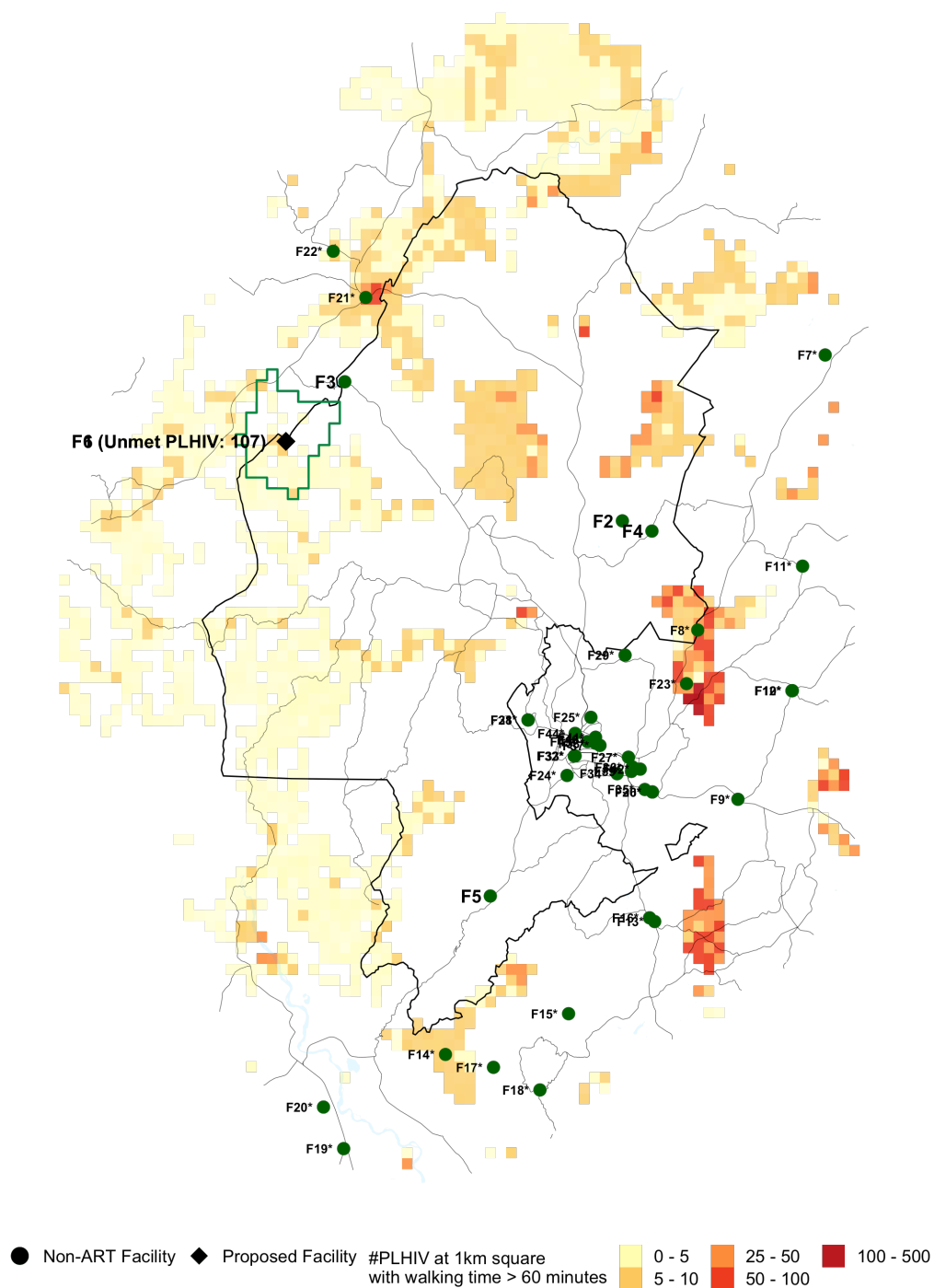


Figure 6: Proposed facility locations. Areas where the walking time to the closest ART facility is <60 minutes have been removed. Green lines indicate the 60-minutes catchment area of the proposed facility.

Appendix (Methods Summary)

The analysis involved several steps:

1. **Creating a map of spatial prevalence by approximately 1km grid cells.** We used cluster-level survey data from the 2015/16 MDHS and MPHIA household surveys and HIV prevalence amongst ANC clients from routine health facility data to obtain a gridded PLHIV prevalence map (1km grid cells).
2. **Calculate the estimated number of PLHIV in each 1km grid cell.**
 - Modelled estimates of total population by 1km grid cell were sourced from the WorldPop project (<https://www.worldpop.org/geodata/summary?id=49698>). Gridded populations are constrained to only grid cells containing built settlements based on satellite imagery.
 - Gridded populations were adjusted to match traditional authority (TA) population data from the 2018 household census, projected forward to 2020 based on district population projections.
 - Gridded HIV prevalence (step 1) was multiplied by population for estimates of the distribution of PLHIV by 1km grid cell.
 - The gridded PLHIV in each district were scaled to align to total PLHIV in each district from the 2020 Naomi model estimates.
3. **Calculate walking travel time for PLHIV to existing ART services.** We used data on land cover terrain type (Global Land Cover 2000), roads (OpenStreetMap), elevation (GMTED2010), and water bodies (NASA Shuttle Radar Topography Mission) to model walking time from each grid cell to 757 public or not-for-profit health facilities providing ART services using the AccessMod software. Walking speed was assumed to be 6-7km/h on roads and 2-3 km/h on non-road surfaces.
4. **Analyse the number and locations of PLHIV residing greater than 60, 90, or 120 minutes walking time from existing ART facilities.** Grid cells were classified by the travel time to the nearest public or not-for-profit ART facility using the travel time model. Maps were filtered for PLHIV residing greater than 60, 90, or 120 minutes, thresholds of interest defined based on discussions with the Department of HIV and AIDS (DHA).
5. **Identify optimal locations to reach the most PLHIV who currently reside greater than 60 or 90 minutes from ART services.** An optimisation algorithm was implemented to systematically select the best facilities and locations where ART service delivery can be introduced to reach the most PLHIV residing outside travel time thresholds.

The list of 757 active facilities currently providing ART services was sourced from DHA-MIS database. Facilities that were private-for-profit were excluded from the analysis of travel time catchments. Health facilities which do not currently provide an ART service, which are candidate locations for expanding ART services, were sourced from facilities visited during the 2018/19 Service Availability and Readiness Assessment (SARA). Candidate facilities included existing health posts which are not staffed full time.