Supplementary appendix

The potential effects of widespread community transmission of SARS-CoV-2 infection in the World Health Organization African Region: a predictive model

1. Background

This supplement provides additional information to enable persons that would want to replicate the process leading to the results to do so. It highlights how the methods explained in the paper have been implemented using the data, eventually leading to the results. It follows a logical approach from the raw data to the eventual published results. It is meant to also facilitate development of similar analyses, for example where the rate of transmission is expected to be markedly different across a country, or across other groups of countries or regions to replicate a similar line of analysis.

The data used for each country is publicly available. There was no primary data collection done for the purpose of this analysis. To ensure the uniformity, same sources were used for the data from each country.

Data on household size[1], number of children in primary school per capita[2], number of children in secondary school per capita[3], proportion of population living in urban areas[4], proportion of urban population living in slums[5], number of motor vehicles per 1000 population[6], country road network size[7], prevalence of HIV (15-24 years)[8], prevalence of diabetes (% of population 20-79 years)[9], % of total population of 65 years[10], % of population using at least basic sanitation services[11] and annual average precipitation in depth (mm/year)[12] was used in calculation of the various factors of the *RoE*.

[1] Household Size and Composition around the world. UN Population-Department of Economic and Social Affairs 2017. https://www.un.org/en/development/desa/population/publications/pdf/ageing/household_size_and_composition_around_the_world_2017_data_booklet.pdf (accessed 20 Apr 2020).
[2] Primary education, pupils | Data. https://data.worldbank.org/indicator/SE.PRM.ENRL (accessed 20 Apr 2020).
[3] Secondary education, pupils | World Bank Open Data. https://data.worldbank.org/indicator/SE.SEC.ENRL (accessed 20 Apr 2020).
[4] Urban population | World Bank Open Data. https://data.worldbank.org/indicator/SP.URB.TOTL (accessed 20 Apr 2020).
[5] Slum Almanac 2015-2016. UN Habitat https://unhabitat.org/sites/default/files/download-manager-files/Slum%20Almanac%202015-2016_PSUP.pdf (accessed 20 Apr 2020).
[6] Our World in Data-Motor vehicle ownership, per 1000 inhabitants, 2014- University of Oxford-Martin Programme of Global Development. https://ourworldindata.org/grapher/motor-vehicle-ownership-per-1000-inhabitants (accessed 20 Apr 2020).
[7] International Road Federation- Better Road Data for Better Policies. https://www.irf.global/statistics/ (accessed 20 Apr 2020).
[8] WHO Global Health Observatory data repository| Prevalence of HIV among adults aged 15 to 49 - Estimates by country. WHO. https://apps.who.int/gho/data/node.main.622?lang%E2%80%99=%E2%80%99en (accessed 20 Apr 2020).
[9] Diabetes prevalence (% of population ages 20 to 79) | World Bank Open Data. https://data.worldbank.org/indicator/SH.STA.DIAB.ZS (accessed 20 Apr 2020).
[10] United Nations Population Division - World Population Prospects. https://population.un.org/wpp/DataQuery/ (accessed 20 Apr 2020).
[11] People using at least basic sanitation services (% of population) | World Bank Open Data. https://data.worldbank.org/indicator/SH.STA.BASS.ZS (accessed 20 Apr 2020).
[12] Average precipitation in depth (mm per year) | World Bank Open Data. https://data.worldbank.org/indicator/AG.LND.PRCP.MM (accessed 21 May 2020).

A discussion on the methods, assumptions, and other attributes are done in the main paper. The transmission dynamics follow the traditional SEIR model with some modifications to cater for observed transmission and outcomes relating to SARS-CoV-2 infection namely definition of a risk of exposure to adjust the attack rate and define the rate of infection, and a vulnerability adjustment factor to adjust the probability of disease severities.

The Risk of Exposure was considered necessary based on social, environmental and behavioral factors influencing the rate of transmission. Four factors were used to derive this:

1. *"The gathering factor"* as a measure of the extent to which congregating of people affects the transmission of SARS-Cov-2;
2. *"The distribution factor"* as a measure of the extent to which the movement or ease of travel of people facilitates the transmission of SARS-Cov-2;
3. *"The hygiene factor*" as a measure of the extent to which personal habits and hygiene practices influence the transmission of SARS-Cov-2; and
4. *"The weather factor" as a* measure of the influence of whether on the transmission of SARS-Cov-2.

On the other hand, the indicators used to estimate the vulnerability adjustment factor were:

1) Proportion of the population aged over 65 years,
2) Proportion of the population aged 15 – 49 years that are HIV positive, and
3) Proportion of the population with diabetes

The rationale for each of these broad factors and sources from which the data was obtained have been described. The specific indicator values for each country used in the calculation are shown in supplementary table 1.

Supplementary table 1: Values for each indicator used in the Risk of Exposure, and vulnerability adjustment factor, by Country

			Gathering factor					Weather factor	Distribution factor		Hygiene factor	Vulnerability adjustment factor		
	Country	**Total population (2019)**	Average house-hold size	*Children in school (primary) per capita*	*Children in school (secondary) per capita*	Proportion of population living in urban areas	Population living in slums (% of urban population)	Precipitation (mm/year)	Road network connectivity per sq km	Vehicles / 1,000 population	People using at least basic sanitation services (% of population)	Population ages 65 and above (% of total)	HIV Prevalence (%population ages 15-49)	Diabetes Prevalence
1	Algeria	42,228,429	5.9	0.10	0.04	72.63	0.59	89	0.05	140	0.88	6.211	0.05	0.07
2	Angola	30,809,762	4.6	0.18	0.07	65.51	0.56	1010	0.04	32	0.50	2.405	2.00	0.05
3	Benin	11,485,048	5	0.19	0.09	47.31	0.62	1039	0.16	24	0.16	3.244	1.00	0.01
4	Botswana	2,254,126	3.7	0.15	0.04	69.45	0.59	416	0.03	177	0.16	3.941	20.30	0.06
5	Burkina Faso	19,751,535	5.7	0.16	0.06	29.36	0.66	748	0.04	16	0.19	2.409	0.70	0.07
6	Burundi	11,175,378	4.8	0.19	0.06	13.03	0.58	1274	1.73	6	0.46	2.562	1.00	0.05
7	Cabo Verde	543,767	4.2	0.12	0.10	65.73	0.59	228	0.33	101	0.74	4.460	0.60	0.02
8	Cameroon	25,216,237	5.2	0.17	0.09	56.37	0.38	1604	0.00	15	0.39	3.165	3.60	0.06
9	Central African Republic	4,666,377	4.9	0.17	0.03	41.36	0.93	1343	0.03	4	0.25	3.655	3.60	0.06
10	Chad	15,477,751	5.8	0.08	0.03	23.06	0.88	322	0.03	6	0.08	2.486	1.30	0.06
11	Comoros	832,322	5.4	0.15	0.09	28.97	0.70	900	0.47	33	0.36	2.893	0.10	0.12
12	Congo, Dem. Rep.	84,068,091	5.3	0.16	0.04	44.46	0.75	1543	0.07	25	0.20	3.020	0.80	0.06
13	Congo, Rep.	5,244,363	4.3	0.08	0.04	66.92	0.47	1646	0.05	27	0.20	3.402	2.60	0.06
14	Cote d'Ivoire	25,069,229	5.4	0.16	0.08	50.78	0.56	1348	0.26	41	0.32	2.933	2.60	0.02
15	Equatorial Guinea	1,308,974	4.7	0.07	0.04	72.14	0.66	2156	0.10	13	0.66	2.846	7.10	0.06
16	Eritrea	4,475,000	4.8	0.08	0.06	41.30	0.59	384	0.04	11	0.12	2.846	0.70	0.05
17	Eswatini	1,136,191	4.7	0.08	0.10	23.80	0.33	788	0.21	89	0.58	3.163	27.30	0.05
18	Ethiopia	109,224,559	4.6	0.08	0.04	20.76	0.74	848	0.11	9	0.07	3.526	1.00	0.04
19	Gabon	2,119,275	4.1	0.08	0.04	89.37	0.37	1831	0.04	14	0.47	4.450	3.80	0.06
20	Gambia, The	2,280,102	8.2	0.15	0.04	61.27	0.35	836	0.37	7	0.39	2.339	1.90	0.02
21	Ghana	29,767,108	3.5	0.15	0.10	56.06	0.38	1187	0.48	32	0.18	3.385	1.70	0.03
22	Guinea	12,414,318	7.2	0.08	0.04	36.14	0.43	1651	0.18	5	0.23	3.135	1.40	0.02
23	Guinea-Bissau	1,874,309	8.3	0.08	0.04	43.36	0.82	1577	0.12	33	0.21	3.002	3.50	0.02
24	Kenya	51,393,010	3.9	0.08	0.04	27.03	0.56	630	0.28	29	0.29	2.686	4.70	0.03
25	Lesotho	2,108,132	3.3	0.08	0.06	28.15	0.51	788	0.19	4	0.43	4.506	23.60	0.05
26	Liberia	4,818,977	5	0.08	0.04	51.15	0.66	2391	0.11	14	0.17	3.057	1.30	0.02
27	Madagascar	26,262,368	4.7	0.19	0.06	37.19	0.77	1513	0.04	27	0.11	2.929	0.30	0.05
28	Malawi	18,143,315	4.5	0.24	0.06	16.94	0.67	1181	0.16	8	0.26	3.552	9.20	0.05
29	Mali	19,077,690	5.7	0.13	0.05	42.36	0.56	282	0.02	12	0.39	3.158	1.40	0.02

			Gathering factor					Weather factor	Distribution factor		Hygiene factor	Vulnerability adjustment factor		
	Country	**Total population (2019)**	Average house-hold size	*Children in school (primary) per capita*	*Children in school (secondary) per capita*	Proportion of population living in urban areas	Population living in slums (% of urban population)	Precipitation (mm/year)	Road network connectivity per sq km	Vehicles / 1,000 population	People using at least basic sanitation services (% of population)	Population ages 65 and above (% of total)	HIV Prevalence (%population ages 15-49)	Diabetes Prevalence
30	Mauritania	4,403,319	6.1	0.15	0.05	53.67	0.80	92	0.01	10	0.48	10.945	0.20	0.07
31	Mauritius	1,265,303	3.5	0.07	0.10	40.79	0.59	2041	1.06	192	0.96	2.979	1.30	0.22
32	Mozambique	29,495,962	4.4	0.22	0.04	35.99	0.80	1032	0.04	14	0.29	3.138	12.60	0.03
33	Namibia	2,448,255	4.4	0.20	0.04	50.03	0.33	285	0.05	106	0.35	9.954	11.80	0.05
34	Niger	22,442,948	7.1	0.08	0.04	16.43	0.70	151	0.01	7	0.14	2.553	0.30	0.02
35	Nigeria	195,874,740	4.6	0.08	0.05	50.34	0.50	1150	0.21	64	0.39	2.751	1.50	0.03
36	Rwanda	12,301,939	4.3	0.20	0.05	17.21	0.53	1212	0.19	5	0.67	2.974	2.50	0.05
37	Sao Tome and Principe	211,028	4	0.08	0.12	72.80	0.87	3200	0.33	2	0.43	2.886	0.05	0.02
38	Senegal	15,854,360	8.3	0.14	0.07	47.19	0.39	686	0.07	44	0.51	3.008	0.40	0.02
39	Seychelles	96,762	3.8	0.10	0.08	56.69	0.59	2330	1.10	176	1.00	8.606	0.05	0.12
40	Sierra Leone	7,650,154	5.6	0.18	0.06	42.06	0.76	2526	0.16	6	0.16	2.538	1.50	0.02
41	South Africa	57,779,622	3.2	0.08	0.09	66.36	0.23	495	0.62	174	0.76	5.344	20.40	0.13
42	South Sudan	10,975,920	5.9	0.08	0.04	19.62	0.96	900	ND	4	0.11	3.441	2.50	0.10
43	Tanzania	56,318,348	4.9	0.18	0.04	33.78	0.51	1071	0.10	7	0.30	3.108	4.60	0.06
44	Togo	7,889,094	4.6	0.20	0.09	41.70	0.51	1168	0.22	27	0.16	2.839	2.30	0.02
45	Uganda	42,723,139	4.7	0.08	0.04	23.77	0.54	1180	0.65	12	0.18	2.168	5.70	0.03
46	Zambia	17,351,822	5.1	0.08	0.04	43.52	0.54	1020	0.05	23	0.26	2.480	11.30	0.05
47	Zimbabwe	14,439,018	4.1	0.18	0.04	32.21	0.25	657	0.25	60	0.36	2.822	12.70	0.02

2. Deriving the factors constituting the risk of exposure

The different indicators used have different units of measurement, making it difficult to consolidate them. We therefore first normalized all the indicators into a uniform scale. To bound the indicators between 0 and 1, and make them interpretable without their natural units of measurements, the normalized values were calculated using the formula:

$$X' = \frac{(x_i - x_{Minimum})}{(x_{Maximum} - x_{Minimum})}$$

Where X is the value of the indicator for a given country and x_i is the actual indicator value. $X_{maximum}$ represents the highest value from the indicator set and $X_{minimum}$ the lowest value. The normalized values for all the indicators is shown in supplementary table 2.

Two factors – gathering and distribution – were constituted from multiple indicators while the other two – hygiene and distribution – were from single indicators.

The gathering factor was calculated as follows:

$$Gathering\ factor = \frac{\left(\begin{array}{c}Normalized\ average\ household\ size + normalized\ children\ in\ primary\ school\ per\ capita + \\ normalized\ children\ in\ secondary\ school\ per\ capita + proportion\ of\ population\ living\ in\ urban\ areas + \\ proportion\ of\ urban\ population\ living\ in\ slums\end{array}\right)}{5}$$

For example, Kenya has an average household size of 3.9 (normalized as 0.137); primary school children per capita of 0.08 (normalized as 0.058); secondary school children per capita of 0.04 (normalized as 0.085) + proportion of population living in urban areas being 27.03 out of 100; and 56 out of 100 people in urban area living in slums. Thus, Gathering factor for Kenya = (0.137+0.058+0.085+0.2703+0.56)/5 = 0.222

This computation was applied for all countries to generate their specific gathering factors.

The calculation of the distribution factor followed a similar approach, using the indicators for the distribution factor.

$$Distribution\ factor = \frac{(\text{normalized roadwork per sq.Km + normalized vehicle density per 1000 population})}{2}$$

In Kenya for example, the road network of 0.28 per sq Km is (normalized as 0.164) and the vehicles per 1,000 population is 29 (normalized as 0.142). Therefore, the distribution factor for Kenya was given as (0.164 + 0.142)/2 = 0.153. This procedure was implemented for all countries.

Cabore JW, *et al. BMJ Global Health* 2020; 5:e002647. doi: 10.1136/bmjgh-2020-002647

Table 2: Normalized values for the indicators constituting the risk of exposure

		Gathering factor						Weather factor	Distribution factor			Hygiene factor
	Country	Average house-hold size	*Children in school per capita*	*Children in school (secondary) per capita*	Proportion of population living in urban areas	Population living in slums (% of urban population)	**AVERAGE VALUE**	**Precipitation (mm/year)**	Road network connectivity per sq km	Vehicles / 1,000 popn	**AVERAGE VALUE**	**People using at least basic sanitation services (% of population)**
1	Algeria	0.529	0.196	0.085	0.588	0.726	**0.425**	**0.332**	0.028	0.726	**0.377**	**0.876**
2	Angola	0.275	0.641	0.392	0.555	0.655	**0.504**	**0.296**	0.024	0.158	**0.091**	**0.499**
3	Benin	0.353	0.706	0.612	0.615	0.473	**0.552**	**0.305**	0.092	0.116	**0.104**	**0.165**
4	Botswana	0.098	0.472	0.085	0.588	0.694	**0.387**	**0.105**	0.016	0.921	**0.468**	**0.165**
5	Burkina Faso	0.490	0.526	0.379	0.658	0.294	**0.469**	**0.212**	0.025	0.074	**0.049**	**0.194**
6	Burundi	0.314	0.709	0.331	0.579	0.130	**0.413**	**0.381**	1.000	0.021	**0.511**	**0.458**
7	Cabo Verde	0.196	0.271	0.737	0.588	0.657	**0.490**	**0.045**	0.194	0.521	**0.357**	**0.739**
8	Cameroon	0.392	0.551	0.623	0.378	0.564	**0.501**	**0.487**	0.001	0.068	**0.035**	**0.391**
9	Central African Republic	0.333	0.595	0.000	0.933	0.414	**0.569**	**0.403**	0.019	0.011	**0.015**	**0.253**
10	Chad	0.510	0.058	0.054	0.882	0.231	**0.347**	**0.075**	0.018	0.021	**0.020**	**0.083**
11	Comoros	0.431	0.451	0.634	0.696	0.290	**0.500**	**0.261**	0.274	0.163	**0.218**	**0.359**
12	Congo, Dem. Rep.	0.412	0.534	0.085	0.748	0.445	**0.445**	**0.467**	0.039	0.121	**0.080**	**0.205**
13	Congo, Rep.	0.216	0.058	0.085	0.469	0.669	**0.299**	**0.500**	0.029	0.132	**0.080**	**0.202**
14	Cote d'Ivoire	0.431	0.487	0.557	0.560	0.508	**0.509**	**0.405**	0.149	0.205	**0.177**	**0.321**
15	Equatorial Guinea	0.294	0.003	0.085	0.662	0.721	**0.353**	**0.664**	0.059	0.058	**0.059**	**0.663**
16	Eritrea	0.314	0.042	0.308	0.588	0.431	**0.336**	**0.095**	0.023	0.047	**0.035**	**0.119**
17	Eswatini	0.294	0.058	0.707	0.327	0.238	**0.325**	**0.225**	0.121	0.458	**0.289**	**0.584**
18	Ethiopia	0.275	0.058	0.085	0.739	0.208	**0.273**	**0.244**	0.064	0.037	**0.050**	**0.073**
19	Gabon	0.176	0.058	0.085	0.370	0.894	**0.317**	**0.560**	0.021	0.063	**0.042**	**0.474**
20	Gambia, The	0.980	0.476	0.085	0.348	0.613	**0.500**	**0.240**	0.214	0.026	**0.120**	**0.392**
21	Ghana	0.059	0.471	0.712	0.379	0.561	**0.436**	**0.353**	0.279	0.158	**0.218**	**0.185**
22	Guinea	0.784	0.058	0.085	0.433	0.361	**0.344**	**0.502**	0.104	0.016	**0.060**	**0.227**
23	Guinea-Bissau	0.980	0.058	0.085	0.823	0.434	**0.476**	**0.478**	0.071	0.163	**0.117**	**0.205**
24	Kenya	0.137	0.058	0.085	0.560	0.270	**0.222**	**0.174**	0.164	0.142	**0.153**	**0.291**
25	Lesotho	0.020	0.058	0.378	0.508	0.282	**0.249**	**0.225**	0.107	0.011	**0.059**	**0.428**
26	Liberia	0.353	0.058	0.085	0.657	0.512	**0.333**	**0.740**	0.064	0.063	**0.063**	**0.170**
27	Madagascar	0.294	0.657	0.316	0.772	0.372	**0.482**	**0.458**	0.021	0.132	**0.076**	**0.105**
28	Malawi	0.255	1.000	0.299	0.667	0.169	**0.478**	**0.351**	0.095	0.032	**0.063**	**0.262**
29	Mali	0.490	0.339	0.272	0.563	0.424	**0.418**	**0.062**	0.011	0.053	**0.032**	**0.393**
30	Mauritania	0.569	0.448	0.260	0.799	0.537	**0.523**	**0.001**	0.006	0.042	**0.024**	**0.484**

		Gathering factor						Weather factor	Distribution factor			Hygiene factor
	Country	Average house-hold size	*Children in school per capita*	*Children in school (secondary) per capita*	Proportion of population living in urban areas	Population living in slums (% of urban population)	**AVERAGE VALUE**	**Precipitation (mm/year)**	Road network connectivity per sq km	Vehicles / 1,000 popn	**AVERAGE VALUE**	**People using at least basic sanitation services (% of population)**
31	Mauritius	0.059	0.000	0.722	0.588	0.408	**0.444**	**0.627**	0.613	0.905	**0.759**	**0.955**
32	Mozambique	0.235	0.872	0.126	0.803	0.360	**0.479**	**0.303**	0.024	0.063	**0.043**	**0.294**
33	Namibia	0.235	0.745	0.085	0.332	0.500	**0.380**	**0.063**	0.031	0.547	**0.289**	**0.345**
34	Niger	0.765	0.058	0.059	0.701	0.164	**0.349**	**0.020**	0.009	0.026	**0.017**	**0.136**
35	Nigeria	0.275	0.058	0.248	0.502	0.503	**0.317**	**0.341**	0.123	0.326	**0.225**	**0.392**
36	Rwanda	0.216	0.763	0.258	0.532	0.172	**0.388**	**0.361**	0.110	0.016	**0.063**	**0.666**
37	Sao Tome and Principe	0.157	0.058	1.000	0.866	0.728	**0.562**	**1.000**	0.193	0.011	**0.102**	**0.430**
38	Senegal	0.980	0.369	0.419	0.394	0.472	**0.527**	**0.192**	0.042	0.221	**0.132**	**0.515**
39	Seychelles	0.118	0.143	0.511	0.588	0.567	**0.385**	**0.720**	0.639	0.916	**0.778**	**1.000**
40	Sierra Leone	0.471	0.622	0.374	0.756	0.421	**0.529**	**0.783**	0.091	0.021	**0.056**	**0.157**
41	South Africa	0.020	0.058	0.622	0.230	0.664	**0.319**	**0.131**	0.358	0.905	**0.632**	**0.757**
42	South Sudan	0.529	0.058	0.085	0.956	0.196	**0.365**	**0.261**	0.130	0.011	**0.070**	**0.113**
43	Tanzania	0.333	0.625	0.092	0.507	0.338	**0.379**	**0.316**	0.056	0.026	**0.041**	**0.299**
44	Togo	0.275	0.721	0.674	0.512	0.417	**0.520**	**0.347**	0.127	0.132	**0.129**	**0.161**
45	Uganda	0.294	0.058	0.085	0.536	0.238	**0.242**	**0.351**	0.374	0.053	**0.213**	**0.185**
46	Zambia	0.373	0.058	0.085	0.540	0.435	**0.298**	**0.299**	0.032	0.111	**0.071**	**0.264**
47	Zimbabwe	0.176	0.653	0.085	0.251	0.322	**0.298**	**0.183**	0.146	0.305	**0.226**	**0.362**

3. Deriving the risk of exposure, and vulnerability adjustment factor

Deriving the Risk of Exposure

The Risk of Exposure was based on interacting the gathering factor, distribution factor, hygiene factor and weather factor. We assumed some interaction between gathering and distribution factors which the product of the interaction will have an add on effect from the weather factor and interact with the hygiene factor as follows.

$$RoE = \frac{[((Gathering\ factor\ X\ Distribution\ factor)+Weather\ factor)]}{2} X\ hygiene\ factor$$

For example, as shown above, Kenya's gathering factor was computed as 0.222 and the distribution factor being 0.153. Also, from supplementary table 2, the weather factor (normalised inverse of precipitation) for Kenya is 0.174 and 29 out of 100 people have access at least basic sanitation.

Therefore, RoE = ((0.222 x 0.153) + 0.174)/2 x 0.291 = 0.0302.

This computation was done for all countries to derive the risk of exposure reported, with the results shown in supplementary table 3.

Supplementary table 3: Derived Risk of Exposure

	Country	Gathering factor value	Weather factor value	Distribution factor value	Hygiene factor value	**Consolidated risk of exposure**
1	Algeria	0.425	0.332	0.377	0.876	**0.216**
2	Angola	0.504	0.296	0.091	0.499	**0.085**
3	Benin	0.552	0.305	0.104	0.165	**0.030**
4	Botswana	0.387	0.105	0.468	0.165	**0.024**
5	Burkina Faso	0.469	0.212	0.049	0.194	**0.023**
6	Burundi	0.413	0.381	0.511	0.458	**0.136**
7	Cabo Verde	0.490	0.045	0.357	0.739	**0.081**
8	Cameroon	0.501	0.487	0.035	0.391	**0.099**
9	Central African Republic	0.569	0.403	0.015	0.253	**0.052**
10	Chad	0.347	0.075	0.020	0.083	**0.003**
11	Comoros	0.500	0.261	0.218	0.359	**0.066**
12	Congo, Dem. Rep.	0.445	0.467	0.080	0.205	**0.051**
13	Congo, Rep.	0.299	0.500	0.080	0.202	**0.053**
14	Cote d'Ivoire	0.509	0.405	0.177	0.321	**0.080**
15	Equatorial Guinea	0.353	0.664	0.059	0.663	**0.227**
16	Eritrea	0.336	0.095	0.035	0.119	**0.006**
17	Eswatini	0.325	0.225	0.289	0.584	**0.093**
18	Ethiopia	0.273	0.244	0.050	0.073	**0.009**
19	Gabon	0.317	0.560	0.042	0.474	**0.136**
20	Gambia, The	0.500	0.240	0.120	0.392	**0.059**
21	Ghana	0.436	0.353	0.218	0.185	**0.041**
22	Guinea	0.344	0.502	0.060	0.227	**0.059**
23	Guinea-Bissau	0.476	0.478	0.117	0.205	**0.055**
24	Kenya	0.222	0.174	0.153	0.291	**0.030**
25	Lesotho	0.249	0.225	0.059	0.428	**0.051**
26	Liberia	0.333	0.740	0.063	0.170	**0.065**

	Country	Gathering factor value	Weather factor value	Distribution factor value	Hygiene factor value	**Consolidated risk of exposure**
27	Madagascar	0.482	0.458	0.076	0.105	**0.026**
28	Malawi	0.478	0.351	0.063	0.262	**0.050**
29	Mali	0.418	0.062	0.032	0.393	**0.015**
30	Mauritania	0.523	0.001	0.024	0.484	**0.003**
31	Mauritius	0.444	0.627	0.759	0.955	**0.461**
32	Mozambique	0.479	0.303	0.043	0.294	**0.048**
33	Namibia	0.380	0.063	0.289	0.345	**0.030**
34	Niger	0.349	0.020	0.017	0.136	**0.002**
35	Nigeria	0.317	0.341	0.225	0.392	**0.081**
36	Rwanda	0.388	0.361	0.063	0.666	**0.128**
37	Sao Tome and Principe	0.562	1.000	0.102	0.430	**0.227**
38	Senegal	0.527	0.192	0.132	0.515	**0.067**
39	Seychelles	0.385	0.720	0.778	1.000	**0.510**
40	Sierra Leone	0.529	0.783	0.056	0.157	**0.064**
41	South Africa	0.319	0.131	0.632	0.757	**0.126**
42	South Sudan	0.365	0.261	0.070	0.113	**0.016**
43	Tanzania	0.379	0.316	0.041	0.299	**0.050**
44	Togo	0.520	0.347	0.129	0.161	**0.033**
45	Uganda	0.242	0.351	0.213	0.185	**0.037**
46	Zambia	0.298	0.299	0.071	0.264	**0.042**
47	Zimbabwe	0.298	0.183	0.226	0.362	**0.045**

Adjusting for vulnerability

As shown in the emerging literature, certain risk factors are associated with adverse outcomes when one is infected with SARS-COV-2. Mainly based on data availability for all the countries, the following variables were used as proxies: diabetes prevalence rate (%) as proxy for non-communicable diseases, HIV prevalence rate (%) as proxy communicable diseases and proportion of population who are 65 years or more as a measure for age group at higher risk. The proxy variables for communicable and non-communicable diseases were assumed to contribute in an interactive way with an add on contribution from ageing. All the indicators for the vulnerability adjustment factor are of the same unit – proportions – and so were not normalized.

$$Vulnerability\ adjustment\ = ((diabetes\ prevalence\ x\ HIV\ Prevalence) +\ \%\ of\ pop\ 65\ yrs\ +))/2$$

The vulnerability adjustment factor was used to adjust the probability of deaths when one is infected with SARS-COV-2. Using Kenya as an example, the country has 3.1% prevalence of diabetes, 4.7% of HIV prevalence while 2.7% of the population are 65 years or older. The vulnerability adjustment factor for Kenya was derived as: ((0.031 x 0.047) + 0.0267)/2 = 0.014. Thus, we assumed that Kenya may experience at least 1.4% higher mortality rate due to this vulnerability. As shown in supplementary table 4, the process as repeated for all countries.

Supplementary table 4: Derived vulnerability adjustment factor

	Country	Population ages 65 and above (% of total)	HIV Prevalence (%population ages 15-49)	Diabetes Prevalence	Vulnerability adjustment factor
1	Algeria	6.211	0.05	0.07	**0.031**
2	Angola	2.405	2.00	0.05	**0.012**
3	Benin	3.244	1.00	0.01	**0.016**
4	Botswana	3.941	20.30	0.06	**0.026**
5	Burkina Faso	2.409	0.70	0.07	**0.012**
6	Burundi	2.562	1.00	0.05	**0.013**
7	Cabo Verde	4.460	0.60	0.02	**0.022**
8	Cameroon	3.165	3.60	0.06	**0.017**
9	Central African Republic	3.655	3.60	0.06	**0.019**
10	Chad	2.486	1.30	0.06	**0.013**
11	Comoros	2.893	0.10	0.12	**0.015**
12	Congo, Dem. Rep.	3.020	0.80	0.06	**0.015**
13	Congo, Rep.	3.402	2.60	0.06	**0.018**
14	Cote d'Ivoire	2.933	2.60	0.02	**0.015**
15	Equatorial Guinea	2.846	7.10	0.06	**0.016**
16	Eritrea	2.846	0.70	0.05	**0.014**
17	Eswatini	3.163	27.30	0.05	**0.022**
18	Ethiopia	3.526	1.00	0.04	**0.018**
19	Gabon	4.450	3.80	0.06	**0.023**
20	Gambia, The	2.339	1.90	0.02	**0.012**
21	Ghana	3.385	1.70	0.03	**0.017**
22	Guinea	3.135	1.40	0.02	**0.016**
23	Guinea-Bissau	3.002	3.50	0.02	**0.015**
24	Kenya	2.686	4.70	0.03	**0.014**
25	Lesotho	4.506	23.60	0.05	**0.028**
26	Liberia	3.057	1.30	0.02	**0.015**
27	Madagascar	2.929	0.30	0.05	**0.015**
28	Malawi	3.552	9.20	0.05	**0.020**
29	Mali	3.158	1.40	0.02	**0.016**
30	Mauritania	10.945	0.20	0.07	**0.055**
31	Mauritius	2.979	1.30	0.22	**0.016**
32	Mozambique	3.138	12.60	0.03	**0.018**
33	Namibia	9.954	11.80	0.05	**0.052**
34	Niger	2.553	0.30	0.02	**0.013**
35	Nigeria	2.751	1.50	0.03	**0.014**
36	Rwanda	2.974	2.50	0.05	**0.016**
37	Sao Tome and Principe	2.886	0.05	0.02	**0.014**
38	Senegal	3.008	0.40	0.02	**0.015**
39	Seychelles	8.606	0.05	0.12	**0.043**
40	Sierra Leone	2.538	1.50	0.02	**0.013**
41	South Africa	5.344	20.40	0.13	**0.040**
42	South Sudan	3.441	2.50	0.10	**0.018**
43	Tanzania	3.108	4.60	0.06	**0.017**
44	Togo	2.839	2.30	0.02	**0.014**
45	Uganda	2.168	5.70	0.03	**0.012**
46	Zambia	2.480	11.30	0.05	**0.015**
47	Zimbabwe	2.822	12.70	0.02	**0.015**

4. Applying the model

As described in figure 2 of the main paper, the number of people in a country that will be exposed to the virus at any given time if widespread community transmission is established is determined by the risk of exposure. Thus, it is applied to the whole population of a given country or territory and the resulting population is then considered the one exposed to the virus.

$$Exposed\ population\ at\ the\ initial\ cycle\ = National\ population\ X\ Risk\ of\ Exposure$$

For instance, Kenya's population of 51,393,010 according to the UN population division and the risk of exposure of 3.02% (as calculated above) in the absence of non-pharmaceutical interventions that limits exposure, about 1,552,069 people may be exposed to the virus at the initial cycle of the model.

From the point of exposure throughout the incubation period, the exposed persons faces a risk of getting infected depending on the attach rate of the virus. As shown in table 1 in the main paper, an average attach rate of 6.5% was used in the base model.

$$Number\ infected\ = (Exposed\ population\ X\ Attack\ Rate)$$

With the Kenya's example, number infected at the initial cycle = 1,552,069 x 6.5% = 100,951. In the subsequent cycle, these infected ones are excluded from the number at risk.

Once infected, individuals depending on their vulnerabilities faces a risk of having asymptomatic, mild, moderate, severe or critical form of the infection. The distribution of the total infected persons at any given cycle to these states are driven by the transition probabilities described in the main paper. These probabilities are adjusted for those who get the severe or critical form of the infection by the vulnerability adjustment factor to reflect its influence on the numbers of persons having this transition state.

The model was designed to run a weekly cycle for a duration of 52 weeks. Thus, the computation described was repeated for the horizon of the model and the aggregated output reported.

5. Issues for further methodological exploration

We explored several analytical approaches, many of which were hampered by data challenges. However, the results we got are comparable with what is seen in the countries, such as the lower rate of transmission, lower severe disease and lower death rates. Additionally, in sensitivity analysis we explored several the impact of the assumptions and variables on the results which we found that the results of the sensitivity analysis was mostly within our best and worst case scenarios. However, the following areas would benefit from more extensive exploration if data is more available.

1. Indicators constituting the Risk of Exposure. Although its results are comparable with what is seen in the region, the data challenges limited the applied indicators. Where there is more data, it would be worth exploring additional indicators. For example, the UV index to complement the weather factor.
2. Methods of interaction of the factors constituting the risk of exposure. We recognize there are different ways the factors can interact to get the risk of exposure. We explored using reported cases to work backwards and predict the mechanism of interaction, but the under-reporting due to different testing strategies make it difficult to assume current cases represent the full picture of the outbreak. We therefore interacted them as represented based on our knowledge of factors influencing transmission of infectious diseases. With data from sero-epidemiological studies in the countries, this can be further explored.
3. Transition probabilities would best be derived from the population of a country as compared to other countries. This may reduce the need for the risk of exposure and vulnerability index. However, as the African Countries included were all in the early stages of their outbreaks, we had to apply probabilities derived from other countries, necessitating the adjustments. As the outbreak progresses in the region, it would be worthwhile exploring context-specific estimates of these probabilities.

The tool from which country specific results are detailed is available in each of the 47 countries of the WHO African Region, through the office of the WHO Representative. The probabilities used are constantly updated to reflect evolving knowledge about the SARS-CoV-2. For this publication, the version 1.3 was used.