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National Bureau of Statistics
Ministry of National Planning and Infrastructure

Leveraging Big Data Sources to Estimate the demographic and Economic Impacts and Implications of COVID-19 in Maldives

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Introduction

The COVID-19 pandemic is having an unprecedented global impact on societies and economies across the world. In the Maldives, while the number of COVID-19 confirmed cases remains relatively low compared to many other countries and the number of deaths is under 50 as of December 14, the socio-economic toll is significant. According to the Ministry of National Planning, Housing and Infrastructure, over 22,000 people have lost their jobs due to the pandemic.¹ Certain GDP forecasts predict growth reductions reaching 29.7% in the worst-case scenario (figure 2).

Often times, economic opportunity is directly linked with mobility, especially in counties heavily reliant on the service sector and tourism. In the Maldives, the population's movement is very much dependent on the geographic distribution of the 187 inhabited islands, the tourist resorts and industrial islands and the services and opportunities available in those islands. Geographic mobility is one of the key factors to be examined for the proper implementation of government's different policies. In addition, because of its distinctive geographic features internal and international migration is occurring on a large scale and more than 60% of the population is expected to live in greater Malé, the capital city, of which many are migrants already living in highly densely populated.

The objectives of this *project* "Leveraging Big Data Sources to Estimate the demographic and Economic Impacts and Implications of COVID-19 in Maldives" are three-fold:

- (i) Developing machine-learning algorithms to estimate population density, movement, and poverty indicators to obtain greater levels of granularity,
- (ii) Comparison of pre- and post- COVID-19 mobility patterns in Maldives, and
- (iii) Developing the capacity of the NBS team to conduct such analyses in-house through trainings.

Initially, the project intended to utilize Call Detail Records (CDRs) obtained from the national telecommunications providers to draw the pre-COVID-19 baseline and assess the impacts of COVID-19 on mobility and selected socio-economic indicators on a more granular. However, given the inconclusive efforts to obtain telecommunications data for the analysis of COVID-19 impact in Maldives, an analysis using mobility data provided by the Facebook For Good program was performed.

¹ Shaahunaz, Fathmath. "Over 22,000 Lost Jobs Due To Pandemic: Housing Minister". *The Edition*, 2020, https://edition.mv/covid_19/20839.

The analysis presented in this report summarizes the following activities performed to fulfill the aforementioned project objectives:

1. Studying how the population dynamics have been impacted in Maldives following COVID-19 related confinement and mobility restrictions measures using mobility data from the Facebook Geinsights platform.
2. Coupling the Facebook mobility data with other socio-economic data available through NBS to obtain insights on the potential socioeconomic shifts and whether it could be used as a proxy to these socio-economic indicators.

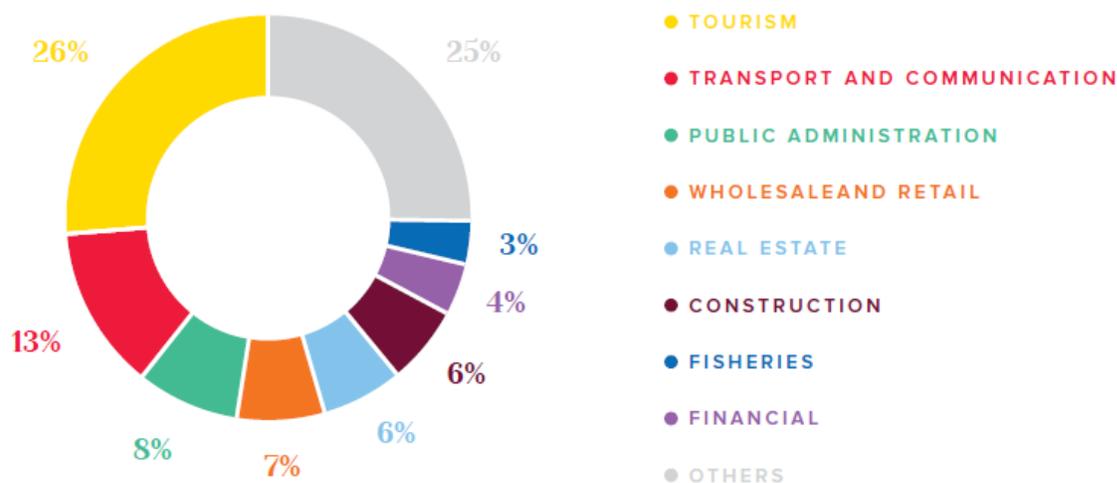
Throughout the analysis we will try to answer the following research questions:

- 1) How did the population mobility dynamics and population density change as the COVID-19 timeline progressed and various mobility restrictions measures were introduced?
- 2) How did the mobility dynamics correlate with the count and distribution of COVID-19 cases? Comparing the citizen response to confinement (mobility) & COVID-curves.
- 3) Can mobility data be used as a proxy to employment/unemployment indicators?

Country context

Maldives is an island nation located in the Indian Ocean southwest of Sri Lanka and India. It is made up of 20 administrative atolls and the capital, Male city, which is part of the Kaafu Atoll. The tourism sector accounted for 26% of the Maldivian GDP composition in 2019 (Figure 1). As the COVID-19 pandemic progressed and entry restrictions started being implemented, the tourism arrivals declined by 63.4% year-on-year in March 2020 alone. Therefore, Maldives has been severely impacted by the shutdown of its main industry for several months.

Figure 1. GDP composition of 2019.



Source: National Bureau of Statistics, visualization from the UNDP Maldives COVID-19 rapid livelihood assessment report.²

Construction is another sector that has been greatly affected given the restrictions of mobility, the drying up of the external financing and the impact of COVID-19 the foreign

² *Rapid Livelihood Assessment: Impact Of The COVID-19 Crisis In The Maldives.* UNDP & Ministry Of Economic Development, Republic Of Maldives, 25 August 2020, <https://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/rapid-livelihood-assessment-impact-of-covid-19-crisis-in-the-maldives.html>.

workers, who are predominantly employed in this sector. Bangladeshi workers, who mainly work in this sector accounted for half of COVID-19 cases in the Maldives.³

According to the Maldives Development Update by the World Bank, the economic growth in Maldives is projected to contract by between 13 and 17.5% in 2020.⁴ Figure 2 below summarizes the various GDP forecasts for 2020.

Figure 2. Summary of GDP forecasts for 2020 from various sources

FORECASTED FALL IN GDP FOR 2020	BEST CASE SCENARIO	WORST CASE SCENARIO
Government of Maldives (24 April 2020)	-11.5%	-29.7%
International Monetary Fund (16 April 2020)		-8.1%
The World Bank (12 April 2020)	-8.5%	-13%
Government of Maldives (18 April 2020)	-7.7%	-17.7%
Asian Development Bank (6 March 2020)	-1.4%	-4.1%

In this context, the current study aims to contribute to developing methods for socio-economic analysis using non-traditional data sources that can aid statistics offices to generate faster insights into the socio-economic impact analyses through validated proxies and using population dynamics to derive new useful insights.

Source: Visualization from the UNDP Maldives COVID-19 rapid livelihood assessment report (see footnote 2).

Statistics on Internet and social media usage in Maldives

Given that this study is relying on the data obtained from Facebook, it is important to understand the extent of the Internet penetration and social media usage in the Maldives. The Internet penetration in the Maldives was estimated to be 71% (380,000 users) in January 2020.⁵ Social media penetration is estimated to be at the same rate as the Internet penetration, indicating that everyone who is connected to the Internet also uses some sort of social media. In terms of mobile penetration, the number of mobile connections was estimated to be 888,500 in January 2020, representing 166% of the

³ *Maldives Development Update: In Stormy Seas*. The World Bank, June 2020, <http://documents1.worldbank.org/curated/en/336011591808041663/pdf/Maldives-Development-Update-In-Stormy-Seas.pdf>. June 2020.

⁴ "Investments In Renewable Energy Can Support Post COVID-19 (Coronavirus) Economic Recovery In The Maldives". *World Bank*, 15 June 2020, <https://www.worldbank.org/en/news/press-release/2020/06/15/investment-renewable-energy-covid-coronavirus-economic-recovery-maldives>.

⁵ Kemp, Simon. "Digital 2020: The Maldives — Datareportal – Global Digital Insights". *Datareportal – Global Digital Insights*, 18 February 2020, <https://datareportal.com/reports/digital-2020-maldives>.

population. In 2019, mobile phones accounted for 59.8% of the web traffic, a 9.6% increase from 2018.⁶

The number of people using Facebook is estimated to be 340,000 corresponding to 89.5% of the population connected to the Internet and 77% of the population aged 13+.⁷ Females are estimated to make up 33.3% of the audience, and males, respectively, 66.7% (based on ad audience and stats). Percentage of Facebook users accessing the website via a mobile phone is estimated to be 99.4%, with 88.4% accessing it uniquely through a mobile phone device.⁸

According to the statistics of the Communications Authority of Maldives (CAM), for September 2020 the number of total mobile broadband subscriptions represented 252,679 people and total fixed broadband subscriptions were 60,464 (figure 3).⁹

Figure 3. Telecommunications statistics - September 2020.

Fixed Telephone Lines		Mobile	
Total number of Fixed lines (includes Payphones)	14,983	Total number of mobile Subscriptions	735,249
Male' Region (incl. Villingili & Hulhumale)	10,986	Mobile subscriptions - Postpaid	161,914
Other Regions (Including Resorts and Uninhabited Islands)	3,997	Mobile subscriptions - Prepaid	573,335

Teledensity *		Internet	
Fixed lines	2.69	Total Fixed Broadband Subscriptions	60,464
Mobile Subscriptions	131.90	Total Mobile Broadband Subscriptions	252,679
Fixed Broadband	10.85	Data with Voice	174,400
Mobile Broadband	45.33	Data Only	47,979
		LTE - Fixed Broadband	30,300

Source: Communications Authority of Maldives, <https://www.cam.gov.mv/Statistics.htm>.

Timeline of measures taken and COVID-19 cases

The government of Maldives has acted early in adopting measures to prevent and minimize the spread of the virus on the territory of Maldives. The early measures included

⁶ Ibid.

⁷ Number of people that can be reached via adverts on Facebook (estimated by Facebook). Ibid.

⁸ Ibid.

⁹ "Telecommunications Data - September 2020". *Cam.Gov.Mv*, 2020, <https://www.cam.gov.mv/Statistics.htm>.

the restriction of the passenger flows starting from February 3rd for passengers coming from China. Throughout the months of February and March, the government of Maldives adopted additional entry restrictions as well as mobility restrictions within Maldives.

Since the middle of March 2020, the Government of Maldives has put in place strict containment measures, including closing government offices and education facilities, closing eateries, imposing travel bans to and from resorts, quarantining all incoming travelers to the Maldives, and barring tourists who were transferred to resorts from travelling to any inhabited islands. Since the community outbreak, the Greater Malé Region and several islands were under a 24-hour lockdown with restricted movement, and a nationwide ban on travel and public gatherings was imposed. The lockdown easing measures were implemented in a phased approach starting at the end of May 2020 and comprising three phases. Government offices and schools started gradually reopening on 1 July 2020, and the country reopened borders and started accepting tourists on July 15.¹⁰

The table below summarizes the main dates and the number of cumulative COVID-19 cases registered around these dates:

Table 1. Summary of the key measures taken and the number of confirmed COVID-19 cases at that time.

Dates	Measure Taken	COVID-19 cases
April 15	24-hour lockdown in the Greater Male region.	22
April 16	Ban on nationwide travel and public gatherings.	25
April 17	Lockdown extended for another 14 days as cases increase.	28
May 14	Lockdown extended in Greater Malé Region until May 28 th .	982
May 29	Lockdown measures start to ease in the Greater Malé Region.	1591

¹⁰ Most of the timeline information was obtained from the UNDP Maldives rapid livelihood assessment report on the Impact of the COVID-19 crisis in the Maldives. See footnote 2.

May 29-June 14	First phase of easing measures started.	
June 15 - June 30	Second phase of easing measures started.	
June 16	Nationwide restrictions on travel and public gatherings lifted	2,094
July 15	State of Public Health Emergency is extended. Borders reopen and 40 resorts resume operations.	2,831
August 1	Hotels on inhabited islands open for tourists.	3,949
November 5	The State of Public Health Emergency is extended until December 5.	11,893

Data and methodology

Data sources

Non-traditional data sources

Facebook Population, Tile Level (Facebook Platform Geoinsights¹¹)

Facebook population datasets from the GeoInsights platform reporting a percentage change in population at the tile level for the period March 30 to December 7, 2020 were used. The tile information in these datasets is given in the format of quadkeys (zoom 14) which are a way of indexing and storing tiles where the two-dimensional tile XY coordinates are combined into one-dimensional strings called quadtree keys, or quadkeys for short. Each quadkey uniquely identifies a single tile at a particular level of detail. This Facebook data gives the ID quadkeys along with the corresponding coordinates and the percentage change of population with reference to a benchmark time point pre-COVID-19.

Facebook Movement Between Tiles (Facebook Platform Geoinsights)

¹¹ <https://www.facebook.com/geoinsights-portal/>

The “Movement Between Tiles” dataset contains data that report a percentage change of people moving from a starting point to an end point compared with a pre-COVID-19 reference. Because this data only provides information for 9 of 21 Atolls it was decided to assign the coordinates (of these starting and end points) of the Geometry column to polygons of the 21 Atolls. The spatial files for the Maldives were obtained from <https://bit.ly/3a56eds>. With this assignment it was possible to capture 20 of the 21 Atolls. Finally, the assignment of the coordinates allowed to distinguish flows of intra- and inter-atolls mobility.

Facebook Colocation Datasets (Facebook Platform Geoinsights)

The “Colocation” dataset contains data that reports a probability that people from one place might come into contact with people from the same place (intra-Atoll) or from different locations (inter-atolls).

Traditional data sources

The following datasets were received from the National Bureau of Statistics of Maldives and utilized in the analysis:

- Population density in 2020: The population data presents population data by administrative and non-administrative islands for each atoll and includes the disaggregation by the Maldivian and foreign populations.
- Unemployment data from 2016 and 2019: labor force statistics (number of employed, unemployed, outside of labor force, total labor force) obtained from the Household Income & Expenditure Surveys of 2016 and 2019 were provided by the NBS and used in the analysis.

Methodology

Tools and format

Facebook Population, Tile Level (Facebook Platform Geoinsights)

For spatial visualization, datasets that communicate a percentage change in population at the tile level for the period March 30 to December 7, 2020 were used. The information in these datasets is given in Quadkeys, with its coordinates and with the percentage change of population, change with respect to a preCOVID-19 reference point. For spatial

visualization, these files were loaded into kepler.gl and the color gradient was adjusted to 6 bin quantiles, which helped to intuitively visualize the internal population changes. A green-to-red color gradient was used to indicate reduction or increase in percentage changes, relative to a baseline, respectively. Finally, a temporary filter was added in kepler. This was previously constructed and implied merging the date variable with a synthetic time column, since kepler only recognizes a chronological variable composed of date and time. Thus, this filter allowed a temporal analysis of population changes.

Facebook Movement Between Tiles (Facebook Platform Geoinsights)

From the Movement Between Tiles files, the median per day and for the entire country of the percentage change was calculated. This *mobility percentage change* denotes the difference between the number of users who moved from a starting point to an end point. Note that *this percentage change is not a mobility index* reported as such, but rather an indicator that communicates the increase or decrease in flows of people.

Mobility exploratory analysis

To explore the degree of mobilization of people in the country, the following approach was used based on the Facebook Movement data at the Tiles level. Both the geographic coordinates from the “*geometry*” column that mark the beginning and end of the movements as well as the value of the percentage change were used. This value denotes the difference between the number of users who moved from point A to point B. To study the behavior at the national level the median was calculated per day and for all atolls. Previously, it was necessary to spatially assign the corresponding coordinates to the polygons of the spatial files of the atolls to identify more Atolls in the data than were initially indicated in the raw data.

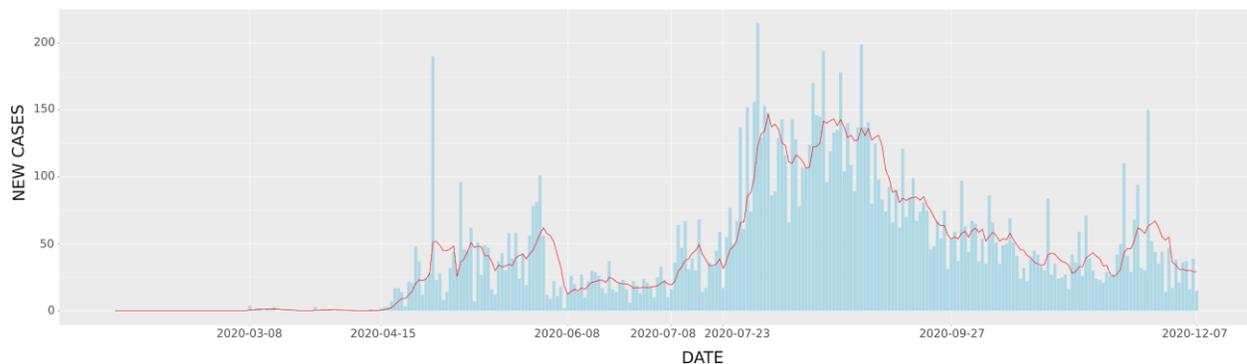
Results

Population mobility dynamics

COVID-19 new cases curve

Figure 4 below shows the curve of the evolution of the daily new cases as per the official COVID-19 numbers (obtained from the Center for Systems Science and Engineering Data Repository (CSSE, Johns Hopkins University)¹². We observe two periods with a peak of cases. The first is from March 15 to June 8 and the second from July 23 to September 29. Both periods are separated by a phase from June 8 to July 8, with relatively few new cases per day. By looking at this data, it is possible that the final peak of the last days of November will mark the beginning of another important period of contagion.

Figure 4. The curve of COVID-19 new cases in Maldives.



Data source: CSSE, Johns Hopkins. Plot done using the R library tidyCovid19¹³.

Population changes at the Quadkey level in 2020

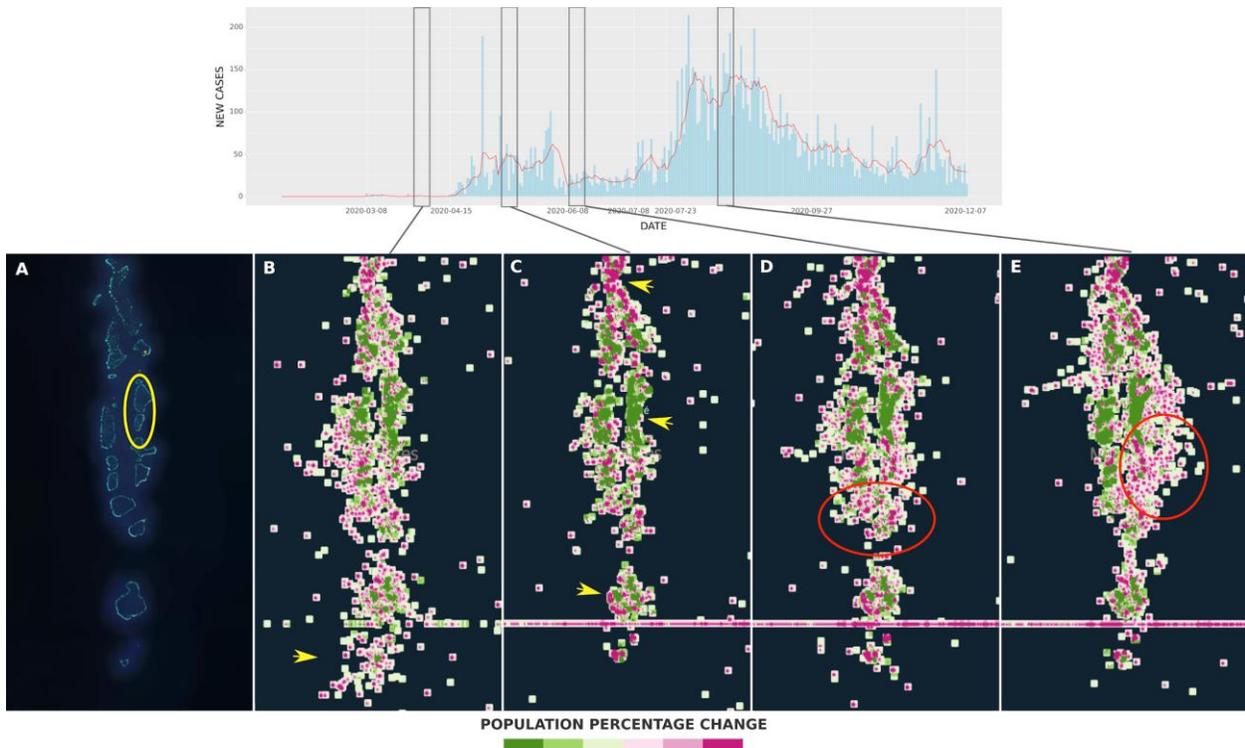
From the COVID-19 new daily cases curve (Figure 4), 4 weeks were selected to perform the population analysis using the Facebook datasets on population at tile levels (figure

¹² "

¹³ Gassen, Joachim. "Download, Tidy And Visualize Covid-19 Related Data". *Joachim-Gassen.Github.io*, 2020, <https://joachim-gassen.github.io/tidyCovid19/>.

5). The green-to-red color gradient shows the percentage decrease and increase of population, respectively, compared to a pre-COVID reference point.

Figure 5. Population percentage changes at different time periods selected from the new COVID-19 cases curve (Fig 4).



Data source: Facebook Geoinsights.

Subfigure 5A shows the area of the Greater Malé Region (Kaafu Atoll) in yellow from a satellite view mode.

Subfigure 5B corresponds to the week of *March 29th to April 4th* which represents the first week for which data is available and coincides with a period in which important health policy interventions have not yet been declared. Certain mobility restrictions, such as the closure of all government offices and schools and education providers were implemented as early as March 17-19. However, there were no atoll-wide lockdowns yet.

Subfigure 5C shows the population density during the week of *May 10th to 16th*, which is within the lockdown period (April 15 to May 29) and according to the COVID-19 curve it is within the first major peak of cases (see the 2020-04-15 to 2020-06-08 period in

figure 4). In C, we can observe that in lockdown there is a denser green zone (compared to pre-COVID B; see central arrow) with a reduced population concentration which suggests people could have followed the stay-at-home recommendations.

Subfigure 5D corresponds to the week of *June 7th to 13th* and was selected because it shows an initial phase of a period in which measures start to be relaxed and coincides with a relatively low new COVID cases curve. Here, when certain measures are relaxed, it is observed that an area stands out that increases its relative population (red circle).

Subfigure 5E corresponds to the week of *August 16th to 22nd* and was selected because it is in the middle of the highest peak of the COVID-19 new cases curve. By mid-August, during the highest COVID-19 peak of the year, an area with a strong increase in population is seen (red circle). Note that this area in red falls outside the nearest Atolls (Vaavu and Meemu) suggesting potentially tourist, maritime and/or fishing activity.

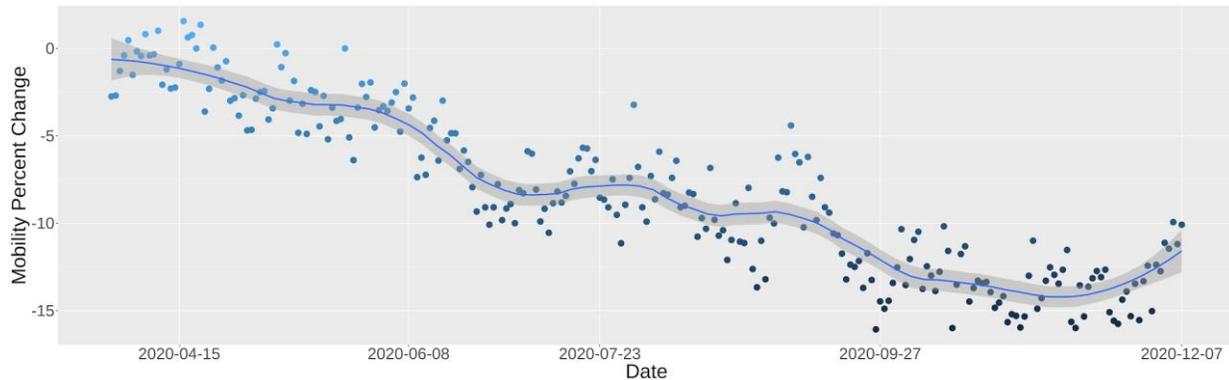
As seen in figure 5, Facebook population data at the tile level show important changes and their comparison with key dates provides clues about the the effect of the measures on the concentration of people. For example, during the lockdown period, greener areas corresponding to a reduced population density are observed in the center of the country (subfigure C). Besides that, during the second peak of COVID-19 infections, we can observe an area with an important increase in mobility (subfigure E).

Trend of the mobility flows at the national level

At the national level in Maldives, there is an overall trend of decreasing mobility.

The curve below (figure 6) shows the Maldives mobility percent change. A downward trend can be observed, that is, daily points for the whole country with percentage changes that decrease over time. In particular, when compared with quarantine intervention dates, it is observed that the lockdown dates show percentage changes with a downward trend, a trend that extends over time indicating that certain areas still have not recovered their pre-COVID-19 mobility levels.

Figure 6. Maldives Mobility percent change.



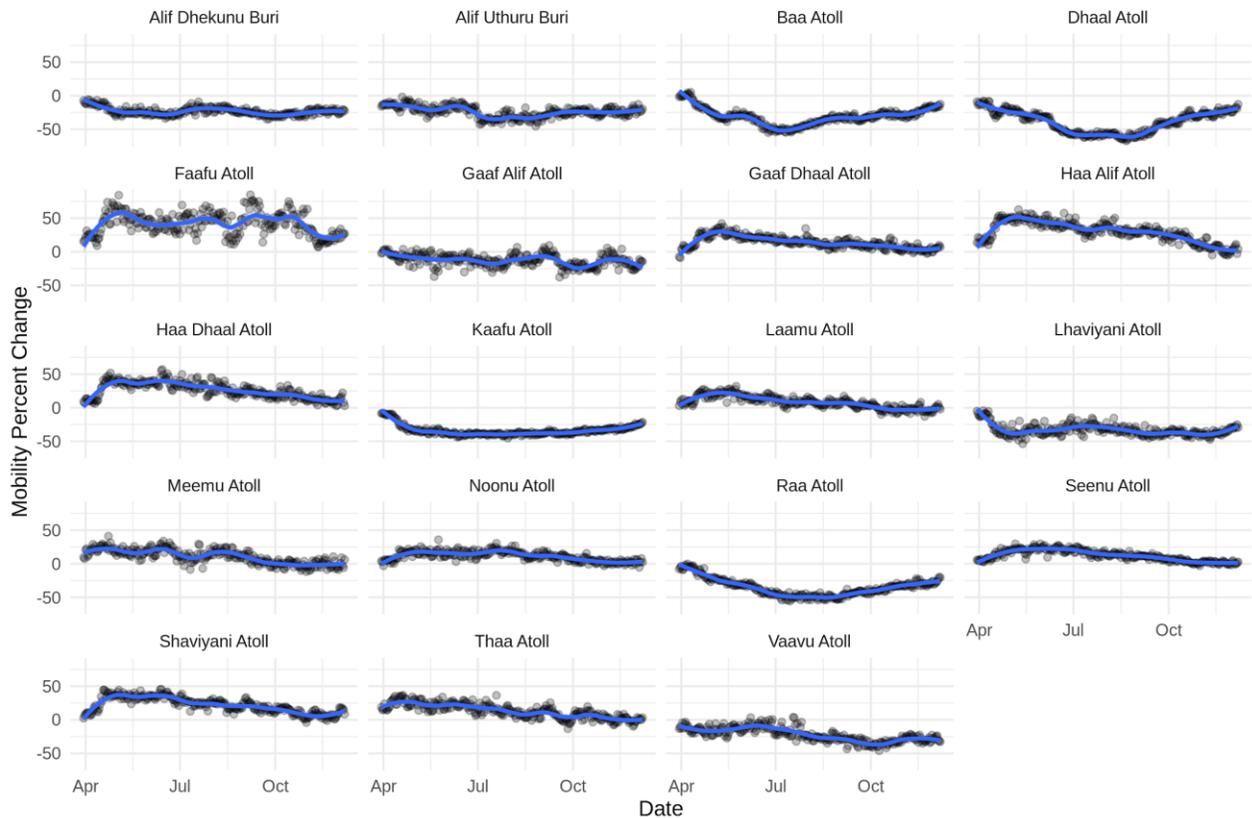
The y-axis shows the mobility percentage change of daily points for the whole country. Positive changes indicate that there was an increase in the number of people moving internally in Atolls from a pre-COVID baseline. Negative changes point to a decrease.

A decrease starting mid-April can be observed (the lockdown in the Greater Malé region started on April 15). The lockdown measures start to be eased on May 29; however, the mobility continues to decrease beginning of June and comes to a plateau around mid-July (July 15th borders are reopened and resorts resume operations). It is interesting to note that at the end of August, there is another dip in mobility that starts to increase only towards the end of November.

Trend of the mobility flows at the Atoll level

For a more detailed exploration of the changes in mobility within the country, the median per day of this indicator was calculated for each of the 19 Atolls for which data are available. The Figure 7 summarizes the mobility percent change for each atoll as the various mobility restrictions were implemented in the period from April to November. Atolls that saw a *decrease in intra-atoll mobility* include *Alif Dhekuni, Gaaf Ali, Lhaviyani and Vaavu, and to a greater degree Dhaal, Baa, Raa and Kaafu*. On the other hand, atolls that have seen an *increase in intra-atoll mobility* activity are: *Faafu, Gaaf Dhaal, Haa Alif, Haa Dhaal, Laamu, Meemu, Noonu, Seenu, Shaviyani and Thaa*.

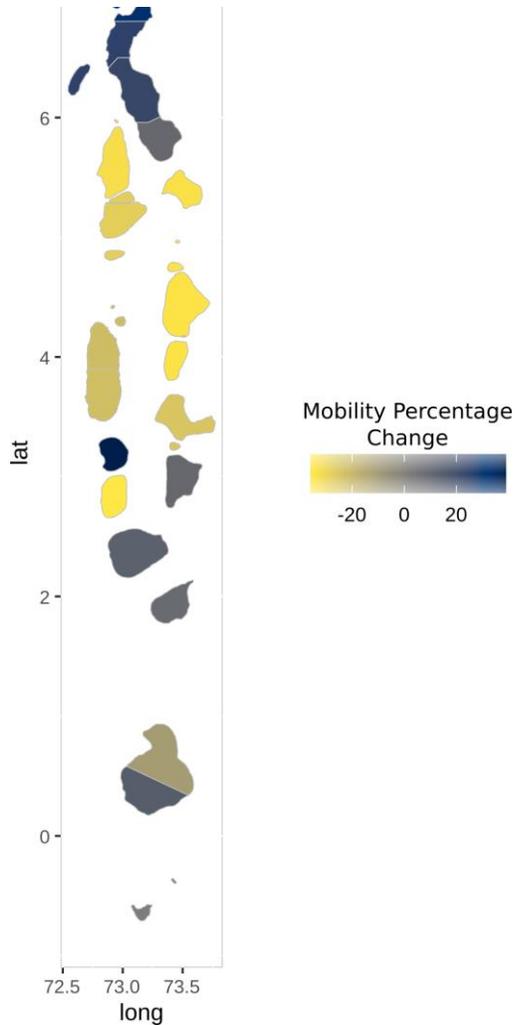
Figure 7. Mobility curve by Atoll.



In Y is shown the percentage change for each of the Atolls. Positive changes indicate that there was an increase in the number of people moving internally in Atolls compared to a pre-COVID baseline. Negative changes point to a decrease.

From the exploration of the mobility curve, the median of the mobility change for the entire data period (March-November) was calculated to obtain a general panorama of

Figure 8. Median change in mobility over 2020 at the Atoll level.



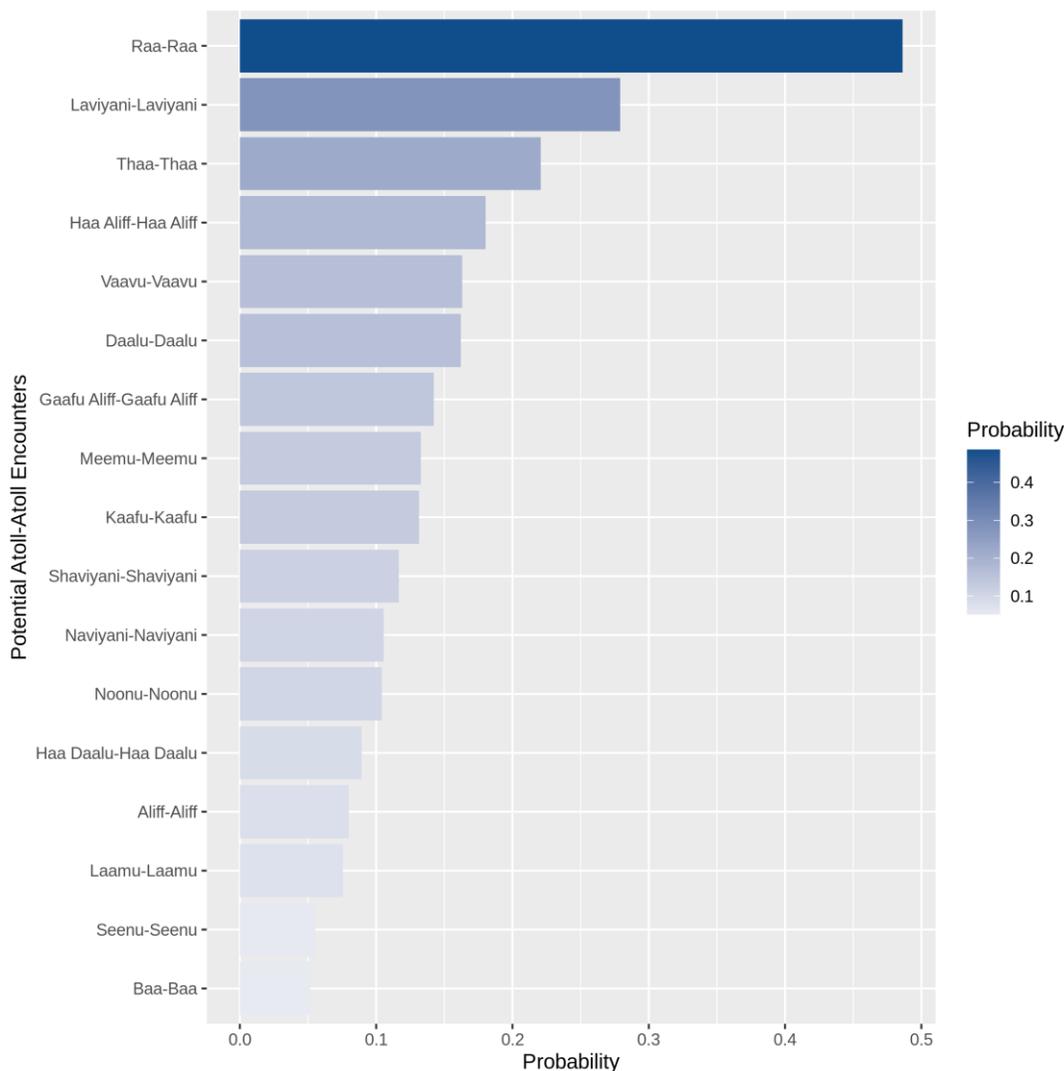
the mobility trend at the atoll level, which we visualized with a choropleth map. This map shows the degree of associated mobility change (figure 8).

The calculation of a median mobility per atoll and for the whole year allows to identify atolls in the center of the country that collectively reduce significantly their mobility in comparison with atolls in the "periphery" of the country.

To study the patterns inside the atolls we studied the probability of two people meeting within the same Atoll. As figure 9 shows, the probability of two people meeting each other is high in Raa and low in Baa. There are different factors that could contribute to that, among them, population density, population mobility and transport infrastructure. On the one hand, it could be interpreted that the mobility is the highest in Raa, and the mobility in Baa is the lowest. Another factor is the population density that could increase the probabilities of encounters. The bar plot below (figure 9) is the average probability of encounters throughout the entire Facebook Colocation dataset (March to September).



Figure 9. Probability of encounters within the same Atoll.



Source: Facebook Colocation Maps

To explore in more detail the behavior of these intra-atoll encounter probabilities, the average of these probabilities was calculated for different intra-atoll encounters for the weeks that were analyzed previously in figure 5 (see table 2 below). The encounter column gives the names of the encounters within a given atoll and the columns with the dates indicate the start of that particular week. The averages per column and per row are also indicated.

It is observed, for example, that the mean probability of encounter, in the week of March 29 is the highest (0.1338571), for all the atolls shown, compared to the other weeks. The

week of March 29 is when, although some health initiatives had already been declared, the COVID-19 cases start to increase. On the other hand, the averages of all weeks indicated by atoll (rows) show that Lhaviyani is the one where the probability of meeting is greater (probability=0.27725). In the case of Kaafu, the probability of a higher encounter (0.139) is observed during the week of June 07, the week when sanitary quarantine measures began to be relaxed.

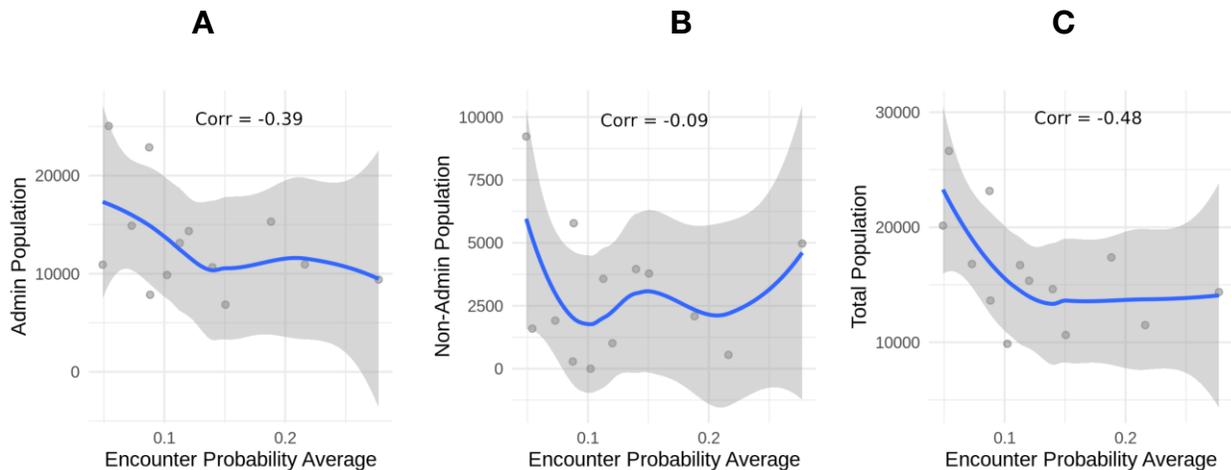
Conclusion: the information contained in these Facebook colocation datasets is useful for the clues they offer about the probability of encounters that can be disaggregated for the periods of interest. This information is potentially useful for crossover with the Facebook population information as well as with the Facebook movement between tiles.

Table 2. Encounter probabilities among the Atolls and the weeks shown.

Encounter	ENCOUNTER PROBABILITY				Average
	March_29	May_10	June_07	August_16	
Laviyani-Laviyani	0.2780000	0.2750000	0.272	0.2840000	0.27725
Thaa-Thaa	0.2220000	0.2070000	0.229	0.2070000	0.21625
Haa Aliff-Haa Aliff	0.1830000	0.1740000	0.214	0.1820000	0.18825
Shaviyani-Shaviyani	0.1610000	0.1040000	0.097	0.1190000	0.12025
Daalu-Daalu	0.1520000	0.1530000	0.160	0.1370000	0.15050
Gaafu Aliff-Gaafu Aliff	0.1430000	0.1480000	0.126	0.1420000	0.13975
Kaafu-Kaafu	0.1270000	0.1370000	0.139	0.1300000	0.13325
Naviyani-Naviyani	0.1140000	0.0980000	0.104	0.0930000	0.10225
Aliff-Aliff	0.1090000	0.0970000	0.071	0.0760000	0.08825
Noonu-Noonu	0.1050000	0.1250000	0.120	0.1010000	0.11275
Haa Daalu-Haa Daalu	0.0890000	0.1000000	0.100	0.0610000	0.08750
Laamu-Laamu	0.0810000	0.0690000	0.067	0.0750000	0.07300
Baa-Baa	0.0550000	0.0450000	0.040	0.0560000	0.04900
Seenu-Seenu	0.0550000	0.0520000	0.053	0.0560000	0.05400
Average	0.1338571	0.1274286	0.128	0.1227857	NA

Data source: Facebook Colocation Datasets

Figure 10. The correlation between the population and the average probability of encounters. A = Population of the administrative islands (Maldivian and foreign); B = Population of the non-administrative islands (Maldivian and foreign); C = Total population.

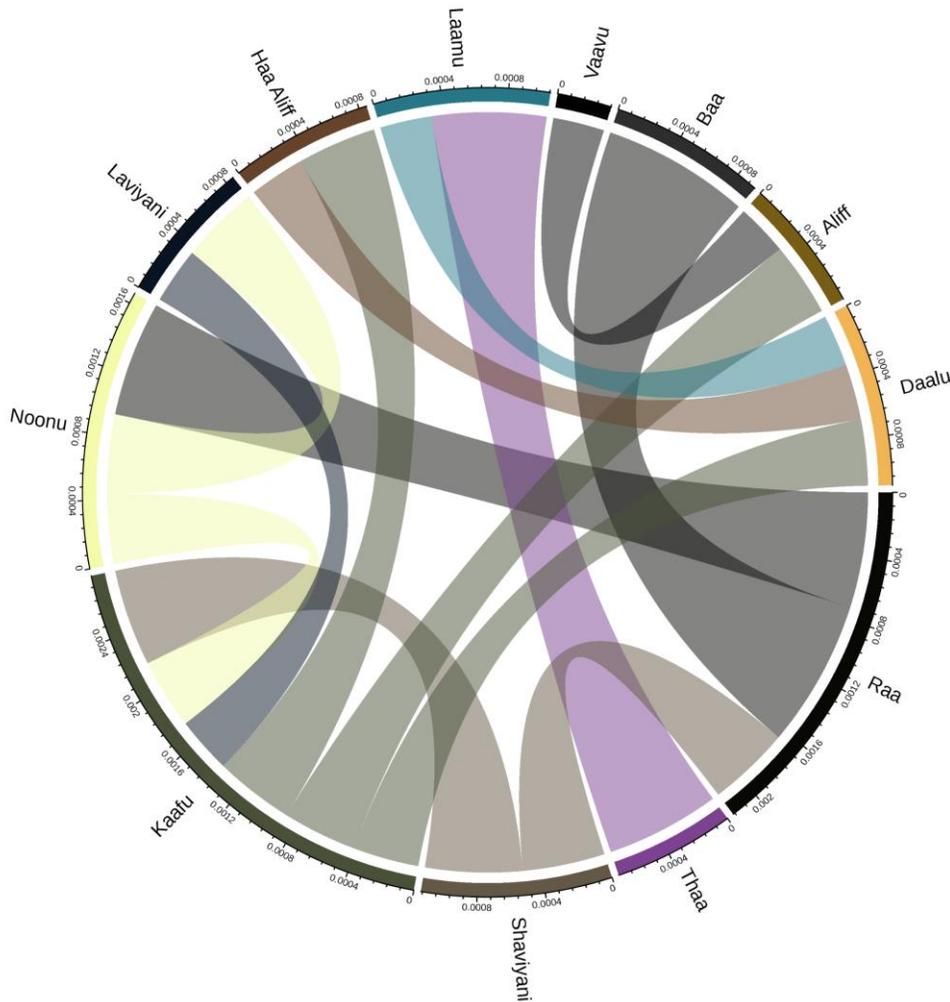


To further understand whether the population density plays a big role in the probability of encounters as calculated by Facebook, we plotted the population information provided by the NBS per administrative and non-administrative islands and compared it with the probability data. The figure 10 above compares the correlations between the administrative-, the non-administrative islands' population and the average probability of encounters. The results show that all of the cases have a negative sign. The non-administrative islands have the lowest correlation between encounters and the population, which can be explained by the fact that they are not residential islands and therefore, non-planned encounters are very limited. In addition, given that the majority of the population on the non-administrative islands consists of foreign workers, it could be possible that the majority would have left the islands during this year.

The subfigure 10A shows a correlation of -0.39 between the population of the administrative islands and the encounter probability indicating that there is no particular relationship between the two.



Figure 11. Probability of encounters between different Atolls.



Data Source: Facebook Geoinsights

The encounter probability information from the Facebook Colocation Datasets also allows to explore the encounter probability between different Atolls (movement inter-Atolls). And although the probabilities are between 2 and 3 orders of magnitude smaller, they give an idea of the potential dynamics of encounters. In the figure 11, the value of the probability of encounter between atolls is given on the outer edge of the circle. Among the atolls presented, Kaafu stands out for the largest number of links to other atolls, which makes sense given its socioeconomic importance and role as a connectivity hub. In addition, the widest ribbons (with the highest values of probability of encounter) are those that are established between Laamu and Thaa, Baa with Raa, and Noonu and Raa. These atolls are distinguished by the physical closeness they have. This could be

due to the internal dynamics of the country, the number of population and the infrastructure. Although this data does not communicate higher probabilities such as those observed among the atolls themselves (table 2), it does allow us to outline a panorama of possible encounters. They also provide clues about economic connections between different regions. *Taken to another level and using the COVID cases per atoll, this type of information can be useful in epidemiological terms to define infection risk routes.*

Employment and unemployment

Percentage change in unemployment between 2016 and 2019 at Atoll level

Information about unemployment for the years 2016 and 2019 provided by the NBS is given in the table 3 below. Of interest to note is that half of the atolls show an increase in the unemployment ratio. The Kaafu atoll, for example, goes from 3.5 to 4.3%, representing a percentage change of 23%. This percentage change is shown in the following choropleth map (figure 13).

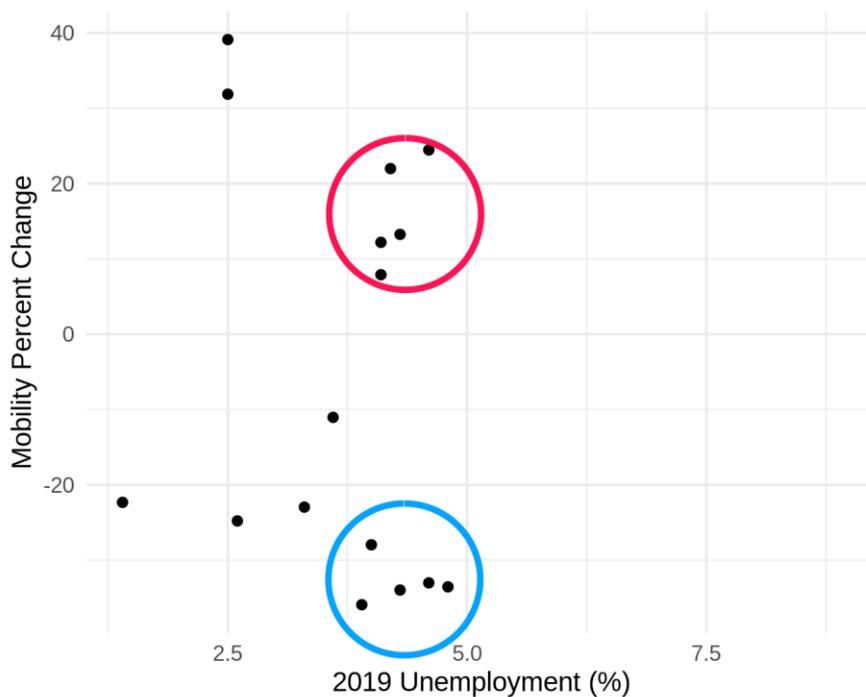
Table 3. Unemployment % change between 2016-2019 by atoll.

ATOLL	UNEMPLOYMENT 2016	UNEMPLOYMENT 2019	PERC_CHANGE
Faafu Atoll	1.4	2.5	79
Shaviyani Atoll	3.0	4.2	40
Vaavu Atoll	2.1	2.6	24
Kaafu Atoll	3.5	4.3	23
Dhaal Atoll	3.2	3.9	22
Haa Dhaal Atoll	4.2	4.6	10
Laamu Atoll	3.8	4.1	8
Seenu Atoll	8.4	8.9	6
Gaaf Dhaal Atoll	4.2	4.3	2
Haa Alif Atoll	2.7	2.5	-7
Alif Dhekunu Buri	3.6	3.3	-8
Raa Atoll	5.3	4.6	-13
Male	7.5	6.1	-19
Gaaf Alif Atoll	5.4	3.6	-33
Lhaviyani Atoll	7.8	4.8	-38
Baa Atoll	6.7	4.0	-40
Thaa Atoll	9.2	4.1	-55
Alif Uthuru Buri	3.9	1.4	-64
Gnaviyani Atoll	8.7	NA	NA
Meemu Atoll	3.0	NA	NA
Noonu Atoll	4.4	NA	NA

Data Source: National Bureau of Statistics, Maldives

The median change of mobility per atolls vs. the % of unemployment per atoll for 2019 was plotted (figure 12). No significant correlation is observed between the two variables. Only the previous observation of the map in figure 8 is reinforced by identifying two clusters of points (in red with mobility increase and blue with mobility decrease) which, when viewed on a map, have a differential location (figure 13). The atolls in the red cluster are Haa Dhaalu, Shaviyani, Thaa, Laamu and Gaaf Dhaal with values from 9 to 25% in mobility increase. Atolls in the blue cluster are Kaafu, Lhaviyani, Baa, Raa and Dhaalu with a mobility contraction around -30%.

Figure 12. Scatter plot of mobility and unemployment.



It must be noted that the mobility percent change data corresponds to the period from March to November 2020, while the unemployment data is from 2019. Therefore, there might be some important changes in the employment data of 2020 that are not reflected in this analysis.

One cluster corresponds to a *high decrease* in mobility and high unemployment rates, and the other cluster corresponds to a *high increase* in mobility rates and high unemployment rates. While we cannot draw any clear conclusions from this finding, it is important to understand better and disaggregate the different characteristics of these

atolls (such as economic important, number of resorts present, etc) to draw more informed conclusions about the mobility dynamics and its potential ties to employment and unemployment data.

Figure 14. Choropleth map of the unemployment % change between 2016 and 2019.

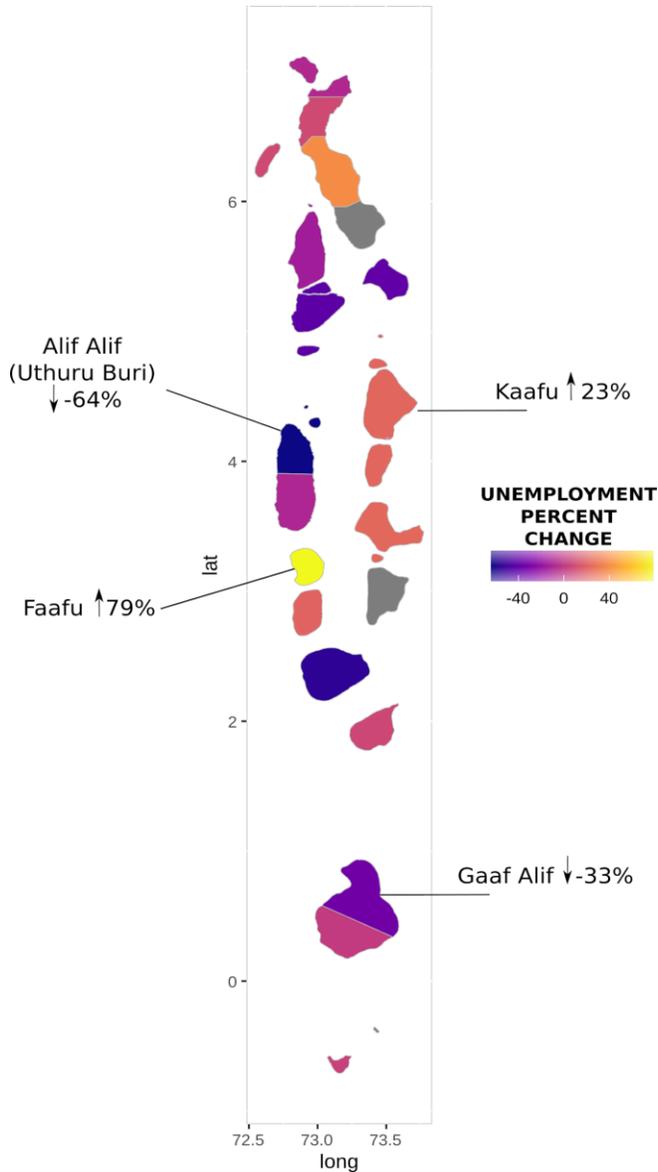


Figure 13. Map of atolls identified in the section above. A: Atolls with significant mobility contraction. B: Atolls with strong increase in mobility.



No specific correlation between mobility and unemployment was found. We observe two clusters of atolls that show similar values of the unemployment rate, but are located in differentially separated areas with opposite mobility values.

Conclusion

Facebook mobility data provides useful information to analyze a landscape of events associated with the COVID-19 context. For example, with the information on population tiles it is possible to identify population hotspots through time with a potential risk and sources of contagion.

On the other hand, data from Movement between Tiles allowed the construction of mobility indicators at the atoll level which, when viewed spatially, communicate areas of greater and lesser mobility in the country. For example, atolls in the vicinity of Kaafu reduced their mobility significantly, while atolls in the peripheries increased their mobility.

The data on probability of encounters allows us to identify those atolls with the highest and lowest value of potential encounters. They also allow us to compare periods of interest delineating a potential network of encounters between different atolls. We explored these data with official population data and found correlation values that while interesting need further exploration and analysis.

The unemployment data, when compared with the mobility data, does not provide important clues of association, although they reinforced the observation of atoll clusters with different mobility profiles. It would be desirable to collect and compare the unemployment data for 2020 with the mobility to draw more robust conclusions.

The following questions could be investigated further to deepen the analysis:

- How can the mobility reductions and increases per each atoll be described and explained better?
- What are the characteristics of these atolls that contribute to mobility (economic activity, presence of certain industries, higher proportion of foreign migrant population, etc)?
- What is the role of the transport, health and education infrastructure?
- How do income and poverty levels influence the levels of mobility?