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Geospatial mapping of 2-hour access to timely essential surgery in the Philippines

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ABSTRACT

Objectives Timely access to safe and affordable surgery is essential for universal health coverage. To date, there are no studies evaluating 2-hour access to Bellwether procedures (caesarean section, laparotomy, open fracture management) in the Philippines. The objectives of this study were to measure the proportion of the population able to reach a Bellwether hospital within 2 hours in the Philippines and to identify areas in the country with the most surgically underserved populations.

Methods All public hospitals with Bellwether capacities were identified from the Philippines Ministry of Health website. The service area tool in ArcGIS Pro was used to determine the population within a 2-hour drive time of a Bellwether facility. Finally, suitability modelling was conducted to identify potential future sites for a surgical facility that targets the most underserved regions in the Philippines.

Results 428 Bellwether capable hospitals were identified. 85.1% of the population lived within 2 hours of one of these facilities. However, 6 regions had less than 80% of its population living within 2 hours of a Bellwether capable facility: Bicol, Eastern Visayas, Zamboanga, Autonomous region of Muslim Mindanao, Caraga and Mimaropa. Suitability analysis identified four regions—Caraga, Mimaropa, Calabarzon and Zamboanga—as ideal locations to build a new hospital with surgical capacity to improve access rates.

Conclusion 85.1% of the population of the Philippines are able to reach Bellwether capable hospitals within 2 hours, with regional disparities in terms of access rates. However, other factors such as weather, traffic conditions, financial access, availability of 24-hour surgical services and access to motorised vehicles should also be taken into consideration, as they also affect actual access rates.

INTRODUCTION

In 2015, the Lancet Commission on Global Surgery (LCoGS) proposed six core surgical indicators to monitor access to safe, affordable surgical and anaesthesia care.1 They were developed to define, assess and inform surgical system preparedness, service delivery and cost efficiency. The first indicator measures the proportion of a country’s population that lives within 2 hours of a Bellwether capable facility, which can be determined through its provision of caesarean section, laparotomy and treatment of open fractures. This indicator is a proxy for timely access to essential surgery with a 2-hour access (2HA) rate of 80% considered to be adequate.2

Geospatial mapping of 2HA has been conducted in various regions of the world, but not in the Philippines.3–14 Consisting of about 7000 islands, the Philippines is situated in the tropical region of Southeast Asia. As of 2020, it had a population of 109 million people which makes delivery of healthcare services difficult.15 16 Alkire et al had previously reported that in Southeast Asia, where the country is situated, 91.1% of the population does not have access to timely, safe and affordable surgery.17 Thus far, no country...
level breakdown has been done to evaluate surgical access rates within the Philippines.

This study presents the first geospatial analysis of the 2HA to timely essential surgery in the Philippines, which is challenging given its widespread population across its numerous islands. The objective of this study is twofold: first, to measure the proportion of the population residing within 2 hours of a public hospital and second, to identify potential sites in for the development of infrastructure to enable surgical access that can target the most underserved populations. The overarching aim is to provide a macrolevel estimate on access rates based on population distribution, hospital distribution and existing road networks, thereby enabling the government and its relevant stakeholders to act strategically for national surgical planning.

METHODS
Hospital data
In May 2022, all public hospitals in the Philippines were identified from a comprehensive inventory of licensed government and private hospitals, published by the Philippines Department of Health. All public hospitals are preclassified into three levels by the state. Level 1 hospitals provide emergency care and treatment, general administrative and ancillary services, primary care of prevalent diseases in the locality and clinical services such as general medicine, paediatrics, obstetrics/non-surgical gynaecology and minor surgery. Level 1 hospitals also have, at the minimum, an operating room, a recovery room, maternity facilities, isolation facilities, a clinical laboratory, an imaging facility and a pharmacy, all of which should be licensed by the Department of Health. Level 2 hospitals, on top of the requirements for level 1, are departmentalised and have intensive care units, respiratory therapy services, a tertiary clinical laboratory and a level 2 imaging facility with mobile X-ray equipment. Finally, level 3 hospitals, in addition to the levels 1 and 2 requirements, are also teaching/training hospitals with accredited residency training programmes in the four major specialties: medicine, paediatrics, obstetrics and gynaecology and surgery. Additionally, a level 3 hospital has a blood bank, an ambulatory surgery clinic, a dialysis facility and level 3 imaging and laboratory facilities.

For the purposes of this study, all hospitals that fall under levels 1–3 offer services that fulfil the definition of a Bellwether capable facility. Thus, the final list comprised of 428 public Bellwether capable hospitals across the Philippines can be divided into three main island groups: Luzon, Visayas and Mindanao. These islands are further divided into 17 separate regions, of which 2 are autonomous administrative regions (Cordillera and Muslim Majority Mindanao). There are a total of 428 public Bellwether capable hospitals across the Philippines. Further, the Global Positioning Satellite (GPS) coordinates for each public hospital were used in the analysis.

RESULTS
The Philippines can be divided into three main island groups: Luzon, Visayas and Mindanao. These islands are further divided into 17 separate regions, of which 2 are autonomous administrative regions (Cordillera and Muslim Majority Mindanao). There are a total of 428 public Bellwether capable hospitals across the Philippines, with their GPS coordinates, were entered into ArcGIS Pro (V.2.9.3) and stored as point features.

Population data
Gridded population data for the Philippines was taken from WorldPop (www.worldpop.org). The data was downloaded as a 100m resolution raster file for 2020, which was the latest available year (online supplemental figure 1). Unconstrained top-down methods, which employ machine learning to layer data from various population and housing censuses and human settlements, were used to produce the raster. More details on this methodology can be obtained from works by Stevens et al, Sorichetta et al and Gaughan et al.

Network analysis
The Network Analysis function in ArcGIS Pro was used to determine the proportion of the Philippines population residing within 2 hours of a Bellwether capable facility. A subset of the Network Analysis Tool, the service area solver generates unique service areas around each hospital by applying the Dijkstra’s algorithm. This algorithm is typically used to find the shortest path between two points. It also considers real-world transportation features such as road networks and turn restrictions when elucidating the shortest routes. The algorithm was further customised for this study by specifying that the service area must be within a 120 min drive time from the hospital. The polygons that were generated according to this criterion were merged and overlapped with the population raster, in order to determine the proportion of people that reside within the areas demarcated by the Network Analysis Tool.

Suitability modelling
Finally, to identify potential sites in the Philippines where the most underserved populations can be reached, suitability modelling was conducted. The Suitability Modeler is an ArcGIS Pro function that determines the best location to site or preserve a facility by transforming and weighting a set of given criteria through a nonlinear, iterative process. The result of the analysis is a map with the most suitable areas marked in green and the least suitable areas in red. In this study, a larger suitability score was provided to an area outside of the 2HA service area if it (1) had a higher population count and (2) was further away from an existing Bellwether capable facility. Both criteria were given equal weighting in this process.

Patient and public involvement
None.
Philippines. There are 263 public Bellwether capable hospitals in Luzon, while 78 are in Visayas and 87 are in Mindanao. The overall population density in the Philippines is 363 per km² based on the 2020 Census of the Philippines Department of Statistics.

Overall, 85.1% of the population lived within 2 hours of a Bellwether capable hospital, which is well below the LCoGS access rate target of 80% for every country by 2030 (figure 1). All three island groups met the LCoGS indicator of at least 80% of the population being able to reach a Bellwether capable hospital within 2 hours (table 1). Total population is highest in the Luzon Island group with 89.8% of the population having 2HA to essential surgery.

Two-hour access analysis by region
At the regional level, geospatial analysis showed that six regions did not achieve the first LCoGS indicator target of 80%—Bicol, Eastern Visayas, Zamboanga, Autonomous region of Muslim Mindanao, Caraga and Mimaropa (table 2). Access to essential surgery is lowest (31.1%) in the Autonomous Region of Muslim Mindanao. Meanwhile, 2HA to essential surgery is highest in the National Capital Region (NCR) as it has 48 hospitals and the highest population density.

Two-hour access to Bellwether procedures is largely affected by population distribution in comparison to island distribution and land area. The most densely populated areas had better access rates. For example, Calabarzon has a 2HA of 95.7% and it has the largest population size of 15 million people and population density of 952 people per km². This is followed by the NCR with a population of 13 million (2HA of 94.5%) and Central Luzon region with 12 million people (2HA of 87.6%). Meanwhile, access rates were lowest in the Autonomous Region in Muslim Mindanao which spans 36,650 km² (2HA of 31.8%) and Mimaropa which covers 29,006 km² (2HA of 45.5%).

Two-hour access analysis by demographics
Overall, there was little difference in 2HA by gender, as 83.8% of women and 85.3% of men were able to access essential surgery within a 2-hour period (online supplemental table 1). However, when stratified by gender and age, less than 80% of women within the age of 35–45 years and 50–55 years were able to reach a Bellwether capable hospital within 2 hours.

Suitability analysis
Suitability analysis also revealed potential sites for future surgical facilities, particularly in Caraga, Mimaropa, Calabarzon and Zamboanga (figure 2). All three regions—Caraga, Mimaropa and Zamboanga—have low 2HA to surgery as they all had the least number of hospitals compared with their population size and density (online supplemental figures 2–4). Interestingly, an area in Calabarzon was also identified as an area which is ideal for siting a new healthcare facility, despite the region having a 2HA of 92% overall, as most of the hospitals were centred near Manila (online supplemental figure 5).

DISCUSSION
This is the first study done to evaluate timely access to essential emergency surgery in the Philippines. In this geospatial analysis, we demonstrate that 2HA to Bellwether capable hospitals in the Philippines is 85.1%, which is above the LCoGS indicator target of 80%. This is comparable to results from a geospatial analysis study conducted in another Southeast Asian country—Malaysia—which demonstrates a 2-hour essential surgery access rate of 94%. In contrast, another study in the Pacific Islands indicated that only 5 out of 13 countries in the Pacific Islands had 2HA rates of >80% for their population (Nauru, Cook Islands, Tonga, New Zealand and Australia).

However, when categorised by region, there are stark disparities in terms of access to essential surgery as six regions did not meet the LCoGS target. This implies that health equity in surgery is variable within the different regions of the Philippines. A suitability analysis was subsequently performed to find out which potential areas can be further developed to site a Bellwether capable hospital to improve the health inequities between regions. The selection criteria were intentionally chosen to capture the greatest number of people who live furthest away from existing Bellwether capable facilities.

Four regions—Caraga, Mimaropa, Calabarzon and Zamboanga—were identified to fit our selection criteria. This would improve 2HA rates from 85% to 90% overall in the Philippines. However, further feasibility assessment would be needed to evaluate if infrastructure required to provide surgical services—such as clean water, waste management and reliable electricity—is available. There also needs to be available surgical, anaesthetic and obstetric manpower to enable 24-hour provision of essential and emergency surgical services. Our findings may help guide the government in national surgical planning in the future.

There is a significant concentration of public hospitals in Luzon, compared with the other island groups. This may be because the population density is highest in Luzon, with more than 50% of the whole population based in Luzon. In particular, the NCR—which houses the capital of the Philippines, Manila—is the most populous region in the country. However, access rates may be overestimated here, as the hospitals may be overcrowded and not able to meet the demands of such a large population.

Access by age and gender are both evenly distributed with most people able to reach a Bellwether capable hospital within 2 hours. Women within the 35–45 years old and 50–55 years old have a slightly lower 2HA which may have implications in terms of access to obstetric and gynaecological services in this age group. This may be because they tend to live in more rural areas to look after their family or for lower cost of living.
Figure 1  Two-hour Bellwether access for public hospitals in the Philippines.

Legend

❤️ Bellwether capable hospital

2-Hour Access service area
There are some methodologic limitations for our study. First, the Philippines archipelago consists of more than 7000 islands which are widely distributed. We were unable to calculate for boat or air transportation in ArcGIS. Moreover, time taken for air and sea transportation is often variable as it depends on sea and weather conditions, as well as mode of transport (eg, ferry vs high-speed motorboats, helicopter vs planes). For the sake of consistency, we have standardised it to only account for land transportation times. Those who live in remote islands who require air or sea transportation to hospitals were considered to be outside the 2HA zone for a Bellwether capable hospital.

It is also very likely that the 2HA estimations are optimistic as we did not account for variability in traffic conditions and temporary road closures due to seasonal monsoons, floods or earthquakes. In addition, not everyone in the Philippines is able to afford cars or motorised vehicles which may result in variability in the calculated 2HA estimates. According to the Philippines Land Transportation Authority, the number of registered motorcycles and tricycles was reported at 6174345 in 2017. This translates to an estimated 6 vehicles per 100 persons. Although this number is low, there are various methods of motorised public transportation such as jeepneys, multicabs, megataxis, tricycles and ‘habal-habal’ which are relatively affordable to the general population in the Philippines.

One of the underlying assumptions was that hospitals were able to provide Bellwether procedures 24 hours a day and 7 days a week. However, some of the facilities may not be open around the clock and there may be difficulties accessing essential surgery in some regions where the surgical providers or operating theatres are not always available. Due to logistical constraints, we are not able to conduct facility assessment across all 428 public hospitals in the Philippines. A separate study on facility assessments on several hospitals in the Philippines as proxy is still underway.

### Table 1
Two-hour access (2HA) to Bellwether capable hospitals based on island groups—Luzon, Visayas, Mindanao

<table>
<thead>
<tr>
<th>Island</th>
<th>Total population</th>
<th>Hospitals, n</th>
<th>Population within 2HA</th>
<th>Percentage population within 2HA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luzon</td>
<td>61631180</td>
<td>263</td>
<td>55345902</td>
<td>89.8</td>
</tr>
<tr>
<td>Visayas</td>
<td>20325632</td>
<td>78</td>
<td>17850441</td>
<td>87.8</td>
</tr>
<tr>
<td>Mindanao</td>
<td>25122044</td>
<td>87</td>
<td>200710454</td>
<td>80.0</td>
</tr>
</tbody>
</table>


### Table 2
Summary of 2-hour access (2HA) to Bellwether capable facilities by region in the Philippines

<table>
<thead>
<tr>
<th>Region</th>
<th>Population (2020)</th>
<th>Area (km²)</th>
<th>Population density/km²</th>
<th>2HA to Bellwether facility (%)</th>
<th>Public hospitals, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region I (Ilocos Region)</td>
<td>5420047</td>
<td>12946</td>
<td>419</td>
<td>93.0</td>
<td>34</td>
</tr>
<tr>
<td>Region II (Cagayan Region)</td>
<td>3726896</td>
<td>29836</td>
<td>125</td>
<td>89.2</td>
<td>24</td>
</tr>
<tr>
<td>Region III (Central Luzon)</td>
<td>12193941</td>
<td>21906</td>
<td>557</td>
<td>87.6</td>
<td>50</td>
</tr>
<tr>
<td>Region IV (Calabarzon)</td>
<td>15788527</td>
<td>16576</td>
<td>952</td>
<td>95.7</td>
<td>56</td>
</tr>
<tr>
<td>Region V (Bicol Region)</td>
<td>6261745</td>
<td>18114</td>
<td>346</td>
<td>78.8</td>
<td>22</td>
</tr>
<tr>
<td>Region VI (Western Visayas)</td>
<td>8135984</td>
<td>20778</td>
<td>392</td>
<td>86.7</td>
<td>35</td>
</tr>
<tr>
<td>Region VII (Central Visayas)</td>
<td>8018996</td>
<td>15872</td>
<td>505</td>
<td>93.7</td>
<td>21</td>
</tr>
<tr>
<td>Region VIII (Eastern Visayas)</td>
<td>4802229</td>
<td>23234</td>
<td>207</td>
<td>68.4</td>
<td>23</td>
</tr>
<tr>
<td>Region IX (Zamboanga Peninsula)</td>
<td>3921729</td>
<td>16904</td>
<td>232</td>
<td>69.1</td>
<td>10</td>
</tr>
<tr>
<td>Region X (Northern Mindanao)</td>
<td>5087967</td>
<td>20458</td>
<td>249</td>
<td>100.0</td>
<td>22</td>
</tr>
<tr>
<td>Region XI (Davao)</td>
<td>5313019</td>
<td>20433</td>
<td>260</td>
<td>86.4</td>
<td>12</td>
</tr>
<tr>
<td>Region XII (Soccsksargen)</td>
<td>4943337</td>
<td>22786</td>
<td>217</td>
<td>85.3</td>
<td>13</td>
</tr>
<tr>
<td>National Capital Region</td>
<td>13955490</td>
<td>619</td>
<td>22545</td>
<td>94.5</td>
<td>48</td>
</tr>
<tr>
<td>Cordillera Administrative Region</td>
<td>1861798</td>
<td>19818</td>
<td>94</td>
<td>86.2</td>
<td>14</td>
</tr>
<tr>
<td>Autonomous Region in Muslim Mindanao</td>
<td>4132160</td>
<td>36650</td>
<td>113</td>
<td>31.8</td>
<td>18</td>
</tr>
<tr>
<td>Region XIII (Caraga)</td>
<td>2806768</td>
<td>21120</td>
<td>133</td>
<td>76.7</td>
<td>12</td>
</tr>
<tr>
<td>Mimaropa Region</td>
<td>3210452</td>
<td>29606</td>
<td>108</td>
<td>45.5</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>109581085</td>
<td>347656</td>
<td>315</td>
<td>85.1</td>
<td>428</td>
</tr>
</tbody>
</table>

Another limitation of the study is that the analysis did not include private hospitals. In the Philippines, the healthcare system can be divided into public and private health services where patients must pay out of pocket for private healthcare services. However, this can be addressed by a separate study as our software is not able.

Figure 2  Suitability analysis to improve access for essential surgery in the underserved regions in the Philippines.
to perform geospatial analysis of more than 1000-point features.

CONCLUSIONS

In conclusion, 85.1% of the Philippines population is able to reach a Bellwether capable hospital within 2 hours. However, regional analysis shows that access is below the recommended 80% by the Lancet Commission of Global surgery in 6 regions. Suitability analysis demonstrated that timely access to surgical procedures can be improved by building new hospitals in the four recommended sites in Caraga, Mimaropa, Calabarzon and Zamboanga. The results of this study will hopefully help inform the Philippines government in terms of national surgical, obstetric and anaesthesia planning.

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