Revealing the value of geospatial information with isochrone maps for improving the management of heart attacks in South Africa

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An isoline connects points that have the same value, while an isochrone connects points on a map with the same travel time to a point. They are useful, amongst others, for transportation planning (e.g., Biazzo et al., 2019; Wiśniewski, 2017), for showing the time it takes runoff in a drainage basin to reach a lake (e.g., Ovcharuk et al. 2020; Ashmore et al., 2020) or for assessing accessibility of public services (e.g., Basu & Alves, 2019; Snyman, 2017). During the current COVID-19 pandemic, isochrones were used to assess whether citizens would be able to walk or cycle to everything they need within a given timeframe (Altaweel, 2020; Chu, 2020).

The Bill of Rights in the South African Constitution (1996) protects the right to life, therefore improving emergency management services and access to hospitals is a priority. In this essay we describe a map (see Figure 1), recently prepared for the South African Heart Association STEMI SA Early Intervention Initiative, that envisages to improve systems of care to afford timely and appropriate management of ST-elevation Myocardial Infarction (STEMI) heart attacks. The Community-Oriented Primary Care

(COPC) research unit at our university collaborates in the effort. The unit is engaged in several initiatives aimed at improving the integration of patient care in the public district health system. This particular map shows travel times to public hospitals with a catheterization lab (cathlab) where the blood flow to the heart muscle during a heart attack is restored by mechanical means. Percutaneous coronary intervention (PCI) is the procedure by which acute narrowing in heart arteries is treated with a balloon or stent and primary PCI is the most effective strategy to ensure reperfusion (restoration of blood flow), if performed within 120 min of STEMI diagnosis (Neumann, et al., 2019).

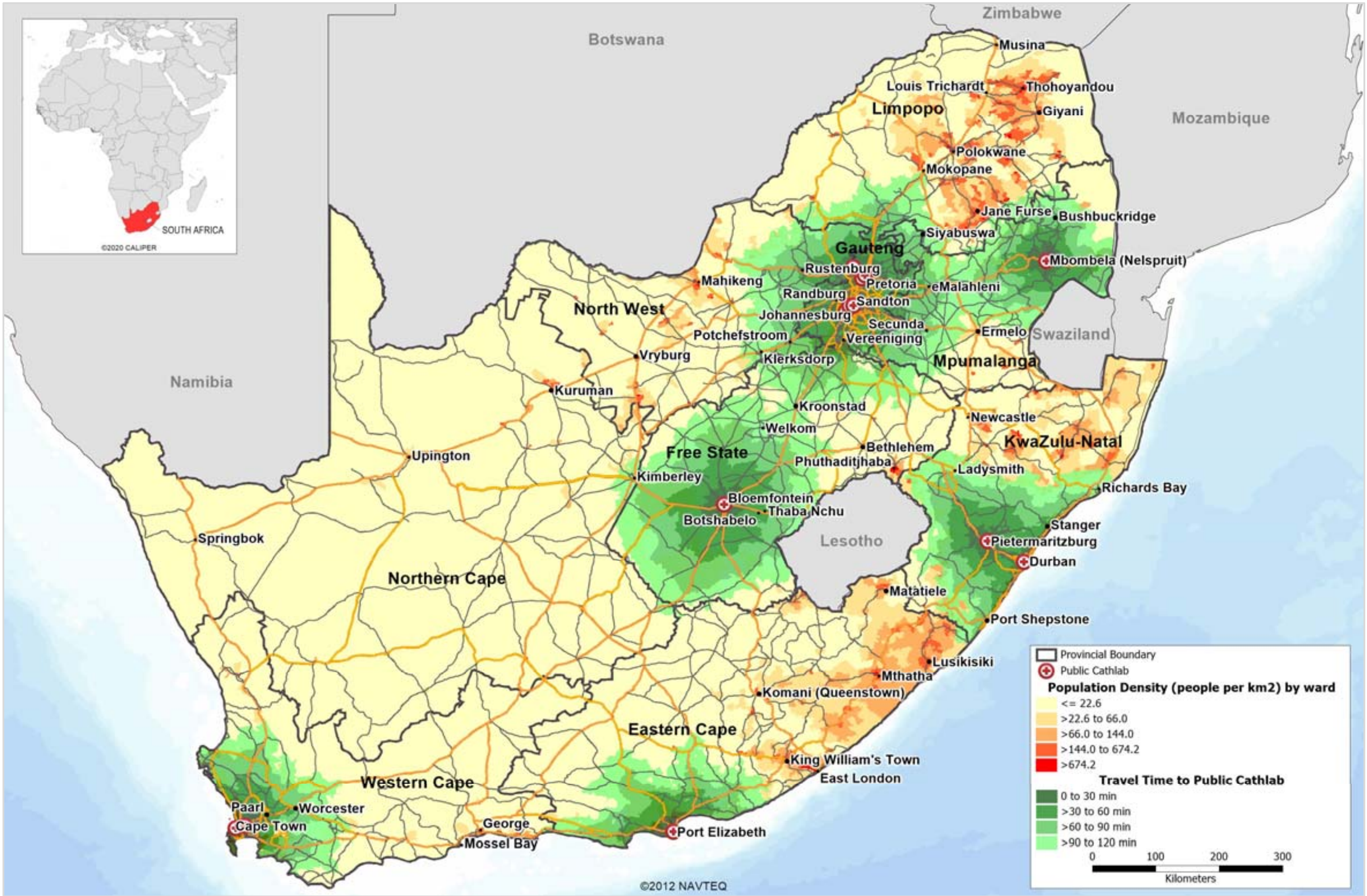

Figure 1. Travel times to public hospitals with cathlabs in South Africa

The map in Figure 1 shows geographic access to public cathlabs based on a maximum drive-time threshold of two hours, which is sub-divided into thirty-minute intervals. Most people in South Africa use minibus taxis, therefore modes of transport that do not make use of the road network are negligible when assessing accessibility. Maptitude[1] was utilised for the isochrone modelling and map visualization. Requirements for accurate and precise isochrone modelling include a routable road or travel network with distance and drive-time attributes. For the purpose of this study, the data package for South Africa, shipped with the Maptitude software, was used together with OpenStreetMap placenames. Areas on the map that are highlighted in sequential shades of red depict population density (people per km^2) by ward, and these are not within two-hour reach of a cathlab. The Northern Cape and Limpopo provinces, as well as large parts of the North West, KwaZulu-Natal and the Eastern Cape, are particularly underserviced. While a population density of more than 674.2 people per km^2 in the highest class may be low in comparison to international high-density cities, it is virtually the same as the population density for Gauteng (Statistics South Africa, 2011a), South Africa's most densely populated province and economic powerhouse. The significance of this map is twofold: firstly, the isochrones show areas that are within acceptable reach from public cathlabs; and secondly, the map reveals densely populated areas where access to cathlabs is inadequate and needs to be improved.

STEMI management in South Africa is compromised by a disparity in access to health services in the public domain (Statistics South Africa, 2011b), and in particular regarding access to hospitals with cathlabs (Stassen, et al., 2017). Of the 65 PCI facilities in South Africa, in 2021, only 11 are public facilities and their distribution

[1] www.caliper.com/maptovu.htm

across provinces is poor, as is evident from our observations. In addition, extended drive times from remote regions and also inappropriate referral pathways directly impact time to treatment. Reperfusion delays due to inter-hospital transfers, as opposed to direct admission to a PCI-capable hospital is a major determinant of poor patient outcome (Kawecki et al., 2017). A small study (Snyders & Delport, 2014) performed in the public sector in the City of Tshwane, the capital of South Africa, illustrates the relevance of referral pathways regarding travel time to a PCI-capable hospital. A median time duration of more than seven hours was reported from symptom onset to arrival at a PCI-capable hospital with inter-facility transfer, whereas the duration with direct access only took two hours. An adequately powered study that may provide an indication of treatment delays for the South African context, revealed a median delay of 3.6 hours from onset of symptoms to arrival at a hospital (Schamroth, 2012). This is well beyond the 120-minute cut-off for primary PCI, clearly illustrating the need for structed referral pathways, appropriate placement of, and increase in the number of PCI-facilities, and also the need to implement alternative treatment strategies.

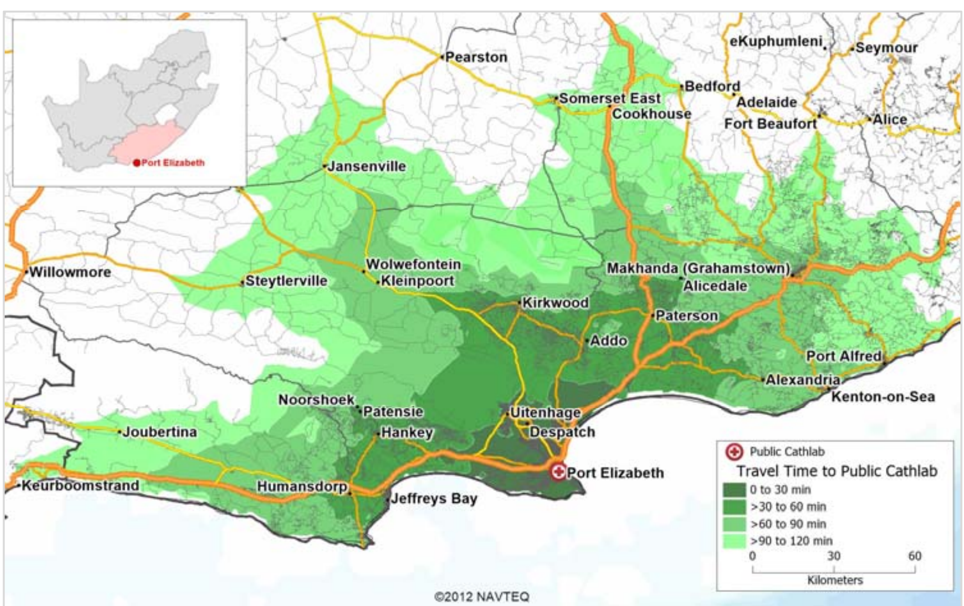

Figure 2. Travel times to the public hospital with a cathlab in Port Elizabeth, South Africa

The maps in this essay support initiatives that contribute to United Nations Sustainable Development Goal (SDG) 3, Quality healthcare and well-being, however, isochrones are equally useful for measuring progress against indicators for many other SDGs, e.g., travel times to schools for SDG 4, Quality education; to banks for SDG 8, Decent work and economic growth; and to green spaces for SDG 11, Sustainable cities and communities. Such travel times can be measured and visualized for different modes of transport, e.g., vehicles on roads, public transport, cycling or walking. The importance of the road network for accessibility towards inclusive and sustainable industrialization is reflected specifically in one of the indicators for SDG 9, which measures the proportion of the rural population who live within 2km of an all-season road. The impact of the road network on travel times, and therefore accessibility, is clearly visible in the map in Figure 2: the shapes of the travel time polygons show how a highway or road significantly reduces the travel time to a public hospital, thus expanding the reach of the hospital.

In our careers, we have experienced the value of isochrone maps in various ways. The third author has employed geospatial maps in international presentations to illustrate the complexities of STEMI management in South Africa (Delport, 2017), using, amongst others, the travel time polygons prepared for South Africa, published in Stassen et al. (2018). The maps that the second author recently prepared (Figures 1 and 2) afforded the opportunity to visualise different layers of information. This promoted the appreciation of relevance of any observation within a given context. The plan is to use the isochrone maps to enhance the understanding of role players in STEMI management regarding travel time barriers and referral pathways, and to use them to assist PCI-capable hospitals in constituting structured regional referral networks.

The second author has used isochrones extensively in consultation projects to advise retail clients, such as Nando's (a fast food chain originating from South Africa), on accessibility and catchment areas of current and future outlets. For his Masters, he measured access to Thusong Service Centres, multi-purpose centres aimed at bringing government services into rural communities of South Africa. He developed a method to measure access even in rural areas where people walk long distances to reach facilities and where footpaths are typically not mapped (Snyman, 2017).

The first author completed her undergraduate studies in computer science. She spent her first 15 years of working life at two start-up companies, one developing the first desktop geographic information system for Windows (ReGIS) and the other pioneering geospatial data products with national coverage for South Africa. When she returned to university, she was excited to share what she had learnt about geospatial information with students, a topic that was not offered in computer science departments at the time. She developed a course in spatial databases (to our knowledge, still the only such course in South Africa).

When preparing the first lectures, she wondered how she could convey the value of geospatial information to computer science students in their seventh semester who had already studied information systems and databases extensively and were sceptical that she could teach them anything new. She remembered the map of isochrones around hospitals prepared for a client and since then, has used the same map, not only for the spatial databases course, but also to introduce first year students to geoinformatics and cartography, stating "This map shows where in South Africa you should not get a heart attack". Watching their faces, it takes a minute or two for students to read the legend, interpret the map, locate an area without hospitals and then, invariably, the lights go on in their faces. They smile and nod, and she knows that they grasp the value of geospatial information and maps, and are ready for the course that lies ahead...

We like isochrone maps because of the simplicity with which they achieve the purpose of the map, e.g. in the case of an emergency, who can reach a hospital in time? In today's fast moving world, who can get a Nando's meal within an hour? Instead of overwhelming a target audience with too much information in the form of tables, graphs or map symbols, isochrones convey the message of the map succinctly, yet in a visually appealing way. They strike a balance between scale and content – despite a small scale, a significant amount of content can be conveyed. In addition, by demarcating regions by travel time intervals, they aid in informing the development of regional systems of care, which directly impacts patients' lives.

Our experience is that isochrone maps can be understood even by those who do not work with maps and data often. They are therefore useful for creating a first impression of a situation, e.g. in a boardroom presentation or an introductory class. Once the message of the map has sunk in, decision makers, clients or students are intrigued and start asking follow-up questions, requesting more details about travel times, the travel network, accessibility and technical details of isochrone creation. Despite their simplicity and visually appealing presentation, isochrone maps are data-driven: as one zooms in to a larger scale, more information appears at a higher resolution, so that one can interpret and discuss the results and their implications at different levels of detail.

Isochrones are useful in a wide range of applications, from environmental to transportation and socio-economic challenges. For many of these challenges, SDG indicators have been defined and data is being collected to monitor progress. In our world of ever-increasing volumes of geographic information, isochrone maps have an important role to play in making sense of all that information.

Acknowledgements

We have to confess that not one of us is a qualified cartographer, but we love maps and have worked with maps for the largest parts of our professional lives. We are therefore grateful to have been included in this invitation to cartographers to write about cartography.

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