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Improving Iraqi school dental services: A GIS-based study of service location optimisation

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Background: The United Nations (UN) estimated the population of Iraq in 2005 at almost 29 million, of which nearly 14 million were children aged 0-14 years. Iraq is aiming to improve child oral health, and subsequent child general health, through school dental services, offered by primary health care centres. ***Objective***: To develop and test a GIS-based planning approach for the Hillah district of Iraq as a model for the rest of the country. All data were gathered from open sources. ***Setting***: The city has 98 neighbourhoods, with a total child population of 368 274, occupying 161 Sq. km^2, with 14 fixed primary health care dental clinics. ***Design***: Accessibility zones were created using GIS, based on the ability of dentists to make their way to schools. ***Outcome measures***: A total of 23 307 of 0-4 year-olds (14%) and 74 384 (45%) of 0-15 year-olds lived outside the accessibility zones. ***Result***: Areas where services are not available to the child population were identified, whether or not they attended primary schools. ***Conclusion***: Reforming the existing dental health services in Iraq can be achieved by careful planning and appropriate utilisation of health resources.

Keywords*: School dental service, Iraq, dental care, GIS*

INTRODUCTION

Many countries have realised the significance of child well-being and its impact on society (Armfield *et al.*, 2009, Petersen, 2003). In the last few decades many developed countries have supported the improvement of child oral health through optimisation of school dental services in preventive dentistry and dental health promotion. This has occurred in coordination with other public health initiatives, such as the use of fluoridated water and toothpaste. In addition, the growing emphasis placed by the dental profession on the prevention of oral diseases and the gradually increasing appreciation by the community of the desirability for good dental health has contributed to improved child oral health (Carr, 1982). Over the same period, developing countries have continued to experience poor oral health. Iraq is one of many developing countries that has witnessed deterioration in health status and other aspects of life.

The United Nations (UN) estimated the population of Iraq in 2005 at almost 29 million, with children aged 0-14 years old comprising nearly 14 million (Tripp, 2002). As child dental health is important, the Iraq health ministry has entered partnerships with international organisations (WHO, UNICEF, UNFPAP, WFP, and USAID) to improve child oral health and subsequent child general health, through school dental services, offered in primary health care centres (Kleine, 2010). These clinics provide services for primary school children to alleviate the burden of oral disease. The program was implemented just more than 10 years ago, which has made it vulnerable to several challenges. Whilst such a program is seen as a valuable contribution to child dental health, it has faced many obstacles, which have led to an increase in health inequalities amongst Iraqi children, especially between rural and urban areas. The use of geographic information systems (GIS) to map Iraqi school dental services, offers many advantages in reforming dental health policy in Iraq, and the ability to identify areas where spatial access to public dental services might be an issue. The aim of this study was to develop and test a GIS-based planning approach for child dental services the Hillah district of Iraq, as a model for the rest of the country.

METHODS

Region

Al-Hillah city is the administrative centre of Babylon province. The city is divided into two parts: a) regional Hillah City, which is the financial and administrative centre of Babylon province, and b) Al-Kifil city and Abi-Ghraq city, which are the rural parts. The city is situated between latitude 32° 36' 1" N and 32° 8' 45" N, and longitude 44° 14' 9" E and 44° 33' 39" E. It occupies an area of 878 kms^2 which constitutes 17% of the total area of Babylon province. In 2015 the city population was 856,804, (40.9% of the total population of Babylon province) (Ali *et al.*, 2016). Regional Hillah city was selected as the study area as it has the highest population density in the province, and to restrict the complexity introduced by the different factors that influence access in rural and urban areas.

Data gathering and Study Design

All data were gathered from open sources and no patient specific data was used, thus no ethical approval was required.

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Data sources

Fixed primary health care clinics: School dental services are run through the primary health care clinics (PHCCs) in Iraq. Details of the 14 PHCCs in Hillah city were obtained from the Babylon Health Governorate, and their location longitudes and latitudes were acquired from the Babylon statistical department. The locations of the clinics were cross-checked using Google earth and Google maps. The data were retrieved from Iraq, collected into Microsoft Excel (version 2011 from Microsoft Corporation), and integrated using QGIS version 2.14. (Boston, USA). However, a spatial administrative map of Hillah city was not available, requiring a hand-drawn map to be uploaded into QGIS, utilising the program's georeferencing tool.

Primary schools: The educational system in Iraq is controlled by the government, offering free education in primary schools, high schools and university. Primary education in Iraq is mandatory for children aged 6-12 years old, and consists of 6 grades (year levels). All children have a full dental examination at the beginning of each year. The complete list of primary schools in Hillah city was obtained from the Iraq ministry of education website, along with the number of children in each school. The longitudes and latitudes of all the primary school locations were retrieved from the Iraq ministry of education website, and again cross-checked using Google earth and Google maps.

Population statistics: All population data were obtained from the Babylon statistical department, including the population count in each neighbourhood.

Exclusion and inclusion criteria: Every neighbourhood, primary health clinic and state funded primary school in regional Hillah city was included. Private schools were excluded as they were not covered by the government school dental service program at the time.

Catchment area methodology

Every primary health care clinic has the responsibility to provide dental care to a number of assigned schools. A dentist or dentists from each clinic then has to travel to the schools (that their clinic is responsible for) to examine the children, and those children who need dental treatment have to visit the primary healthcare clinics to receive treatment, including restorations and preventive care. As enrolment in schools in Babylon is about 89%, that leaves 11% of primary school children to seek and obtain dental care directly at a primary health clinic (and not through the school program) (Central Statistical Organisation, 2015). Schools in different health districts are assigned to primary health care clinics within that same health district. In terms of geographic distribution however, some schools might be much closer to a primary health care clinic in a different/neighbouring health district.

Each dental clinic location was mapped. Geographic access to dentists was estimated using three different methods:

Buffer zones

Around each dental clinic a buffer zone was drawn. Buffer zones are areas of specified width, drawn around map elements (Aronoff, 1989), in this case, dental clinics. Different radii buffer zones were drawn to reflect the number of primary schools that a dentist could reach, despite their association with another health district or the presence of major roads and rivers. Four buffer zones of (500, 1000, 1500 and 2000) metre radii were drawn around each clinic. The different radii buffer zones indicated the extent of service coverage and identified gaps in coverage.

Dentist reach zones

We also estimated the distance a dentist could travel to the nearest primary schools from a starting point (the PHCC). We drew zones based on personal knowledge of the area, taking into account the existing road networks and physical barriers. We first drew zones for the distance that a dentist can travel on foot to a school, to reflect the lack of availability of government transport support.

Accessibility zones

Accessibility zones represent areas around a defined clinic that people can reach easily, regardless of any bureaucratic link between their area of residence and a specific health district. A zone was drawn to represent the closest areas to a clinic that is geographically accessible to the population, regardless of whether their area of residence was associated with a specific health district. This zone assumed people could choose where to obtain primary health care, recognising that most people select a particular clinic, (rather than a doctor) when deciding where to go. Such a choice may be based on the proximity of a clinic or advice from a friend or family member (Haynes *et al*., 2003).

Over the past two decades, the operationalisation of geographical accessibility measures in health studies has become easier, largely due to developments in GIS (Phillipe *et al*., 2008). Here, geographical accessibility refers to the ease with which people in a given area can reach health services facilities. Four types of distance are typically used for calculating geographic accessibility: Euclidean distance (straight-line), Manhattan distance (distance along two sides of a right-angled triangle opposed to the hypotenuse), shortest network path distance and shortest network time (Masoodi and Rahimzadeh, 2015). Other customised methods have been developed such as (crow-fly distance). However, each method has its own limitations, often underestimating the effects of physical barriers such as major rivers or hills, and of intra-urban congestion (David *et al*., 1998). Others have used a combination of the Floating Catchment Area (FCA) method, minimum distance method and Response Time (RT) technique determine the accessibility of health services (Masoodi, 2015).

RESULTS

Fourteen fixed primary health care clinics were geocoded in regional Hillah city (Figure 1). The city has 98 neighbourhoods with a total child population of 368 274 who occupy an area of 161 (Sq. Km).

Buffer zones

In order to examine the dentist's accessibility to primary schools, we created buffer zones around each clinic of four

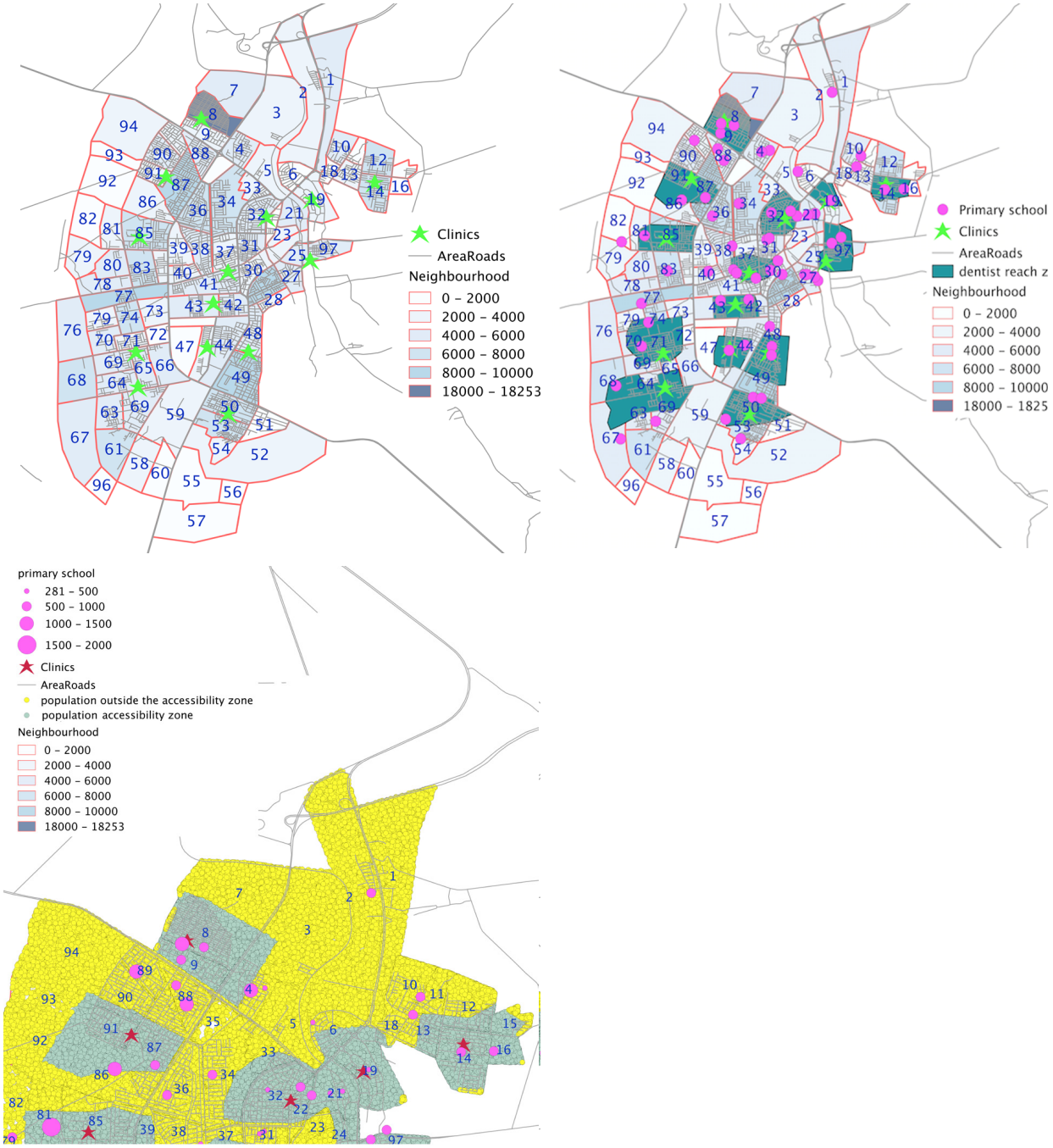

Figure 1. The distribution of fixed primary health care clinics over regional Hillah city (top left), primary schools within each dentist reach zone (top right), and population outside (yellow areas) and inside (green areas) the accessibility zones (bottom left).

different radii (500, 1000, 1500, 2000m). Buffer zones did not take into account the presence of major roads and rivers (to distinguish them from the dentist reach zones). Some schools were only 500m from a primary health clinic (Al-baqir clinic), but were located within another health district. A 1000m was shown as the optimal radius to cover the maximum number of schools, and increase the number of children to potentially examine around each clinic, without undue overlap (Table 1). For four clinics (Al-Imam, Shheed al Eslam, Muhendiseen and Al-Asatitha) 1500m and 2000m buffer zones covered the same number of schools, due to the irregular distribution of primary schools around these clinics.

Dentist Reach: This zone was drawn around each primary health care clinic based on personal area knowledge to represent the distance that a dentist can travel to reach the primary schools (Figure 1). Due to the irregular distribution of primary schools, zones may cover one or more primary schools (Table 2). Almost half (48%) of the children in Hillah city lived outside the dentist reach zones.

Accessibility zones

This zone represent the closest areas to a defined clinic that people can easily reach, despite their association with a specific health district. We estimated the child population outside of these accessibility zones, based on the national percentage of the child population and the total population count in each neighbourhood (Figure 1). A total of 23307 of 0-4 year olds (14%) and 74384 (45%) of 0-15-year olds lived outside these accessibility zones.

Table 1. The child population-to-dentist ratio per primary health clinic

	Population	*Dentist*	*P:D*
Al-Imam	1870	2	935
Shheed Al Eslam	856	1	856
Muhendiseen	2963	2	1482
Al-Asatitha	1895	1	1895
Al-Zahraa	2688	3	896
Al-Nahdah	1652	3	551
Merjan	399	1	399
Nadir Al-Namuthagy	3491	3	1164
Al-Kawther	1223	2	612
Babil Training Health	1877	3	626
Al-Baqir	2167	3	722
Al-Aqsa	2347	4	587
Al-Khalisa	1460	2	730
Al-Hadi	771	2	386

DISCUSSION

This study has described access to school dental services in the regional Hillah city using spatial analysis (GIS). The study provides a novel method for calculating the distance to which dentists can travel on foot to capture the maximum possible number of primary schools. Our dentist reach zones cover almost half of all the primary schools, and would allow 52% of children to be examined by a dentist. However, the irregular distribution of primary health care clinics leads to variation in the number of schools in each dentist reach zone, which would create variation in dentists' workloads and the availability of services.

We also used a different scenario by standardising the distances that dentists could travel to reach primary schools by creating four buffer zones of different radii (500,1000,1500, 2000m) around each clinic, without taking into account the presence of major rivers and roads. Although some primary schools are only 500m away from a primary health care clinic, it was the responsibility of another, geographically much further away clinic. Most primary schools were 1500-2000m away from four primary health clinics (Al-Imam, Shheed al Eslam, Muhendiseen and Al-Asatitha). This is considered to be a considerable distance that dentists cannot cross without transport assistance.

A 1000m radius around all PHCCs creates the optimal buffer zone, by covering the highest possible number of primary schools, and would increase the number of children potentially examined.

However, the dentist reach zone is considered the most realistic distance that dentists can easily travel to reach primary schools without any transport assistance. Results indicate that almost a fifth (18%) of primary schools in regional Hillah city are more than 1000m away from a primary health care clinic, making these clinics only accessible for dentists with transport options.

It is clear that the current situation is not ideal, as dentists cannot easily access some schools, and children might not be examined at appropriate intervals. Children might also not be able to visit primary health care clinics if in need of dental treatment. Against a background of poor oral health, a change in existing policy for school dental services in this region is required. The involvement of all primary school children within the school dental services programs might also be achieved by utilizing mobile dental clinics, in order to reach more schools, or by selecting the primary schools that each primary health care clinic is responsible for, on a geographic basis, rather than a health district basis. As the school dental services program in Iraq is in its infancy, having only started after 2006, ongoing monitoring and analysis of the program and its management will identify problems, and provide opportunity for improvement. Aspects of successful school

Table 2. Number of children within 500m, 1000m 1500m and 2000m buffer zones for each clinic.

	500			*1000*			*1500*			*2000*		
	P	*D*	*P:D*	*P*	*D*	*P:D*	*P*	*D*	*P:D*	*P*	*D*	*P:D*
Al-Imam	0	0	0	1870	2	935	2728	3	909	2728	3	909
Shheed Al Eslam	0	0	0	2359	1	2359	3215	2	1608	4009	3	1336
Muhendiseen	0	0	0	2963	2	1482	4423	3	1474	4423	3	1474
Al-Asatitha	0	0	0	3500	2	1750	4309	3	1436	4309	3	1436
Al-Zahraa	2688	3	896	5545	6	924	7143	8	893	7143	8	893
Al-Nahdah	1404	3	468	1404	3	468	1404	3	468	1404	3	468
Merjan	726	2	363	1178	2	589	1651	3	550	1651	3	550
Nadir Al-Namuthagy	1183	1	1183	2674	3	891	2674	3	891	2674	3	891
Al-Kawther	1223	2	612	1223	2	612	1223	2	612	1223	2	612
Babil Training Health	1202	3	401	3464	7	495	4098	8	512	4098	8	512
Al-Baqir	2442	4	611	4763	7	680	4763	7	680	4763	7	680
Al-Aqsa	2050	3	683	3651	5	730	4370	6	728	4370	6	728
Al-Khalisa	1460	2	730	2860	4	715	2860	4	715	2860	4	715
Al-Hadi	1091	2	510	1902	3	634	1902	3	634	1902	3	634

P=child population, D=dentists

dental programs from other parts of the world might also be adopted. For example, the Australian school dental program provides easy access to large numbers of children in one setting, the ability to examine children in a familiar environment, and the involvement of teachers and school staff in oral health education and promotion programs (Jürgensen and Petersen, 2013).

The accessibility zone reflected the acceptable distance to a primary health care clinic that people can easily reach, irrespective of their association with a specific health district. The accessibility zones are also important, as these are the only option for children who are: i) referred by the dentist (who visited the school) to receive further treatment at the clinic, or ii) children who are not in enrolled in school, and need to attend the primary health care clinic for treatment. People often tend to choose the nearest clinic based on travel time. There are also other factors that people may consider when choosing a primary health care clinic, such as the quality and the quantity of services that are offered, opening hours and numbers of specialised services offered. However, the travel time appears to be a powerful determinant that can influence people's choice to a great extent (Robin *et al*., 2003), (Pearce *et al*., 2006).

The numbers of 1-4 year-old children and children aged less than 15 years located outside the accessibility zones were estimated to be 23307 (14% of the total population) and 74 384 (45% of the total population) respectively. These children cannot easily reach a primary health care clinic.

The accessibility zones vary in distance around each clinic in order to provide good geographic access to clinics regardless of bureaucratic links with other health districts. These data could assist health planners and health authorities to change the existing health district boundaries, or allow for more flexible arrangements in terms of which clinics people can use.

The comparison of the total child population outside the accessibility zones and the 1000m buffer zones showed that the accessibility zone is the most reasonable distance that cover the highest possible number of people (parents with their children) who can easily reach dental services. There were 3.7% of the child population living outside the 2000m buffer zones, who cannot be reached easily by dentists. Offering dental services through mobile dental clinics could solve some of the accessibility problems, especially at the city margins. These mobile dental clinics could visit the underserved population on a regular basis (every 6 months), which could reduce the dental health inequalities that exist amongst the children.

CONCLUSIONS

This study examined two aspects of dental service access: i) the ease of access to assigned schools by dentists from primary health care clinics, and ii) the ease of access for child patients to a primary health care clinic. In terms of both aspects, areas were spatially identified where access would be easy for the highest numbers of children. Reforming the existing dental health policy in Iraq is essential to ensure better oral health for the child population, which can be achieved by appropriate utilisation of health resources.

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