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GIS as a Decision Support Tool in Health Informatics: Spatial Analysis of Public Dental Care Services in Sri Lanka

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Abstract. Our study aimed to demonstrate the use of Geographic Information Systems (GIS) to assess the distribution of public dental clinics in Sri Lanka by developing a baseline population based geographic model. Population data was obtained from the Population & Housing Census (2001) and socioeconomic data from the Household Income & Expenditure Survey (HIES) 2002. Public dental clinic locations were obtained from the office of the Chief Dental Officer. About 3 million people (11.7%) out of a total of 2.2 million lived in Divisional Secretariat (DS) divisions devoid of public dental clinics were further disadvantaged by poverty prevalence rates exceeding 30% in their respective divisions. Moreover, 14% of the total population lived in a DS division without a public dental clinic. Of people below the poverty line, about 2.76 million lived in DS divisions where there was no public dental clinic. Therefore, it is concluded that distribution of public dental clinics in Sri Lanka has obvious limitations in serving the rural poor. The spatial approach provides a useful decision-support tool in health informatics with an enormous potential to harness in equity based public health care planning.

Keywords. GIS; spatial analysis; public dental clinics; poverty; Sri Lanka.

I. Introduction

A community's opportunity to access dental care is a key human right. Dental Services provide a basis for alleviation of pain and suffering as well as improving quality of life of people [1, 2]. For health planners it is essential to understand whether the geographic distribution of health care facilities reflects the population characteristics to identify access blocks to services [3]. Geographic Information Systems (GIS) consists of a computer based system for the input, storage, maintenance, management retrieval, analysis and output of geographic or location based information [4]. It facilitates determining spatial relationships by simultaneous display/overlay of an array of data on multiple maps and is identified as the basis for data linkage and analysis in the 21st century[5].Against this backdrop, this study was the first to apply current high resolution GIS to map access to public dental care services in Sri Lanka. Sri Lanka (formally known as Ceylon) is a small island situated in the Indian Ocean with a total area of approximately 62 705 square kilometers (km2) and a variable and difficult

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terrain. The island stretches to a maximum length of 435 km and a width of 225 km. Its total estimated mid-year population (in 2009) is 20.6 million with clearly evident demographic transition depicting rapidly expanding elderly and middle aged age groups [6]. For the purposes of administration Sri Lanka is divided into 9 provinces, 25 districts. These districts are further divided into administrative sub-units known as divisional secretariats. These were originally based on the feudal counties, the korales and ratas. Accordingly, there are a total of 323 Divisional Secretariat (DS) divisions.

Sri Lanka boasts of a well-developed public health infrastructure as a developing country with some kind of public health care facility available within a 5 km radius [7]. Public health care services in Sri Lanka are provided "free-of-charge" at the point of delivery. Sri Lankan oral health care delivery system is dominated by the public sector (70%), which is closely being integrated into the existing network of public hospitals organized in a hierarchy based on number of patient-beds, availability of medical specialties and location [8]. Accordingly, all teaching hospitals, provincial and district general hospitals, base hospitals and the majority of district (divisional hospitals) and some rural hospitals and primary care units have public dental clinics. Community Dental Clinics are located elsewhere and Adolescent Dental Clinics which are located in schools primarily catering to school children above the age of 13 years but could be accessed by other age groups as well [8].

Sri Lankan public dental care delivery system comprised of general dental care as well as specialized services such as Oral & Maxillo-Facial surgery, Orthodontics, Restorative Dentistry as well as Preventive Dentistry. Nevertheless, there are emerging challenges to the existing delivery model with regards to its sustainability and coverage in the impetus placed on ensuring equity-based public oral health care for Sri Lankans. Especially, competing priorities in curative health care, recovery of cost of highly expensive material used for advanced dental care i.e. fixed orthodontic appliances, inadequate infrastructure in existing public hospitals, laboratory facilities and dental technicians have become major impediments in improving accessibility and affordability to advanced dental care.

Hence, the need has arisen for developing a basic model for existing public oral health care services in the country with the application of GIS to identify the access gaps. This has become more important as the ground work preparation is taking place to formulate a national oral health policy for Sri Lanka [9]. Hence, the aim of this study was to develop a baseline geographic model of Sri Lankan public oral health care services coupled with basic population characteristics.

II. Materials and methods

The country has recently ended a long-standing, 30-year-old internal conflict centered in the North and East which had a substantial economic burden to the developing nation. Prevailed situation has made data collection difficult in the North and East and additionally makes it more complex for evidence-based health planning. Therefore, present analysis does not include North and East areas.

The primary data for this study came from the Ministry of Health and Department of Census and Statistics in Sri Lanka [10]. Population data from the previous census of population and housing (2001) [10] and Household Income & Expenditure Survey (HIES) 2002 was used as the baseline population data [11] comprising of 251 (77.7%) out of 323 DS divisions with a total of 15.3 million people (i.e. excluding those from the North and East). Of these, some 3.1 million lived below the poverty line and the overall prevalence of poverty was 20.3%. These data included an index of poverty: Headcount Index: HI (calculated as the proportion of people below the poverty line compared with the total population in each district) was stratified into 6 levels avoiding overlapping with each other (1= 0-10% : 2= >10-20%: 3= >20-30%, 4= >30-40%, 5= >40-50 & and 6= >50-100%) as they applied to each Divisional Secretariat (DS) divisions.

Major road and rail routes were obtained from open source websites in a data format that was usable for the GIS software. Dental clinic locations by DS divisions was prepared by the first author (IP), accessed from the data-base maintained at Office of the Chief Dental Officer (Deputy Director General of Dental Services) at the Ministry of Health for this study. Verification and validation of this data was done with the involvement of relevant Hospital authorities and Programme Planning Officers/Medical Officer Planning of respective health regions.

The data included all categories of public dental clinics: outpatient dental clinics, specialized clinics: Oral and Maxillo-Facial Surgery, Orthodontics (treatment for mal-aligned teeth and related abnormalities), Restorative Dentistry (Conservative Care) and Preventive Dentistry, adolescent dental clinics, community dental clinics and mobile dental units. Mobile dental units provide screening and basic dental treatment for selected population groups living in peripheries. However, for this analysis a given mobile dental unit was included only into its' base DS division. Our analysis did not include school dental clinics which are manned by school dental therapists and cater to pre-school and school children aged 3-13 years.

In general, any Sri Lankan can seek care from any type of an out patient dental clinic located at any health care institution and if they need specialized care they are being referred to the nearest specialized care unit by the given outpatient clinic. However, for children needing care for mal-aligned teeth and related abnormalities (orthodontic care), direct referrals is accepted to the specialized clinics.

All data were collated in Excel (version 2003 from Microsoft corp) and geographic integration of the data was completed using ArcGIS (version 9.3 from ESRI corp). Using the ARCGIS software spatial analysis tools, an empirical two kilometers buffer zones were applied to each major road and each DS division was identified with/without a centroid falling within the buffer.

III. Results

Our analysis included 251 (77.7%) out of 323 DS divisions and a total of 15.3 million people living in them (ie excluding those from the North and East). The population

prevalence and severity of poverty data by Divisional Secretariat (DS) divisions is presented in Figures 1, 2 & Table 1.

Figure 1 shows basic population data for Sri Lanka displayed by DS divisions (grey boundaries) and collated into districts (yellow boundaries). The different intensities of purple colour represent different poverty stratifications: the darker the intensity the greater the level of poverty.

As illustrated in Table 1, the highest number: 6.02 million (39.2%) of people lived in DS divisions where the prevalence of poverty was >20-30%. Another 4.2 million (27.2%) lived in DS divisions where the prevalence of poverty was >10-20%.

Data pertaining to the number of people living in DS divisions clustered by different levels of poverty and availability of public dental clinics is presented in (Figures 3, 4 and Table 2). Of the over 2.5million people living in DS divisions where rates of poverty exceed 30%, about 300,000 people (11.7%) lived in DS divisions without any public dental clinics (Figures 3, 4 and Table 2). Where as of the 6.8million people who lived in DS divisions where poverty prevalence was less than 20%, 667,000 people (9.8%) lived in DS divisions without a public dental clinic (Figures 3,4 and Table 2).

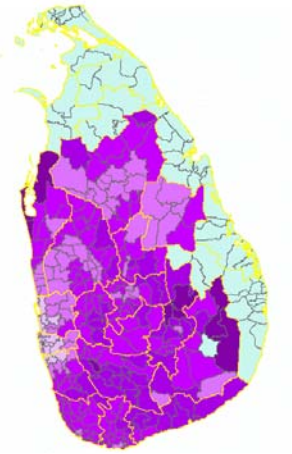

Figure 1. Basic population data. Note: Areas in pale blue have no available data.

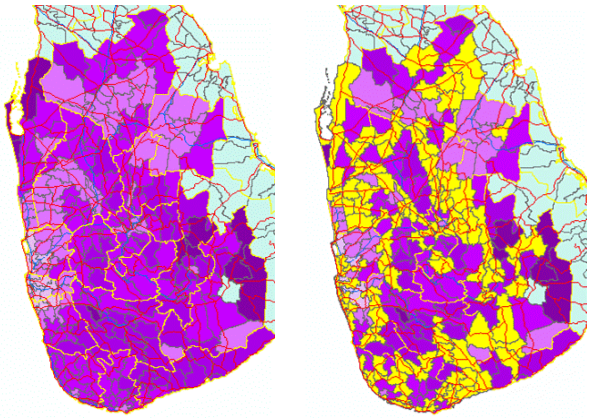

Figure 2. The addition of major roads (red) and rail (dark blue) to the basic population data is illustrated (left). Two kilometer buffer zones applied to each major road and the all DS divisions that have a centroid falling within the buffer are highlighted in yellow (right). The different intensities of purple colour represent different poverty stratifications: the darker the intensity the greater the level of poverty

Fourteen percent of the total population lived in a DS division without a public dental clinic; however, about half of these (1.0million) people lived within 2 km of a major road (Table 3). Of people below the poverty line about 276,000 people lived in DS divisions where there was no public dental clinic and they were more than 2km away from the nearest major road (Table 3).

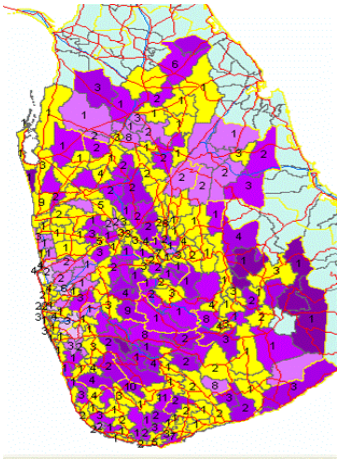

Figure 3. The total number of public dental clinics (all types: outpatient dental clinics, specialized clinics: oral & maxillofacial surgery, restorative dentistry, orthodontics, dental public health, adolescent dental clinics, mobile units etc.) for all DS divisions. Two kilometers buffer zones applied to each major road and the all DS divisions that have a centroid falling within the buffer are highlighted in yellow. The different intensities of purple colour represent different poverty stratifications: the darker the intensity the greater the level of poverty.

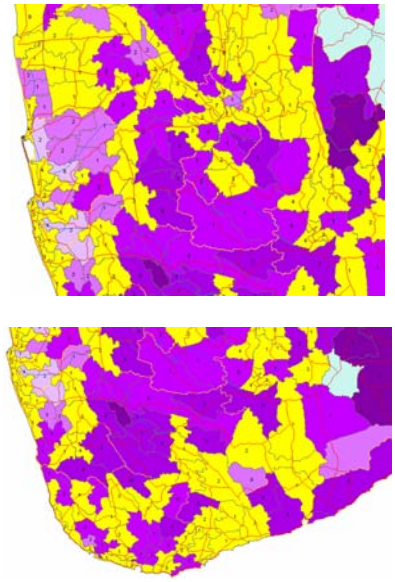

Figure 4. Higher magnification views of the Western and Central regions (top) and South and South-West regions (bottom) of Sri Lanka displaying the total number of public dental clinic per DS division compared to the socioeconomic and access factors (major roads). Two kilometers buffer zones applied to each major road and the all DS divisions that have a centroid falling within the buffer are highlighted in yellow. The different intensities of purple colour represent different poverty stratifications: the darker the intensity the greater the level of poverty.

IV. Discussion

Accessing dental services in developing countries is often difficult and especially in countries with difficult terrain. The primary oral health disease (dental caries) in both developed countries (eg Australia) [12] and developing countries (eg Sri Lanka) [13] is a disease suffered along socio-economic gradients: the poor suffering greater burdens of disease than the wealthy. In this situation it makes it even more complex to provide services because it is often the wealthier areas of a country that have greater access to services [14]. Mapping and analysis of the distribution of dental services coupled with population characteristics becomes important in this context. Having emerged from nearly three decades of civil war which contributed to poverty particularly by undermining economic development Sri Lanka is aspiring to be the "Wonder of Asia" enriched with prosperity and peace. Against this backdrop, our analysis demonstrates application of GIS to develop a geographic model of public dental services coupled with population characteristics in Sri Lanka.

However, the findings of this study should be interpreted cautiously due to some limiting factors which could have influenced the results. Compared to developed countries, there are many limitations in the availability/accessibility of real-time data usable for spatial analysis. For example, there is no comprehensive, open source, web-based public dental clinic locations for Sri Lanka. Present analysis was based on the

socioeconomic data collected at Household Income & Expenditure Survey (HIES) 2002 which matches with the Population & Housing Census conducted in 2001.New National Census is currently on progress. Despite more recent Household Income & Expenditure Surveys conducted in 2010/2009 and 2007/2006 poverty statistics were not available by DS divisions. However, some caution should be taken as Sri Lanka has made socioeconomic progress recently; becoming a lower-middle income country with a GDP per capita of USD 4500 (in 2009) [15]. Recent Sri Lankan development policies are aimed at acceleration of economic growth with a sustainable 6-8% growth targeted for the next 5 years with the ultimate objective of achieving upper middle income status over the next decade [15]. The public dental clinic data used in this study was most recent as applied to 2010 which was overlapped with population and socioeconomic data in 2002 and this could have influenced the findings of this study. However, there was no data available for location of public dental clinics for the year 2002 which would have better matched the temporal population data. The number of public dental clinics especially in some difficult terrains has increased from 2002 to 2010 thus better reflecting the socioeconomic progress made by Sri Lanka over the years. Furthermore, as revealed by official sources, dental equipment worth Rs.30 million was procured and distributed among those clinics.

As revealed by our results, over half the people living below the poverty line (1.7million) lived in DS divisions with a centroid more than 2 km from a main road (Table 3 B). Equally of the 2.2 million people who lived in DS divisions without a single fixed public dental clinic and about 300,000 of these people were from DS divisions where there is more than a third of the population lived under poverty (Table 2). However, mobile dental clinics provide the main source of basic dental care for these areas: there are about 7 mobile dental units providing out reach services in remote areas particularly serving for such populations. Unfortunately no information was available on conduct of such mobile dental clinics to be included in this analysis. Nevertheless, accessibility issues seem concentrated more among poor living in rural and remote areas with difficult terrains compared to their better off and metropolitan counterparts. These findings corroborate the National Oral Health Survey 2002/2003 findings, as the ratio of urban to rural respondents who reported a distance more than 10 km for the nearest public dental clinic was 1: 125 [8]. Such remarkable metropolitan-rural disparities in access to public dental care need increased efforts to narrow them down. Functional status of the public dental clinics was not considered in this analysis as it was beyond the scope. Importantly, interruptions to the services by public dental clinics are common in urban and rural areas due to non-functional components dental units compounded by lack of knowledge and skills in maintenance by clinic staff and shortage of skilled labour by biomedical engineering units. Remote areas with difficult terrains are worst affected in this regard. Moreover, transfers of Dental Surgeons to metropolitan areas from these areas poses problems for the functional status of public dental clinics.

Table 1. The total population of Sri Lankan sample excluding North and East divided into five percentage bands based on headcount Index (HI) of DS divisions. For example there were 2.5million people living in DS divisions where up to 10% of the population lived below the poverty line.

HI % BAND	Population* n (%)
1= 0-10%	2547(16.6)
2= >10-20%	4252(27.7)
3= >20-30%	6024(39.2)
4= >30-40%	2190(14.2)
5= >40-50%	254 (1.7)
6= >50-100%	91 (0.6)
Total	15358(100.0)

Table 2. The total population of Sri Lankan sample excluding North and East divided into 6 percentage bands derived from (HI) compared with the number of public dental clinics in each DS division . For example, there are 54,000 people living in districts where > 40-50%of the population is living under the poverty line and there are no dental chairs.

Clinics	Headcount Index (HI)						
	1	*2*	*3*	*4*	*5*	*6*	Total
0	189	479	1256	244	54	0	2222
1	872	1693	1954	682	200	91	5492
2	456	1165	1101	713	0	0	3435
3	389	607	1034	169	0	0	2200
4	477	0	192	312	0	0	981
5	0	156	49	0	0	0	206
6	164	0	18	0	0	0	183
7	0	0	127	0	0	0	127
8	0	151	200	0	0	0	351
9	0	0	37	43	0	0	80
10	0	0	0	26	0	0	26
11	0	0	55	0	0	0	55
Grand Total	2547	4252	6024	2190	254	91	15358

Population in 000's (*1*=0-10%: *2*= >10-20%: *3*= >20-30%, *4*= >30-40%, *5*= >40-50 & and *6*= >50-100%)

2.3 Availability and Accessibility to Public Dental Clinics by DS division

Overall, our findings suggest quite clearly that a strong effort has to be made to target services at poorer and remote DS divisions as such vulnerable groups in the country are disadvantaged by poverty, high oral disease burden and access to public or private dental care compared to their affluent and metropolitan counterparts. This is compounded by a severe mal-distribution in the dental workforce in Sri Lanka. For example, nearly one third of the country's dental surgeons are concentrated in the capital district of Colombo (within the Western province), which has only 11% of the country's population [16]. As a remedial measure 20% of newly recruited Dental Surgeons to public service from 2006-2010 was posted to new rural public dental clinics according to official sources. However, retention of them over longer periods in rural and remote areas as mentioned before has become problematic as common developed countries due to many factors such as family issues [17].

Nevertheless, Sri Lankan dental care delivery system is dominated by the public sector, as the relatively small private dental care service sector in Sri Lanka is

unorganized, unregulated, competitive and individualistic. About 67% the Sri Lankan population uses public dental care services and the rest uses private dental care services 8. Further the private dental care sector is highly concentrated, both economically and geographically [16]. This means that a small number of experienced private dental surgeons "professionally" dominate the market and earn the bulk of the income, and are concentrated in a small number of big cities [16]. Furthermore, the average Sri Lankan patient, who seeks private dental care, prefers to go to a private dental surgeon who is in permanent government employment and does part time private practice based on the notion that Government employed dental surgeons are better qualified and experienced. Hence, it is crucial to improve the access to public dental clinics for the economically disadvantaged rural population in Sri Lanka.

Table 3A. The total number of people living in DS divisions with or without public dental clinics. The DS divisions have been divided into those within 2km radius of a major road and those outside this buffer.

Total Number of Public Dental Clinics	Near Major Road		
	Yes	No	Grand Total
0	1063	1159	2222
1	2841	2651	5492
2	1565	1870	3435
3	1291	908	2200
4	600	381	981
5	206	0	206
6	0	183	183
7	77	50	127
8	66	285	351
9	37	43	80
10	0	26	26
11	0	55	55
Grand total	7745	7613	15358

Population in 000's

Table 3B The total number of people below the poverty line living in DS divisions with or without public dental clinics. The DS divisions have been divided into those within 2km radius of a major road and those outside this buffer.

Total Number of	Near Major Road		
Public Dental Clinics	Yes	No	Grand Total
0	229	276	505
1	537	620	1157
2	301	406	707
3	239	179	418
4	103	77	180
5	38	0	38
6	0	21	21
7	15	11	27
8	11	67	78
9	8	15	23
10	0	9	9
11	0	16	16
Grand Total	1482	1696	3178

Population in 000's

V. Conclusion

In conclusion, our findings demonstrated the obvious limitations in distribution of public dental clinics in Sri Lanka for serving the rural poor thus making inhabitants lived in poverty stricken DS divisions more disadvantaged accessing public dental clinics compared to their metropolitan and better-off counterparts. Nevertheless, as a rapidly developing economy Sri Lanka possesses the opportunity to continue to carefully plan its development of dental services particularly as the majority of service is provided through the government (public) sector and considerable investment is made on the infrastructure and human resource development for public dental clinics. Therefore, this study highlights the ongoing need for monitoring the geographic distribution of services to ensure they match the evolving socioeconomic gradient of dental disease. The spatial approach provides a useful decision- support tool in health informatics with a substantial potential to harness in planning public health care services not only in Sri Lanka but in other developing countries as well. Moreover, formulating web-based, open source- health care facility locations with exact street addresses is imperative to many developing countries such as Sri Lanka where such information systems are underdeveloped. It may also be important to validate this basic geographic model of public dental care distribution with most updated population data made available for GIS applications.

Spatial approach provides an innovative decision- support tool in health informatics with a substantial potential to harness in planning, monitoring and evaluation of public health care services such as dental care.

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