J Digit Imaging (2014) 27:41–48
DOI 10.1007/s10278-013-9627-2

An Indicator to Estimate the Access to Imaging Services in the Costa Rican Public Health System

Alfonso Rosales-López · Martha R. Ortiz-Posadas

Published online: 7 August 2013

Abstract The aim of this work was to develop an indicator that estimates the population's access to imaging services (IS) of health care facilities in the Costa Rican Public Health System, taking into account five aspects: (a) health care facilities infrastructure, (b) capacity of the IS according to the installed technological resources, (c) epidemiological aspects, (d) demographic aspects, and (e) location of the health facility in relation to the Capital. To achieve this, 14 variables and 7 indicators were defined. These indicators were integrated into a mathematical function which resulted in a global indicator that throws quantitative data that represents the level of access of a population to the IS in their geographic region of influence. The application of the indicator was performed in eight health facility sub-networks with defined geographical regions within the territory of Costa Rica. The level of access to the imaging service of the inhabitants of the eight sub-networks results that three of them obtained a bad access, located in east and north-central of the country; other three sub-networks obtained regular access, located in the west; and the last two who obtained a good access are located in the center of the country. The results showed that the imaging services are not equitable in each sub-network. Knowing this, it is possible to work on healthcare technology management proposals in order to strengthen the regional imaging services, contributing to decentralizing the services of the general hospitals located in the Capital.

A. Rosales-López · M. R. Ortiz-Posadas
Direction of Special Projects Management, Caja Costarricense del Seguro Social, San José, Costa Rica

A. Rosales-López · M. R. Ortiz-Posadas (✉)
Electrical Engineering Department, Universidad Autónoma Metropolitana-Iztapalapa, Av. San Rafael Atlixco #186, Col. Vicentina, C. P. 09340, Del Iztapalapa Mexico City, Mexico
e-mail: posa@xanum.uam.mx

Keywords Imaging service assessment · Health service research · Health technology evaluation · Evaluation studies · Costa Rican Public Health System

Background

The Costa Rican public health system (CCSS for its Spanish acronym), provides all the health services (promotion, preventive, curative, and rehabilitation of diseases), with a universal and solidarity coverage to the 4,476,614 inhabitants of the country [1], through a health system that is divided into 103 geographic regions called health areas (HA), who provide primary care (first level of health care). The second level of healthcare consists of seven regional hospitals (RH) that offer the four basic specialties and 13 peripheral hospitals (PH) with lower resolution capacity but that also provide the services in the four basic specialties. The third level of health care consists of three general hospitals (GH) and six specialty hospitals; these six operate autonomously according to their specialty, and all of them are located in San Jose, the Capital (Costa Rican Public Health System, [2]). As for the resolution capacity of the imaging services (IS) according to the installed technological resources, by the 2006, the CCSS had installed a total of 257 diagnostic imaging equipment in all of their health care facilities (Costa Rican Public Health System, [2]), of which 58 (22.6 %) are mobile X-ray, being the most used imaging technology in the CCSS, followed by 57 (22.2 %) ultrasounds and 44 (17.1 %) mobile C-arm X-rays. On the other hand, with only seven computed tomography-scanners, this is the technology less used in the CCSS, followed by 14 mammography and 18 dental X-rays. For their part, conventional X-rays and fluoroscopy together account for 59 equipments representing one fifth of the total 257, the same percentage as the mobile X-rays and ultrasound independently.

Furthermore, in order to have better control and supervision of the offered health care services, the CCSS adopted a territorial division that defines three networks of health facilities, which are: Northwest, East, and South. The Northwest network has the largest population (1,901,911 inhabitants), and in its 13 hospitals, the largest number of imaging equipment (104); thus, for every 18,288 people, there is one equipment. In the East network live 1,452,500 inhabitants, and its five hospitals have together 67 imaging equipment, with a ratio of 21,679 people per equipment. Finally, in the South network live 1,122,203inhabitants, and there are only 42 of the equipments distributed among its six hospitals, resulting in 26,719 people per imaging equipment. Besides that, it is noteworthy to mention that the IS of the CCSS are centralized mainly in the three GH located in the Capital. Thus, a 67 % of the conventional radiology studies, 72.2 % of the fluoroscopies, 77.5 % of the studies of the mammograms, and 100 % of CT scans produced during 2005 were conducted in these three GH [3].

With the analysis presented to this point, it is possible to say that the Costa Rican Public Health System is not exempt from the problem of resources and services concentration; therefore, the aim of this study was to design and validate an indicator that estimates the population's access to services imaging in different geographical, allowing to determine quantitatively the access differences that exist in each region analyzed. This estimation was made considering five aspects that help to characterize the access to the Imaging Services, which are: (a) health care facilities infrastructure, (b) resolution capacity of the IS according to the installed technological resources, (c) epidemiological aspects, (d) demographic aspects, and (e) location of the health facility in relation to the Capital (San José).

Methodology

Based on the five previous aspects four stages were carried out to design the indicator that estimates quantitatively the level of access to imaging services (AIS): (1) A set of variables were defined to describe the current state of the IS in a specific region; (2) a group of partial indicators were designed to acquire information regarding the condition the population's access to the IS; (3) by a mathematical function, a global indicator was designed to integrate the partial indicators, to represent quantitatively the AIS of the inhabitants of a particular geographic region of influence; and (4) the global indicator was validated in eight different regions covering the whole country [4]. The following describes each of these stages.

Definition of Variables

A set of variables that describe the current access and state of the IS were defined in terms of: facilities infrastructure, installed technological resources, epidemiological and demographic aspects, and geographical location of the region of analysis. Due to the different nature of the variables, their domain takes very different values, which is why a normalization procedure was performed by dividing the value of particular variable by the maximum value of their domain.

Design of Partial Indicators

Designing of indicators was performed using the variables previously defined. Each indicator represents one aspect that influences the AIS in a specified region. The indicators were also normalized under the same criteria used previously (due to the nature of the variables, the domains of the indicators will take different values), so each result was divided by the maximum value of each domain. Additionally, it was considered that not all indicators are equally important on the AIS; for this reason, a relevancy factor within the interval [0, 1] was assigned to the indicators, based on specifics criteria for each partial indicator.

Design of Global Indicator

In order to obtain an overall data reflecting the level of access to the IS in a given region, all the partial indicators were included in a mathematical function. This global indicator takes values in the range [0, 1], where 1 means that the region of analysis has not access problems, and 0 means the opposite. Additionally, this range was divided into five sub-ranges, and to each one of them, a qualitative value was assigned, in order to provide qualitative representation to the numerical value obtained with the global indicator; these sub-ranges are described below:

[0.0, 0.39]: Very bad access
[0.40, 0.49]: Bad access
[0.50, 0.59]: Regular access
[0.60, 0.69]: Good access
[0.70, 1.0]: Very good access

This qualitative representation will facilitate the interpretation of the results to the potential users of this tool, those who work in healthcare technology management, and decisions makers of the departments of planning and/or designing of new infrastructure in the Costa Rican Public Health System.

Validation

The validation was performed in eight health facility subnetworks with defined geographical regions within the territory of Costa Rica (Fig. 1), seven of which correspond to the regions with dependence to a RH (before reaching the third level facilities) and one to a PH which covers an important region in the center of the country. In each of these subnetworks, the partial indicators were calculated, as well as

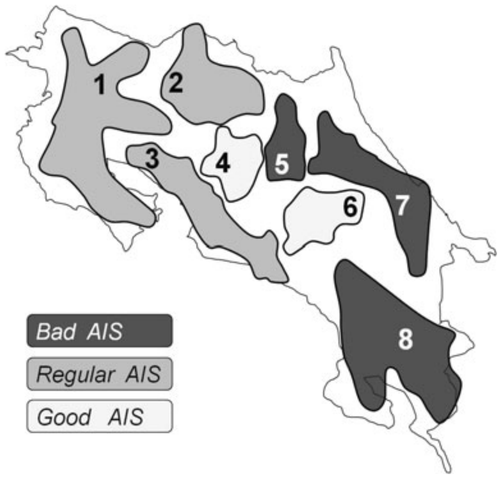

Fig. 1 Geographic location of the eight sub-networks in Costa Rica

the mathematical function to get the value of the global indicator AIS.

Results

Definition of Variables

In total, 14 variables (V_i) were defined; the following is a description of each of them according to the five aspects of analysis to the access.

1. Health care infrastructure:

   $V_1=HS$ Number of hospitals in the region of analysis

2. Resolution capacity of the IS according to the installed technological resources:

   $V_2=EQ$ Total number of imaging equipment installed in *HS*
   $V_3=RX$ Number of X-ray equipment installed in the IS
   $V_4=FL$ Number of fluoroscopy equipment installed in the IS
   $V_5=MA$ Number of mammography equipment installed in the IS
   $V_6=CT$ Number of CT scanner equipments installed in the IS
   $V_7=US$ Number of ultrasound equipments installed in the IS
   $V_8=MO$ Number of different imaging modalities available in the *HS*

3. Demographic aspects:

   $V_9=PO$ Number of inhabitants in the region of analysis

4. Epidemiologic aspects (considering the three leading causes of death in the country):

   $V_{10}=M_1$ Number of HA with over-mortality in cancer
   $V_{11}=M_2$ Number of HA with over-mortality by heart diseases
   $V_{12}=M_3$ Number of HA with over-mortality by respiratory diseases

5. Location of the *HS* in relation to the Capital:

   $V_{13}=DI$ Distance (kilometers) between the capital and the longest town of the region of analysis.
   $V_{14}=TI$ Time (minutes) required to travel the distance *DI*

The domain of all variables corresponds to the natural numbers; however, the values they take are very different from each other, since each V_i has a unique bounded range M_i within that domain. For example, $V_1=HS$ (number of hospitals in the region of analysis) has its domain in the range M_1=[0, 5], because there is no region of analysis with more than five hospitals. On the other hand, the domain of $V_9=PO$ (number of inhabitants in the region of analysis) has a value of six digits, since all the regions have an average of 400,000 inhabitants (Table 1), so the range of its domain is defined as M_9=[300,000, 600,000].

Design of Partial Indicators

A group of seven partial indicators were designed to estimate quantitatively the level of access to the IS. Additionally, a relevancy factor *w* within the interval [0, 1] was assigned to each indicator, based on specifics criteria for each one. Thus, the highest relevance factor ($w=1$) was assigned in cases where the indicator has a direct impact on access to local services (through technological and infrastructure resources); the middle relevance factor ($w=0.6$) considers those indicators that affect the access but not restrict it (e.g., having all the different types of imaging modalities, the causes of mortality considered in the analysis, distance to the closest health care facility with a IS with conditions to offer a better service); and the lowest relevance factor ($w=0.3$) was assigned to the indicators that have no direct influence on the access but help to describe the region of analysis (e.g., number of inhabitants per hospital and the number of inhabitants that would require attention in the third level of health care). The following will be the description of each indicator (I_k), the mathematical function that defines it, and the relevancy factor assigned.

$I_{1:}$ Number of inhabitants per hospital (w_1=0.3). This indicator calculates the ratio between the number of inhabitants and the number of hospitals in a particular region and is defined by the function (1).

$$I_1 = HS/PO \quad (1)$$

Table 1 Variables data of the eight sub-networks in the CCSS

Sub-network	PO	HS	EQ	RX	FL	MA	CT	US	MO	M_1	$\overline{M_1}$	M_2	$\overline{M_2}$	M_3	$\overline{M_3}$	DI	$\overline{DI}$	TI	$\overline{TI}$
Liberia	326 329	3	19	10	2	1	1	5	5	0	*0.0*	5	*1.0*	6	*1.0*	200	*0.6*	330	*0.8*
San Carlos	187 827	2	9	5	1	1	0	2	4	1	*0.3*	0	*0.0*	0	*0.0*	300	*0.9*	300	*0.8*
Puntarenas	243 430	2	14	7	1	1	0	5	4	2	*0.5*	0	*0.0*	2	*0.3*	200	*0.6*	210	*0.5*
Alajuela	592 021	3	23	15	2	2	1	3	5	1	*0.3*	4	*0.8*	2	*0.3*	60	*0.2*	75	*0.2*
Heredia	421 830	1	12	5	1	1	0	5	4	2	*0.5*	1	*0.2*	0	*0.0*	200	*0.6*	180	*0.5*
Cartago	451 088	2	18	10	4	1	1	2	5	4	*1.0*	1	*0.2*	1	*0.2*	70	*0.2*	120	*0.3*
Limón	458 549	2	11	7	1	1	0	2	4	2	*0.5*	1	*0.2*	2	*0.3*	150	*0.4*	210	*0.5*
Pérez Z.	303 616	5	19	14	1	1	0	3	4	1	*0.3*	0	*0.0*	2	*0.3*	350	*1.0*	390	*1.0*

Results emphasized in italics

$I_{2:}$ Number of inhabitants per imaging equipment (w_2=1.0). It calculates the ratio between the number of inhabitants of the region and the total number of installed imaging equipment at its hospitals, being defined by the function (2).

$$I_2 = EQ/PO \tag{2}$$

$I_{3:}$ Diagnostic imaging modalities (w_3=0.6). It determines the availability in the region of the five imaging modalities used in the CCSS: conventional X-ray, fluoroscopy, mammography, CT, and ultrasonography. For that, the variable V_8= MO was divided by 5 to ensure that the result will have a value between the range [0, 1], as shown in the function (3).

$$I_3 = MO/5 \tag{3}$$

$I_{4:}$ Regions over-mortality level in (w_4=0.6). Refers to the number of HA in the region with over-mortality in any of the three leading causes of death in Costa Rica, which are cancer, heart diseases, and respiratory diseases. This indicator estimates a unique value representing the level of over-mortality in the region of analysis. For this, each variable M_i has an assigned relevance factor ρ_i which considers the different imaging modalities used in the diagnosis of the disease in question. For example, the variable M_1, which represents cancer, has the highest relevance factor ρ_1=1, since for its diagnosis any of the five imaging modalities mentioned above can be used. To cardiac diseases, (M_2) was assigned a factor of ρ_2=0.75 because the diagnosis can be made with only four of the five modalities (mammography is excluded because it is used just for the detection of breast cancer). Finally, for respiratory diseases (M_3), the factor assigned is ρ_3=0.5, because the diagnosis can be made with three imaging modalities (RX, FL, and CT). Each of these variables was multiplied by its factor of relevance, and the result was included in a normalized sum, which when divided by $n = \rho_1 + \rho_2 + \rho_3$=2.25, ensures that the result of the indicator is in the range [0, 1]; as shown in function (4).

$$\boldsymbol{I}_4 = \sum\nolimits_{i=1}^{3} (\boldsymbol{\rho}_i \boldsymbol{M}_i)/\boldsymbol{n} = \sum\nolimits_{i=1}^{3} (\boldsymbol{\rho}_i \boldsymbol{M}_i)/2.25 \tag{4}$$

$I_{5:}$ Potential target population requiring services in the third health care level (w_5=0.3). This indicator estimates the percentage of population that requires third health care level attention, corresponding to 8 % of the total number of inhabitants of the region [5] and was defined by the function (5).

$$I_5 = 0.08(PO) \tag{5}$$

$I_{6:}$ Distance to the Capital (w_6=0.6). It takes into account the distance in kilometers between the Capital (San Jose) and the farthest town of the analysis region. Its importance is emphasized given the mainly mountainous relief of Costa Rica, and its roadway infrastructure which has mostly single-lane roads in each way; the situation which makes transportation difficult the from one place to another. It is defined by function (6).

$$I_6 = DI_{km} \tag{6}$$

$I_{7:}$ Time to travel DI (w_7=1.0). It takes into account the time (measured in minutes) required to travel the distance *DI*, defined by function (7).

$$I_7 = TI_{min} \tag{7}$$

Design of Global Indicator AIS (Level of Access to Imaging Services)

The partial indicators were integrated into a mathematical function (8) to obtain an overall data reflecting the level of

AIS which the inhabitants of a given region have. Note that the function is the sum of all partial indicators (I_k) divided by a normalization factor N that represents the sum of all relevance factors w_k as follows: N=0.3+1+0.6+0.6+0.3+0.6+1=4.4. The normalization is done to ensure that the result of the AIS will take a value within in the interval [0, 1].

$$AIS = \sum_{k=1}^{7}(I_k)/N = \sum_{k}^{7}(I_k)/4.4 \qquad (8)$$

Level Estimation of Access to the Imaging Services

The validation of the model described above was applied in the eight sub-networks of the CCSS identified as follows: (1) Liberia, (2) San Carlos, (3) Puntarenas, (4) Alajuela, (5) Heredia, (6) Cartago, (7) Limón, and (8) Pérez-Zeledón (Fig. 1). To illustrate the use of the model, it will be applied in an explicit way to the sub-network of Liberia, and then the results for the remaining seven sub-networks will be presented.

Variable Selection

The data from each of the variables obtained in the eight sub-networks are shown in Table 1. Note that the sub-network of Liberia has a population (PO) of 326,329 inhabitants, having three hospitals (HS), two that are PH and one, RH and having a total of 19 imaging equipment (EQ), distributed as follows: ten RX, two FL, one MA, one CT, and five US (e.g., Costa Rican Public Health System, [6]), which means that by having the five imaging modalities, the value obtained for MO=5. Note also that in the region there is no over-mortality in HA from cancer (M_1=0), but there are five HA with over-mortality from heart diseases (M_2=5) and six areas with over-mortality on respiratory diseases (M_3=6). Finally, the variables related to the geographical location (DI and TI) show that Liberia is at 200 km from the Capital, and traveling that distance by land takes 330 min (four and a half hours). This same analysis was made for the remaining seven sub-networks.

The following procedure was to normalize the variables M_1, M_2, M_3, DI, and TI to have a value within the range [0, 1]; this is done by dividing the value V_i between the upper bound of its domain $M_{\text{i-up}}$ and rounding the result. For example, in the column for TI of Table 1, the domain of this variable is M_{TI}=[75, 390] (lower and upper value), meaning that to normalize the values of each result of V_{TI}, the corresponding value must be divided by 390; in the example of Liberia, who has a TI=330, the resulting normalized value is $\overline{\boldsymbol{TI}} = 0.8$. The normalized values for these five variables are denoted with $\overline{V_I}$ and are also shown in Table 1. The variables RX, FL, MA, CT, and US not require to be normalized, because when they are used in the corresponding partial indicator, the results will remain within the range [0, 1]. On the other hand, the variables PO, HS, and EQ were excluded from this normalization process, because they will be normalized once they are integrated to their corresponding partial indicator, as will be seen below.

Application of Partial Indicators

The application of the partial indicators for all sub-networks was done using the functions (1–7), and the results are shown in Table 2. Note that, with the exception of the indicators I_1, I_2, and I_5, all the results take values within the range [0, 1], because for their calculation were used the normalized variables of the previous section. So, the normalization of I_1, I_2, and I_5, consist of dividing the value I_k (in parenthesis) by the upper bound of its domain $\Delta_{\text{k-sup}}$. For example, the indicator I_1 has a domain ΔI_1=[60 723, 421 830], so every value I_1 of each sub-network was divided by $\Delta_{1\text{up}}$=421,830. This for the case of Liberia is I_1=108,776/421,830=0.3. Thus, the normalized results of all the indicators for all sub-networks are shown (in italics) in Table 2.

By analyzing the results of the indicators, it was observed that some of them show no direct impact for the estimation of access to imaging services. For example, the region that has the largest number of inhabitants per hospital had the highest result of the indicator I_1 (near to the unit), meaning that people who live in that region have less opportunity to receive the services than those who live in a region where the result of I_1

Table 2 Results of the seven partial indicators in the sub-networks of the CCSS

Sub-network	I_1		I_2		I_3	I_4	I_5		I_6	I_7
Liberia	(108,776)	*0.3*	(17,175)	*0.4*	*1.0*	*0.6*	(26,106)	*0.6*	*0.6*	*0.8*
San Carlos	(93,914)	*0.2*	(20,870)	*0.5*	*0.8*	*0.1*	(15,026)	*0.3*	*0.9*	*0.8*
Puntarenas	(121,715)	*0.3*	(17,388)	*0.4*	*0.8*	*0.3*	(19,474)	*0.4*	*0.6*	*0.5*
Alajuela	(197,340)	*0.5*	(25,740)	*0.6*	*1.0*	*0.5*	(47,361)	*1.0*	*0.2*	*0.2*
Heredia	(421,830)	*1.0*	(35,153)	*0.8*	*0.8*	*0.3*	(33,746)	*0.7*	*0.6*	*0.5*
Cartago	(225,544)	*0.5*	(25,060)	*0.6*	*1.0*	*0.5*	(36,087)	*0.8*	*0.2*	*0.3*
Limón	(229,275)	*0.5*	(41,686)	*1.0*	*0.8*	*0.4*	(36,683)	*0.8*	*0.4*	*0.5*
Pérez Z.	(60,723)	*0.1*	(15,980)	*0.4*	*0.8*	*0.2*	(24,289)	*0.5*	*1.0*	*1.0*

Results emphasized in italics

represents the lowest number of inhabitants per hospital. In order that the result of each indicator adds value to the access, a complement procedure was applied with $I_k = 1 - I_k$, and therefore the contribution would be directly proportional to the value obtained by the indicator. It is worth mentioning that the only indicator that did not require the complement was I_3 (diagnostic imaging modalities), because its direct result does add value to the AIS.

Furthermore, it must be remembered that each indicator has a relevancy factor (w_k) assigned, which must be multiplied for the value of the indicator. So, the complete processing for each indicator was made with the Eq. 9, as follows with the example of Liberia.

$$
\begin{aligned}
I_k &= (1 - I_k) w_k \\
I_{1_{Liberia}} &= (1 - I_{1_{Liberia}}) 0.3 = (1 - 0.3) 0.3 = (0.7) 0.3 = 0.2
\end{aligned}
\tag{9}
$$

The final result of all partial indicators for the eight sub-networks is shown in Table 3. Note that there are several results with value 0 (for example, $I_{1\text{Heredia}}$). In this regard, it should be mentioned that in this work a value of zero represents a direct indicator whose value was the maximum before performing the complement procedure, namely $I_{1\text{Heredia}} = 1.0$ (Table 2) which by the complement became zero and does not add value to the result of AIS.

Application of Global Indicator AIS

To calculate the AIS, the function (8) was used together with the final results of the partial indicators shown in Table 3. Following will be illustrated the estimation to the sub-network Liberia:

$$
\begin{aligned}
AIS_{Liberia} &= \sum_{k=1}^{7} (I_k)/4.4 = (I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7)/4.4 \\
AIS_{Liberia} &= (0.2 + 0.6 + 0.6 + 0.3 + 0.1 + 0.3 + 0.2)/4.4 = 0.51
\end{aligned}
$$

Table 3 Final results of the partial indicators and its relevance factor w_k

Sub-network	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Liberia	0.2	0.6	0.6	0.3	0.1	0.3	0.2
San Carlos	0.2	0.5	0.5	0.5	0.2	0.1	0.2
Puntarenas	0.2	0.6	0.5	0.4	0.2	0.3	0.5
Alajuela	0.2	0.4	0.6	0.3	0.0	0.5	0.8
Heredia	0.0	0.2	0.5	0.4	0.1	0.3	0.5
Cartago	0.1	0.4	0.6	0.3	0.1	0.5	0.7
Limón	0.1	0.0	0.5	0.4	0.1	0.3	0.5
Pérez Z	0.3	0.6	0.5	0.5	0.1	0.0	0.0
w_k	0.3	1.0	0.6	0.6	0.3	0.6	1.0

In the same way the AIS calculation was conducted for the other sub-networks, the qualitative representation was assigned according to the five sub-intervals above declared, to facilitate the interpretation of the AIS results. Note that all AIS values were within the range [0, 1].

1. AIS Liberia=0.51	(Regular access)
2. AIS San Carlos=0.52	(Regular access)
3. AIS Puntarenas=0.59	(Regular access)
4. AIS Alajuela=0.63	(Good access)
5. AIS Heredia=0.44	(Bad access)
6. AIS Cartago=0.60	(Good access)
7. AIS Limón=0.43	(Bad access)
8. AIS Pérez Zeledón=0.45	(Bad access)

Discussion

The geographic location of the eight sub-networks is presented in Fig. 1, in which with different gray levels are shown with the corresponding results of the AIS in each one. Note that the sub-networks of Heredia (5), Limón (7), and Perez Zeledón (8), which obtained a *bad access*, are located in east and north-central of the country (note that Heredia, although located in the center of the country, obtained a bad result). The sub-networks with regular access: Liberia (1), San Carlos (2), and Puntarenas (3) are located in the west; and the last two who obtained a *good access*, Alajuela (4) and Cartago (6), are located in the center of the country. With these results, it appears to be a relation of the proximity of analyzed regions and the Capital (located in the center of the country) with the level of AIS, since the last two sub-networks are closest to the Capital and became the best results of AIS, which means that the inhabitants of these regions have greater opportunity to access the imaging services offered by the General Hospitals located in the Capital. Despite this relation, the Heredia sub-network exemplifies that the geographical location is not the only factor that determines the level of access, since it is also located in the center of the country and obtained one of the worst results of the analysis. In contrast with the more distant sub-networks, which, besides the geographical location, have fewer resources, a situation that compromises the access to their inhabitants and that is reflected in *regular* and *bad* results of AIS.

Also, a comparative analysis was made between the technological capacity installed in the CCSS Hospitals in 2006 (Table 1) and the new equipment acquired until 2010 (Costa Rican Public Health System, [7]). The hypothesis was that the investment made by the institution during these 4 years should reflect a strengthening in each sub-network by the installation of new imaging technology and,

Table 4 Number of diagnostic imaging equipment installed in 2006 and 2010

Sub-network	AIS	RX		MA		CT		US	
		2006	*2010*	2006	*2010*	2006	*2010*	2006	*2010*
Liberia	Regular	10	*14*	1	*1*	1	*1*	5	*9*
San Carlos	Regular	5	*8*	1	*2*	0	*0*	2	*7*
Puntarenas	Regular	7	*10*	1	*1*	0	*0*	5	*5*
Alajuela	Good	15	*17*	2	*2*	1	*1*	3	*10*
Heredia	Bad	5	*5*	1	*1*	0	*0*	5	*8*
Cartago	Good	10	*17*	1	*1*	1	*1*	2	*8*
Limón	Bad	7	*13*	1	*1*	0	*0*	2	*5*
Pérez Z.	Bad	14	*18*	1	*2*	0	*0*	3	*10*
Total		73	*102*	9	*11*	3	*3*	27	*62*

Results emphasized in italics

therefore, the provision of better attention of the imaging services to the inhabitants of Costa Rica.

The difference between the equipment installed till 2006 and those installed till 2010 is shown in Table 4. Observe that there was an increase in the number of RX's (39 %), mammography equipment (22 %), and ultrasounds (129 %). However, the number of CT's did not change. This indicates that, although the CCSS made a considerable investment during those 4 years, it did not solve the problem of concentration and distribution of the imaging equipment in the different regions. Note the three sub-networks that resulted with a bad AIS evaluation: In Heredia, the investment was made only in ultrasounds, and the rest of the technologies remained in the same number; in the case of Limon, the increase was made in six RXs and three US; and in Pérez Z the increase was by four RX, one MA and seven US. Furthermore, in the case of the two sub-networks that received a result of good AIS (Alajuela and Cartago), the increase of technology was by two and seven RX (respectively), plus seven and six USs. Finally, the three sub-networks with regular AIS presented the same situation: The increase of technology was made only in RXs and USs.

In all cases, it is clear that an effort was made to improve the technological capacity. However, there is still a lack of CTs in five sub-networks (San Carlos, Puntarenas, Heredia, Limón, and Pérez Z), coinciding with those that resulted with a bad and regular AIS. This means that there is still a technology deficit to provide the inhabitants of these regions the opportunity to get diagnoses with CT studies, without having to travel to the General Hospitals in the Capital. In this sense, the CCSS needs to develop an investment politic to purchase the CT scans required, in order to provide these studies to the inhabitants of these five regions.

Conclusion

The work here presented allowed the designing an indicator with which it is possible to estimate quantitatively the level of access to the imaging services (AIS) that the inhabitants of eight geographical regions of Costa Rica have. The validation of this indicator was performed in eight sub-networks that showed administrative dependence of their health care facilities from the first to the second health care level (since these sub-networks are distributed throughout the territory of the country).

The results allowed classifying two of them with good AIS; three with *regular* AIS; and the last three with *bad* AIS. These results demonstrate that there are differences in the access that the inhabitants of various regions of the country have to the imaging services offered by the CCSS, demonstrating that these services are not equitable for all people as they should be.

The comparative analysis of the equipment installed in 2006 and 2010 reveals that the technological investment efforts made by the institution have generally been designed to ease the level of accessibility to medical imaging services (AIS). However, in the case of sub-networks with bad AIS, technological gaps remain significant in terms of not being able to offer tomography studies of the population of their region. So it reaffirms the need to strengthen technologically these regions, in order to provide their inhabitants access to all medical imaging modalities, in the same way as those people who live in regions that have the required technology to provide an integral and quality health service.

Consequently, and knowing which are the deficiencies of access in each sub-network, it is possible to work in healthcare technology acquisition and management proposals with the main objective to strengthen the regional imaging services, in order to provide equitable and self-sufficient services (at least for the target population), in a way that contributes to decentralize and alleviate the congestion of the concentrated services of the General Hospitals located in the capital. Furthermore, although the indicators (partials and global) were designed to estimate the AIS in the CCSS, they can be used to evaluate any imaging service of any health institution.

References

1. National Institute of Statistics and Census (INEC for its Spanish acronym): *Monthly indicators*. Available at: http://www.inec.go.cr/ Consulted in June, 2008.
2. Costa Rican Public Health System: *Institutional Proceedings 2006*. Organizational Communication Management, 2006a. (In Spanish)
3. Costa Rican Public Health System: *General Statistics of Health Services 1980–2005.* Department of Health Statistics, Health Information Management, Medical Division Management, 2006b. *(In Spanish)*
4. Rosales-López A and Ortiz-Posadas MR: A distribution strategy for imaging centers in the Costa Rican Public Health System. In: Dössel-Schllegel (Eds.), IFMBE Proceedings World Congress on Medical Physics and Biomedical Engineering. Munich, Germany, 2009
5. Barquín-Calderón M: Hospital management. Chapter 2: Health systems and services, 7th edition. McGraw Hill, México, 2003 (In Spanish)
6. Costa Rican Public Health System: *Coverage social security, social security indicators 2006*. Statistics Department, 2006c. (In Spanish)
7. Costa Rican Public Health System: *Inventary of diagnostic imaging equipment*. Medical Equipment Management, Institutional Equipment Direction, 2010. (In Spanish)