

Designing a GIS-based Platform for Efficient Cost Control and Management of Diagnostic Imaging Examinations

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Abstract

Nowadays, there is a growing demand for health services of high quality and low-cost. The development of digital technology has created a large volume of information. In the health sector, the largest amount of data is transmitted by radiology laboratories because of the diagnostic imaging examination data. The aim of this project is to create an online platform for the rational management of total cost and revenues of diagnostic imaging examinations of hospital units. Geographic Information Systems (GIS) are used for design of interactive maps that are uploaded on a central information system. GIS systems are used for the spatial analysis of quantitative and qualitative variables. The platform acts as a surveillance system that enables users to analyze financial data and share their results. The results concern 23 Hospital Units (H.U.s) of the 6th Health Region in Greece in the period from 2012 to 2015. A spatial analysis was performed in correlation with the statistical analysis. There is an overtime reduction of the number of diagnostic imaging examinations. There is also a strong linear correlation between the cost, revenues of diagnostic imaging examinations and the number of hospital beds.

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1 Introduction

Health care quality improvement increases total expenditure and raises some serious problems which affect access to health care services and insurance patients' cover [1]. Health care indicators are used globally for calculating measurable variables. These variables are related to the number of preventable visits in the Emergency Departments (ER), the nursing skills correlated to patients' mortality and the cost of healthcare services [2], [3].

The cost of health care is equivalent to the total operating expenditure and includes all types of health care indicators. Quality cost describes the difference between the actual cost of health care services and the reduced cost, if patients' needs conform to health care services [4]. The effectiveness of a hospital unit (H.U.) is mainly assessed by measuring health outcomes. The process is completed by using medical data and comparing care plan guidelines. In several cases nursing or medical staff is asked to determine patient's status and implement electronic health records. Patients' electronic record concerns certain demographic factors, health related evidence, cost treatment and total discharge rates [5].

OECD data reveals that in 2013 – 2016 the hospital discharge rates were estimated at almost 5.000 to 25.000 dollars yearly per 100.000 for most OECD countries. The mean discharges rate was almost 15.500 dollars. In the European Union the same rate was estimated at almost 8.000 to 25.000 dollars yearly while the mean rate was 25.000 dollars [6].

Imaging examinations performed for therapeutic and diagnosing purposes play a significant role in the estimating cost procedure. These kinds of examinations determine the diagnostic effect and can be harmful to the human body, in cases of unnecessary use of X-rays. The term ALARA (As Low As Reasonably Achievable) is used for preventing unnecessary imaging radiation exposure [7], [8], [9], [10]. Greece is among the European countries with the greatest number of CT and MRI exams. They are estimated at 150 and 64 accordingly per 1.000 inhabitants in 2013 – 2017 [11], [12]. The rise of digital technology creates new applications for cost reduction and limitation of radiation dose of diagnostic imaging examinations. Health professions students and health professionals must be prepared to address future patients' needs [13].

Geographic Information Systems (GIS) are a useful tool for developing web-based applications which improve the efficiency of hospital units. They are increasingly recognized tools in health sector [14] and they are used for comparing relative costs, assessing health care insurance benefits and improving outcomes [15], [16]. Geographic Information Systems have emerged in the past decades as the information systems capable of assisting in effective disease control and epidemiology [17], [18].

The growing use of GIS in all fields of task has extended their capabilities. They play a strong role in health sector in order to achieve cost savings and promote efficient improvements [19], [20]. The use of GIS also becomes essential in analyzing and visualizing quantitative and qualitative data, stored in health data

bases, in order to solve problems and make decisions [21], [22], [23]. These spatially orientated systems use analytic tools for enhancing functionality [24], [25], [26], [27] and grouping imaging examinations, according to the total cost and revenues of the hospital units.

2 Object

The purpose of this paper is to design an online platform for effective cost control and management of diagnostic imaging examinations. The project will provide evidence - based research to guide health management in reducing the excessive cost of diagnostic exams. The paper proposes an alternative method for the geographical recording of total expenditures and revenues of the laboratory departments of the hospital units.

Spatial analysis will also help health managers to identify the most efficient and beneficial laboratories of the hospital units. The GIS-based platform is intended to act as a cost surveillance system in the decision-making process. It will offer an innovative approach for saving funds available for investments in public health and advancing in health care practice.

3 Material and Method

ArcGIS software is used for the digital processing of the available data. Data concerns the total cost and revenues of the diagnostic imaging examinations as well as the number of diagnostic tests performed in 94 public Greek hospitals and Health Centers in the 6th Health Region. In this study, diagnostic imaging examinations concern all the exams that are performed in the radiology departments of the Hospital Units. All available data was acquired by the Department of Health Data Processing and Analysis of the Ministry of Health. Some of the data was recovered from the hospital units themselves, following the relevant authorization given by the 6th Health Region. Data concerns the period 2012-2015.

Significant difficulties occurred during data acquire, due to the transition from the old National Health Informative System (esynet) to the new Business Intelligence (BI) system. 6th Health Region is divided in the territory of:

- Peloponnese that includes all hospitals in the prefecture of Arcadia, Laconia, Sparta, Korinthos, Messinia and Argolida. The total number of the H.U.s in this territory is estimated at almost 30.
- Western Greece that includes the public hospitals in the prefecture of Achaia, Iliia and Aitolokarnania. There are almost 29 H.U.s located in the territory of Western Greece.

- Epirus that includes the hospitals in the prefecture of Ioannina, Thesprotia, Arta and Preveza. The total number of the H.U.s of this specific territory is estimated at 21.
- Ionian Islands that include the hospital units of Corfu, Lefkada, Kefalonia and Zakynthos. The total number of the H.U.s, located in this territory, is the smallest one, compared to the rest of the territories and it is estimated at 14.
The GIS-based platform is created in 3 different steps:
- **1st Step:** The ArcCatalog application is used for creating the shape files that contain all available financial data (Figure 1). Shape files consist of points, lines, and polygons and are used for the digitization of raw data. Data is grouped on attribute tables by the number of exams, total cost and revenues per year. Several tools of the ArcCatalog application unleash users' potential and enable them to visualize their results. They are mainly used for creating buffer polygons and computing geometric intersections or units in input features as well as measuring quantitative data. By using these tools, data is summed up and sorted by year. Files can be copied and stored in a geodatabase, consisting of spatially distributed elements defined in the space as points, lines or surfaces.
- **2nd Step:** The shape files are uploaded on ArcMap application and a map layer is downloaded by a variety of GIS samples authorized by ESRI. Financial data are presented on bar diagrams with different color per year for each territory and prefecture of the 6th Health Region. At this point an interactive map ('smart map') is created that allows users to interact with the system. By clicking on the bar diagrams, pop-up windows emerge that contain all financial data of the diagnostic exams. Users can extract big data in a very short time. A variety of statistic tools is at users' disposal. Descriptive statistics can be calculated very easily and presented on the interactive maps (Figure 2). In this study, the standard deviation, the maximum and minimum price of total cost and revenues as well as the mean number of diagnostic imaging examinations are estimated. Statistical results are presented on bar diagrams.

FID	Shape	Id	Hospital	Territory	Cost_2012	Cost_2013	Cost_2014	Cost_2015	Reven_2012	Reven_2013	Reven_2014	Reven_2015	Ben_2012	Ben_2013	Ben_2014	Ben_2015
0	Point	0.H.U. 1		Peloponnese	167342	205793	165564	154310	1590000	1581310	1596390	891865	1423460	137520	1420630	737555
1	Point	0.H.U. 2		Peloponnese	61863	67347	135092	124797	672444	727504	869228	965397	610591	660157	73398	849600
2	Point	0.H.U. 3		Peloponnese	74296	89259	88258	81986	292456	390173	355147	297102	218160	300914	266889	215116
3	Point	0.H.U. 4		Peloponnese	52873	73166	49878	51543	453977	453862	447189	516865	401104	380696	397311	465322
4	Point	0.H.U. 5		Peloponnese	66995	61511	84714	79341	428971	419570	373692	403653	361976	358059	288978	324312
5	Point	0.H.U. 6		Western Greece	405103	429462	471575	409474	6679190	6207450	5805170	6409930	6274090	5777990	5333600	5997460
6	Point	0.H.U. 7		Western Greece	2184390	2035360	1999660	2289450	5238500	5449900	5723000	6417740	3054110	3414530	3724240	4128290
7	Point	0.H.U. 8		Western Greece	132877	43281	148634	111869	605274	783343	860021	870110	472397	740062	710187	758241
8	Point	0.H.U. 9		Western Greece	147229	159104	60489	25692	623445	761193	685999	580341	476216	602089	625510	554649
9	Point	0.H.U. 10		Western Greece	56869	52755	52755	73290	276394	235346	229929	268841	219525	182591	169647	195651
10	Point	0.H.U. 11		Western Greece	40223	35732	46364	34441	177403	196172	335022	148735	137180	160440	288658	114294
11	Point	0.H.U. 12		Epirus	169941	132561	123542	31878	1588550	1535430	2001110	1874850	1347610	1802670	1617570	1842960
12	Point	0.H.U. 13		Epirus	320479	198743	198026	194702	7202540	6851530	6895000	5991700	6882060	8652790	5696970	5797000
13	Point	0.H.U. 14		Epirus	148328	145509	116875	100024	860472	849306	915272	918880	712144	703797	798397	818956
14	Point	0.H.U. 15		Epirus	35371	36000	42926	42294	262839	157278	270229	239439	219268	121278	227303	197145
15	Point	0.H.U. 16		Epirus	44991	37711	68467	31666	256919	231333	155933	179878	211928	193622	87466	148212
16	Point	0.H.U. 17		Ionian Islands	136779	136492	158222	102354	863735	655416	662789	542675	526956	518924	504567	440321
17	Point	0.H.U. 18		Ionian Islands	60420	66874	77813	45727	193307	222217	289576	198288	152687	155343	211763	150361
18	Point	0.H.U. 19		Ionian Islands	3262	9695	12097	7553	28475	25433	27505	19792	25213	15738	15408	12239
19	Point	0.H.U. 20		Ionian Islands	39415	47262	42023	51900	356167	342974	416486	440081	316752	295712	376283	388181
20	Point	0.H.U. 21		Ionian Islands	24170	32180	82674	73138	220362	182872	313554	300542	196192	150692	230880	227404

Figure 1: Arc Catalog Application of GIS

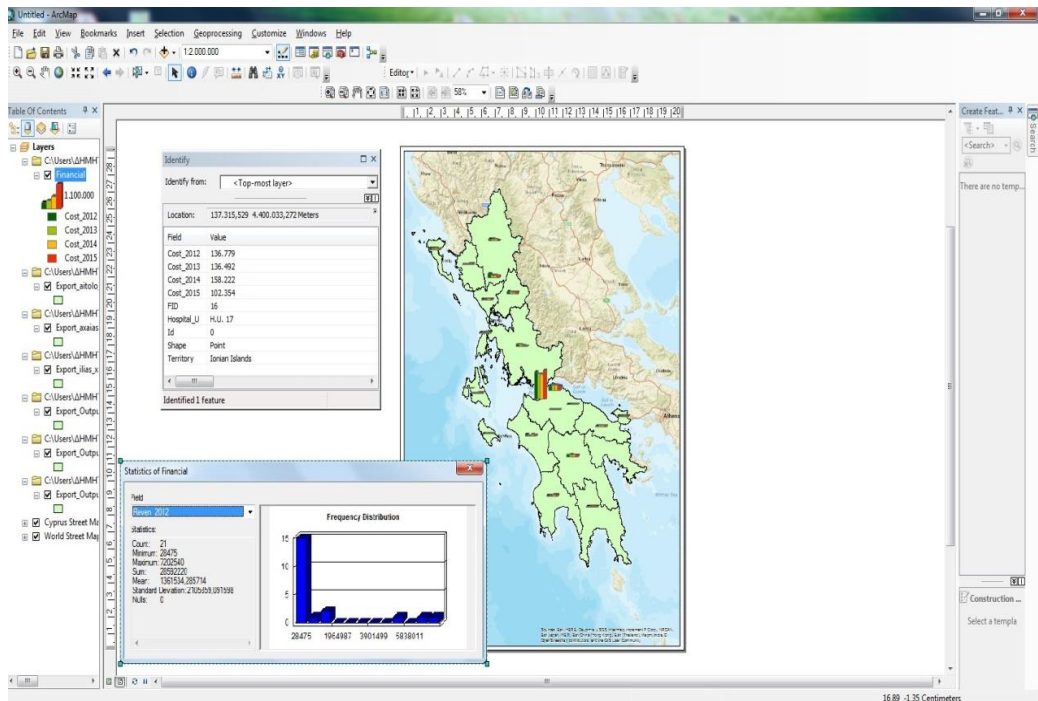


Figure 2: ArcMap Application of GIS

- **3^d Step:** At this point, all files are uploaded on the Map Layout application and 6 ‘smart’ maps are created (Figure 3, 4, 5, 6, 7, 8). They consist of the total cost data, revenues data, number of diagnostic exams and the estimated benefit or loss of each H.U. accordingly. Users can print the maps and analyze their results on graphs and tables that are embedded on the maps. These maps form the digital platform that is uploaded on a GIS server and shared by users. GIS-web applications enable users to run the platform on a tablet or mobile phone (Figure 9).

In order to evaluate the financial results of the GIS-based platform, a statistical analysis was performed by using SPSS Statistics 23. The same sample of 94 H.U. was also used for the same period of time. The variables of total cost, revenues, number of examinations and hospital beds were statistically tested according to their level of significance by using the linear regression model and a trend analysis.

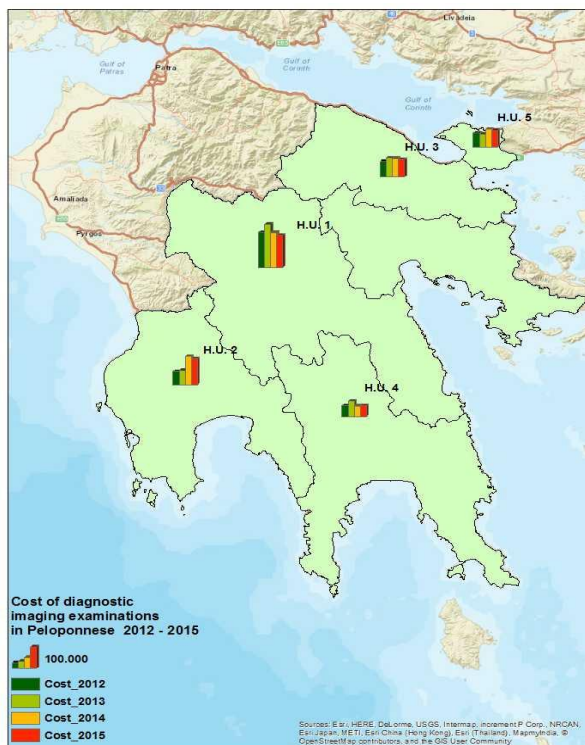


Figure 3: Cost Data in Peloponnese



Figure 4: Cost Data in the 6th Health Region

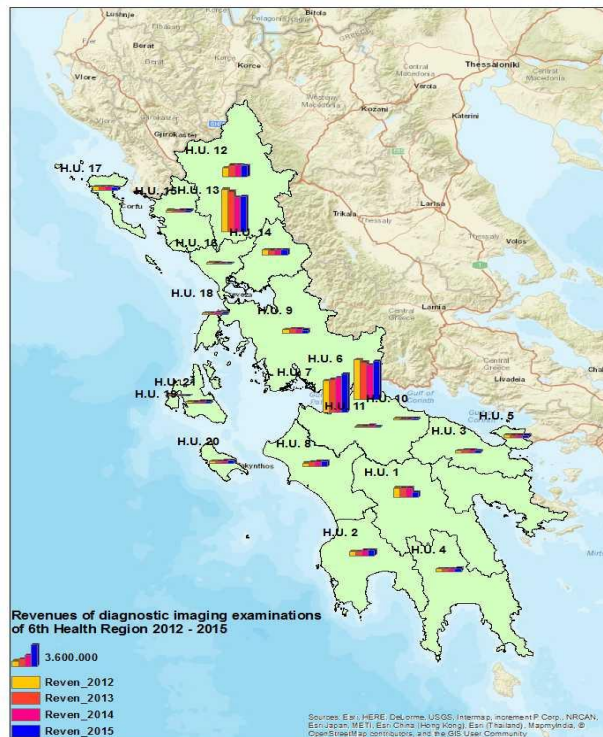


Figure 5: Revenues of Diagnostic Imaging Examinations in the 6th Health Region

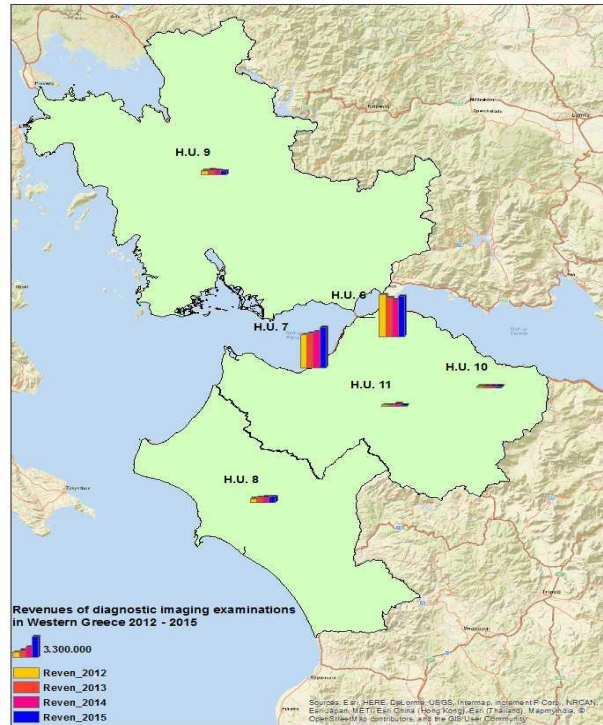


Figure 6: Revenues of Diagnostic Imaging Examinations in Western Greece

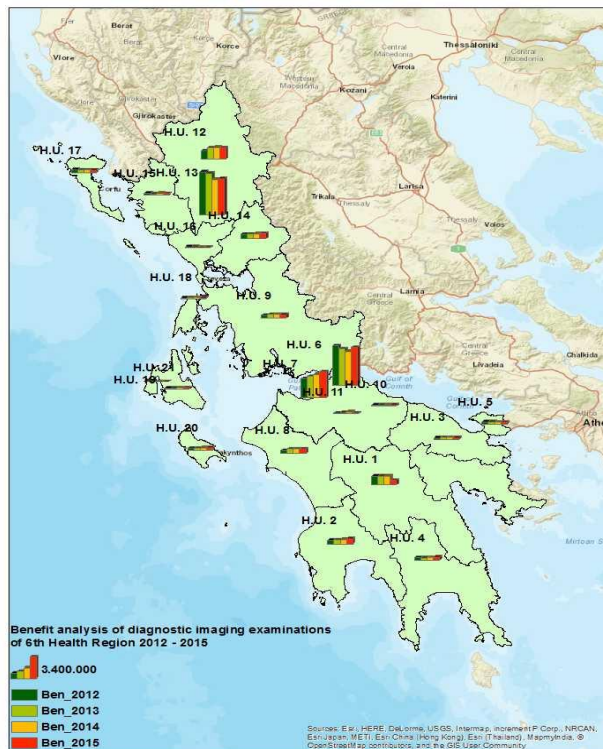


Figure 7: A GIS Benefit Analysis Map of Imaging Examinations in the 6th Health Region

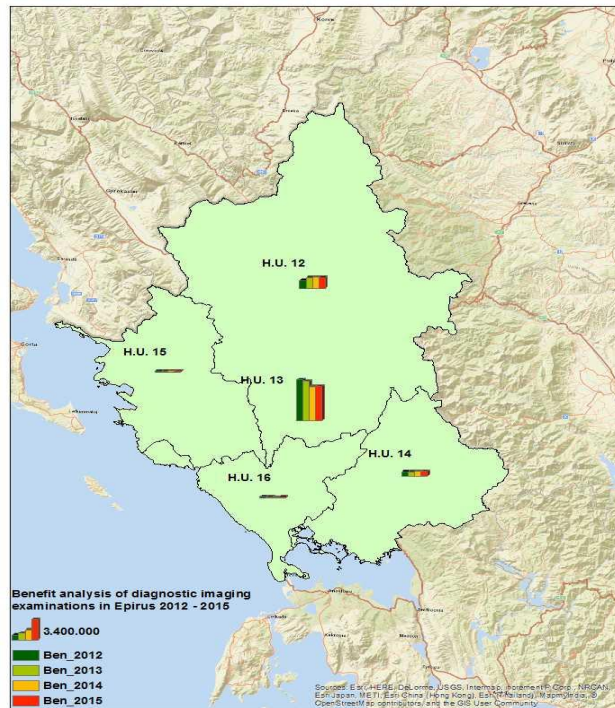


Figure 8: A GIS Benefit Analysis Map of Imaging Examinations in Epirus

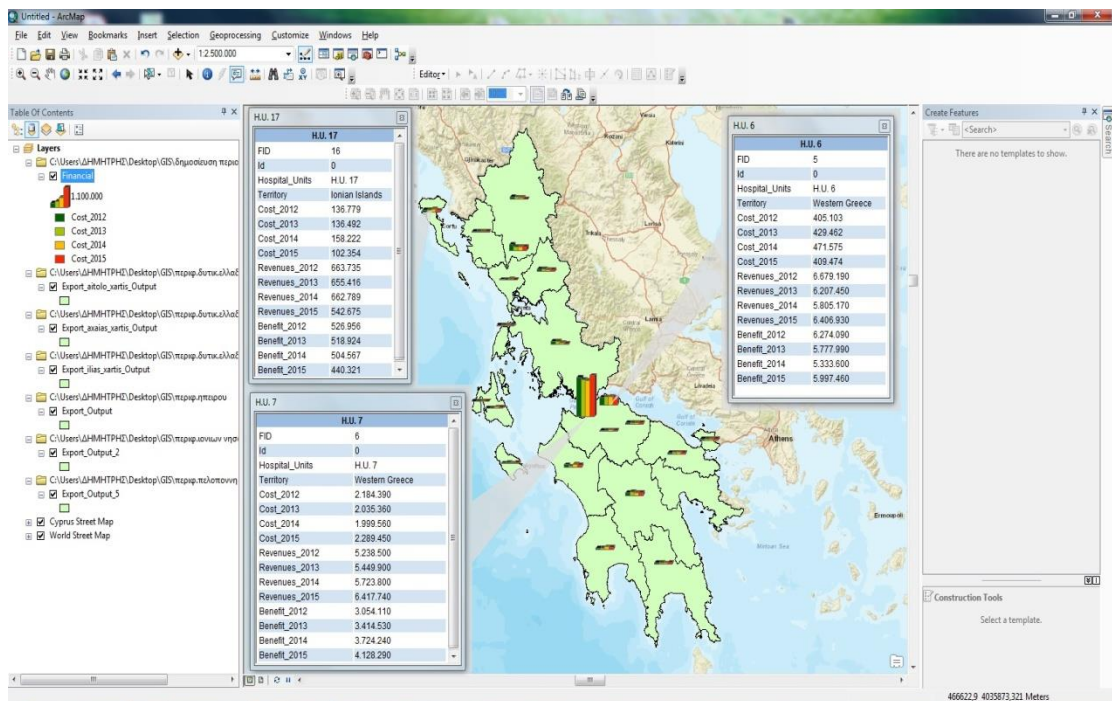


Figure 9: GIS-based Platform for Management of Imaging Examinations

3 Main Results

The cost results of GIS analysis are sorted by territory and are the following (Table 1):

- **Peloponnese:**

- H.U. 1 presents the greatest annual cost compared to the other H.U.s in Peloponnese (Figure 3). In 2012 – 2013, there is a cost increase estimated at 23%. In 2015, the cost is reduced by approximately 25% compared to 2012. The increase in 2012-2013 is estimated at 38.451 euros. The decrease is estimated at 51.483 euros. The total cost of the four-year period for Hospital 1 is estimated at almost 693.000 euros. This number amounts to 1/4 of the total cost of all H.U.s in Peloponnese. The total cost of all H.U.s in Peloponnese is estimated at 22.580.978 euros.
- In 2012 – 2015, H.U. 2 presents a cost increase estimated at 118%, namely 73.220 euros. In 2014 – 2015 there is a 7,5% cost decrease estimated at almost 10.300 euros.
- The estimated cost decrease of H.U. 3 is 8% in 2012 – 2015 that amounts to 7.273 euros.
- H.U. 4 presents a cost decrease in 2015, compared to 2013 estimated at 29,5%. The decrease amounts to almost 21.600 euros. It is well mentioned that the cost in 2015 is almost equal to the cost in 2012.
- In 2012 – 2015, there is a cost increase for H.U. 5 estimated at almost 18.4% that equals to almost 12.340 euros.
- The mean cost rate in 2012 – 2014, is increased by almost 30% while it is decreased for the next period by almost 20%.
- The rest of the H.U.s presents the lowest cost in Peloponnese (Figure 4).

- **Western Greece:**

- The cost of diagnostic imaging tests of H.U. 6 is increased by 1% in 2012 – 2015, namely 4.371 euros. The total cost of the H.U. 6 is the greatest compared to the rest of the H.U.s in the 6th Health Region for the same period of time (Figure 4).
- A small cost increase is also registered in H.U. 7 in 2012 – 2015. The estimated percentage is 4,8% and amounts to almost 105.000 euros.
- In addition, the percentage of cost reduction of H.U. 8 is estimated at approximately 16% or 21.008 euros. A slight increase is also recorded in 2014, compared to 2012. This increase is estimated at around 13% and amounts to almost 17.000 euros. In 2012-2013, there is a great decrease estimated at 67,4%.
- H.U. 9 presents the greatest decrease in 2012 -2015 estimated at 82,5%, that is almost 120.000 euros.
- H.U. 10 and H.U. 11 display the lowest cost in Western Greece in 2012 – 2015 (Figure 4). The cost of H.U. 10 in 2015 is increased by almost 29%

compared to 2012, namely 16.421 euros. The decrease rate of H.U. 11 is estimated at almost 14,4% in the same period.

- The mean cost rate is estimated at almost 114.000 euros and it is invariable in 2012 – 2015.

- **Epirus:**

- In 2012 – 2015, H.U. 12 demonstrates a significant cost reduction estimated at 80% or almost 130.000 euros.
- The corresponding reduction rate of H.U. 13 is approximately 39% that is almost 125.000 euros for the same period. Despite the greater reduction rate of H.U. 12, both hospitals approximately demonstrate the same reduction number.
- The reduction rate of H.U. 14 is estimated at 32,5% in the same period of time.
- A small cost increase is registered in H.U. 15 at approximately 19,6% or 6.923 euros in the same period of time. In 2015, the total cost of all H.U.s in Epirus is significantly reduced, compared to the cost in 2012. The decrease rate is estimated at almost 41%.
- A significant cost decrease is also registered in H.U. 16 and it's estimated at 29,6%.

- **Ionian Islands:**

- In 2012 – 2015, the total cost of diagnostic tests of H.U. 17 is the greatest in Ionian Islands. In 2015, the cost is reduced by 25%, compared to 2012.
- During the same period, a significant reduction was also registered in H.U. 18 and is estimated at 24% that is almost 14.700 euros.
- It is worth mentioning that the cost of H.U. 19 is increased by almost 271% in 2012 – 2014 that amounts to almost 8.800 euros.
- The increase rate of H.U. 20 is also estimated at almost 31,7% that amounts to 12.485 euros.
- There is also a significant increase rate in H.U. 21 in 2012 – 2014. It's estimated at almost 242%, namely 58.500 euros.

Table 1: Cost of Imaging Examinations of Hospital Units of 6th Health Region

Hospitals	Total cost 2012	Total cost 2013	Total cost 2014	Total cost 2015
Peloponnese				
H.U. 1	167.342	205.793	165.564	154.310
H.U. 2	61.863	67.347	135.092	124.797
H.U. 3	74.296	89.259	88.258	81.986
H.U. 4	52.873	73.166	49.878	51.543
H.U. 5	66.995	61.511	84.714	79.341
Western Greece				
H.U. 6	405.103	429.462	471.575	409.474

H.U. 7	2.184.390	2.035.364	1.999.560	2.289.445
H.U. 8	132.877	43.281	149.834	111.869
H.U. 9	147.229	159.104	60.489	25.692
H.U. 10	56.869	52.755	60.282	73.290
H.U. 11	40.223	35.732	46.364	34.441
Epirus				
H.U. 12	160.941	132.561	123.542	31.878
H.U. 13	320.479	198.743	198.026	194.702
H.U. 14	148.328	145.509	116.875	100.024
H.U. 15	35.371	36.000	42.926	42.294
H.U. 16	44.991	37.711	68.467	31.666
Ionian Islands				
H.U. 17	136.779	136.492	158.222	102.354
H.U. 18	60.420	66.874	77.813	45.727
H.U. 19	3.262	9.695	12.097	7.553
H.U. 20	39.415	47.262	40.203	51.900
H.U. 21	24.170	32.180	82.674	73.138

The total revenues of all public hospitals in the 6th Health Region concern of the following diagnostic imaging examinations:

- Magnetic Resonance Imaging scans (MRI)
- Computerized Tomography scans (CT)
- Dental X-rays
- DEXA scan for the diagnosis of osteoporosis
- X-rays
- Digital Subtraction Angiography scans (DSA)
- Scintigraphy scans
- Mammorays
- Radiotherapy scans

GIS analysis also revealed the following revenue results of Greek public hospitals in the 6th Health Region in 2012 – 2015 (Table 2):

- **Peloponnese:**
 - H.U. 1 presents 41% of the total revenues in Peloponnese. This is the greatest percentage that is recorded among all public hospitals in the specific territory. It is worth mentioning that the decrease rate of H.U. 1 is estimated at almost 44%. H.U. 3 presents the lowest total revenues compared to the rest Hospital Units in Peloponnese
- **Western Greece:**
 - The greatest revenues are registered in the public hospitals of Western Greece compared to all hospitals in the 6th Health Region. H.U. 6 presents the greatest revenues in this territory that amount to almost 45% of the total

revenues in Western Greece (Figure 6). The majority of H.U.s. in this territory display a revenue decrease that rates to 4% - 16%. H.U. 7 and H.U. 8. Display an increase rate that is estimated at 22,5% and 43,75% respectively.

- **Epirus:**

- The revenues of H.U. 12 are increased by 24% in 2015 compared to 2012. This is the greatest rate that is recorded among all hospitals of the 6th Health region.
- The decrease rate of H.U 16 is estimated at 30% that amounts to almost 77.000 euros. The lowest total revenues are registered in H.U. 15 and H.U. 16. These amount to 2,5% and 2,2% respectively of the total revenues registered in Epirus.

- **Ionian Islands:**

- The public hospitals in Epirus display the lowest revenues in the 6th Health Region. The relative percentage is estimated at almost 5,3% compared to the total revenues of public hospitals in the 6th Health Region. The total revenues of the majority of H.U.s. are increased by almost 1,5% - 36,4% in 2015, compared to 2012. H.U. 19 displays the lowest revenues in the 6th Health Region as well as in Ionian Islands.
- H.U. 21 displays the greatest increase rate estimated at 36,4%

Table 2: Total Revenues of Imaging Examinations of Hospital Units of 6th Health Region

Hospitals	Total Revenues 2012	Total Revenues 2013	Total Revenues 2014	Total Revenues 2015
Peloponnese				
H.U. 1	1.590.801	1.581.311	1.586.389	891.865
H.U. 2	672.444	727.504	869.028	965.397
H.U. 3	292.456	390.173	355.147	297.102
H.U. 4	453.977	453.862	447.189	516.865
H.U. 5	428.971	419.570	373.692	403.653
Western Greece				
H.U. 6	6.679.190	6.207.449	5.805.173	6.406.931
H.U. 7	5.238.504	5.449.897	5.723.804	6.417.735
H.U. 8	605.274	783.343	860.021	870.110
H.U. 9	623.445	761.193	685.999	580.341
H.U. 10	276.394	235.346	229.929	268.941
H.U. 11	177.403	196.172	335.022	148.735
Epirus				
H.U. 12	1.508.548	1.935.428	2.001.111	1.874.853
H.U. 13	7.202.541	6.851.533	5.894.997	5.991.698
H.U. 14	860.472	849.306	915.272	918.880
H.U. 15	262.839	157.278	270.229	239.439
H.U. 16	256.919	231.333	155.933	179.878

Ionian Islands				
H.U. 17	663.735	655.416	662.789	542.675
H.U. 18	193.307	222.217	289.576	196.288
H.U. 19	28.475	25.433	27.505	19.792
H.U. 20	356.167	342.974	416.486	440.081
H.U. 21	220.362	182.872	313.554	300.542

The cost-benefit analysis shows that the majority of hospitals in Peloponnese present a benefit reduction in 2015 compared to 2012. The estimated percentages for H.U. 1, H.U. 3 and H.U. 5 are almost 48%, 1,4% and 10,4% accordingly. The rest of the hospitals display a benefit increase that is estimated at almost 38% for H.U. 2 and 16% for H.U. 4 (Table 3).

In Western Greece, the majority of public hospitals display a benefit reduction for the same period of time. The relative percentages rate to 4,4% - 16,7% while the percentages of benefit increase rate to 16,4% - 35,1%. H.U. 11 displays the greatest decrease rate that amounts to 16,7% while the decrease rate of H.U. 6 is almost 4,4% (Table 3).

In Epirus, there is also a benefit reduction in 2015 compared to 2012 for the majority of hospitals (Table 3). The estimated percentages rate to almost 13% - 30%. H.U. 12 presents the greatest benefit increase estimated at 36,5% in the same territory. The greatest decrease rate is registered in H.U. 16, namely 30% (Figure 8).

In Ionian Islands, H.U. 19 displays the greatest benefit reduction estimated at 51,4% compared to all hospitals in the 6th Health Region for the same period of time. The estimated reduction amounts to almost 13.000 euros. The same H.U. also displays the lowest benefit in the specific territory (Table 3).

Table 3: Hospital Units Benefit of Imaging Examinations of 6th Health Region

Hospitals	Benefit 2012	Benefit 2013	Benefit 2014	Benefit 2015
Peloponnese				
H.U. 1	1.423.459	1.375.518	1.420.825	737.555
H.U. 2	610.581	660.157	733.936	840.600
H.U. 3	218.160	300.914	266.889	215.116
H.U. 4	401.104	380.696	397.311	465.322
H.U. 5	361.976	358.059	288.978	324.312
Western Greece				
H.U. 6	6.274.087	5.777.987	5.333.598	5.997.457
H.U. 7	3.054.114	3.414.533	3.724.244	4.128.290
H.U. 8	472.397	740.062	710.187	758.241
H.U. 9	476.216	602.089	625.510	554.649
H.U. 10	219.525	182.591	169.647	195.651
H.U. 11	137.180	160.440	288.658	114.294

Epirus				
H.U. 12	1.347.607	1.802.867	1.877.569	1.842.975
H.U. 13	6.882.062	6.652.790	5.696.971	5.796.996
H.U. 14	712.144	703.797	798.397	818.856
H.U. 15	227.468	121.278	227.303	197.145
H.U. 16	211.928	193.622	87.466	148.212
Ionian Islands				
H.U. 17	526.956	518.924	504.567	440.321
H.U. 18	132.887	155.343	211.763	150.561
H.U. 19	25.213	15.738	15.408	12.239
H.U. 20	316.752	295.712	376.283	388.181
H.U. 21	196.192	150.692	230.880	227.404

The SPSS analysis revealed that the majority of hospitals display an overtime reduction of both number of X-rays and CT scans in 2012 – 2015. There is a significant statistical difference of the number of CT scans and X-rays between H.U. 1 and the rest of the public hospitals in the 6th Health Region. The main results are the following (Table 4, Table 5):

- There is a reduction of both number of X-rays and CT scans of H.U. 3 compared to H.U. 1. These are estimated at 34,1% and 29,1% respectively (p-value < 0.001 / p-value= 0.004 < 0.05).
- H.U. 4 displays a 42% reduction rate of the number of X-rays compared to H.U. 1 (p-value < 0.001). The reduction rate of CT scans is estimated at 27,5% and it's statistically significant (p-value < 0.001).
- There is also a statistically significant reduction rate of X-rays in H.U. 2 that is estimated at 39,7% (p-value < 0.001). The relevant rate of CT scans is 25,6% (p-value < 0.001).
- The reduction percentages for both examinations of the H.U. 5 compared to H.U. 1 are also statistically significant (p-value < 0.001, p-value = 0.005 < 0.05) and are estimated at 31,2% and 21,5% respectively.
- H.U. 18 displays an overtime reduction of both examinations compared to H.U. 1. The percentages are estimated at 28,5% and 30,3% respectively and are statistically significant (p-value < 0.001, / p-value < 0.001).
- The overtime reduction rate of both X-rays and CT exams of H.U. 19 is also statistically significant and it's estimated at 45,4% and 29% respectively (p-value < 0.001).
- In terms of geographical spread, there is a significant difference between the number of both X-rays (p-value < 0.001) and CT scans (p-value = 0.021 < 0.05) and the Hospital Units.

Table 4: Statistical X-ray Data of the GIS-based Financial Analysis

Hospitals	B - value	p-value	95% confidence interval	
H.U. 1	Reference variable			
H.U. 2	-39.7%	<0.001*	-48.2%	-31.1%
H.U. 3	-34.1%	<0.001*	-42.7%	-25.6%
H.U. 4	-42.0%	<0.001*	-50.6%	-33.5%
H.U. 5	-31.2%	<0.001*	-39.8%	-22.7%
H.U. 18	28.5%	<0.001*	19.9%	37.0%
H.U. 19	-45.4%	<0.001*	-53.9%	-36.8%

Table 5: Statistical CT scans Data of the GIS-based Financial Analysis

Hospitals	B - value	p-value	95% confidence interval	
H.U. 1	Reference variable			
H.U. 2	-25.6%	<0.001*	-45.2%	-6.0%
H.U. 3	-21.9%	0.004*	-41.5%	-2.3%
H.U. 4	-27.5%	<0.001*	-47.1%	-7.9%
H.U. 5	-21.5%	0.005*	-41.1%	-1.9%
H.U. 18	30.3%	<0.001*	10.7%	49.9%
H.U. 19	-29.0%	<0.001*	-48.6%	-9.4%

The trend analysis also revealed the following X-ray results:

- The number of X-rays performed in the majority of public hospitals in 2013 was greater compared to 2012 by 2,3% but the result isn't statistically significant (p-value=0.408 > 0.05).
- The number of X-rays performed in the majority of public hospitals in 2014 was greater compared to 2012 by 3,9% but the result isn't statistically significant (p-value=0.151 > 0.05).
- On the contrary, the number of X-rays performed in the majority of public hospitals in 2015 was increased by 5,7%. This is a statistically significant result (p-value=0.037 < 0.05).

Table 6: Trend Analysis of X-ray Results

Year	B - value	p-value	95% confidence interval	
2012	Reference year			
2013	2.3%	0.408	-19.9%	24.4%
2014	3.9%	0.151	-18.2%	26.0%
2015	-5.7%	0.037*	-27.8%	16.5%

The trend analysis of CT scans results are the following:

- There is a statistically significant reduction of CT scans in 2012 – 2013 estimated at 23,2% (p-value < 0.001).

- The number of CT scans performed in 2012 – 2014 was reduced by 21,7%. This is also a statistically significant result (p-value < 0.001).
- There is no statistical significance between CT scans in 2012 – 2015. The reduction rate is estimated at 7,5% (p-value=0.178 > 0.05).

In this study, the cost of diagnostic imaging examinations consists of:

- The cost of X-ray films
- The cost of consumables used in the radiology departments such as gauzes, syringes and medicines
- Running costs and maintenance cost of medical equipment used in the radiology departments.

SPSS analysis of the financial data of the GIS-based platform also reveals an overtime strong linear correlation between hospital beds in all territories of the 6th Health Rin 2012 – 2015 and:

- CT revenues
- X-ray revenues
- Cost

Table 7: Trend Analysis of CT Scans Results

Year	B - value	p-value	95% confidence interval	
2012	Reference year			
2013	-23.2%	<0.001*	-42.7%	-3.8%
2014	-21.7%	<0.001*	-41.2%	-2.3%
2015	-7.5%	0.178	-27.0%	11.9%

Furthermore, the authors agree that a linear correlation model should be used between revenues (both X-rays & CT revenues), cost and number of hospital beds for each year separately. In all territories of the 6th Health Region, there is a strong linear correlation between the cost, revenues and the number of hospital beds in 2012 – 2015 (Figure 10, Figure 11, Figure 12 & Figure 13).

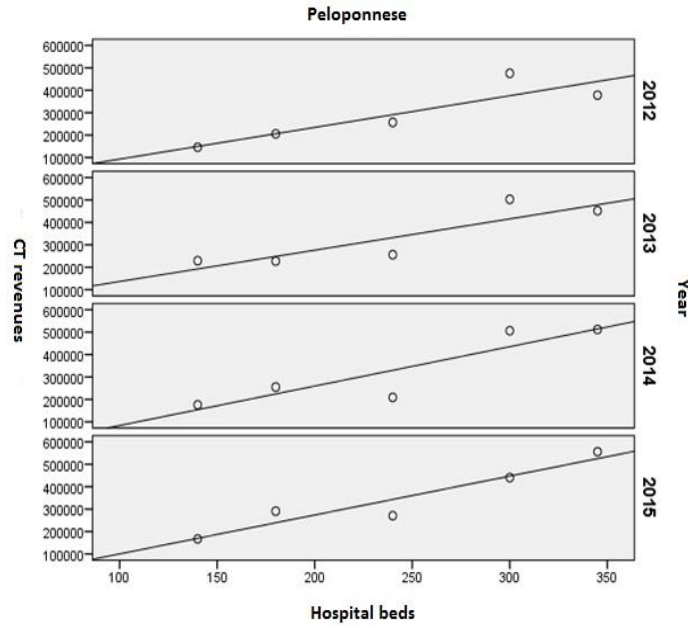


Figure 10: Linear Correlation Diagram between CT Revenues and Number of Hospital Beds in Peloponnese

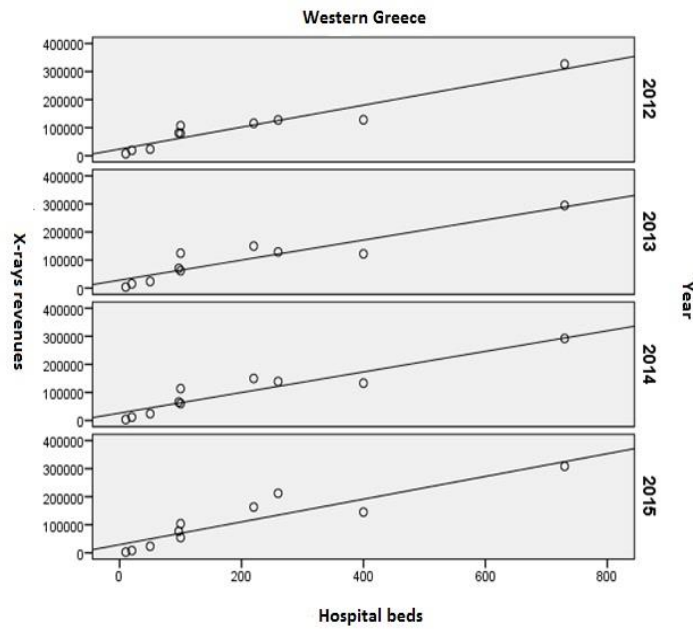


Figure 11: Linear correlation diagram between X-rays revenues and number of hospital beds in Western Greece

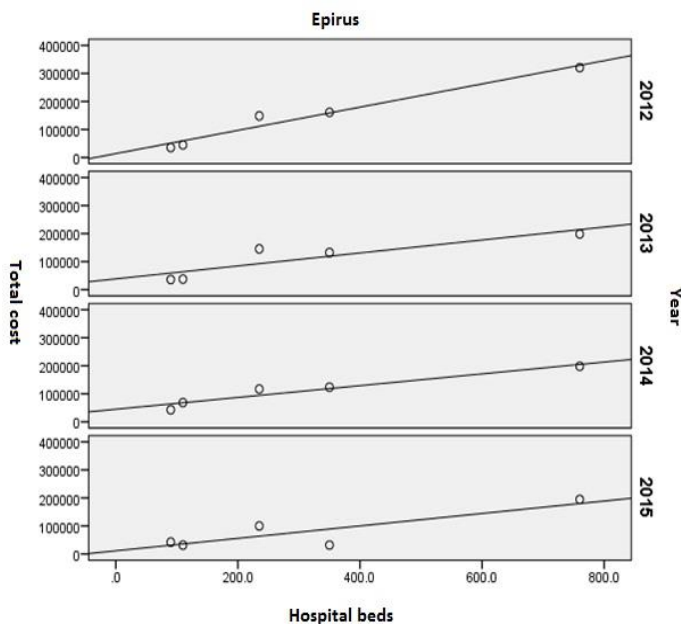


Figure 12: Linear Correlation Diagram between X-rays Revenues and Number of Hospital Beds in Epirus

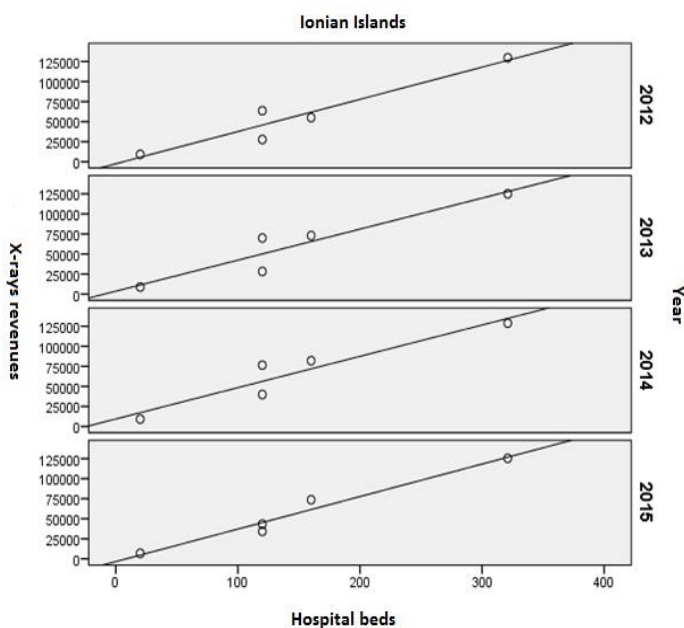


Figure 13: Linear Correlation Diagram between X-rays Revenues and Number of Hospital Beds in Ionian Islands

4 Discussion

Greek Healthcare System has recently adopted e-prescription services in order to limit the excessive number of medical prescriptions [28]. Although this is an encouraging health policy effort, it still lacks of a rational system of financial management of diagnostic imaging examinations. Greek hospitals are in need of a surveillance system that will promote fast processing of financial data. This system is expected to prevent cost overestimation in medical equipments and facilitate the tracking and replacement of obsolete medical devices.

The GIS-based platform reveals that a great number of diagnostic imaging examinations were performed in the majority of public hospitals in the 6th Health Region. Although there is a high prevalence of CT and MRI scans in Greece, this study reveals that there is a significant reduction of CT scans and X-rays in 2012 – 2015. Most Greek hospitals display enough revenues in order to cover their total expenses of providing H.U.s. with the necessary consumables. It is obvious from this study that the total expenditures are great enough to cover patients' need but ineffective spending and waste in Greek healthcare system is still present [29].

The present study also reveals that there is an overtime reduction of the estimated benefit. It means that in a few years, most Greek public hospitals will face several problems of financial austerity. They will have to save funds in order to cover their needs and satisfy patients' needs. The proposed digital platform is expected to help Hospital Units to establish a central surveillance system for the rational management of total revenues and expenditure of public hospitals.

5 Conclusions

The GIS-based platform enables fast data processing in real time and strengthens network connection with all users. It also enables users to exchange and interpret information data without knowledge of the data structure. The complex capabilities of the platform facilitate visual modeling of spatial data and geographic mapping from different projection systems.

Furthermore, the digital platform promotes earlier detection of emergent situations and reduces the time of decision - making. It also supports digital mapping by using open source data. The created maps are interpretable, making it easier for users to interact with the data collected. The whole process is completed by installing the GIS-based platform in a central information system. In this way, real time user's intervention is facilitated and the process of visual modeling is completed. By successfully establishing this digital application, it is possible to draw useful conclusions about the control and management of diagnostic imaging examinations.

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