

## AXIOMATIC DESIGN BASED VOLATILITY ASSESSMENT OF THE ABU DHABI HEALTHCARE LABOR MARKET: PART II - CASE STUDY

**Inas S. Khayal**

ikhayal@masdar.ac.ae

Engineering Systems & Management  
Masdar Institute of Science and Technology  
Box 54224, Abu Dhabi, UAE  
Massachusetts Institute of Technology  
Cambridge, MA, USA

**Amro M. Farid**

afarid@masdar.ac.ae

Engineering Systems & Management  
Masdar Institute of Science and Technology  
Box 54224, Abu Dhabi, UAE  
Massachusetts Institute of Technology  
Cambridge, MA, USA

### ABSTRACT

The progress of a developing nation is often measured by the advancement of its infrastructure. While “hard” infrastructure such as water, power and transportation are often easy to assess, “soft” structures such as healthcare systems are often more challenging. Furthermore, the quality and reliability of a nation’s healthcare system is often driven by the number and diversity of its healthcare professionals. Unfortunately many developing nations often suffer from very constrained segments in their highly skilled labor market and hence must “import” this human capital. Volatility in key healthcare professions can threaten reliable and sustainable healthcare delivery. In this two-part paper, the large flexible system modelling framework from Axiomatic Design Theory is used to assess healthcare delivery capability in Abu Dhabi, United Arab Emirates. Part I provides the methodological developments. Here, each profession type is modelled as a functional requirement and the physical hierarchy is modelled at three levels of decomposition: individuals, healthcare facilities, and regions. The associated knowledge base is filled with the associated number of professionals of a given type provided by the corresponding design parameters. The knowledge base is then evolved on a yearly basis as professionals enter, stay and ultimately leave. In Part II, the Abu Dhabi case study shows results indicative of significant volatility in the healthcare labor market. The work demonstrates that Axiomatic Design Theory as applied to large flexible systems can be applied to data-centric methods in human resources management in the context of skills shortages and high attrition rates.

**Keywords:** healthcare system, Axiomatic Design, large flexible system, human resource management, degrees of freedom, reconfiguration process, reconfigurability.

### 1 INTRODUCTION

Healthcare human resources management (HRM) is key to the development of the Abu Dhabi Emirate. The Abu Dhabi Economic Vision 2030, a roadmap for the Emirate’s economic progress towards a secure society and a dynamic open economy, states human resources development as one of the four key priority areas [Abu Dhabi Council for

Economic Development, 2009]. Therefore, Abu Dhabi has acknowledged that ensuring a nation’s development can be seen to equally depend on the retention of knowledge-based healthcare professionals.

Existing human resources management methods are relatively weak in addressing developing and emerging economies where either human capital has not had a chance to accumulate or where the growth rate of the economy outstrips efforts for human capital development [Beulen, 2009; Kapoor and Sherif, 2012]. Further attention has been given to Gulf Cooperation Council (GCC) countries where the absence of well-established indigenous human capital combined with fast economic and population growth has led to dramatic needs in human resources management [Doh *et al.*, 2011; Horwitz, 2011].

In this paper we apply Axiomatic design as a tool to assess HRM performance. The methodology for this paper is presented in Axiomatic Design Based Volatility Assessment of the Abu Dhabi Healthcare Labor Market: Part I [Farid and Khayal, 2013]. Section 2 presents and discusses the results for the evolution of the Abu Dhabi healthcare labor market over the last five decades. Section 3 concludes the work and presents potential extensions to the research.

### 2 CASE STUDY: EVOLUTION OF ABU DHABI HEALTHCARE HUMAN RESOURCES KNOWLEDGE BASE

In this section, the models presented in Part I are applied to an Abu Dhabi data set of healthcare professionals to draw some conclusions about the emirate’s human resources management practices. Section 2.1 describes the data in detail while Section 2.2 presents and discusses the results.

#### 2.1 DATA

The Abu Dhabi Emirate is the largest of the seven emirates in the United Arab Emirates (UAE) and makes up 80% of the UAE land area. Abu Dhabi city is the capital of the UAE [Anonymous, 2013]. According to the Statistics Centre of Abu Dhabi (SCAD), in 2011 UAE Nationals made up approximately 20% of the population, while the remaining 80% were expatriates. This illustrates the UAE as a country in need of importing much of its healthcare labor market.

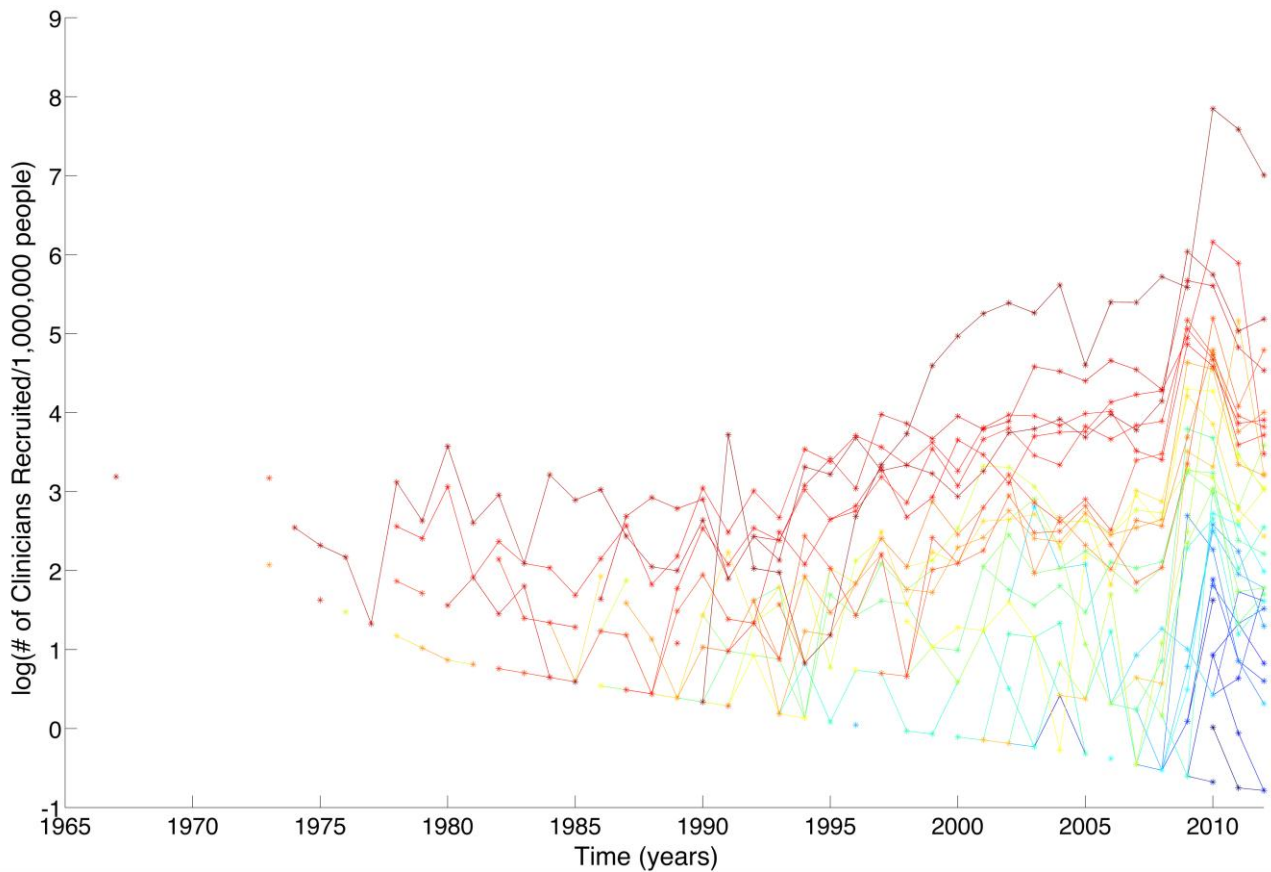


Figure 1. Evolution of healthcare professional recruiting in Abu Dhabi 1967 to 2012.

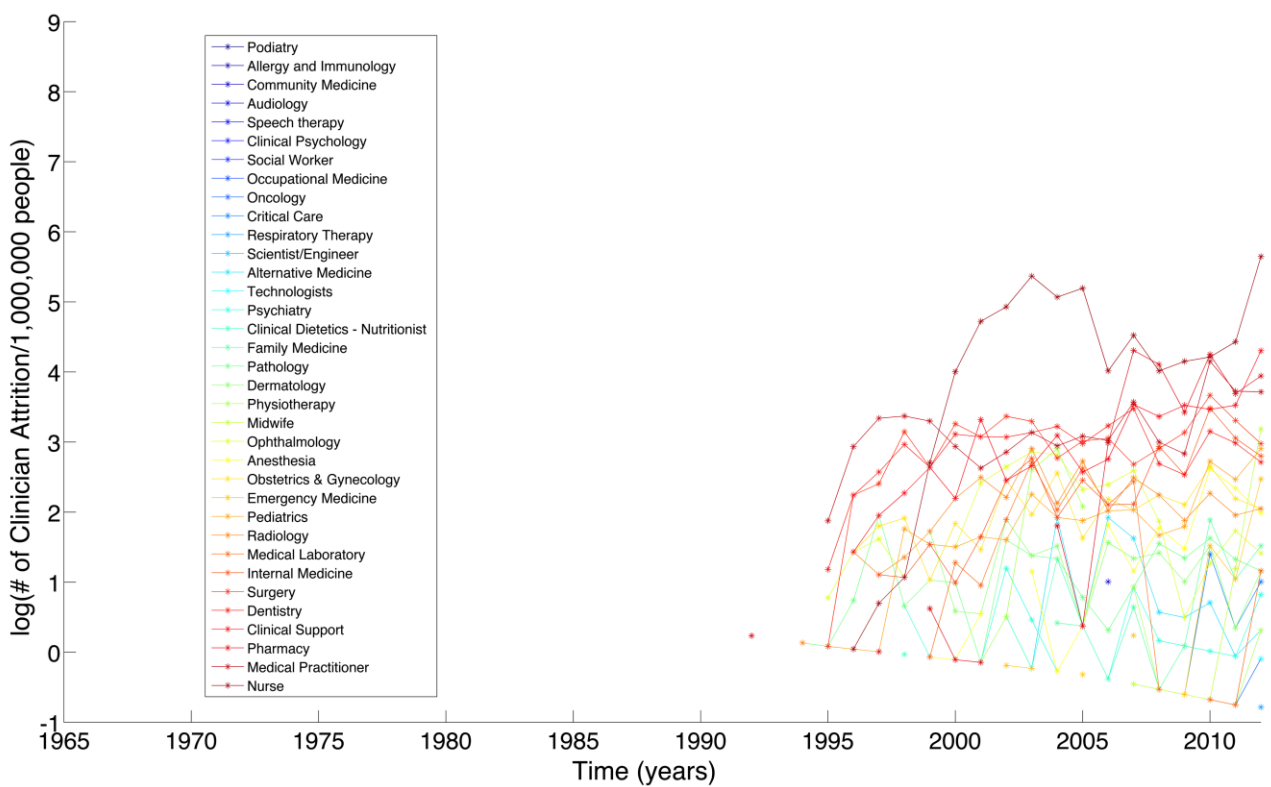


Figure 2. Evolution of healthcare professional attrition in Abu Dhabi 1967 to 2012.

The data used in this paper includes a publicly available list of all clinician licenses issued in the emirate of Abu Dhabi [Health Authority of Abu Dhabi, 2013]. The license list was cleaned and organized with the following attributes used in this case study: physician name, profession, facility licensed at, region (of the Abu Dhabi Emirate), start date and end date. The data used in this analysis spanned from 1967 to 2012, with 35 professions in 1769 facilities in 15 regions.

The numbers of clinicians per year were normalized across the 45 years by dividing the number of physicians by the population in Abu Dhabi. They are presented units of number of clinicians per million people. The population data was derived from SCAD's published report: "Abu Dhabi Development Statistics-Population and Labour Force" [Statistics Center of Abu Dhabi, 2013].

## 2.2 RESULTS & DISCUSSION

The provided data was analyzed given the Axiomatic Design models and measures given the methodology presented in the theory paper [Farid and Khayal, 2013]. The results are presented in terms of healthcare system quality of service, quality of service and healthcare human resources retention.

### 2.2.1 QUALITY OF SERVICE

In this section, quality of service (QoS) is assessed in terms of profession redundancy. Figures 1, 2 and 3 present the evolution of healthcare professional recruiting, attrition and net in Abu Dhabi from 1967 to 2012 on a semi-log scale.

All three figures show a decreasing envelope trend where the exponential population growth is occurring at a faster rate than the process of recruitment or attrition. The data also shows a significant systematic change in healthcare recruiting between 2008 and 2010. The figures show varying trends between professions that have been established the longest, and those that have been available for the shortest period of time in Abu Dhabi. The oldest healthcare professions, such as medical practitioners, pharmacists and dentists, tend to show more stable evolutions. These older healthcare professions also show minimal to no attrition before the 1990s. The recruitment and attrition of professionals appears to be very volatile, while the net seems to be much more stable. This shows specific effort towards attempting to maintain and minimize volatility over the years, given patterns of high and variable attrition.

Table 1 presents the statistical measures of the quality of service. The statistic measures of the coefficient of variation, the regression line slopes  $b_R$ ,  $b_A$ , and  $b$ , and the coefficient of determination (goodness of fit)  $R^2$  give complementary views of the evolution of healthcare professionals. The highest coefficients of variation of professions include nurses and family medicine. These are professions that have been established for approximately 30 years yet show large volatility. The values show that there is very large volatility in these very needed areas. Meanwhile, the regression line slopes demonstrate that the Abu Dhabi healthcare system is still very much in a ramping up phase indicative of a developing nation. Nearly all professions are growing at many multiples of the

population growth rate with the strongest trends in social workers, critical care and respiratory therapy. Finally, the correlation coefficients show the greatest volatility in healthcare professions with least redundancy suggesting the need for further recruiting to maintain quality of service.

**Table 1: Statistical measure of QoS.**

Profession	N	$\mu$	$\sigma/\mu$	$b_R$	$b_A$	b	1- $R^2$
Podiatry	3	1	0.29	NaN	NaN	0.29	0.01
Allergy and Immunology	32	1	0.32	NaN	NaN	-0.02	0.65
Community Medicine	4	4	0.50	NaN	NaN	0.45	0.68
Audiology	15	2	0.75	-0.02	-0.77	0.09	0.75
Speech therapy	12	2	1.03	NaN	NaN	0.11	0.67
Clinical Psychology	10	2	1.30	0.17	0.00	0.22	0.40
Social Worker	3	7	0.76	NaN	NaN	1.03	0.15
Occupational Medicine	12	3	1.21	1.80	0.00	0.24	0.37
Oncology	6	7	0.76	NaN	NaN	0.41	0.22
Critical Care	6	12	0.73	NaN	NaN	0.72	0.34
Respiratory Therapy	4	17	0.64	NaN	NaN	0.79	0.34
Scientist/Eng.	15	6	1.37	NaN	NaN	0.19	0.29
Alternative Medicine	23	12	0.87	NaN	NaN	0.16	0.19
Technologists	9	10	1.35	NaN	NaN	0.55	0.12
Psychiatry	31	8	0.93	0.07	NaN	0.09	0.14
Dietician-Nutritionist	18	7	1.61	NaN	NaN	0.18	0.38
Family Medicine	33	10	2.25	NaN	0.31	0.08	0.64
Pathology	33	26	0.78	NaN	0.02	0.10	0.09
Dermatology	33	29	0.80	NaN	NaN	0.11	0.06
Physiotherapy	15	20	1.10	0.22	NaN	0.18	0.39
Midwife	9	54	1.26	0.78	1.99	0.57	0.09
Ophthalmology	37	38	0.86	0.07	0.01	0.10	0.04
Anesthesia	27	35	1.55	NaN	NaN	0.18	0.05
Obstetrics & Gynecology	40	41	0.96	NaN	NaN	0.09	0.05
Emergency Medicine	11	51	1.74	NaN	NaN	0.56	0.16
Pediatrics	40	51	1.16	0.14	0.09	0.08	0.08
Radiology	32	44	1.31	-0.39	0.00	0.14	0.08
Medical Laboratory	22	60	1.69	NaN	NaN	0.21	0.12
Internal Medicine	40	71	1.24	NaN	NaN	0.08	0.11
Surgery	31	114	0.92	-0.51	0.00	0.12	0.05
Dentistry	35	190	0.68	0.04	-0.02	0.08	0.08
Clinical Support	28	176	1.58	-1.34	0.00	0.24	0.05
Pharmacy	38	261	1.15	0.09	NaN	0.15	0.02
Medical Practitioner	46	193	1.17	0.10	0.05	0.08	0.16
Nurse	28	716	2.04	0.28	0.00	0.29	0.08

where  $N$ =# of years of data;  $\mu$ =mean # of clinicians/million people;  $\sigma/\mu$ = coefficient of variation;  $b_R$ ,  $b_A$  and  $b$ =the slope of the log regression lines for recruitment, attrition, and net, respectively;  $1-R^2$ =measure of volatility.

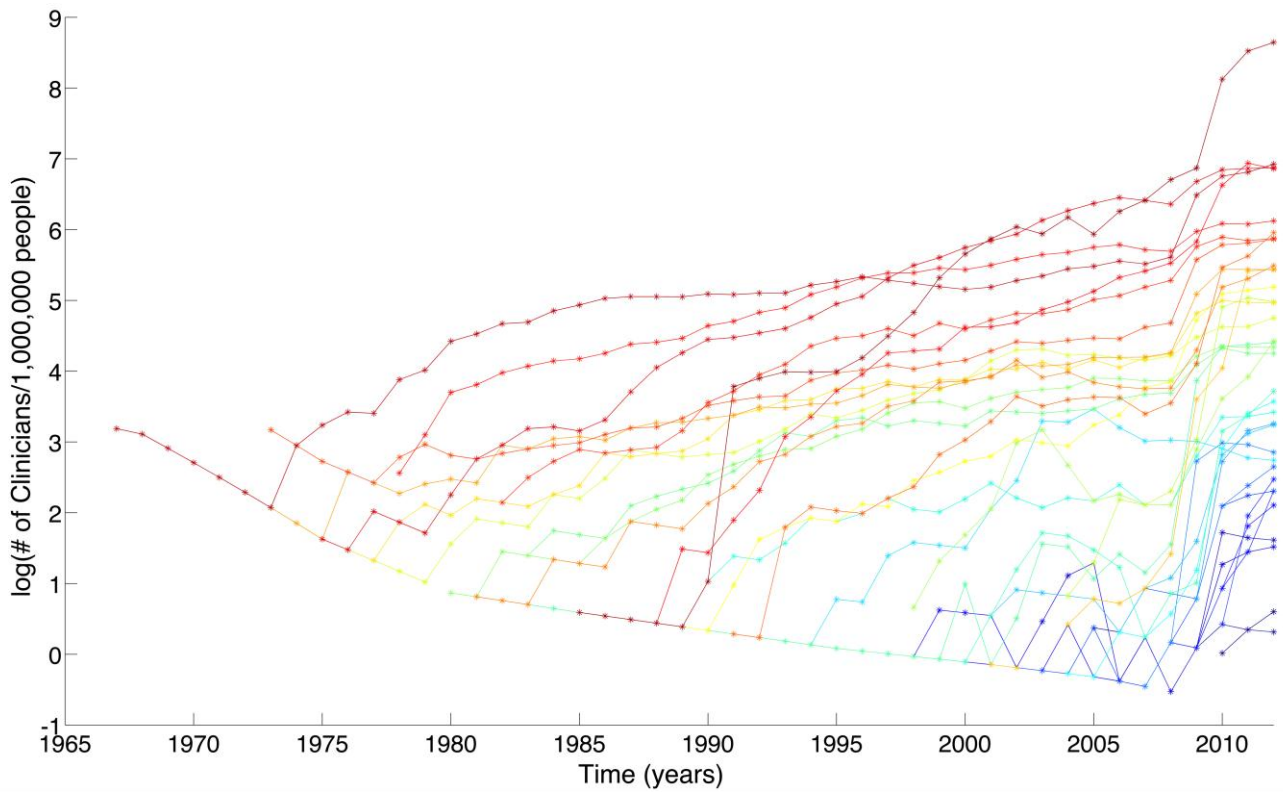


Figure 3. Evolution of healthcare professionals in Abu Dhabi 1967 to 2012.

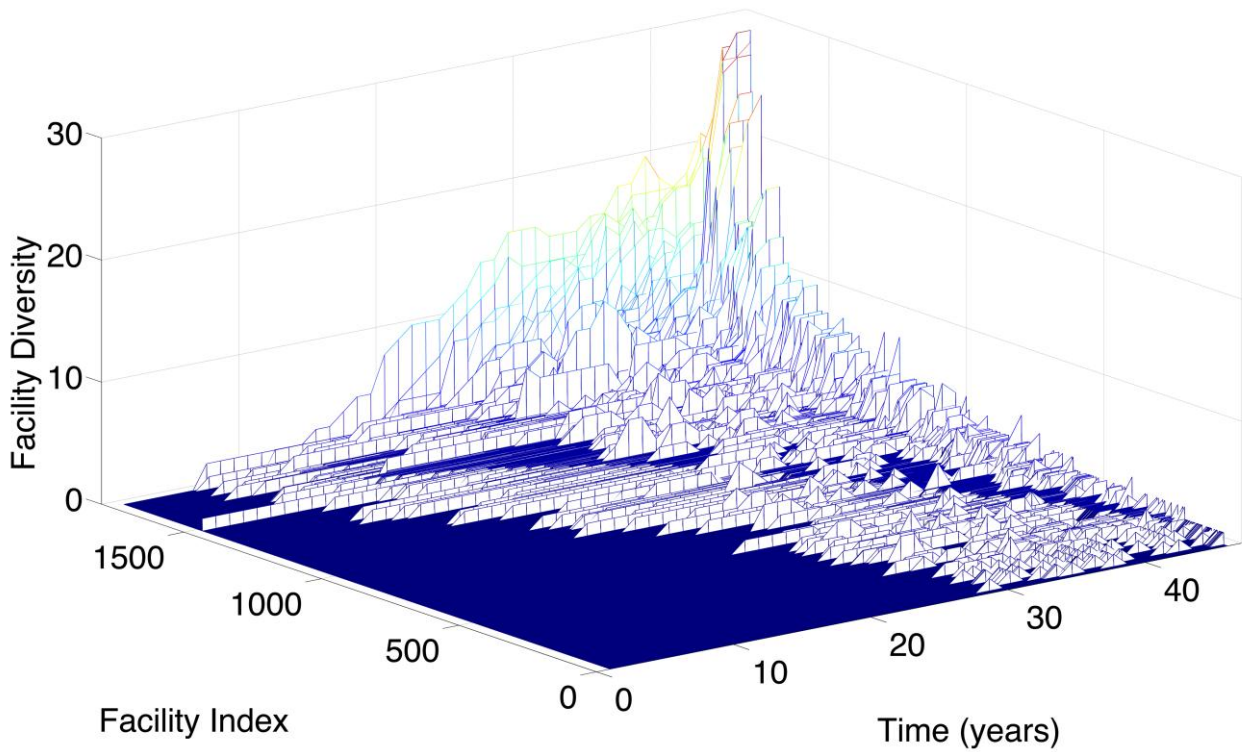


Figure 4. Evolution of the diversity of healthcare professions by facility.

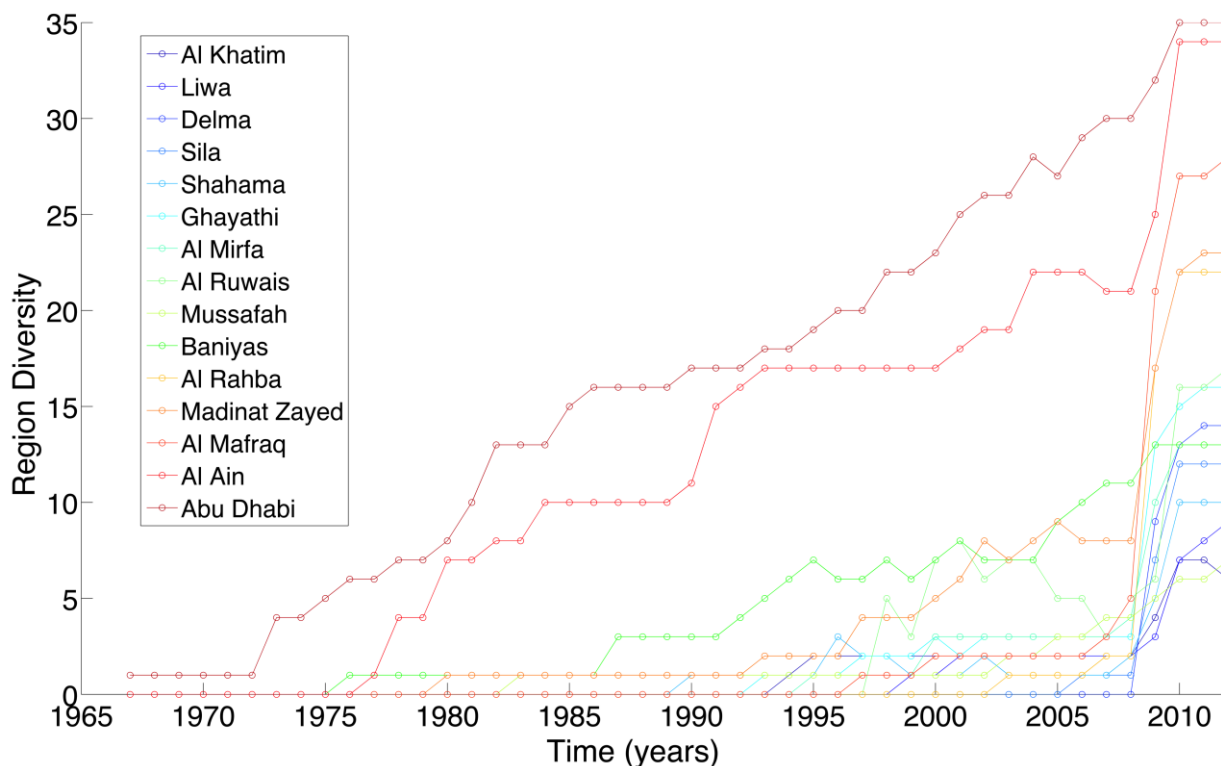


Figure 5. Evolution of the diversity of healthcare professions by region.

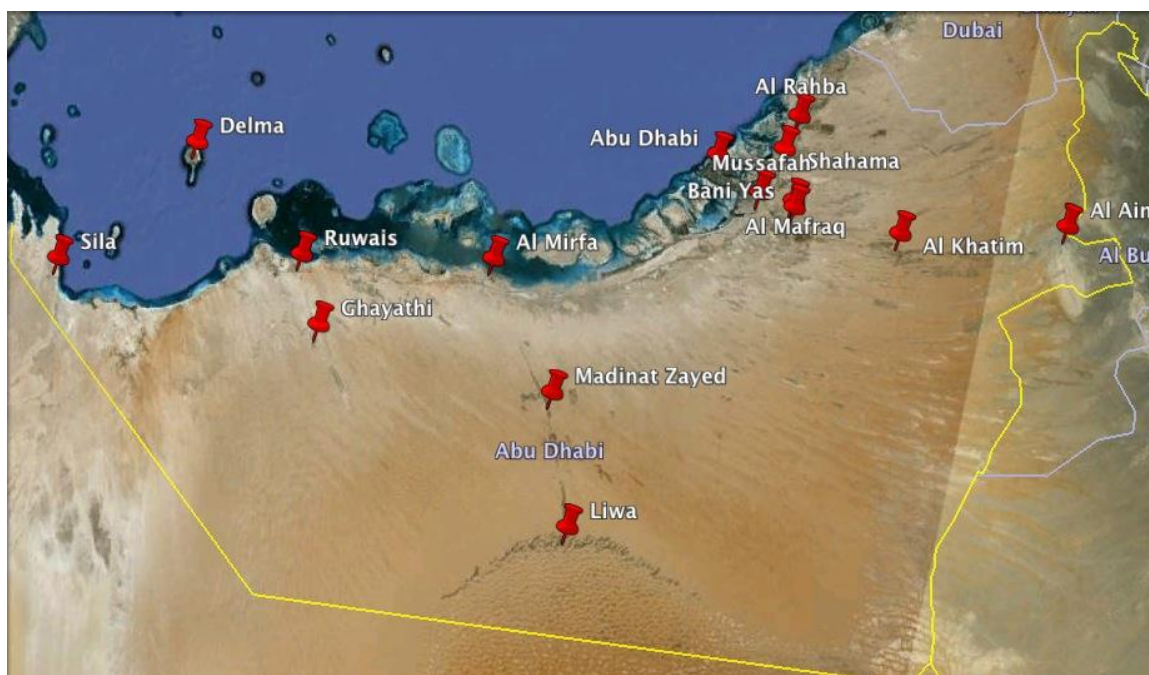


Figure 6. Map of the Abu Dhabi Emirate with the 15 regions presented in this study.

### 2.2.2 CONVENIENCE OF SERVICE

In this section, convenience of service (CoS) is assessed in terms of functional flexibility for facilities as well as regions. Figure 4 shows the evolution of facility diversity over time for the 1769 facilities. Figure 5 shows the evolution of region diversity over time for the 15 regions in the Abu Dhabi

Emirate. Figure 6 illustrates the geolocation of the regions in the Abu Dhabi Emirate.

As can be expected, Figure 5 shows the greatest region diversity in well-established regions (e.g. Abu Dhabi, Al-Ain) with much more basic services than in more rural regions. The region diversity can be described as having a linear trend; however, there appears to be a drastic increase in region diversity for most regions starting in 2009.

Table 2 presents the statistical measures of the convenience of service.

**Table 2. Statistical measures of CoS.**

Region	N	$\mu$	$\sigma/\mu$	b	1-R <sup>2</sup>
Al Khatim	19	3	0.65	0.23	0.51
Liwa	14	3	0.83	0.51	0.38
Delma	4	13	0.19	1.60	0.37
Sila	7	7	0.84	2.36	0.17
Shahama	23	3	1.18	0.29	0.62
Ghayathi	20	5	1.11	0.70	0.41
Al Mirfa	18	5	0.96	0.69	0.32
Al Ruwais	15	8	0.60	0.66	0.64
Mussafah	30	2	0.88	0.16	0.39
Baniyas	37	5	0.74	0.36	0.08
Madinat Zayed	33	6	1.17	0.56	0.33
Al Mafraq	16	8	1.34	1.80	0.38
Al Ain	36	16	0.51	0.73	0.11
Abu Dhabi	46	16	0.64	0.77	0.02

where N=# of years of data;  $\mu$ =mean region diversity;  $\sigma/\mu$ =coefficient of variation; b=the slope of the regression lines for region diversity; 1-R<sup>2</sup>=measure of volatility

The statistical measures show the most consistent expansion in healthcare services in Abu Dhabi, Al Ain, and Baniyas as compared to the other regions that undertook the 2008 regional diversity expansion.

### 2.2.3 RETENTION OF HEALTHCARE KNOWLEDGE

In this section, retention of healthcare knowledge is assessed in terms of the average number of active license times. Figure 7 shows the turnover of healthcare human resources per decade. Figure 8 presents the average license times for each profession per region.

There appears to be very different patterns of turnover between the oldest decades of the 1970s and 1980s and the newest decades of 1990s and 2000s. The older decades retained healthcare professionals very well, while, the more recent decades have progressively shorter active license times.

Pharmacy has highest average license times across the regions of the Abu Dhabi Emirate, closely followed by dentistry. These are the two professions that appear in all regions. Interestingly, the less urban areas of Al Khatim, Baniyas, Liwa and Ghayathi despite having fewer professionals fulfilled, appear to retain their healthcare professions longer than the more urban regions.

### 3 CONCLUSIONS & FUTURE WORK

In conclusion, this paper has modelled healthcare professionals in the Emirate of Abu Dhabi as a large flexible system whose functions are the healthcare professions. The physical hierarchy was modelled at the level of individuals, then aggregated to healthcare facilities and then aggregated further to the regional level. Recruiting and attrition were modelled as reconfiguration processes that allowed for a discrete-time evolution of the system knowledge base. The results showed Abu Dhabi's aggressive efforts to develop its healthcare human resources capital and maintain improving

quality of service despite high attrition rates and the quickly growing population. The results also showed a trend towards improving the flexibility of facilities; consistently in larger cities while abruptly in recent years in more rural areas. The data also showed a continually deteriorating ability to retain healthcare professionals in recent decades, especially in more urban areas. The precision of these results should serve decision-makers to develop HRM policies that stabilize healthcare quality of service, facility convenience and human resources retention where it is needed most.

The paper's results demonstrate the significant potential of Axiomatic Design knowledge bases in the application of human resources management. The knowledge base, especially when viewed at multiple levels of physical hierarchy, allows for data-centric diagnosis methods that can support multi-facility organizations in their recruiting strategies and decisions.

### 4 REFERENCES

- [1] Abu Dhabi Council for Economic Development, "Abu Dhabi Economic Vision 2030," Abu Dhabi, 2009. Available: [https://www.abudhabi.ae/egovPoolPortal\\_WAR/appmanager/ADeGP/Citizen?\\_nfpb=true&\\_pageLabel=p\\_citizen\\_homepage\\_hiddenav&did=131654&lang=en](https://www.abudhabi.ae/egovPoolPortal_WAR/appmanager/ADeGP/Citizen?_nfpb=true&_pageLabel=p_citizen_homepage_hiddenav&did=131654&lang=en). [Accessed: 12-Feb-2013].
- [2] Anonymous, "Abu Dhabi," 2013. [Online]. Available: [http://en.wikipedia.org/wiki/Abu\\_dhabi](http://en.wikipedia.org/wiki/Abu_dhabi). [Accessed: 10-Mar-2013].
- [3] Beulen E., "The contribution of a global service provider's Human Resources Information System (HRIS) to staff retention in emerging markets: comparing issues and implications in six developing countries," *Information Technology & People*, vol. 22, no. 3, pp. 270–288, 2009.
- [4] Doh J.P., Smith R.R., Stumpf S.A., and Tymon Jr. W.G., "Pride and professionals: retaining talent in emerging economies," *Journal of Business Strategy*, vol. 32, no. 5, pp. 35–42, 2011.
- [5] Farid A.M., Khayal I., "Axiomatic Design Based Volatility Assessment of the Abu Dhabi Healthcare Labor Market: Part I – Theory." In Proceedings of the ICAD 2013: The Seventh International Conference on Axiomatic Design. Worcester, MA, USA, – June 26-28, 2013 ICAD2013.
- [6] Horwitz F. M., "Future HRM challenges for multinational firms in Eastern and Central Europe," *Human Resource Management Journal*, vol. 21, no. 4, pp. 432–443, Nov. 2011.
- [7] Kapoor B., and Sherif J., "Global human resources (HR) information systems," *Kybernetes*, vol. 41, no. 1–2, pp. 229–238, 2012.
- [8] Health Authority of Abu Dhabi, "Clinician Licenses," Shafafiya Website, 2013. [Online]. Available: <http://www.shafafiya.org/dictionary/portal/>. [Accessed: 12-Feb-2013].
- [9] Statistics Center of Abu Dhabi, "Abu Dhabi Development Statistics-Population and Labour Force: Population and Demography," Abu Dhabi, UAE, 2013.

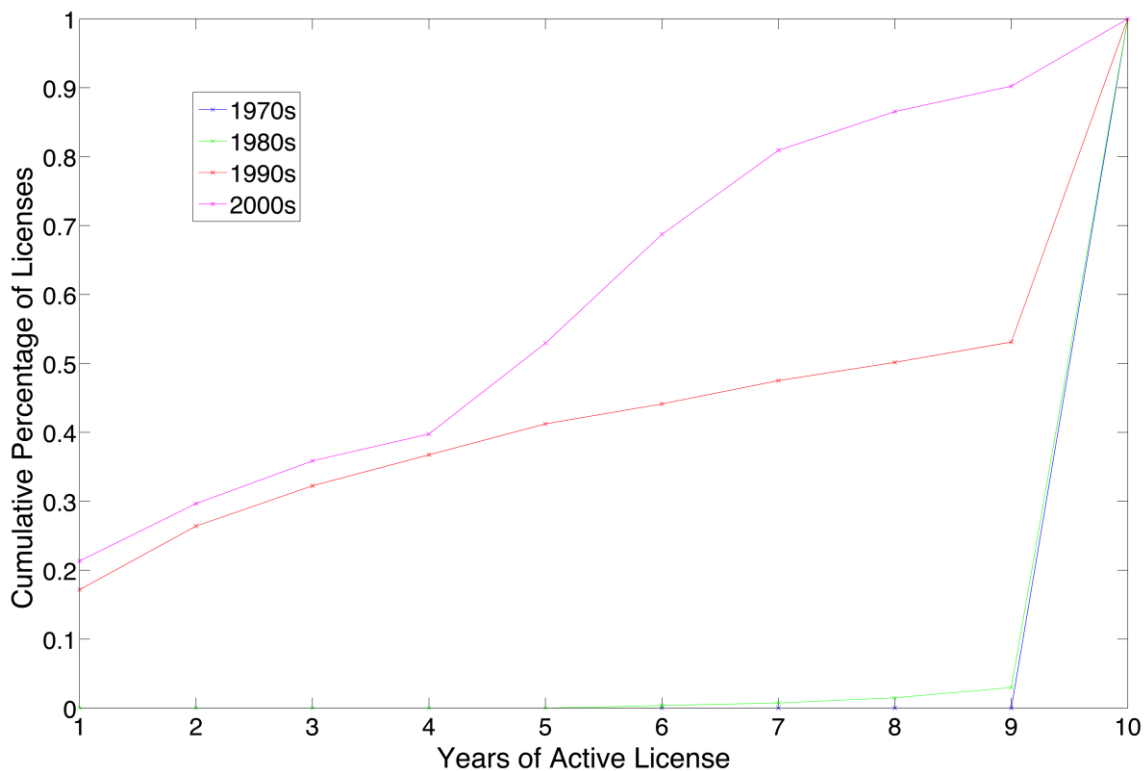


Figure 7. Turnover of healthcare human resources per decade.

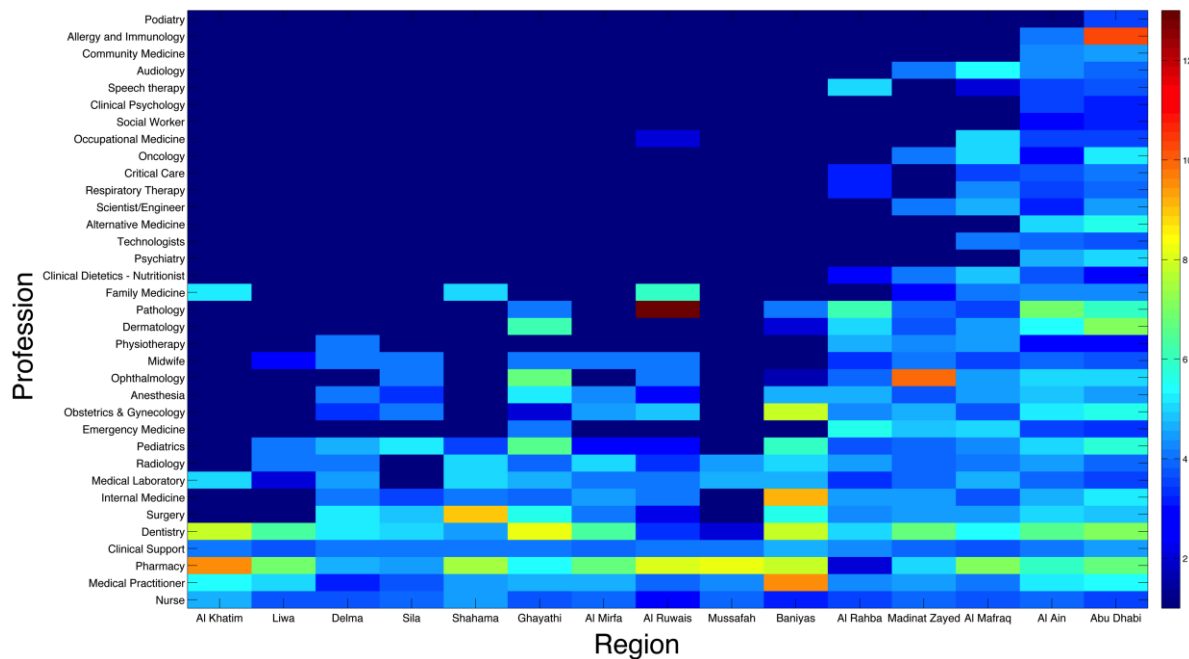


Figure 8. Average license times (in years) by region for each profession.