



Place and health infrastructure in the Gulf Cooperation Council: A systematic scoping review of GIS applications in health

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Abstract

The rising burden of non-communicable diseases is taxing health systems globally. Using data science and information systems is necessary to support public health practices. Geographic Information Systems (GIS) are key to inform and help guide public health policies related to place (*i.e.* location or where one lives) and how it affects health. Despite the increasing use of GIS for public health globally, its applications to health in the Gulf Cooperation Council (GCC) states remains largely unknown. This systematic scoping review aimed to uncover how GIS has been used in the GCC states to understand “place” and “health”. A comprehensive search of the literature was performed in PubMed, Scopus, Science Citation Index Expanded, ScienceDirect, Embase, IEEE Xplore, and ACM Digital Library during June 2020. All journal articles involving the use of GIS for human health applications in the GCC states published in English in peer-reviewed scientific journals were considered. After removing duplicates and applying eligibility criteria, qualitative content analysis was performed for 24 of 630 studies. GIS uses in the GCC states were categorized as health access and planning (n=9), health risk analysis (n=8), disease surveillance (n=6) and community health profiling (n=1). The majority of the uncovered evi-

dence in this study focused on the Kingdom of Saudi Arabia. The results of this study indicate a deficiency of published evidence regarding the use of GIS in support of public health in other GCC states. This stands to compromise planning and strategic decision making in health risk analysis, disease surveillance, community health profiling, health services provision and health interventions.

Introduction

The rising burden of Non-Communicable Diseases (NCDs), such as diabetes and cardiovascular diseases, is exhausting the treatment capacity of health care systems globally (Benziger, 2016). Costs associated with treatment and loss of productivity due to NCDs amount, worldwide, to trillions of dollars annually (Chen *et al.*, 2018). This crisis is affecting many countries globally, including oil-rich nations of the Gulf Cooperation Council (GCC): Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

For the GCC states, this burden is exacerbated by a rising demand for health care services due to sedentary lifestyles (Al-Haifi *et al.*, 2013) characterised by high caloric intake coupled with low levels of physical activity, which have led to an increase in the prevalence of chronic diseases such as diabetes (Mattke *et al.*, 2015). The burden on the GCC health care system is further complicated with increasing life expectancy and immense population growth, especially the expatriate workforce (Khoja *et al.*, 2017). This is further aggravated due to challenges associated with climate change including biodiversity loss, desertification, water scarcity, and sea-level rise (Al-Maamary *et al.*, 2017). Additionally, the turbulent oil prices are greatly affecting oil revenues, the main source for financing government expenditures, including health care (Alkhamis, 2017).

Tackling these complex challenges in light of the rising burden of NCDs related to lifestyle necessitates strong and effective public health interventions (Klautzer *et al.*, 2014), for which understanding the environmental factors and context that people live in is essential (Jokar Arsanjani, 2017; Daniel, 2008). Evidence suggests that “place” (*i.e.* where one lives, works or recreates) affects one’s health (Cozier, 2017). Therefore, connecting “place” with “health” is fundamental to understanding the contextual determinants of health care service delivery and vital for effective planning (Dummer, 2008; Cromley and McLafferty, 2011).

Using data science and information systems is a key priority for public health surveillance and tracking (Khoury *et al.*, 2016). Today, informatics tools and systems can support public health professionals and policy makers to characterise and more effectively address the challenge of NCDs via initiatives accounting for

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the contexts in which people live (Sepúlveda, 2014). The evolution of information science and technology has yielded scalable, usable informatics tools to effectively manage and analyse population health data based on disparate sources including health records, disease registries, and administrative datasets (Massoudi and Chester, 2017; Thiébaud and Thiessard, 2017). One of the most popular, and inherently useful, informatics systems available for public health practice are the Geographic Information Systems (GIS), (Fradelos *et al.*, 2014).

GIS is defined as a “computer system with the capacity to capture, store, analyse, and display geographically-referenced information” (Musa *et al.*, 2013). Leveraging GIS to spatially analyse relevant datasets can enable public health professionals to understand the spread of diseases as well as distribution and accessibility of health care services (Dietrich *et al.*, 2018). GIS have aided public health practice via several applications, including disease surveillance, health risk analysis, community health profiling, and health access and planning (Coffee *et al.*, 2012; Nykiforuk and Flaman, 2011). GIS are used to improve health care quality and efficiency through understanding the relationships between the health of the population and the geographic features of their environment (Shaw and McGuire, 2017).

Informed decisions that consider “place” and “health” together are essential for GCC states to continue to operate their health care systems in light of the financial challenges related to the treatment and management of NCDs. Despite the increasing use of GIS for public health globally (Fletcher-Lartey and Caprarelli, 2016; Jia *et al.*, 2017), its application to place and health in the GCC states remains largely unknown. Earlier studies outside the GCC reported the use of GIS in the healthcare domain in 700+ studies (Nykiforuk and Flaman, 2011; Shaw and McGuire, 2017). This systematic scoping review (Arksey and O’Malley, 2005) aimed to uncover how GIS has been used in the GCC states in relation to health. It also aimed to provide high-level policy recommendations to strengthen the use of GIS for public health planning and interventions.

Materials and methods

Information sources and search strategy

The purpose of this study was to identify knowledge gaps and uncover potential opportunities to apply GIS for public health purposes in the GCC states by following an approach similar to previous studies (Makanga *et al.*, 2016). A comprehensive search of the literature was performed in the following databases: PubMed, Scopus, Science Citation Index Expanded, ScienceDirect, Embase, IEEE Xplore, and ACM Digital Library. The search for the papers was performed over 3 days in June 2020. The strategy involved the use of the terms (Geographic Information System OR GIS OR Spatial OR Spatiotemporal OR Spatial Analysis;) AND each of the following terms: health care; application; intervention; place and health; neighbourhood and health; non-communicable diseases; exercise; physical activity. To strengthen the search strategy, Medical Subject Headings (MeSH) terms were used in PubMed as well as the use of wildcards (*e.g.* health*).

Inclusion and exclusion criteria

Only journal articles published in the English language in peer-reviewed scientific journals were considered. Publication date

restrictions were not applied. Only studies involving the use of GIS for human health applications in the GCC states were included. Papers that focused on solely environmental issues, remote sensing or development of spatial analysis algorithms were excluded. Both descriptive and comparative studies, either quantitative or qualitative, were included.

Screening process

At the initial screening, the title and abstract were examined to ensure their compliance with the inclusion criteria previously mentioned. To identify eligible articles, the title and abstract of each article returned were assessed by the researchers. Rayyan, an online application for systematic reviews (Ouzzani *et al.*, 2016), was used to help organize the abstracts. Two independent reviewers assessed each abstract against the inclusion criteria. Disagreements about inclusion were resolved by discussion and consulting a third expert researcher, when necessary. Full-text articles were extracted only for studies meeting the inclusion criteria. Figure 1 illustrates the screening process (Moher *et al.*, 2009).

Evaluation and analysis

A standardized form was used to extract data items from each of the selected studies, including authors’ names, country or geographic region, date of publication, the journal, and how GIS was applied. Two researchers coded the studies after reading the full manuscript. The researchers examined the content of the included studies to identify the categories describing the main use of the GIS application reported. The organization and definition of these categories corresponded to the earlier work of Nykiforuk and Flaman (2011). Four categories of GIS applications were considered for the purposes of organizing this review: i) Health access and planning: Studies that analyse access to health services and delivery for the purposes of planning and policymaking. ii) Disease surveillance: Studies that involve the tracking of data on the incidence, prevalence, and/or spread of disease. It encompasses studies related to disease a) mapping and b) modelling. iii) Risk analysis: Studies that involve some aspect of health risk management, including assessment, communication, and monitoring of risk relative to its impact on health. These studies are typically linked with environmental health. iv) Community health profiling: Studies that map various information regarding the health of a population in a community or geographic location. This often includes health outcomes as well as direct and indirect factors that influence health.

Importantly, these categories are not mutually exclusive, and the applications of GIS are often mixed in the real world. Categorization disagreements between the researchers were resolved via discussion or through consultations with a senior researcher when necessary.

Results

Overview of included studies

Initially, 506 articles were identified after removing duplicates, 413 studies were excluded during the screening process based on the titles and abstracts. Out of the remaining 93 studies, articles were assessed for eligibility through a full-text review because they involved the use of GIS for human health applications in the

GCC. Of these, 24 studies were included in the qualitative synthesis of evidence as depicted in Figure 1.

Qualitative synthesis of evidence

Overall, all the studies reported using GIS originated from or focused on the Kingdom of Saudi Arabia (KSA), except one in the United Arab Emirates and another one in Kuwait. While there were 20 studies that covered KSA: 11 studies were conducted on the city of Jeddah, one in each of the city of Riyadh and Makkah. At the time of the data collection, the earliest study was published in 2003 and the most recent in 2018. Table 1 presents results for qualitative synthesis of included studies.

Thematic categorization

Most studies were categorized as health access and planning ($n=9$), followed by health risk analysis ($n=8$), disease surveillance ($n=6$) and one study related to community health profiling. Many

of the included studies were not disease specific ($n=9$); the remainder focused on NCDs, including diabetes ($n=4$) and cancer ($n=2$). Other studies focused on Congenital Heart Defects ($n=1$), Cutaneous leishmaniasis ($n=1$), exogenous disease mortality ($n=1$), as well as infectious diseases such as dengue fever ($n=3$), Middle East respiratory syndrome ($n=2$).

Health access and planning

Most studies reported the use of GIS in this topic ($n=9$). Of these, all but one involved KSA; the remaining one (Yagoub, 2011), involved the United Arab Emirates (UAE). Many studies focused on access to health care facilities. Others focused on health care planning issues, such as defining catchment areas for health care facilities (*i.e.* hospitals and primary care centres) as well as studying the demand and supply of health services. One study, Yagoub (2011), focused on diabetes and hypertension.

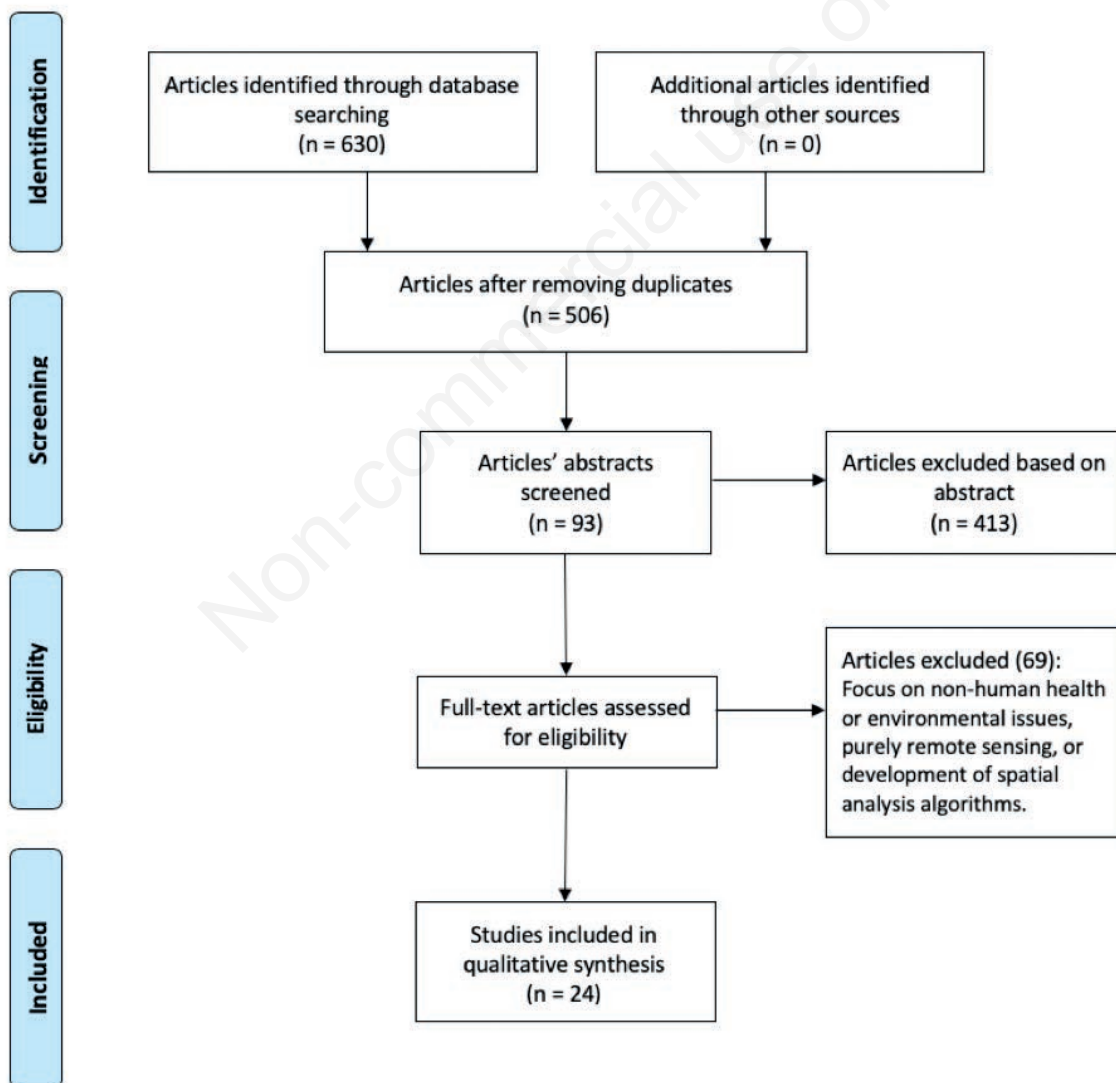


Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram depicting the flow throughout the different phases of the screening and review process.

Health risk analysis

Three of the studies in this category focused on assessing and modelling the risk of Dengue fever in Jeddah, KSA. The remaining papers investigated the outbreak of Middle East Respiratory Syndrome, cancer incidence due to exposure to polluted air, spatiotemporal distribution of road traffic crashes, and the climate effects on Cutaneous leishmaniasis.

Disease surveillance

Most studies in this category focused on NCDs including diabetes and cancer; one study focused on mapping confirmed cases of Dengue fever (Alzahrani *et al.*, 2013). In two of the studies, GIS was used to support a registry system for diabetes (Al-Rubeaan *et al.*, 2013; Subhani, 2009). In another study, the spatial distribution of exogenous disease mortality (*e.g.* infectious diseases like

Table 1. Summary of included studies.

No.	Author (Year)	Location	Disease-specific	Summary of GIS Use
Health access and planning				
1	Murad (2018)	Jeddah, KSA	N/A	Investigated accessibility to health facilities via drive-time analysis technique.
2	Mansour (2016)	Riyadh, KSA	N/A	Assessed geographic variations of service provision and accessibility.
3	Murad (2014)	Jeddah, KSA	N/A	Defined accessibility to health facilities.
4	Murad (2012)	Jeddah, KSA	N/A	Studied accessibility to health facilities.
5	Murad (2011)	Jeddah, KSA	N/A	Explored the demand and supply of health services.
6	Yagoub (2011)	AlAin, UAE	Diabetes, hypertension	Assessed the distribution of health facilities and the impact of climate conditions on health.
7	Murad (2008b)	Jeddah, KSA	N/A	Defined health catchment areas.
8	Murad (2007)	Jeddah, KSA	N/A	Explored the distribution of health demand and defining catchment area.
9	Murad (2004)	Makkah, KSA	N/A	Assessed accessibility to health facilities and patient distribution.
Health risk analysis				
10	Jamal <i>et al.</i> (2019)	Eastern Province, KSA	N/A	Overviewed key descriptive statistics as well as spatial and temporal distribution for road traffic crashes in the Eastern Province, KSA, from 2009 to 2016.
11	Al-Ahmadi <i>et al.</i> (2019)	KSA	Middle East respiratory syndrome	Analysed the spatiotemporal patterns and clusters of laboratory-confirmed MERS-CoV cases reported in KSA between June 2012 and March 2019.
12	Adegboye <i>et al.</i> (2017)	KSA	Middle East respiratory syndrome	Conducted retrospective risk-based analysis of the outbreak.
13	Jaber <i>et al.</i> (2013)	KSA	Cutaneous leishmaniasis	Studied spatial trends of infection and relationships with climate.
14	Al-Ahmadi and Al-Zahrani (2013a)	KSA	Cancer	Conducted spatial analysis of cancer due to air pollution exposure.
15	Khormi and Kumar (2012)	Jeddah, KSA	Dengue fever	Assessed risk based on socioeconomic and environmental factors.
16	Khormi and Kumar (2011)	Jeddah, KSA	Dengue fever	Modelled risk of infection based on socioeconomic parameters.
17	Khormi <i>et al.</i> (2011)	Jeddah, KSA	Dengue fever	Modelled risk of infection spatio-temporally.
Disease surveillance				
18	Al-Ahmadi and Al-Zahrani (2013b)	KSA	Cancer	Explored spatial incidence patterns of common cancers in the country.
19	Alzahrani <i>et al.</i> (2013)	Jeddah, KSA	Dengue fever	Mapped confirmed cases of infection.
20	Al-Rubeaan <i>et al.</i> (2013)	KSA	Diabetes	Used GIS as a registry system for diabetes.
21	Subhani (2009)	KSA	Diabetes	Used GIS as a registry system for diabetes.
22	Greer <i>et al.</i> (2005)	KSA	Congenital Heart Defects (CHD)	Mapped the geographical distribution of Saudi nationals with the condition.
23	Aziz (1990)	Kuwait	Exogenous Disease Mortality	Mapped spatial distribution of exogenous disease mortality according to the international classification of diseases among nationals and expatriates to help reflect the influence of various social, economic, and demographic factors on the patterns of distribution.
Community health profiling				
24	Murad (2008a)	Jeddah, KSA	Diabetes	Performed a spatial epidemiological study to explore variations and distribution of patients with diabetes.



Tuberculosis) was mapped across Kuwait's governorates (Aziz, 1990).

Community health profiling

Only one study fell into this category (Murad, 2008a). The authors reported on the development of a GIS-based epidemiological application to study the distribution of diabetes in Jeddah, KSA. The work involved modelling the spatial variations in the distribution of people living with diabetes in the city.

Discussion

Main findings

Our review revealed 24 refereed papers published in the last two decades with the majority of these papers concerning the KSA; mostly (n=7) originating from King Abdulaziz University, a public university in Jeddah. Only one paper was identified from Kuwait and another from the UAE. Coverage of the remaining GCC states was not evident in the literature indicating that the use of GIS in GCC states needs to increase to keep pace with the levels reported elsewhere (Nykiforuk and Flaman, 2011; Shaw and McGuire, 2017). Compared with current evidence, the low number of studies about the research topic in the region could indicate low levels of maturity concerning the use and adoption of GIS for health in the GCC. This could be attributed to the low numbers of research projects focused on the use of GIS to understand place and health. When compared with earlier studies outside of the GCC, GIS was used in the healthcare domain in significantly more reports than observed here for the GCC (Nykiforuk and Flaman, 2011; Shaw and McGuire, 2017).

Despite oil-based wealth, capacity-limited GCC health care systems are stressed with increasing demands for services due to a growing immigrant population, rising rates of NCDs (Mabry *et al.*, 2016; Khoja *et al.*, 2017), and road traffic injuries affecting people of all ages (Al Makadma 2017). While the GCC states have established public health systems, there is a need to better organize and integrate the various components of these systems (Khoja *et al.*, 2013). GIS is a critical enabler that aids policymakers to make evidence-based and informed location-specific interventions (Fradelos *et al.*, 2014). GIS has been used to assess the accessibility to health care facilities due to their importance on the overall population health and management of NCDs (Kapwata and Manda, 2018). GIS can play a role by offering unparalleled capabilities to aide in the integration of the public health system components via identifying, describing, analysing, predicting, and visualizing issues related to place and health ultimately informing and guiding health policies (Nykiforuk and Flaman, 2011). Examples include improved public health campaign targeting, location specific interventions based on clusters of NDCs, and healthy eating programs targeted at locations with higher rates of obesity. However, the evidence from the GCC about how GIS can be applied to guide policy and practice relative to public health is still in its infancy as indicated from these results.

Since the GCC states share many common features including similar cultural backgrounds, the rapid growth of fast-food restaurants, hot climate, and limited access to sporting venues (Ng *et al.*, 2011), the use of GIS can help better understand this context. For example, GIS can be used to identify, analyse and map unhealthy behaviours (*e.g.* smoking, excessive consumption of alcohol,

unhealthy dietary practices, and inadequate physical activities) in a particular population or specific region (Silva, 2016). Therefore, GIS can be used to decide where and how to implement and subsequently evaluate the impact of specific, targeted public-health interventions.

Our results indicate that the health access and planning category accounted for the majority of studies applying GIS. These studies explored the distribution of primary health care resources and geographic barriers to accessing them in a timely manner. The need for such studies is arguably explainable by the fact that many of the GCC health care systems today face financial hardships to maintain the status-quo and strive for higher efficiency and improved access to their health system (Alkhamis *et al.*, 2014).

Studies falling under health risk analysis naturally focused on communicable and infectious diseases such as dengue fever. Interestingly, half of the studies in this category were from Jeddah, KSA, the closest major city to Makkah (approximately 85 Kilometres away), the holy city of Islam and host of the annual pilgrimage, "Hajj". We argue that these studies were influenced by the fact that Hajj is the world's largest annual mass gathering event that brings people from across the world to a small area of about 12 kilometres that is disease-prone, which in turn promotes the transmission of infections (Salmon-Rousseau *et al.*, 2016). Hajj lasts for 5 days, however, many of the pilgrims usually travel for longer (Mughal *et al.*, 2018). Evidence denotes that mass gatherings similar to Hajj (*e.g.* sports competitions and refugee camps) can be conducive to the transmission of infectious diseases such as invasive meningococcal disease (Muttalif *et al.*, 2019).

However, as indicated by our results, few studies have investigated the impact of environmental changes experienced by the region (*i.e.* climate change and greenhouse gas emissions) on public health. Only one study identified in this review (Al-Ahmadi and Al-Zahrani, 2013a) investigated health (cancer rates) as a function of the physical environment (exposure to polluted air). Given the climate changes across the globe, and the GCC's vulnerability to increased frequency of extreme temperatures due to its hyper-arid desert climate (Ahmadalipour and Moradkhani, 2018; Alahmad *et al.*, 2020), more studies are needed to examine relationships between the environment and health. It is unsurprising that NCDs were the focus of studies in the disease surveillance category. NCDs account for more than two-thirds of total disability-adjusted life years in the Middle East and North Africa region, including the GCC (Asbu *et al.*, 2017). Interestingly, only one study was categorized in the community health profiling category and focused on diabetes (Murad, 2008a). Such studies are useful to explore the required services for particular diseases or conditions and to inform policy-based interventions.

The results of this study indicate a deficiency of published evidence regarding the use of GIS in support of public health in GCC states. More effort is needed in applying GIS technology to understand the interplay between "place and health" in the unique conditions of the GCC states. Given unique cultural and ethnic influences, place and health relationships in the GCC stand to be different from those in other industrialised nations. Understanding differences and similarities to other countries is important to undertake location-based initiatives to address urgent public health needs.

Study strengths and limitations

Significant contributions related to the use of GIS for health applications may exist but could not be captured in this study due

to being published in languages other than English (*i.e.* Arabic), or reported elsewhere (*e.g.* conference proceedings, reports, or newspaper articles). Due to the nature of scientific publications in general, there is an inescapable publication bias with a tendency to report positive results only (Wass, 2019). As a result, there might be other work that could not be included in this study because it was not published, or in the format of non-peer-reviewed technical reports. Although we applied a comprehensive search strategy, there is a small probability that some relevant studies were not captured due to evaluating their titles and abstracts only during the screening phase. Additionally, some studies do not explicitly reference the use of GIS and hence would not be detected through our methods.

Conclusions

Connecting place and health is essential to gain better and deeper insights into how the environment and place in which people live in affects their health. GIS is a key tool that has the potential to positively improve public health practices through understanding and applying interventions based on the knowledge of how context impacts health, both directly *and* indirectly, via complex interactions with intermediary factors. This study highlighted the small number of GIS applications for public health purposes across the GCC states, which compromised planning and strategic decision making in health risk analysis, disease surveillance, community health profiling and health services provision. GCC states face a myriad of socioeconomic challenges and must reform their health care systems to improve their operating environment, reduce costs and increase quality of care. GIS can be a catalyst by providing an evidence-base for effective interventions.

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