Analyze Mesopotamia ancient cities sustainability by using geomatics process in action archeology

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Abstract. Since the foundation stone was laid in 1986, Geomatics is a qualitative leap not only for survey science but also for other sciences, including Archeology. Which led to the emergence of new species, including cyber archeology, that simulates cyberspace’s archaeological reality, so shed the light on a lot of information that was previously difficult to imagine before. Alongside, the action archeology, means interaction with the challenges facing the modern world through archaeology by rebuilding the past, intends to solve the problems of the present. In this context, we will use Geomatics techniques to analyse an ancient Mesopotamian cities, for example Babylon, which considered by archaeologists the world’s finest urban city, almost 1,500 years, The aim is to discover human behavior in order to find out why the sustainable of city has been so long.

1. Introduction
In 1986, Geomatics really was developed as an academic program in the Laval Surveying Department in Quebec, Canada, as an academic program. Refer to the Canadian Natural Resources Authority website [1]

Geomatics: is the science and technology for gathering, analyzing, interpreting, distributing of geographical data and for the geographic information. Geomatics includes a wide range of disciplines that may be grouped together to create a detailed, but understandable image of the physical world and our place in it. Include: surveying, remote sensing, mapping, and Geographic information systems (GIS) and Global Positioning System (GPS).

Thus Geomatics consider as: scientific name given to science and techniques related to spatial and physical data in digital form including geographic information systems and is a further extension of the specialization of urban and regional planning specialization that includes disciplines related to spatial planning, survey engineering, architecture, geology, land and real estate development, and environmental planning, etc”[2]. For all that, it is the foundation of all sciences associated with reconstruction and location.

While Geomatics is a subject describing each method and tool for the acquisition of geographic data. From photogrammetry to land surveying, Geomatics is a scientific term in response to the modern data acquisition techniques in these fields [3]. The Geomatics therefore is a collection of disciplines and techniques that aims to provide support to detect and process unique earth and environment related data.
2. Archaeology
We will take in this search two parts of archaeology:

2.1. Action Archaeology
Archaeology is a broad science with multiple categories, but here we are not going to study archaeology, as we aim to analyse ancient cities with modern methods. Postman wrote: “whatever future we see is only a projection of the past” [4].

Archaeology science involvement or engagement with the problems facing the modern world through archaeology called “action archaeology” [5]. This term was first introduced more than fifty years ago.

“Action Archaeological research can help to solve many of current environmental and sustainable issues. In addition, action archaeology can provide positive and important contributions to the world today. Where, optimistic archaeology can make such important, positive contributions to the world today and in the future. Since this opportunity makes people understand key issues, because archaeological richer data, scientists can Armed with such better test the utility to current and future environment problems [6]. In that addition, Ruddiman see archaeologists have much greater analytical and interpretive tools that they can use to utilize, to gather all data in best collected than ever before. Therefore, he suggest looking at a much wider range of tactics and different strategies to control global warming.

Beyond to global warming, there are a great number of other current issues regard to sustaining human populations, which archaeology can provide important direct action, as well as more general advice [7].

For all that, Sabloff sees: we can use the Prospects for a Sustainable World Be Improved [8]. As well as, (Leeuw) said: “we believe that the time is right and our colleagues are willing to see an enhanced role for archaeologists in the study of contemporary environmental issues” [9].

While, the economist (Krugman), in an “Op-Ed” column, entitled realizes that “lesson” as a “Salt of the Earth” and (subtitled “A lesson from civilization’s cradle”) [10]. He discusses the process of salinization that has contributed to the collapse of Sumerian civilization and concludes: “will we avoid the fate of past civilizations, which have destroyed their environments, then themselves?”

Obviously, this is a provocative and important query. However, it deserves a much finer and more detailed discussion than has been undertaken, given that the explanation can be more complex “Op-Ed” column, and this example shows the importance of effects that cannot be ignored in resolution of current problems and widespread threats to our environment.

So, we need more accuracy and technology to analysis data to reconstruct the past, consequently we attention to cyber archaeology.

2.2. Cyber archeology
In the sense, the reconstruction of previous phenomena in more detail requires analytical development used as increasingly sophisticated applications. Undoubtedly that, evolution in various disciplines, including Geomatics, has led to the development of archaeology and the birth of new disciplines.

Includes (cyber archeology), which has become an imitation of the past and using new hardware, software, technology and disciplines to identify the past. Therefore, gradual developments allow to use a new data to reconstruct many important phenomena in the analysis of historical cities [11].

Although cyber archaeology was first applied to anthropology and communication studies in 1997, Chloe and Jones noted that the greatest role to play in developing cyber archaeology on the global scene, in California Institute of Communications and Information Technology (Calit2) and UCSD team [12].

Nevertheless, the transition from traditional archaeology to digital archaeology (cyber archaeology) started in 1999, using geographical information system and analysis database of recording data [13]. Therefore, the archaeology definition, which is now working with modern devices and techniques to
combine archaeology, various sciences, the Geomatics is one of them, has emerged as a new science known as cyber archaeology [14],[15],[16],[17],[18],[19],[20],[21],[22].

3. Archaeology and spatial organization
Information of Archeological has a duel types, where spread into: time as well as place. For that as Conolly said:” It has ability to maintain multi-layered, multi-scale and multidisciplinary geological information is a key characteristic of GIS technology, so this functionality provides GIS software perfect for Archeological data handling” [23]. As a result of that say geographic Information system is perhaps the most dynamic and comprehensive technology to interpret historical data’s spatial meaning.

That make Jiang agree with that reach that “The main value of Geographic Information System in general can retrieve data and execute spatial evaluate and mathematical models” Consequently, that the way use to explain man’s behavior in space” [24].

Studied human behavior in the past through analysis ancient cities focuses upon explain his action in space, and the reason why things happened and help archeology to understand the site without digging. For all that using extension Space syntax in GIS program for the socio-spatial analysis, it is worth mentioning. Actually, space syntax was pioneered in the year 1970 by Bill Hillier, Julienne Hanson and colleagues in Architecture of Bartlett School from London. Today, space syntax is used in research and design in many universities and professional practices around worldwide [25].

The notion of, space syntax refers to interactions between space and society. These principles support the belief that spatial layout or structure has great impact on human social activities. Over the past two decades, space syntax has been proposed as a new computational language to describe spatial patterns of modern cities [26].

According to Hillier's definition:” An axial map constitutes the least numb of longest axial lines was integration into GIS by derivation a (convex map)” [27].

In other words, Space syntax analysis (SSA) is a tool that can capture the formation of space quantitatively and qualitatively, as well as demonstrate the connection of using the space and human movement. So, it can help us to understand social organization and space [28].

As a result of this utterance, (SSA) that use to studies human behaviour in modern cities, we aim to apply this in our research in archaeology to understand human ancient behaviour that for understand ancient cities.

4. Approach of space syntax
Clearly the ancient city is the ultimate challenge in understanding complexity, and we do have a less than perfect understanding of the highly elusive dynamics of urban transformation. So we use Space Syntax as a powerful approach which descript spatial patterns, and collections of systemic approaches to urban form, networks and to complexity [29],[30] .

To analysis city has to deal essentially with two temporally continuous processes: the morphogenesis / structuration of the city, and its transformation, as expressions of social, economic and material forces, with circular effects. Space syntax deals with the (bi-dimensional) genesis and structuring of cities, throwing light on material properties and functional processes governing the emergence of spatial patterns from cellular, the dynamics of space as an aggregation leading to living urban systems as a sociospatial theory [31].

While, Space syntax is a theory and set of methods for the socio-spatial analysis of settlements and buildings of all kinds and sizes, depending on mathematical algorithms and geospatial computer technology, provide analysis of spatial configurations of all kinds and at all scales [32].

Since, Benedikt had theorised that isovist fields would correspond in the way to movement patterns of people and shown relationship in the space, it was decided to combine isovist fields with space syntax to provide a measure of how well integrated within a plan of an environment [33].

As the streets appears in the excavation results and on the geophysical maps, are closely related to the social, cultural and economic life of the city. It is quite clear that each street line has the same relationship to any other, and the street line accessibility is the same for each, in addition, the streets
are lines of sight and where the importance of a place clearly depends on how far one can see. Then the street is represented the central junction or node is the most accessible [34].

So, the axial line is an axial map of street is suitable method for analysis, with focus on topology [35]. In Space Syntax terminology it is called “axial map” [36]. The axial line and segment analysis are performed in Space Syntax, via a direct link from GIS, which receives and prepares the results once the calculations are completed. By dependent on Space Syntax Tools: Graph analysis and Attributes explorer [37]. Then presenting results of Axial map analysis by colouring the axial lines according to calculated values from red to indigo via orange, yellow, green and blue [38].

Most suitable method for the analysis of the street network is axial line analysis. In order to analyse the urban environment, we need to create its abstracted image with focus on topology. In Space Syntax terminology it is called “axial map”. The axial map of an area is drawn on the basis of open-space structure in a plan and it consists of the least set of straight lines-of-sights that pass through all the open spaces in an urban area [39].

Although space syntax analysis (SSA) has been applied to archaeological contexts for over 20 years, such studies have exploited this potentially valuable tool to analyse and compare only well-defined and fully excavated architectural space, such that clearer definition of buried architectural remains is now becoming possible [40].

With the new agency approach space syntax research gained a new way how to test the hypothesis and verify the results. Another way how to investigate the results, is the integration of SSA in ethnological studies. Studies of the settlement layouts and its correlation with social and spatial forms in 1999 by WIDLOK, together with investigation of Native American sites in 1996 by FERGUSON, and in 2005 by SHAPIRO proved SSA to be useful [41].

5. Space syntax analysis (SSA)
In the way to analyse ancient Babylonian city, use program Space Syntax in the modern version that connect with GIS v.10.3 program. Independently, By created various representations for the components of space by drawn maps of these components, represented in axial map of ancient Babylonian city dependent on satellite image and derivation an liner map from great number of data archaeological excavation and ancient template through many dictate, then the relationships of the components with each other. Within the space syntax, it involves drawing a set of lines through the plan, then created a graph using the axial lines themselves as nodes, so that each line was considered connected to others that it intersected. From graph, calculated how well ‘integrated’ each line was with respect to all the others in the graph.

6. Space Syntax analysis Parameters:
We will use in our search tow parameters of space syntax:

6.1. Connectivity index
The value of Connectivity is measured by the number of axes that directly associated with each single axis in the urban system, the increase in the number of axes that directly related to each other indicates the high flexibility in movement provided by space [42].

6.2. Integration index
Integration: in the system the number of steps took to get from one line to all other lines if it has low number the line considered integrated. The most integrated lines correlate with high levels of movement [31]. In short, the less depth a space is from the complex as a whole, the more integrated it vice versa. This parameter can be also described as to-movement potential [43]. Space syntax makes the pattern of integration visible pictorially, in different parts of the network, by giving axial lines a colour coding.

This parameter can be calculated by this equation:
Integration = \frac{D_n}{RA} \quad Local (R3) = \frac{D_n}{RA} \quad global (Rn) = \frac{D_n}{RA}

D_n = \left[ 2(n \log_2(n^2/3 - 1) + 1) \right] + (n - 1)(n - 2)^{-1}

Where Rn: is the depth in complete steps in the total depth, for all depth can calculated in the space, So Rn value cover the integration for n value of depth in standard axis net.

7. Ancient Babylonian city
Babylon was the most important city in history. It was built in square shape on both sides of the Euphrates River, the city was protected by double walls have ten gates and a canal around it, the northern part of city contained a green area, orchards and gardens that believed it was the Hanging Gardens of Babylon, as well as some royal palaces. In addition to the king’s palace, and the temple (also Jupiter Balus multi-storey (ziggurat)), are located in the city centre,”[44] ‘Figure 1’. Kotkin Rename Babylon to "The First Urban ColossusT"[44], Babylon a new capital of Mesopotamian Empire at 1900 B.C.[45]. Later about 1,500 years it has still the greatest cities, as well as has urban culture of the world’s to that time, and never have seen before anywhere [46].

When Herodotus’s wrote about Babylon, it was still a sacred place, centre of learning, largest urban city in the worlds. With a population near to 250,000, despite of it wasn’t capital, as well as its enormous spectacular architecture, “the city still surpassed in splendour any city in the world” [47].

In our search we have been identified and analyzed with respect to equity of access by two parameter of space syntax analysis: connectivity and Integration to Religious facilities as: religious temples and shrines provide access to ritual practices whose importance,Given the historical researches, to analysis services at the historical site of Teotihuacan in Mexico, that Large, densely populated ancient cities provide religious facilities access for many reasons one of them is to interact face to face that promote social integration [48].

Additionally, to all above and from Mills search on the urban fabric of ancient Babylonian city by using ancient written tablet from Mesopotamia, he Ratiocinate that:” the streets of Mesopotamian cities they were important locales for communication and public activities during which the social order, they was cemented by various social, economic, political, religious functions. For instance through their functions as a place of judgement and as a locale for processions of the gods or the ruler during religious festivals and triumphal parades”[49].
Mills said :”The Fabric of Cities: Aspects of Urbanism, Urban Topography and Society started in Mesopotamia”. As mentioned all above, we focus specifically on Religious facilities, and streets that provide easy access to religious facilities. That allow residents of densely populated cities with opportunities to congregate for a variety purposes; and represent the identity of society.

In other words, we can not the human behavior in ancient cities, for reveal some advantages and schematic ideas about the use of space in these cities. In all above we don’t want to improve how great are these cities, but we aim to argue “What makes cities great, sustainable and what leads to their gradual demise?

8. Sustainable ancient cities
sustainable ancient cities as Kotkin improve in his book The City (a global history), contends that over the past 5,000 years, from the rise of the first cities to the present day, “three critical factors have determined the overall health of cities: the sacredness of place, the ability to provide security and project power, and last the animating role of commerce.” And “Where these factors are present, urban culture flourishes. When these elements weaken, cities dissipate and eventually recede out of history.”8 Archaeological research strongly supports Kotkin’s argument [50].

About thierd element of Kotkin we don’t discuse the how great commercial of Mesopotamia cities and Algaze 2008 argue that in his study “Mesopotamia was the only region whose earliest indigenous cities may have had a significant economic component [51].
So we will study two of the sustainable factors of ancient city in Babylonian: sacredness of place appears when city have people shared sense of sacred place, civic identity, or moral order, to identify the sacredness of place we must know how easy to reach from every part of city to improve that by technical way we go to analysis connectivity of ancient Babylonian city to check the connectivity to sacredness place and urban integration that depend on integrated isovists by visual integration [52]. to dominate elements on urban space, secondly the other element provide security and project power is going to discuss by reach to gates is easy and Fort side by side by enclosed by walled cities to remarkably prosperous by historical standards.

9. Mechanism to analysis
After a brief explanation of the city and its history and based on the hypothesis of research we applied sophisticated analyses on some archaeological cities, and choose the city of Babylon as a model for application:

**Figure 1a.** Map of ancient Babylon
Plan, Inner city, Babylon [53].
9.1. Connectivity index

The different points of access to the network in this part of the city certainly play a major role, namely the Ishtar gate, the east gate and the access to the inner part of the site especially the temples site. However, perhaps other important points in the city deserved easy access as well: religious or administrative centres, public places etc.

The explain of easy access to these points, so it refer to explain the urban plan of ancient city and the eco-social system of the city. By using program ArcView GIS and active the index (AXWOMAN) we draw (axial map) to analyse Babylon ancient data as ‘Figure 2’ shown below:

![Figure 2. Map of axial line Connective of ancient Babylonian in Space Syntax](image)

By researcher result of connective parameter

The result refers to:

The results of application showed that the value of Connectivity was (9), which represent the open roads with high Connective to the axes of movement and with space that dominate to the other parts of the city, while the value of Connectivity lower to value (1) to represent closed or less connected roads, especially in the north of the city where it is represented by blue and green colour, while red represents the greatest value of Connectivity as Table below:

| No. | Line type         | Value | Mean              |
|-----|-------------------|-------|-------------------|
| 1   | Bold line         | 8-9   | strongest connectivity |
| 2   | Continuous line   | 6-7   | High connectivity lower than above |
| 3   | Dashed line       | 5     | Less connectivity |
| 4   | Double dash dot line | 3-4 | Less connectivity than above |
| 5   | Dot line          | 1-2   | lower connectivity |

*Value of line type refer to number of streets that connecting from this street.*

Of course, the main street possesses the strongest visual connectivity (in first line in Table 1) as it is much wider streets. We also have a strong connectivity for the southern gate. Strong connectivity’s also appear at the intersections of streets, a logical observation, as the crossroads benefit from relations of intervisibility on two axes. This information is all the more interesting as it enables an estimation of the orthogonality of the crossroads. We see that most of the intersections with first line
in Table 1 refer to strong connectivity, except for the street at the ramparts and street to castle. These crossroads therefore, constitute important points for access to the different sectors of the southern part of the city.

In regard to the transverse streets, (in first line in Table 1) possesses the strongest visual connectivity; this connectivity is weaker in its west extremities. The linearity and the width of the road were preserved for the largest part of its outline in order to ensure a good circulation of people and goods.

As for the longitudinal streets (second line in Table 1) and (in third line in Table 1) streets so have the strongest connectivity. Here, the visibility graph analysis reveals a hierarchy which is not easily perceptible through a classic observation of the plan. The street favoured for access to the southern gate appears to have been (second line in Table 1), which leads to Ishtar gate, which has a strong connectivity. For the eastern part, one can clearly see that tow street (five line type in Table 1), three in (in forth line type in Table 1) around the river that reflect week Street and dominates three street (in second line in Table 1) that circulation city as a stronger street that ensuring easy access to inner site of city area.

9.2. Integration index
Integration defined as the number of steps it takes to get from one line to all other lines in the system. If this number is low, then the line is considered integrated, if this number is high the line is segregated. The most integrated lines correlate with high levels of movement [54].

In short, the less depth a space is from the complex as a whole, the more integrated it will be, and vice versa. This parameter can be also described as to-movement potential.

The integration as well as choice values reflect a part of the decision process that humans undergo before moving anywhere in a system. At first moment, a human decides on an origin and a destination. This destination is the to-movement. More accessible destinations are more likely to feature as a destination and, as a result, are the most integrated, whereas the most inaccessible destinations are the least integrated. Secondly, before a human can start moving, he or she needs to select the streets (lines) that must be passed through to go from origin to destination, or the through-movement. Both integration and connectivity are measures of accessibility. Space syntax makes the pattern of integration visible pictorially, in different parts of the network, by giving axial lines a colour coding [55].

After we use the integration value tools in ‘Figure 3’ we found that:
The result refers to:
The highest value of integration near to (3) then in hierarchy the axial line from (first to fifth type in Table 2) where each axis has its own numerical value represented into minimum value (0.9) as Table 2 below:

Table 2. A Type of line of integration parameter drawn in ‘Figure 3’ above.

| No. | Line type                  | Value a                  | Mean                 |
|-----|----------------------------|--------------------------|----------------------|
| 1   | Bold line                  | 2.573-3.003              | strongest integration|
| 2   | Line with circles          | 2.143-2.573              | High integration lower than above |
| 3   | Dashed line                | 1.713-2.143              | Less integration     |
| 4   | Double dash dot line       | 1.283-1.713              | Less integration than above |
| 5   | Dot line                   | 0.854-1.283              | lower integration    |

a Value of line type refer to visual line value in integration parameter.

The (first and second lines in Table 2) represent the spaces of high integration, urban spaces with high occupancy by people and kinetic pressure on its roads, as well as, attract different land uses, mostly they are movement axis that connected different parts of city. Minimum Integration value (0.9) represented in (last line type in Table 2) that is spaces in lower or isolated integrity, do not encourage movement within them and are occupied by less people, one of them the road passing the palaces.

As a technical result we found that:
- The possibility of analyzing the behavior of people in the past and understand the ancient cities more accurately through modern software and the interaction of archeology with Geomatics.
- Get more accurate and more data so we can rebuild the past through analysis them.
- Identify behavior of the ancient people and sustainable of their culture.
- Techniques for analyze modern cities can be applied to ancient cities.

10. Conclusions:
1. Easy access to the centre of city indicates strength, hegemony and no fear from enemy. Easy access to the religious centre reflects the dominance of the sacredness on the neighbouring places, all that reflect sacredness of place and civic identity and how easy to reach from every part of city by technical way analysis connectivity and connectivity visual integration.

2. Easy access to the procession road from all parts of the city reflects the strength of their belief and adherence to their identity as well as Ziggurat dominate to other parts of the city not only on the skyline of the city, but it is having high level of easy access. So, the Cities in these regions are frequently relatively safe because of connectivity element improve the reach to gates is easy and the number of them refer to how much strong it is and reflect fair of them enemies, it works side by side with the enclosed walls and forts remarkably prosperous by historical standards.

3. The argue of culture sustainable of heritage city elements as ancient Babylonian case study reach to improve the ancient Mesopotamia have sustainable city and by ancient people thought not in them technic, we will get culture sustainable.

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