ANTHROPOGENETIC INTENSITY INDICATOR; MEASURING HUMAN IMPACT ALONG COASTAL AREAS.

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ABSTRACT

'Anthropogenetic intensity' is a recently proposed indicator, designed to calculate the volume of man-made constructions in a coastal area, according to its land uses at a specific time. The indicator's critical factors include the area of each land use, the real height of every construction, weights for each land use and their distance from the shoreline. The general objective of this paper is to provide the indicator's implementation through a series of realized case studies. Multi-temporal, multi-region and multi-land cover classification schemes are utilized to evaluate the applicability of the indicator. Such process, can contribute towards the development of a more comprehensive approach of coastal areas in the perspective of territorial cohesion, at local level and especially along non-urban areas. In addition, this indicator will be considered as successful if it could enrich the argument about the typology of coastal areas.
Keywords: 'Anthropogenetic intensity' indicator, coastal management, coastal typology, regional planning.
Stream: C
Topic: C4? Or other?

1. INTRODUCTION – RELATED WORK

Coastal areas are special arenas of human-environment interactions. Their particular characteristics attract human activities in an increasing rate. As a result, coastal environment needs to be controlled by means of policies such as spatial planning, integrated coastal area management, environmental assessment etc. Worldwide, the entire coastal system faces a rather uncertain future. [EEA 2006, UNFPA 2007]. Furthermore, there is no adequate information to cope with the real magnitude of human impact along coastal areas [UNEP 2001]. Coastal ecosystems and landscape are under severe pressure due to: tourism development, intensive agriculture, uncontrolled urban expansion etc. When these activities are developed together on a narrow coastal strip, problems tend to arise, creating conflicts. At the same time, the expected growth, particularly in tourism, increases human pressure on natural, rural and urban environments. In Hellas, as in the rest of the Mediterranean region, the process of coastal overdevelopment has been progressing for several decades. It leads almost inevitably to an artificial land cover of the natural environment.

In this context, the study/monitoring of coastal areas through indicators is strongly recommended by the international bodies devoted to coastal issues. The research on indicators as an analysis tool is wide spread along the scientific community [indicatively: Bossel 1999]. Indicators, may became essential analysis tools to convert data into information [UN 1996, OECD 1998, OECD 2000, EEA 2005]. In addition, the use of systems designed to support spatial data collection and analysis, such as remote sensing and geographic information, is almost compulsory for planners and policy makers concerned with coastal spatial planning and management [EC 1999, Longley & Batty 1996].

Indicators useful for the management procedure can be divided into several categories: environmental, socioeconomic, spatial or other special types. Numerous indicator systems have been launched until now, mainly for environmental use [UN 1996]. Those systems are classified into international, national and (rarely) local level of application. Nevertheless, they are not specialized on coastal areas, while those few related to coastal areas are rather suitable for a national or international approach, e.g. the "130 Indicators for sustainable development in the Mediterranean Region" [UNEP 2000]. Recently, many ambitious initiatives have been introduced, aiming to solve problems such as the fragmentation of datasets and sources, lack of harmonization between datasets at different geographical scales, gaps in availability etc. [Nebert 2004].

On the other hand, the land/surface dimension is absent across the previous mentioned efforts, even throughout those related to local level [UNEP 2000, NOAA 2007]. Some other efforts satisfy the previously mentioned spatial notion at local level, but they limit their interest in the islands. Concerning the Hellenic land policy, it is remarkable that until now, no national spatial/physical plan has been legitimately approved. On the other hand, there is a general lack of coordination (associated to coastal areas) between physical planning and socio-economic development.

The deficiency of detailed and appropriate catalogues concerning the terrestrial part of Hellenic coastal areas' types and the absence of the land/field dimension throughout the local level indicators gives the initiative to consider the creation of new indicators. In this framework, we are particularly concerned with the coastal abiotic environment near the seafront, in a zone up to 10 km width. In general, the main factors that have to be incorporated are: a) position and geometry, as they can expressed by the distance from the shoreline and b) the human impact along a coastal area, as it can be expressed by the area of land uses and the height of the related constructions. Such indicators should be able to facilitate:

- The classification of coastal areas at local level and the creation of a related typology.
- The modelling and prediction of the potential development dynamics of a (not only Hellenic) coastal area.

Since the above mentioned ideal indicators are to be applied along the Hellenic coasts (in the context of spatial planning procedure), they are not accompanied -for the time being- by additional parameters, applicable to other coasts all over the world, such as tidal range etc.

Towards the direction of specifically addressing coastal assessment at a local scale, this paper portrays and investigates the applicability of a novel indicator defined in [Kiousopoulos and Lagas, 2005] through a series of multi-temporal, multi-scale, and multi-area paradigms. The proposed "Anthropogenetic Intensity" (AI) is a spatial indicator that aims to measure the human impact on coastal areas, by calculating the total volume of man-made activities. It aims to reveal the degree of economic activities along a coast, the intensity of land uses and the total landscape tensions caused by human interference. In order to study and finally measure the "Anthropogenetic Intensity", the "volume" or the "mean height" of buildings and all other constructions on a coastal area, at a specific point in time, are used. The critical point is not only the selection of the appropriate land uses/covers classification but the weights with which each of the uses/covers will be endowed.

This paper is part of a broader research program, regarding the monitoring of coastal spatial changes in different scales (AMICA, "Appraisal of man-made interventions along the Hellenic coastal areas"). "The Project is co-funded by the European Social Fund and National Resources - (EPEAEK II) ARXIMHDHS."

The research questions that might arise from such a research are placed below:

1. Which are the most common land uses of a Greek coastal area?
2. What is the difference of the AI from time to time, and from region to region? Does the human impact overload the environment in coastal regions and how?
3. How implementation through a GIS based multiple imagery integration provides safe estimates of the proposed indicator?

The focus of this paper resides mainly in the second and third research questions while addressing the implementation methodology and variables to realize the AI indicator evaluation. In section 2, the AI indicator is introduced, while section 3 describes the general methodology for the realization of the indicator along with its essential design variables. Section 4, illustrates the above findings with case-studies and finally the paper concludes with a discussion about the results and future focus.

2. ANTHROPOGENETIC INTENSITY

Coastal areas attract a big variety of human activities and each (coastal) land use "annoys" - pressures the physical landscape and environment in a varying (and more or less aggravating) degree. AI aims to answer the question "How intense are the man-made activities along a coastal area?" In this context, it measures the man-made "volume" and provides information about the amount of human intervention on the terrestrial part of a coastal zone.

The geographical scales (size) of the coastal area should be corresponding to local level of approach. Because of the fact that the related coastal study depends usually on administrative boundaries, the total study area could be 20 sq. km, more or less. This area is rather equal to the mean area of Hellenic local authorities according to the old division of the administration system. On the other hand, for reasons of specific studies, very small areas could be chosen as well (e.g. coastal area of 5 sq. km).

The AI indicator along with its preconditions and theoretic approach is introduced in [Kiousopoulos and Liagas, 2005; Kiousopoulos, 2007]. At first level of approach, every land use (and probably land cover) is represented by its surface area. Secondly, its physical (mean) height becomes a critical size. At a third level, weights are used to express the real environmental “annoyance”. With those parameters AI can be calculated according to equation (1). In addition, the distance from the shoreline (as it is expressed by the integer part of the distance value in km) leads to the calculation of the AI with the following alternative equation (2). According to the second (full) version of the AI formula, all the AI values are positive inside a coastal zone of 10 km from the shoreline.

$$AI = \frac{\sum_{1}^{v} s_i \cdot h_i \cdot w_i}{S} \tag{1}$$

$$AI = \frac{\sum_{1}^{v} s_i \cdot h_i \cdot w_i \cdot \left(1 - 0{,}1 \cdot \operatorname{int} D_i\right)}{S} \tag{2}$$

where: s_i: is the area of each polygon with the same land use/cover,
h_i: is the physical (mean) height of man-made constructions, in meters, for each land use polygon
w_i : are the weights for each land use/cover,
int D: is the integer part of the distance (D, in km) from the shoreline, for each land use polygon.
S: is the the total area of all the polygons under examination,

AI reveals the degree of economic activities along a coast, the intensity of land uses and the total landscape “annoyance” caused by human interference. It is expressed in meters and this value depicts the “mean height” of buildings and all other constructions on a coastal area, at a specific point of time. The value AI = 0 m (zero meters) indicates a pure natural coastal environment, without any man-made intervention.

3. IMPLEMENTATION METHODOLOGY

The implementation outline towards the AI indicator evaluation is shown in figure (1). According to the design issues concerning the land uses to be classified, their physical heights and weights, precision requirements and temporal concerns, the corresponding region of interest and proper imagery are selected. This process of region and land use selection is not of a primary concern for this paper. The gray boxes in the figure imply an optional process according to the application at hand.

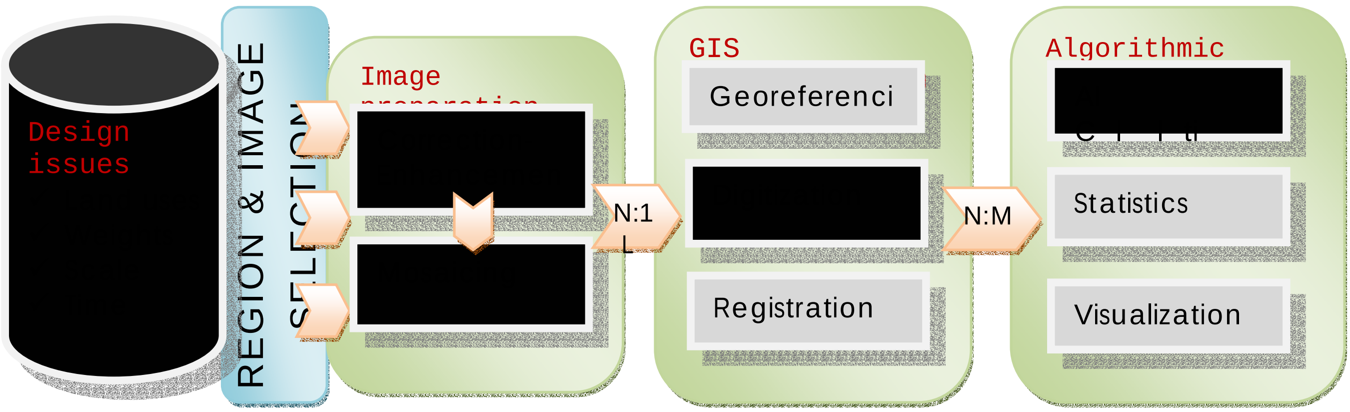

Figure 1: Implementation outline towards AI indicator calculation.

In the first processing step concerning image preparation, images are corrected due to geometry, radiometry, relief distortions, etc. Images may be of various types including orthophotos, satellite imagery, aerial photography, multi-spectral imagery, google-earth® screen views, etc. Image enhancement is also performed to provide more comprehensible images. Mosaicing or image to image relative registration, ties the various images to form the input for the second processing step termed as the GIS classification process.

The enhanced sets of images are inserted into the GIS environment. Georeferencing is not required but it is highly recommended in order to be able to register more information related to the geographic region of interest. The digitization process defines polygon type closed regions for each land use, including roads, buildings, etc.

According to the land use classification and desired detail, the digitizing expert estimates the precision for delineating each use, based on image interpretation. E.g. for the digitization of a region at a 1/200000 scale, residential areas rather than single houses are of a primary concern. An additional step may require an image to image, or rather a mosaic to mosaic registration as an optional step to better register sets of images depicting the same region in different times. A series of exports, including raster, vector, ascii, simple statistical, and query products may be created for further analysis.

This final "algorithmic products" processing step includes the actual AI indicator calculation, statistical and visualization products. Simple calculation of equations (1) and (2) upon the land-use classification map provides single values for each set of images - mosaic. In addition, vector to raster exports are fed to designed algorithms to e.g. visually and statistically depict differences between various temporal instances. Under this perspective, the thematic land use map enriched with the weighted AI heights through a designed algorithm is converted into a synthetic digital elevation model termed as "Anthropogenetic Intensity Elevation Model" (AIEM). Imagery or land use raster maps are inserted into image processing software and are consequently draped upon the AIEM to produce 3-dimensional realistic views where elevation is analogous to human intervention, while flying simulations are created for visualization and comprehension purposes.

The different types of scaling regarding the AI indicator estimation can be classified according to the land uses, selected imagery and digitization scale. Land use or "design" scale refers to the project definition scale under which our process develops the indicator and becomes the design and target scale which accompanies the AI indicator for a specific study. It is intrinsically estimated through research efforts, defining possible land use detail and assigning it to a theoretical scale [Corine, 1994; Lilesand and Kiefer, 1993]. On the other hand, the imagery, or "medium scale" is the spatial resolution of the images including or not all errors due to geometry, radiometry, georeferencing, relief and other distortions. Finally, digitization or "product scale" is the detail under which the GIS developer digitizes and extracts the land use parcels, and includes errors due to registration, storing, extraction and further processing of the produced classification map. Product scale should be higher than design scale and is expected to be less than the medium scale. Beyond the various scale concerns, the variables that play an important role for designing and evaluating the AI calculation include the size of the region under speculation and the temporal step between epochs of interest. Modifying these variables, multi-scale, multi-temporal and multi-spatial size feeds can be evaluated as conceptually demonstrated in figure (2).

Figure 2: a) Time, b) spatial resolution, c) spatial scale - region size, d) land use scale and e) digitization scale.

4. CASE STUDIES

The area considered to test the competence of the AI indicator is the coastal area of Navpaktos, Hellas. Based on the availability of data, coastal nature of the region and recent development the case study area selected resides in the greater region between Navpactos and Antirrion part of Aetolia-Akarnania, a rather rural prefecture. From the design point of view this set of experiments includes the calculation of the AI indicator on the same region under two epochs, considering a larger region and under several design/land-use scales.

4.1 Multi-temporal consideration

In the first set of experiments referred as "Navpaktos I", the evaluation and comparison of an area of 4,2 sq. km and its shoreline of 5,2 km, was conducted between two epochs between 1985 and 2007. The land uses shown in table 1, correspond to the Corine Land Cover Nomenclature (level 2 and 3) including slight variations to honor Greek particularities.

LAND USES	**NAVPAKTOS I**	**NAVPAKTOS II**

	height (m)	Weight	height (m)	Weight
Continuous Urban Fabric Area	15,0	2,0		
Discontinuous Urban Fabric Area	10,0	2,0	5,0	1,0
Tourism	10,0	2,0		
Industry	8,0	4,0		
Highway	4,0	4,0	4,0	4,0
Local Road	3,0	3,0		
Dirt Road	3,0	2,0		
Permanent Crops	3,0	0,5		
Annual Crops	1,0	0,5		
Olive Groves	3,0	0,5		
Open Spaces with little or non vegetation	1,0	0,5		
Shrubs and/or herbaceous vegetation	1,0	0,5		
Trees	3,0	0,0	3,0	0,5
River	0	0,0	0,0	0,0
Seashore	0	0,0		
Sports	15,0	2,0		
Horticultural-Cerials-Pasture Land			1,0	0,5
Forests			10,0	0,0
Industry- Deposits			8,0	4,0
Secondary- Rural Roads			3,0	3,0
Forestal – Dirt Road			3,0	2,0
Ports			10,0	4,0
Intermediate cities			15,0	2,0
Villages			5,0	1,0
Individual Buildings			10,0	2,0

Table 1: Land uses and related parameters.

4.1.1 Image Preparation

For the first epoch, imagery comprised from a strip of 5 aerial photos acquired from the Mapping and Cadastral Organization of Greece (OKHE) with the following attributes: a) scale: 1/6000, b) date: 2-5-1985, c) size: (30x30)cm and d) color: Grayscale. The second set of images was extracted from Google Earth ® with the following characteristics: a) scale: 1 meter pixel size resolution, equivalent to 1/5000, b) date: 2007, c) size: one block exactly as needed and d) color: RGB. The hardcopy aerial photos where scanned and processed in digital image processing software to reduce errors, enhance eligibility and construct their mosaic (figure 3).

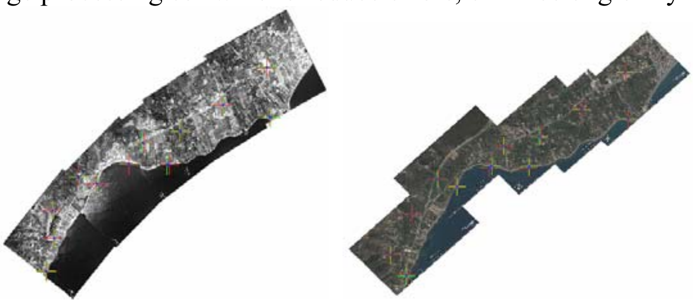

Figure 3: Mosaic of aerial photos of 1985 from OKHE and satellite imagery of 2007, from Google Earth.

4.1.2 GIS classification

Step 1: In the GIS software a geodatabase of Navpaktos was created, where several feature classes of polygon type were created in order to host each land use. The geodatabase was georeferenced in the Hellenic geodetic coordinate system 1987 (EGSA87).

Step 2: Image georeferencing was conducted using known control point coordinates (GCPs) in EGSA87 system acquired from maps of the Greek Ministry of Agriculture, of 1/5000 precision. Many control points distributed throughout the imagery, along the coast and in the overlap regions.

Step 3: Digitization and creation of feature class polygons based on image interpretation and land uses produced thematic maps. After digitalization, the topology of the created maps was resolved to diminish possible polygon errors.

Step 4: Finally, several products were created in order to aid further processing. Each thematic map was extracted from vector to raster form. Other products included ASCII conversions and calculation of land use area and distance from the shoreline.

4.1.3 Algorithmic Products

Using data analysis software based on land use areas, weights and the AI indicator equation (1) we acquired a value of **4,10 m** for 1985 and **8,70 m** for 2007. There is a modification of **4,60 m**, between 1985 and 2007 which shows an **112%** rise of the AI intensity, during a period of 22 years. As shown in figure (4), the change of the areas and the appearance of new land use by the time (e.g. tourism) or the disappearance of some others (e.g. trees) is obvious. Furthermore, feeding the raster maps into a sequence of designed algorithms in a programming environment, a set of (x, y, z) coordinates were created, where z portrays the AI heights – weights. Using the created elevation model in an image processing – remote sensing software along with the mosaic or thematic map a series of 3-dimensional surface views and videos were created for enhanced visual comprehension.

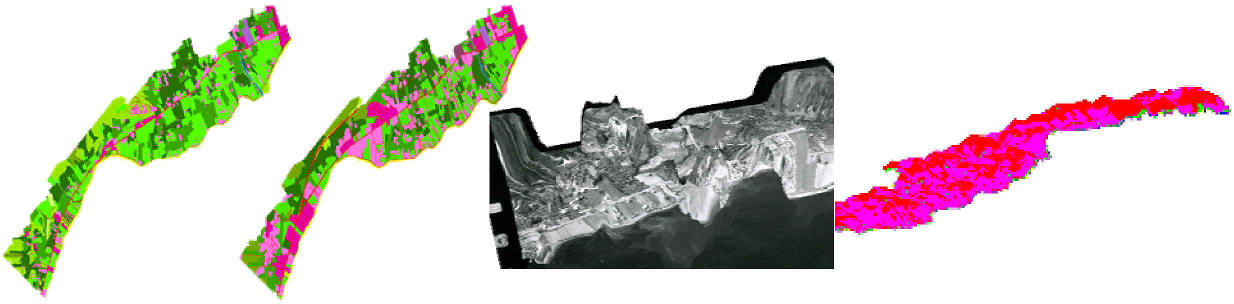

Figure 4: Digitized thematic maps of 1985 and 2007, aerial photograph draped on the AIEM and the region in a 3-dimensional view.

4.2 Multi- sized region consideration

In the same region of Navpaktos, a greater area of 185,4 sq. km and its shoreline of 21 km termed as “Navpaktos II” was considered (figure 5), incorporating the area of the first experimental set. AI indicator was tested only for the year 2007, and an image from Google Earth 2007 ® was used under a scale of 1/25.000. The critical difference between the two cases is the different set of land uses and the related weights that have been used (Table 1). On the other hand, the rest of the procedure remained similar. The AI value for 2007 was **1,41m**. The area used in the second case study was considerably larger than the first case study. Nevertheless, the extra space of the second case study is mainly occupied by forests, trees and Horticultural-Cerials-Pasture Land which do not contribute to the AI. As a result, the indicator of AI is significantly smaller than the first case study.

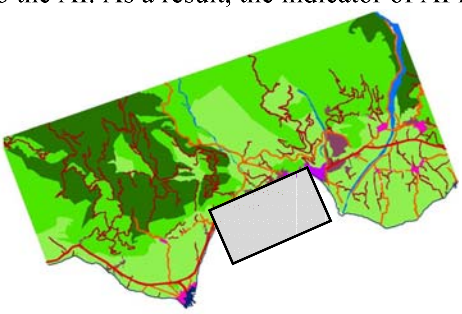

Figure 5: Thematic land use map of Navpaktos II region and highlighted Navpaktos I region.

4.3 Multi-design scale consideration

Decreasing the land uses from 16 to 6 (first and second level of CORINE land cover nomenclature), we acquire weights and heights shown in table 3. Each height and weight is calculated as the mean heights and weights used in "Navpaktos I" of 16 land uses.

LAND USES	NAVPAKTOS I		NAVPAKTOS II	
	height (m)	Weight	height (m)	weight
Artificial Surfaces	11,6	2,4	8,6	2
Transport	3,3	3	5	3,3
Agricultural Areas	2,3	0,5	2	0,5
Forests and semi-natural areas	1	0,5	10	0
Water Bodies		0	0	0
Seashore		0	0	0

Table 2: Land uses and corresponding heights for 6 classes.

AI value for 1985 was **4,67 m**, while in 2007 IT was equal to **10,04 m**. The modification of **5,37m**, between 1985 and 2007 corresponds to an increase of **115%** of the man-made activities intensity.

Further decreasing the land use classes from 6 to 3, classes and corresponding heights are shown in table 3.

LAND USES	NAVPAKTOS I		NAVPAKTOS II	
	height (m)	weight	height (m)	weight
Human Impact land uses(Artificial Surfaces, Transport, etc.)	7,5	2,7	6,8	2,6
Agricultural Areas	2,3	0,5	2	0,5
Nature(Forests and semi natural areas, water bodies, seashore)	0,3	0,2	5	0

Table 3: Land uses and corresponding heights for 6 classes.

The AI value for 1985 was **4,08 m**, while in 2007 it was equal to **8,37 m** showing a **105%** AI increase. It is obvious that through these settings, decrease in land uses from 16 to 6 did not altered the increase rate of the AI, while further decrease of land uses to 3 gave a slightly different AI increase rate. The produced thematic maps are shown in figure 6.

Figure 6: Thematic maps, after reduction of land use classes to 6 and 3.

For the greater Navpaktos region as presented in section 4.2, six (6) land uses generated an AI of **1,89**, while three (3) land uses gave an AI of **1,97.**

It is noted that the land use level scales utilized correspond to a design scale of more than 1/75000, while digitization scale was based upon the 1/5000 – 1/25000 images. Thus, the actual digitization scale remains considerably higher than the design scale and the relations of the three scales discussed in section 3 are preserved. The measured values of the AI are encouraging. Indeed, the two values of NAVPAKTOS I as well as their difference correspond to the obvious man-made activities shown throughout the figures.

5. CONCLUSIONS – FUTURE WORK

AI aims to enrich the spatial planning procedure and to promote the spatial notion into the indicators sets. The advantage of this indicator is that it can be used to measure the total stress from man-made activities exclusively for coastal areas. It incorporates the spatial concept and it seems to be very functional for planners and local authorities. The most important and valuable conclusions can derive from the differences of AI values at the same coast at two different epochs and at different coasts of the same epoch. The magnitude of those differences can be used as an alert to activate already established mechanisms in order to control the land exploitation and organize the related reactions, in the context of coastal land use policy.

There is no doubt that the idea of Anthropogenetic Intensity needs further development. The ongoing research will be considered as successful, if the proposed indicator can promote the coastal identity and enable the comparison among all coastal areas. In parallel, the following two critical questions should be answered:

- Could Anthropogenetic Intensity be "the one" indicator to assess sufficiently the total pressure on a coastal area and base (some) decisions on it?
- Could coastal typology be based on Anthropogenetic Intensity?

Several case studies are already in progress, in order to test AI indicator in different places (Hellenic coastal areas). Through these attempts, all involved parameters are changed, in order to improve the reliability of the AI formula, e.g., the scale of approach (in order to examine if the AI indicator could be adjusted to different geographical scales), the set of land uses and the related weights, the depth of the examined coastal area, the source of the digital data etc. Finally, remote sensing based semi-automatic classification is being tested to promote an easier digitization and AI calculation process.

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