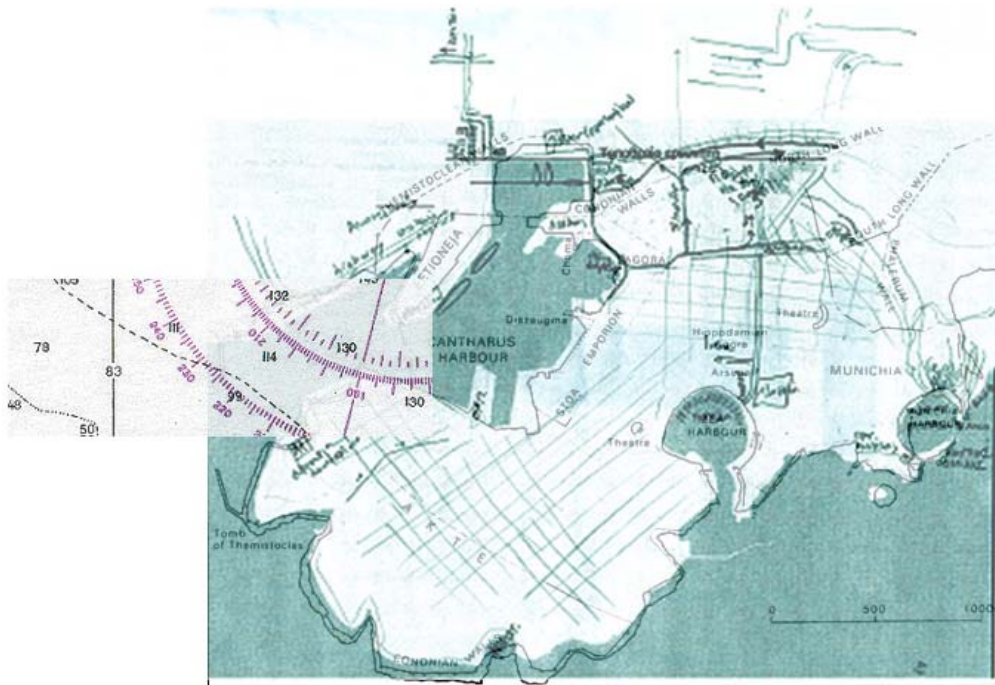University College of London

Bartlett School,

MSc Built Environment, Advanced Architectural Studies

The implications of the "palimpsest" of the grids of the main city of Piraeus on creation, transmission and application of cognitive knowledge.

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Abstract

This research aims to investigate the local rules and constraints which govern the individual behaviours of the pedestrians of Piraeus, Port of Athens, Greece, by examining the relationship between the spatial syntax of mental representations and the spatial syntax of the environment. The overlaid urban grids of the main city create a "palimpsest" on which the mental spatial models of the users are constructed. Invoking three different *criteria*, three experiments were conducted in the city's key-locations – *Peraiki Coast*, *Mikrolimano* and *Sotiros Dios St*. The first criterion concerned people's *access* to spatial information (target locations that are out of sight vs. locations with visual access). The second and the third criterion concerned the *types* of the reference systems; egocentric vs. allocentric and global vs. local scale respectively. The configurational, geographical and topological characteristics of the peninsula provide rather an ambiguous sense of the ease or difficulty of the cognitive understanding of the site. Using *syntactical tools* of space syntax methodology (axial maps, visibility graphs, isovists) and *descriptive statistics* (mean averages, deviation averages, z-test, central limit theorem test) in the experiments, the close relation between the concepts of intelligibility, spatial configurations and visuo-spatial representations is demonstrated. The information provided to the pedestrians has an impact on their wayfinding and navigation processes. It is concluded that the cognitive knowledge of the pedestrians of *Piraeus* (etymological "the place over the passage") is created, transmitted and applied by the geometrical forms of the city, the morphology of the local visual field – which involves issues of configuration and scale of a space layout – and by topological relations. The most ancient grid although it contains the elements that have shaped the city's contemporary urban space, are not easily recognisable by "strangers", but they are mostly found in *"inhabitants'"* internal representations. On the contrary, the elements from the modern times are more frequently cited and they appear to dominate the cognitive model of all users.

Keywords: spatial cognition, wayfinding, experiments, cognitive maps, mental maps, allocentric, egocentric, spatial syntax, space syntax.

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To my beloved parents

Chapter 1: Introduction

Human navigation and **wayfinding** in general and in built environments in particular have been studied extensively in the past in *Architectural Design* (T. Gaerling, E. Lindberg, and Maentylae, 1983,) in *Artificial Intelligence* (B. Kuipers,1978; D. McDermott and E. Davis, 1984, D. Leiser and A. Zilbershatz, 1989,), in *Environmental Psychology* and *Behavioural Geography* (Gibson, 1950; Piaget and Inhelder, 1967; Hart and Moore, 1973; Garling and Golledge, 1989; Garling and Evans, 1991) and in *Cognitive Science* (A. Siegel and S. White, 1975, R. Golledge, 1992; S. Hirtle and B. Heidron,1993).

The effectiveness and the efficiency of navigational/wayfinding performance involve precision and comprehensiveness of knowing "where we are" (i.e. orientation) and they are determined by individual's **spatial cognition**. Cognition is about knowledge: its acquisition, storage and retrieval, manipulation, and use by individuals. Broadly construed, cognitive systems include sensation and perception, thinking, imagery, memory, learning, language, reasoning and spatial problem solving. The spatial knowledge of an environment is depicted in a **cognitive map**, i.e. mental model of the relative locations and attributes of phenomena in a spatial environment.

The complexity, and variability of both the urban environment of **Piraeus**, **port of Athens** (and the biggest port of South-eastern Europe), and the wayfinding abilities (familiarity, spatial acuity, attentional capacity) of its pedestrians, poses a methodological challenge to separate out and study the specific aspects. The overlaid urban grids of the main city create a "palimpsest" on which the mental spatial models of the users are constructed. This thesis tends to set out the relationship between the *spatial syntax* of the physical environment of the centre and the *spatial cognition* of its *users*; the latter are the *Locals*[1] *(the "inhabitants")*, the **Regional Locals** (partially "*strangers*") and the **Visitors** *(*pure "strangers"*)*.

The methodology of this research is based on the syntactical tools of **space syntax approach** and the statistical tools of **descriptive statistics**. Space syntax is a set of techniques (Hillier B. and Hanson J., 1984) for explaining the substantial proportion of the variance between aggregate human movement rates in different locations in both urban and building interior space. In recent studies linking *space syntax* with *cognitive science*, it

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[1] The three different groups are going to be explicitly described in the Chapter 3 of the paper.

has been claimed that the spatial configuration encourages or impedes aspects of human activity through spatial cognition and subsequent movement behaviour (Hillier B., 1996a; Kim, Y. O., & Penn, A. 2004). In this research, Space Syntax's analytic methods (axial analysis, Segment analysis – angular, metric and topological –visibility graph analysis, isovists analysis) are used in order to analyse the qualities of the spatial configuration of the centre of Piraeus. Furthermore, the significant correlations between attributes of its spatial configuration and the observed pedestrian movement patterns are supported *statistically* through various statistical methods. Mean averages, deviation averages, the central limit theorem and the z-test are the some methods that have been used in this thesis.

The research is structured in **four** parts. The *first* part (chapter 2) presents the growth of the centre of Piraeus through the distinct historic phases and a theoretical review of how people cognise the built environment while navigating through it and what kind of knowledge (information) they may retrieve and use in a wayfinding performance.

The *second* part (chapter 3) presents the research methodology, the description of the survey procedure/subjects and the three criteria that have been set for the conduction of the three experiments that have been carried out in Peraiki Coast, in Mikrolimano and in Sotiros Dios St. The experiments were conducted within *egocentric* and *allocentric* frames of reference that are analytically explained in the next part.

The *third* part (chapter 4) describes the Experiments individually, the survey that has been carried out, the data analysis, the syntactical approach and the key findings from each experiment.

Finally, the *fourth* part (chapter 5) attempts to summarize the findings of the regression analysis and to present the conclusion of this research. It is concluded that the way people navigate through Piraeus is not only guided by "metric" distance, but also by "geometrical" and "topological" laws that underlie the urban grid. The cognitive knowledge that individuals create and apply in order to navigate through the centre is actually a progressive learning and constant "upgrading" of the structure, the entities and relations of space. The syntactical and the geometrical properties of the spatial configuration of the centre, play a direct role in the acquisition and the interpretation of knowledge of the environment. The configurational regularity of the palimpsest's overlaid grids, act like the background against which the geometrical forms, the morphology of the local visual field and topological relations are sought.

Chapter 2: Literature review

Before presenting the literature review, it would be important to describe the context of references and bibliography that has been used in this thesis. The relevant literature could be considered as a **tripartite scheme**; the *first part* concerns the Greek and the foreign bibliography that is relevant to the history of Piraeus and the socio-economic situation that has shaped the city's space through various historical circumstances. It also includes the bibliography that concerns the terms and names of the locations (ancient and current) that have been used in this thesis. The *second part* involves the bibliography regarding the cognitive issues and the methodology of the research. The *third part* concerns a more general bibliography about the use and the language of space and it could be regarded as the link between the two aforementioned parts.

2.1   The passage of time

2.1.1   Historical growth of Piraeus

The city of Piraeus or *Peiraeus* (Modern Greek: Πειραιάς *Peiraiás* or *Pireás*, Ancient Greek / <u>Katharevousa</u>: Πειραιεὺς *Pireéfs*[2]) is a city in the periphery of Attica, Greece, located south – west of Athens (Fig.1). The city has a history of many centuries and has, in fact, been inhabited since about 2,600 B.C. An insignificant settlement at first, Piraeus was to become the Main Port of Athens at about the beginning of the 5th century B.C. (493-483 B.C.) Since the classical period (Pericles's "Golden Century"), Piraeus was established as the major naval and commercial port, and it was planned by **Hippodamus** (Appendix A) of Miletus, the most famous Greek urban theorist and city planner. Aristotle tells us that Hippodamian ideas on both "the nature of the ideal city-state and its layout were based on the division of the population and its territory; thus, he divided his ideal town into three classes, and he separated urban land into three types" (E. J. Owens, 1991, p.60). The *scholion*[3] of

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[2] Merriam-Webster's Collegiate(r) Dictionary, Tenth Edition, copyrighted 2002 by Merriam-Webster, Incorporated.

[3] [med.L., ad. Gr. "σχόλιον" <u>SCHOLION</u>, f. "σχολὴ" <u>SCHOOL</u> *n.*[1] Cf. F. *scolie* fem. (from the med.L. plural) in sense 1, *scolie* masc. in sense 1b.] **a.** An explanatory note or comment; *spec.* an ancient exegetical note or comment upon a passage in a Greek or Latin author. **b.** In certain mathematical works (e.g. Newton's *Principia*): A note added by the author illustrating or further developing some point treated in the text. Source: Oxford English Dictionary online, Draft Revision, June 2002

Aristophanes's *Knights*[4] 328 also makes both an illuminating and relevant comment regarding the planning of Piraeus. The **flatter central part** of the Piraeus was laid out in **a regular grid** (Fig.2), with four main streets oriented northeast-southwest, and a number of main streets (five?) oriented northwest-southeast. These seem to define a series of large parcels of land, about 250 x 275 m, which were subdivided by smaller streets into house blocks (Von Eickstedt, Hoepfner and Schwandner, 22-50, Garland, 1987, p.144-45).

Fig. 1 Piraeus is the port of Athens, located in the south-west part of Attica.

<http://dictionary.oed.com/cgi/entry/50215566?query_type=word&queryword=scholion&first=1&max_to_show=10&single=1&sort_type=alpha>, [Accessed 30/07/2006].

[4] Aristophanes "Knights" (schol. vet. on 328). Trans. Tassos Roussos. (1994). Publications Archaia Elliniki Grammateia.
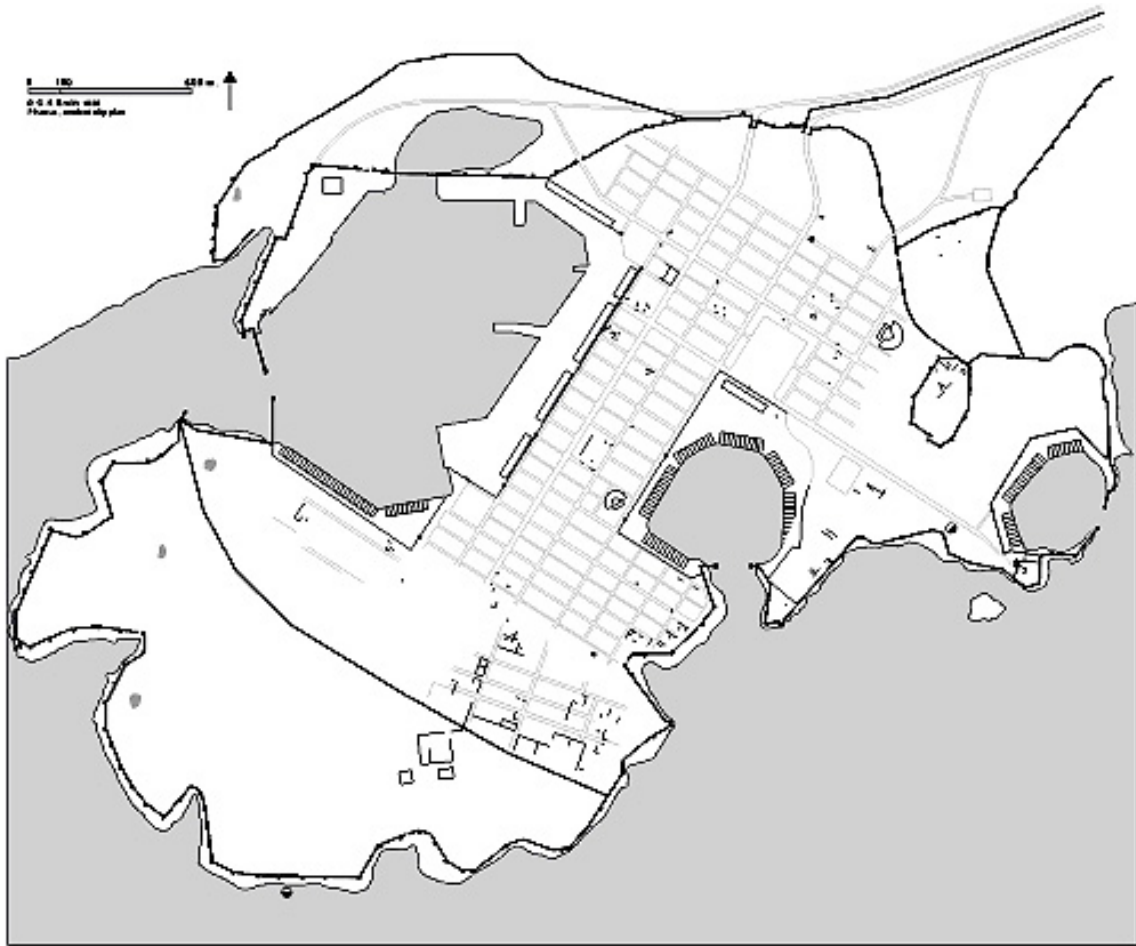
Fig. 2 Piraeus, Fortification Walls (Appendix B) (Date: ca. 480 B.C. - 390 B.C. Period: Classical) and city planning from Hippodamus. Plan copyright C. H. Smith 1989, based on Moutopoulos (artist, 1973), in N.D. Papachadzi 1974 98-99 fig. 25.

Piraeus was connected to Athens through the **Long Walls**[5] (Fig.3), which were built during the time of Themistocles, after his victory at Salamis, in the mid-fifth century B.C (Plutarch, Lysander 14. 4; Xenophon, Hellenica 2. 2. 3). The Long Walls were completed under Pericles. The two walls were 1 stade[6] (160 meters) apart, 6000 meters long, and 20 meters high. The **three natural harbors** (Zea and Munychia on the East and Kantharos on the West) of the "barren peninsula" (Steinhauer G. 1998, p. 9) were used for grain ships, merchant ships, and warships (Fig.4). Through the two well fortified Long Walls, from Piraeus

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[5] The names of the locations (mainly the ancient ones) that are being used in this research follow the terminology used in (Steinhauer George, 1998).

[6] Stade= <u>STADIUM</u>: An ancient measure of length; An ancient Greek and Roman measure of length, varying according to time and place, but most commonly equal to 600 Greek or Roman feet, or one-eighth of a Roman mile. (In the English Bible rendered by *furlong*.) Source: Oxford English Dictionary online, Draft Revision, June 2002 <u><http://dictionary.oed.com/cgi/entry/50235659?query_type=word&queryword=stade+&first=1&max_to_show=10&sort_type=alpha&result_place=1>,</u> [Accessed 30/07/2006].

to Athens, Athens was connected to the sea and could receive supplies during the Peloponnesian War. After the Athenians surrendered to the Spartans in 404 B.C., the Long Walls were destroyed. Konon rebuilt them in 393. They were destroyed again by the Roman general Sulla, in 86 B.C.
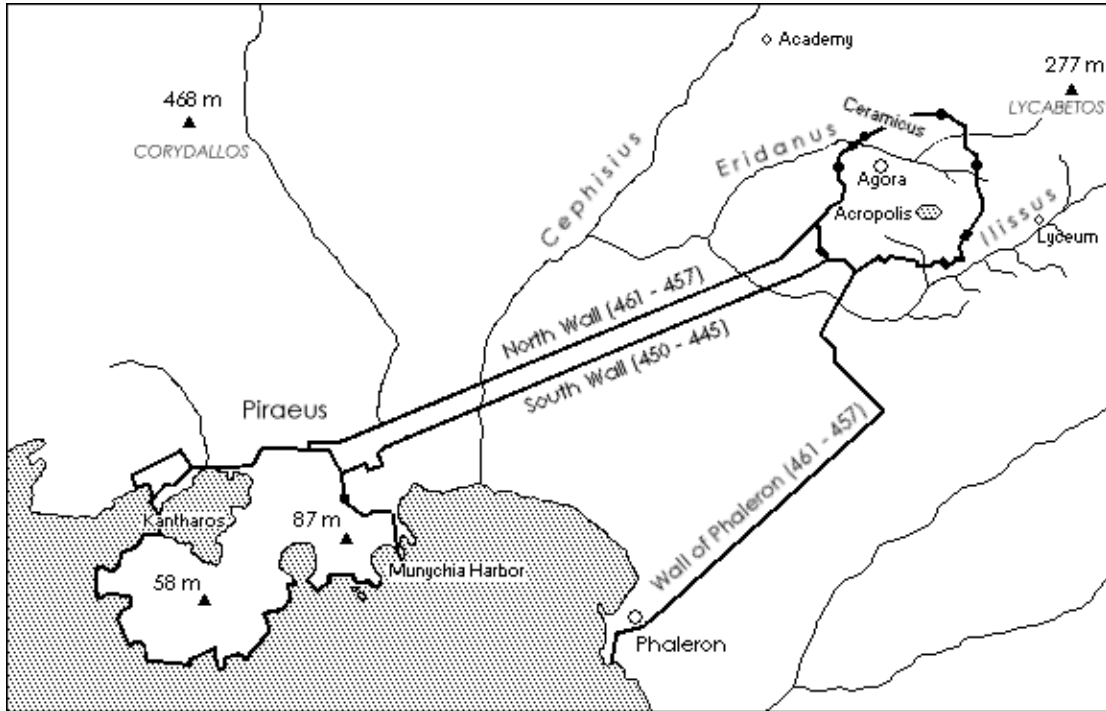
Fig. 3 The connection of Piraeus to Athens through the Long Walls in ancient times.
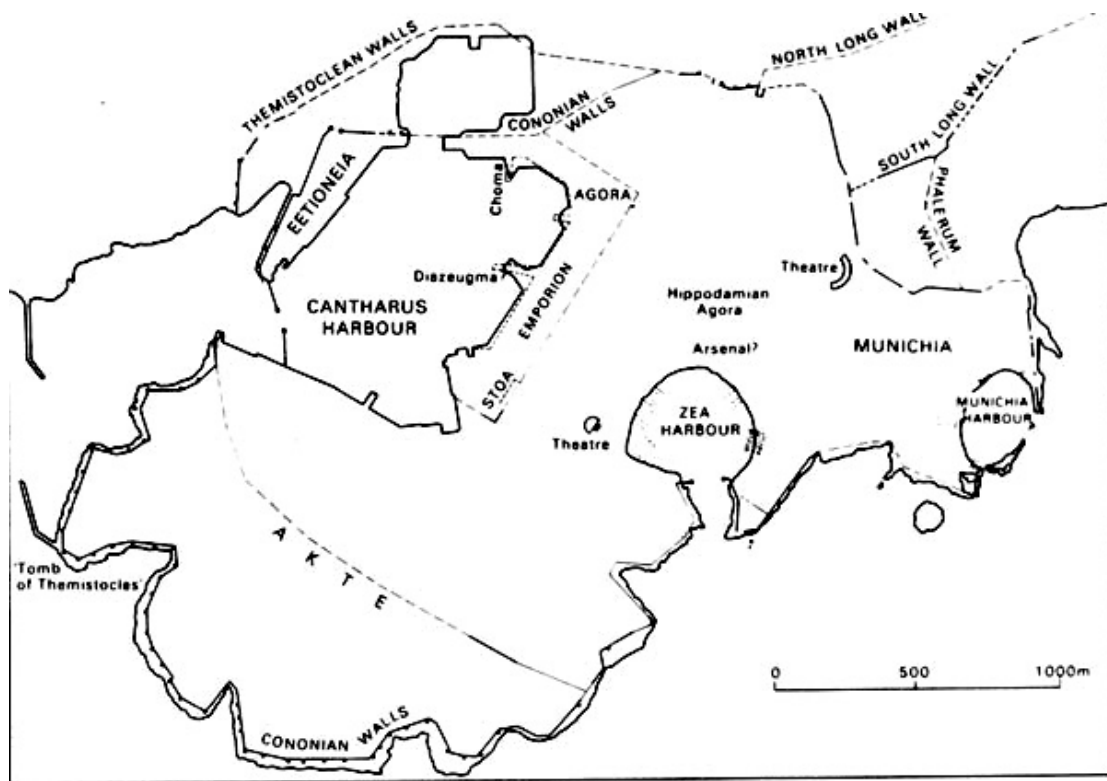
Fig. 4 Map of ancient Piraeus according to Judeich (1931).

The first centuries **After Christ** and the **Middle Ages** were dark ages for the city of Piraeus. "For around 15 centuries there was no city" (Chatzimanolakis J., 1996) The planning of the *modern* city and the harbour of Piraeus was accomplished by the architects **Kleanthis, Schaubert** and **Klenze** after the proclamation of Athens as the capital of the newly formed Greek state in 1834[7], using the Hippodamian system of town planning once again. In the beginning of the 19th century the **industrial growth** of the city provoked a dynamic demographic growth[8]. From 1834, **Hydriots**, **Chiots** and immigrants from other places occupied Piraeus. (Appendix C) Therefore, during modern times, the urban center of Classical Piraeus was expanded and occupied the whole peninsula, which has a topography rich in height variation (Fig.5). Piraeus contains both the rocky heights of the peninsula and of Munychia (which is now called Kastella). The latter is located at the highest point in the whole peninsula, rising 91.44 m. above the sea. The variation in height is suggested that adds to cognitive problems as the lines of sight are interrupted; the pedestrians have to reckon the height of the hills in the process of wayfinding.

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[7] The Municipality of Piraeus was founded in 1835, with first mayor the Hydraean Kyriakos Serfiotis.

[8] "The beginning of the industrial growth of Piraeus is discussed in the report of the city's provost G. Angelopoulos, in 1852. Angelopoulos mentions the function of a shipyard and a corderia of the French Clement which was established in 1837...there was also a soap factory, a winery, a silk factory, a glass factory, a coachbuilder's". (Belavilas N., 2002).

North of Main Harbour

Munychia
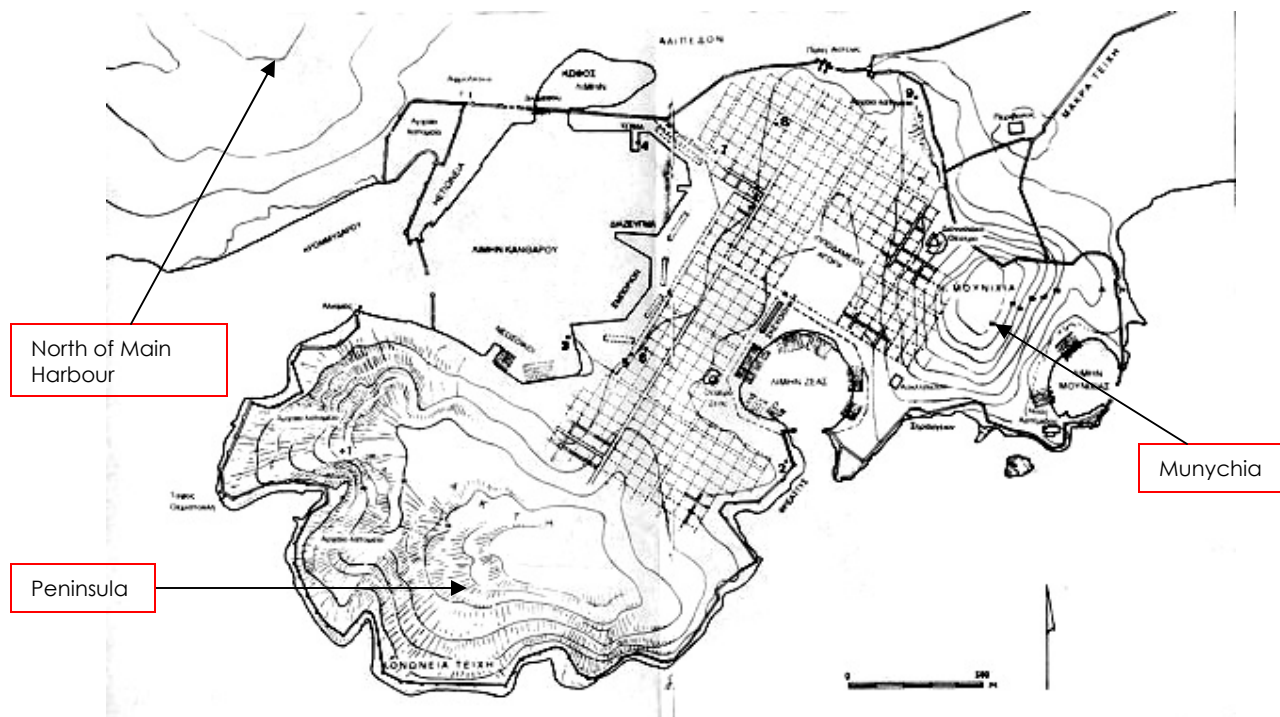
Peninsula

Fig. 5 The rich topography of Piraeus entails in cognitive difficulties while wayfinding; the hill in the north part of the Main Harbour, the height of the peninsula and the hill of Munychia (Kastella) interrupt the lines of sight.

2.1.2   The "palimpsest"

This urban environment which has a long history through centuries is constructed in multidimensional terms. For B. Lawson "spaces form important constituent parts of what we might call the 'settings' in which we behave" (B. Lawson, 2001, p.23). However, as each city is a "mosaic of social worlds" (Robert Park, 1952, p.81), these behavioural settings comprise both the physical and the social environment. The consecutive *occasions* that happen in a **place**[9] give rise to **spaces**, as they have built into them "some way of acknowledging or even measuring the passage of time" (B. Lawson, 2001, p.29). This passage of time embodies the *knowledge that shapes the city* "which arises from the

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[9] Michel De Certeau (1986), in his work on *spatial stories*, makes a distinction between "*place"* ("*lieu")* that organised, planned and policed and its elements are distributed in relationships of coexistence. "*Spaces"*(*"espaces")* are determined by actions of historical subjects, temporal, ephemeral, full of meaning; they exist only when one takes into consideration vectors of direction, velocities and time variables. In the view that follows the work of Bill Hillier and his work *Space is the Machine,* "Places are not local things. They are moments in large-scale things, the large-scale things we call cities. Places do not make cities. It is cities that make places. This distinction is vital. We cannot make places without understanding cities. Once again we find ourselves needing, above all, an understanding of the city as a functioning physical and spatial object" (Hillier, 1996, p. 151).

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pervasive intervention of the **human cognitive subject** in the shaping and working of the city" (Hillier, B., 2003, p.1).

In this way, the urban environment of Piraeus could be characterised as a "**palimpsest**" of urban grids, a multi-layered record of streets, squares and passages that are being explored by the everyday pedestrians – both inhabitants and visitors. Everybody, while *walking in the City* read, it "as a **text** but, crucially they also write it" *(*Michel de Certeau, 1984, Ch VII). When people navigate through this "palimpsest", they create and simultaneously receive multiple cues that use for updating their spatial position and orientation. In order to *find their way* from one place to another, the pedestrians' behaviour is affected by miscellaneous concepts/mechanisms, such as sensation, perception, belief, attitude, knowledge, reasoning, intentionality, information processing, learning, image, affect, personality, language, and so on. During every route the pedestrians become "ordinary practitioners of the city" (M. De Certeau, 1986) who live "down below", inhabiting the city; "they are *walkers*, *Wandersmänner[10]*"(M. De Certeau, 1986), who use and transform space, defying the geometrical discipline imposed by urban development. When someone is "reading" the urban text (i.e. the city) of Piraeus, he/she discovers the local characteristics such as topographic coincidences, architectural heritage, archaeological findings, the historical importance of specific sites, patterns of public space, legends and local myths that are all parts of the city's *genious loci*[11] ("spirit of place").

As Tadao Ando quotes "*genious loci* is plurality, existing simultaneously on different levels. It moves through the land, the air and water as well as through history. These streams are constantly colliding and converging" (Tadao Ando, 1992). The "hidden" dynamics of local history and myths of Piraeus create a vibrant, multi-layered urban place; among the most important spatial components the following could be distinguished (Appendix D):

- The ancient **Main Gate** of Piraeus
- The **Eetioneia Gate**

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[10] De Certeau is using the tem "*walkers*" – "*Wandersmänner*" (i,e. the "wanderers") because according to him "walking" is an ordinary but transformative way of using space, For de Certeau, walking is a form of enunciation, akin to a speech act. Like figurative language, which strays from literal meaning, walking, introduces new significations, ambiguities, and voices into an existing spatial system.

[11] "Genius loci" is a term literally translated as "spirit of place", the unique nature of a given site in space. Christian Norberg-Schulz refers to Genius loci as "…that "opposite" man has to come to terms with in order to dwell in a particular place" (Christian Norberg-Schulz, 1980).

- The **ancient Wall** in the peninsula of Piraeus (**Konon Walls**)
- The **Hellinistic Theater at Zea**
- The **shipsheds of Zea**
- The **Arsenal (Skeuotheke) of Philo**

Also:

- The **Municipal Theatre**
- The **Train Station**
- The **Tower** (the skyscraper) of Piraeus
- **KERANIS Tobacco Factory**
- **Elais olive oil Factory**

2.2   Spatial cognition and Wayfinding performance

As mentioned before, to **find the way** from one place to another, is a task that involves the act of traveling from origin to destination plus the act of spatial problem solving. Therefore, the task encompasses a person's cognition of his/her environment; cognition of the different spatial components of the "palimpsest", in order to use them for updating his/her spatial position and orientation.

Spatial cognition concerns "the study of knowledge and beliefs about spatial properties of objects and events in the world. Cognition is about *knowledge*: its acquisition, storage and retrieval, manipulation and use" (Montello, D. R. 2001, p.14771). Spatial knowledge changes over time, through processes of learning and development. The two aforementioned processes change not only a child's spatial knowledge and reasoning, but that of an adult as well. Both *physical maturation* and *perceptual and navigational experience* (Cornell, Heth, & Alberts, 1994; Golledge, Klatzky, & Loomis, 1996) influence the development of the knowledge. The acquisition, the development and the application of knowledge establish different movement behaviour, and therefore discrete approach in a *wayfinding* task.

The human reasoning and decision-making involved in spatial behaviour has gained insight from the work of **Kevin Lynch** (1960), who argued that "images" (Glossary of terms) of cities guide people's behaviour and experiences of those cities. Lynch is also attributed to be the first who used the definition of wayfinding in the aforementioned book, "The Image of the City", where he describes wayfinding as based on "a consistent use and

organisation of definite sensory cues from the external environment". Lynch determined the concept of *place legibility* (Glossary of terms) by identifying five distinct elements in the city: **Paths** (shared travel corridors e.g. streetscape), **Edges** (linear and enclosing but not functioning), **Districts** (large spaces with common features), **Nodes** (major points where behaviour is focused) and **Landmarks** (distinctive features used for reference). All these elements could be considered as wayfinding "devices". However, although Lynch In his definition of wayfinding stresses the importance of our senses to the act of wayfinding, yet omits to describe how it is that we use this information.

Arthur and Passini in (Arthur and Passini 1992), describe wayfinding as "all the perceptual, cognitive, and decision-making processes necessary to find one's way", a definition which suggests that the process of wayfinding has cognitive and perceptual aspects, combined with recognition of the necessity to make reference to the act of spatial problem solving. Therefore, according to them, wayfinding is a two-stage process during which people must solve a wide variety of problems in architectural and urban spaces that involve both "decision making" (formulating an action plan) and "decision executing" (implementing the plan).

Concerning the knowledge we use while navigating, **Norman** in (Norman D, 1988) makes a distinction between two different kinds of knowledge that are both essential in our daily functioning; *"knowledge (or information) in the head"* and *"knowledge in the world"*: "Because you know that the information is available in the environment, the information you intentionally code in memory need to be precise enough only to sustain the quality of behaviour you desire. This is one reason people can function well in their environment and still be unable to describe what they do. For example, a person can travel accurately through a city without being able to describe the route precisely" (Norman D, 1988).

If we consider these two types of knowledge in the context of the act of **wayfinding**, as Ruth Conroy-Dalton suggests in (Ruth Conroy-Dalton, 2001), "one of the difficulties inherent in examining the 'knowledge in the world', is that we can readily identify some visual cues, yet find it difficult to identify others for which we have no concept or no name", while 'knowledge in the head' may be regarded "as strategy, deliberate actions/decisions, and applications of past experience and memory" (Ruth Conroy-Dalton, 2001, Ch.2 p.27). However, since 'knowledge in the head' is obviously the more difficult of the two areas of knowledge to gauge, recent researchers examine "secondary sources of information only - what people *say* they did or are doing" (Ruth Conroy-Dalton, 2001, Ch.2 p.28).

Through the discussion of different and often complicated definitions of the term "wayfinding", a definition that seems to satisfy all aspect of the task is the following:

"Wayfinding is the act of traveling to a destination by a continuous, recursive process of making route-choices whilst evaluating previous spatial decisions against constant cognition of the environment." (Conroy-Dalton, 2001).

2.3   Mental Representations and Cognitive Maps

According to Lynch, the definite sensory cues from the external environment form its mental image which we use as a reference when performing wayfinding tasks. The aforementioned image of the city could reveal the degree of legibility of an environment. The latter could be apprehended over time as a pattern of high continuity with many distinctive parts clearly interconnected and defined by a spatial syntax.

This **spatial syntax** of the environment consists of properties that include location, size, distance, direction, separation and connection, shape, pattern, and movement. Using the spatial syntax, people form their own "texts" of a place, **mental representations** of the spaces whether from navigation or from maps or from descriptions or from a combination, that allow them to arrive at their destinations and to give directions to others with some success. Therefore, with the help of various sources, such as signs, maps, descriptions, and images, people integrate perceptual stimuli into an internal, consistent representation of the environment. Coined by Tolman in a 1948 paper to refer to internally represented spatial models of the environment (Edward C. Tolman, 1948), these internal representations are called *cognitive maps*[12]. The term "cognitive map" has been extendedly studied and analysed. One definition that seems to satisfy all aspect of the task is the following: A cognitive map: "... is a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of phenomena in his/her everyday spatial environment" (Downs and Stea, 1973, p.9).

Cognitive maps store conscious perceptions, but also automatic (subconscious) encodings[13] of spatial relations to help determine an individual's current position, where certain objects are in surrounding space, and how to get from one place to another. This type of internal representation is also known as a "subjective structure", a "mental map", a

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[12] For the mental representations, the term "mental map" was used by Kevin Lynch in "*The Image of the City*" (1960). In his research, Lynch gives an account of a research project, carried out in three American cities. (Los Angeles, Boston and Jersey City with comparisons to Florence and Venice) The project resulted in the evolution of the concept of legibility depending on the people's "mental maps'". In the present research this term will also be used.

[13] Passing by a specific building multiple times without consciously taking note of its presence will nevertheless be reflected in a human's cognitive mapping. (Attnaeve F.and Farrar P.D., 1977).

"cognitive collage" (Tversky Barbara, 1992), a "cognitive configuration" (Golledge R. G., 1969), and an internal GIS (geographical information system) (Golledge R.G., Scott. M. Bell, and Valerie Dougherty 1994).

Cognitive maps are representations of sets of connected places, which are systematically related by groups of spatial transformation rules (O'Keefe John and Nadel Lynn., 1978). O'Keefe and his colleagues have proposed that the physical implementation of the cognitive mapping system in the brain is located in the *hippocampus* which contains neural units that fire when an individual is in a specific location within an environment. The hippocampus is the central brain structure implicated in spatial navigation and the neuronal substrate in which a "cognitive map" of the external environment is created (O'Keefe and Dostrovsky J., 1971)

Although many cognitive theories of space influential in the built environment emphasise the *position of the subject* at the centre of the map, in the cognitive neuro-science the distinction between **allocentric** (object to object) and **ego-centred** (body to object) models of cognition is a crucial matter. The ***allocentric navigation*** enables humans and animals to generate an internal representational system based on the Cartesian or Polar coordinates of the environment. (Klatzky, R. L., 1998). Therefore, a topographical representation of the environment is generated by using multiple relevant landmarks of their surroundings. These external cues are used to establish a complex representation which would include the distance between them and to the individual's own relative position. The ***egocentric navigation*** implies using other available information such as internal cues, motor input, vestibular and directional information. The egocentric representation makes use of a polar coordinate system in which the origin is at ego and the reference axis is ego's axis of orientation[14]; it conveys the location of a point by egocentric distance and the egocentric bearing[15] (Klatzky, R. L., 1998). In the following diagram (Fig.6) the basic terms are explained.

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[14] "The axis of orientation of an object is a line between points on the object that defines a canonical direction in space. Not all objects have an axis of orientation; for example, an object that is radially symmetrical has none. The axis of orientation of a person within a space is aligned with the sagittal plane". (Klatzky, R. L. (1998).

[15] Technically, *heading* is your facing direction, *course* is your movement direction and *bearing* is the direction to a landmark relative to some reference direction. For a terrestrial animal, heading and course are the same unless the animal is not moving "forward", in the direction it is facing (Gallistel, 1990; Loomis et al., 1999; Montello, 2005).
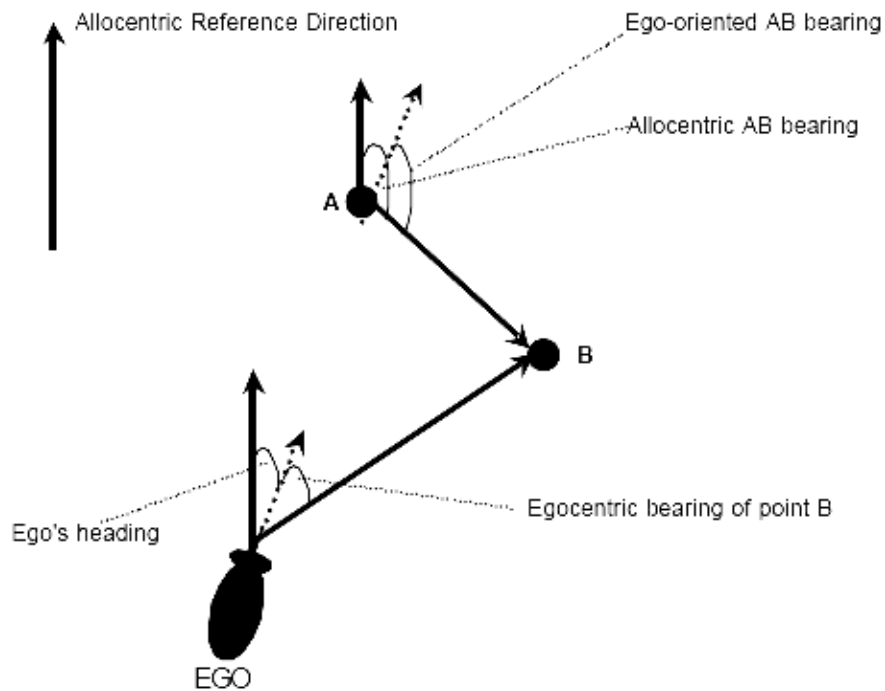
Fig. 6 Explanation of the basic terms (Klatzky, R. L. 1998).

2.4 The spatial knowledge

The construction of the cognitive map derives from the interpretation of the *spatial knowledge* of the environment. The spatial knowledge that is acquired in order to navigate is knowledge about **landmarks** or **reference points**, **route knowledge** and **survey** or configural **knowledge** (Schacter and Nadel, 1991; Siegel and White, 1975; Thorndyke and Stasz, 1980; Tversky 1993). *Landmarks* are unique objects at fixed locations, *routes* correspond to fixed sequences of locations as experienced in traversing a route; *survey* knowledge abstracts from specific sequences and integrates knowledge from different experiences into a single model (Werner St. et.al, 1997). Following Hart and Moore (Hart and Moore, 1976) who refined the concepts from an interpretation of earlier work by Piaget and Inhelder (Piaget and Inhelder, 1967), it could be demonstrated that the most basic form of knowledge is the **landmark knowledge,** which is developed by acquiring information about discrete features in the environment, so as to be able to identify a place. Following Montello in (Montello D.R., 2001), the **route knowledge** is the second stage and it is based on travel routines that connect ordered sequences of landmarks. In the last stage is the **survey knowledge,** where we are able to make judgments about where certain objects are located with respect to other objects in the environment. When

this knowledge has been acquired the individual can tell the direction to different places and knows where certain landmarks are located north or south of a junction.

The aforementioned classification is essential to this research, as it is suggested that the pedestrians of Piraeus discretionary invoke different types of spatial knowledge in order to perform wayfinding task. In the following chapter, the kind of spatial knowledge that the pedestrians use will be clarified.

Chapter 3: Research Methodology

The study of all the aforementioned processes and tasks is crucial in order to comprehend the context in which both the experiments were conducted and the research methodology was applied. This chapter describes the way theory described above is related to the research, the survey, and discusses the criteria according to which the three experiments were conducted. Furthermore, the limitations and constraints that were encountered during their application are described as well.

3.1   Description of the survey procedure/ subjects

3.1.1   The Experiments/Criteria for the Experiments

The survey consists of three experiments that were conducted in the centre of Piraeus.[16] The first experiment was conducted in **Peraiki Coast**, the second in **Mikrolimano** and the third one in **Sotiros Dios St.** The aforementioned locations are key-locations (geographically) to the city since ancient times; First, Peraiki Coast inscribes the peninsula, and especially the area where there are the best-preserved ancient remains of the fortifications which "still set the tone of the modern town to those approaching from the sea" (Steinhauer G. 1998, p.14). Second, Mikrolimano was the seaport of the strongly defended hill that controlled the entrance to the harbour of Munychia and today is one of the most important destinations for the city with the anchorage yachts and the other small sailing boats that could be found in the Yacht club of Greece. Third, Sotiros Dios St. is located in the pivot point of the flatter central part of Piraeus' oldest regular grid and today is a *pedestrian area* and one of the most commercial streets of Piraeus.

However, the *geomorphology* of the sites was not the only factor that played crucial role in their selection. In order to investigate the hypothesis of this thesis in a complete way, different criteria were used so as to define the experiments. The first criterion concerned the *access* to spatial information (target locations that are out of sight vs. locations with visual access). The second and the third criterion concerned the *types* of the reference systems; egocentric vs. allocentric and global vs. local scale respectively.

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[16] The experiments were conducted from the 13th of June until the 23rd of June 2006.

3.1.2   The subjects

This thesis aims to set out the relationship between the *spatial syntax* of the physical environment of the centre and the *spatial cognition* of its *users*. The latter are classified in three groups; first, there are the **Locals**, *inhabitants*[17], whose social identity is durably recorded in the urban form of Piraeus by control of space or set of spaces. Second, there are the **Regional Locals**, partial *strangers*, who live around Piraeus and they visit it frequently, and whose rights of presence in the city exist and distinguish them from the world of pure strangers, but not in a durable way and not through control of spaces. Third, there are the **Visitors**, pure strangers, whose presence in the city is durable.

The different forms of spatial knowledge of the pedestrians of Piraeus entail different movement behaviour, different wayfinding performance and construction of different cognitive maps of the city. Following the classification of Montello D. (Montello D.R., 2001) it could be claimed that the **Visitors** of Piraeus have the most basic form of knowledge, the *landmark knowledge*; the **Regional Locals** have the *route knowledge*, which implies that they should be able to find the way to a destination, and, after elaboration, to find the way back (Schacter and Nadel, 1991; Siegel and White, 1975). They should also be able to give judgments of directions on the route and estimates of distance and they are half-familiar with the place (Glossary of terms). Last, the **Locals,** as they are fully familiar with the environment, it is argued that they have *survey knowledge*, knowledge of two dimensional layouts that includes the simultaneous interrelations of locations (Thorndyke and Stasz, 1980). The application of survey knowledge should enable a person to find new ways. This last and more progressed stage (Montello, 1997) is the one where the knowledge simultaneously embraces more locations, their interrelations and allows for detouring, shortcutting and creative navigation. As Locals have this knowledge, they tend to describe the location of the target in a *hierarchical* manner, becoming more and more detailed. Additionally, turn-by-turn directions are longer, typically exceeding the capacities of human short-term memory (Miller, 1956). For instance, when Locals described the route from Korai Sq. to Marina Zeas, they took into account the length of routes, the time to travel a route, the number of turns along a route and the aesthetics of the routes.

Taking every classification into consideration, the following diagram could be drawn in order to clarify all the above terms within the context of the thesis.

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[17] The distinction between "*inhabitants*" and "*visitors*" is followed by Hanson, Hanson and Peponis in (Hanson J. & Hillier B. & Peponis J., 1984, p. 65-67).

	Landmark Knowledge (Egocentric navigation)	**Route Knowledge** (Egocentric navigation)	**Survey Knowledge** (Allocentric navigation)
	local scale	local scale	global scale
Locals	√	√	√
Regional Locals	√	√	
Visitors	√		

··············	**Experiment 1**: Landmark + Route Knowledge
··············	**Experiment 2**: Survey + Landmark Knowledge
··············	**Experiment 3**: Route + Survey Knowledge
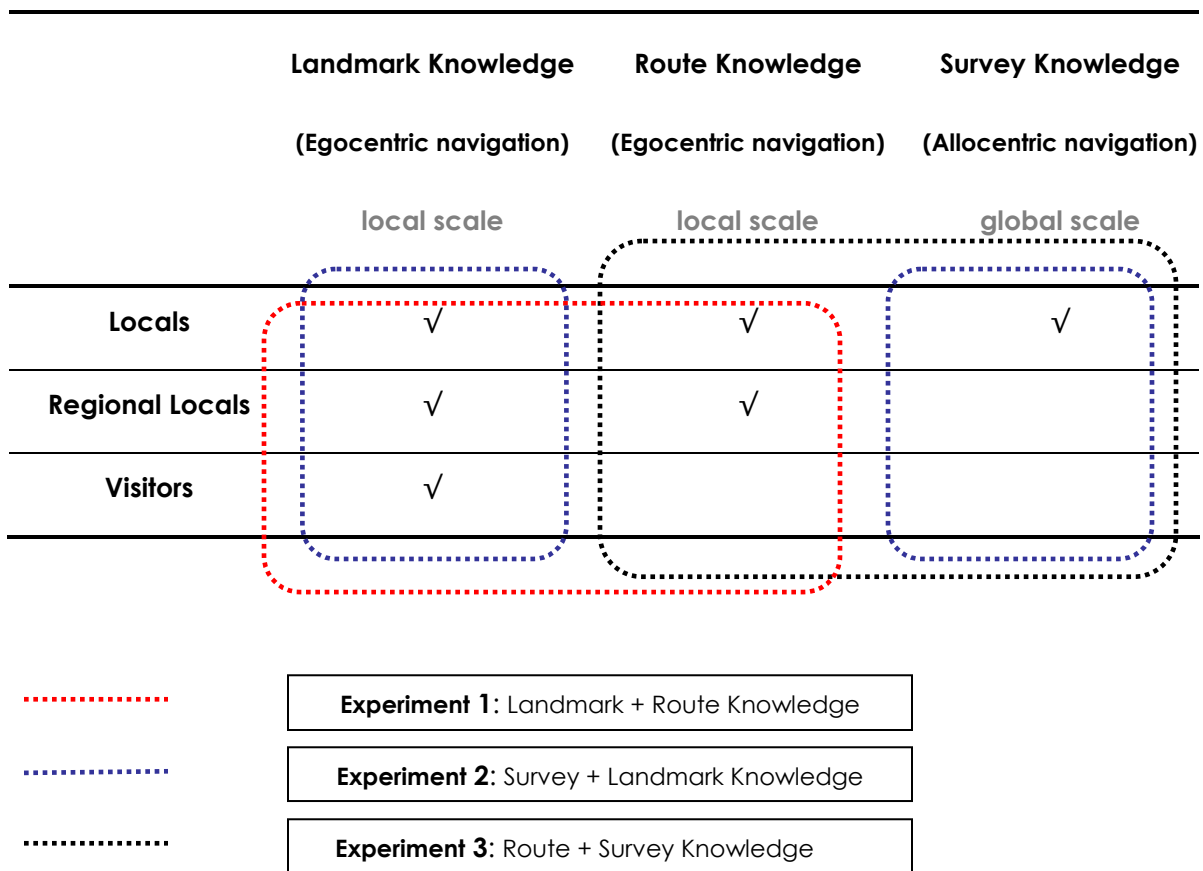
3.2   Spatial Analysis

To comprehend the terms and the notions applied in the next chapter of the Experiments, an account of the steps that the analysis will follow, coupled with an introduction of the space syntax measures used is necessary.

The spatial analysis of the research is based on **Space Syntax Analytic Methods**. (Appendix E) Space Syntax is a set of theories and techniques that explains the substantial proportion of the variance between aggregate human movement rates in different locations in both urban and building interior space. The concept of **"spatial configuration"** is very important in this theory, as it concerns relations which take into account other relations in a complex (Hillier, 1996). In recent studies linking *space syntax* with *cognitive science*, it has been claimed that the spatial configuration encourages or impedes aspects of human activity through spatial cognition and subsequent movement behaviour (Hillier B., 1996a; Kim, Y. O., & Penn, A. 2004).

The way the configuration is being understood and the way the information about configuration is organised, is expressed by the concept of **"intelligibility"**, which Bill Hillier describes in "Space is the Machine" (1996). According to Hillier, "between function and structure is the notion of *intelligibility*, defined as the degree to which what can *be seen* and experienced locally in the system allows the large-scale system to be learnt without conscious effort" (Hillier, 1996, p.215).

Chapter 4: The Experiments

4.1   Experiment_01 – Peraiki Coast

4.1.1   The survey

The experiment was conducted in the Peraiki Akti (Fig. 7), in the coastal section of the fortification walls that today are preserved for a length of 2.5 km., in the form in which it was built by Konon in 394 B.C. The reason for this selection was that when walking along the coast extensive visual information of the ancient fortification system is available, but not for the rest of the city. The questionnaires (Appendix F) were given to a sample of 85 people (31 locals, 27 regional locals and 27 visitors) (Fig. 8) during a weekday and a weekend (13/06/06 and 18/06/06). Fig. 9 shows the experimental layout; the zone was divided into 6 parts, according to the geomorphology of the coast. Given a diagrammatic map of the coast, participating subjects were instructed to *point the location they believed they were and the reasons for their certainty*. The participants/subjects were also asked the frequency of their visit, and the degree of certainty of their answer.

Fig. 7 The coastal zone of Peraiki with the remains of Konon Walls (393 B.C.).

This experiment was conducted within an **egocentric** frame of reference, as the requested locations were represented with respect to the particular perspective of a perceiver. The participants, in order to respond, had to make self-centered representations of the Coast and make a judgment according to the visual cues and their *spatial knowledge*.[18]

Comparing people's perceived location with their actual position, a high degree of deviation is highlighted. Fig.10 shows the Average Deviation (in meters) (Glossary of Statistical terms) for each group of participants/subjects. Locals' memory (Average Deviation 374m) appears to be by far more precise than Regional Locals' memory (Average Deviation 749m.) The latter group, although it uses route knowledge, based on travel routines that connect ordered sequences of landmarks, and it is half – familiar with the Coast, it appears to give the least accurate answers to define their location, even in comparison to the Visitors (Average Deviation 529 m.) that they visit the Coast for the first

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[18] We are referring to the *landmark* knowledge, the *route* knowledge or the *survey* knowledge that an individual has.

or second time. The implications of this discussion will be analysed in the following parts of this section.
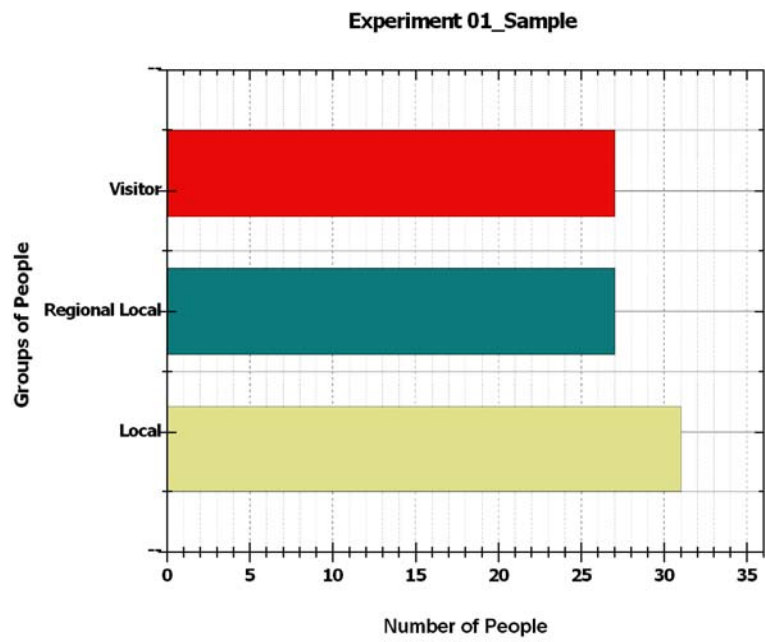
Fig. 8 The three groups of participants/subjects: Visitors, Regional Locals, Locals.
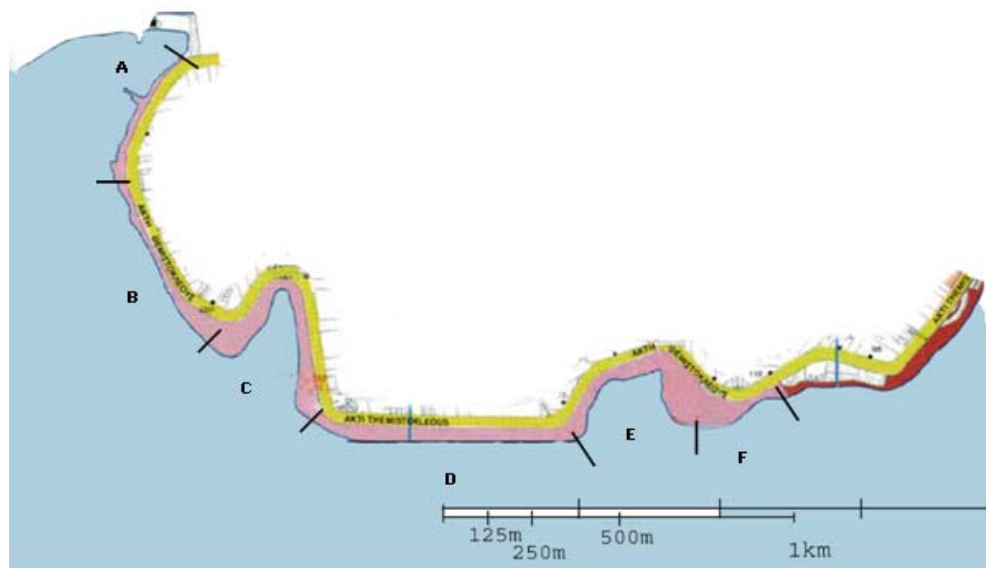
Fig. 9 The layout divided into 6 parts, according to the geomorphology of the coast.
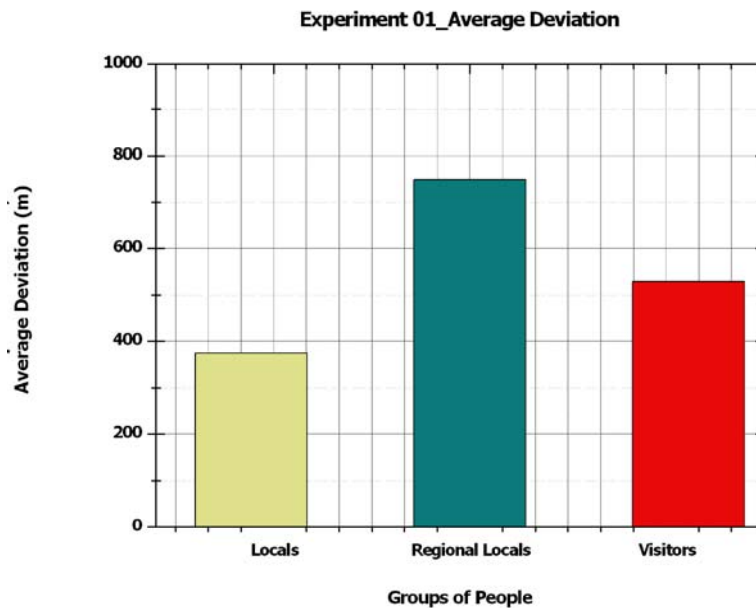
Fig. 10 Average Deviation (in meters) for each group of participants/subjects.

4.1.2   Data analysis/Observations

This part of the research explores people's degree of familiarity with the Peraiki Coast and with certain features of predefined routes in relation to the acquisition of the cognitive knowledge. The diagrammatic map of the coast that was given to the participants could be characterised as *a cognitive map addressed to Recognition Tasks* (Golledge, R. 1992) *with indication of Self-Location*. The Pie Chart displaying the *Reasons of certainty* (Fig. 11) could highlight the degree that movement behaviour could be affected not only by visual cues, such as Landmarks, but also by environmental features such as the configuration of the coastline or the distance and time of walking estimation (Ittelson, 1973; Canter & Tagg, 1975; Cadwallader, 1979; Golledge, R. 1987). Furthermore, wayfinding performance is appeared to be aided by maps. To a considerable degree, the maps determine the extent of a subject's knowledge of its environment. Among the participants, 60% of the overall sample assert the configurational, geographical and topological characteristics of Peraiki Coast as reasons to ensure their answer; the linearity of the coast outline, the curvature of the small creeks and the outline of the coast they have just walked (which have all been classified as *Natural Environment* in this paper) is the spatial information which was transmitted and then applied. Moreover, for 23% of the participants, the *Landmarks* (the Naval College, the Cross, the church, the Cape of Aphrodite, Porfuras basketball court, parts of Konon's ancient wall) were strong elements so as to gauge their

location. Estimation of *Time of Walking* and *Maps* were used less (9,8% and 6,9%), while only 1% of the participants mentioned another factor that affected their answer.
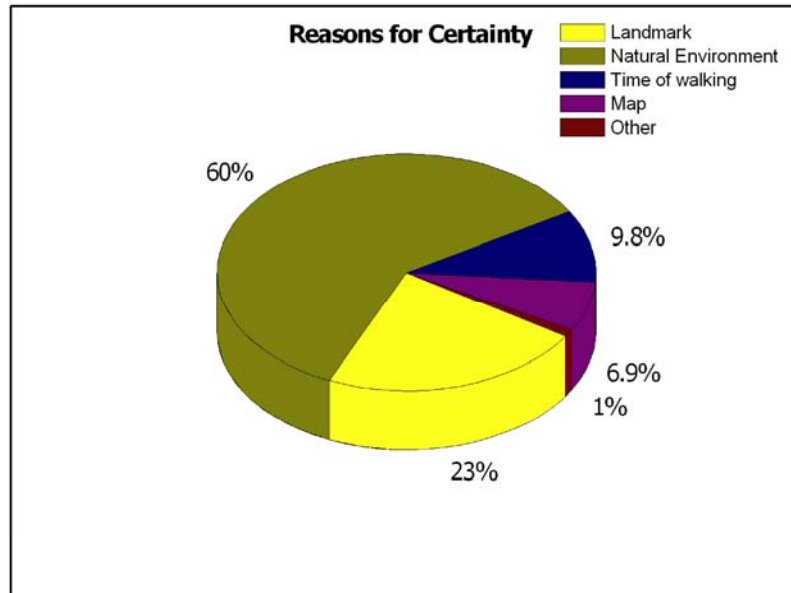
Fig. 11 Factors that affect movement behaviour.

Fig. 12 illustrates the answers of all three groups. Although the Regional Locals are half-familiar with the environment, the majority appears to invoke the *Natural Environment* as indicator of their location. Following Gale et al. (1990) and Peron et al. (1990), who urge that familiarity itself is a "complex multidimensional concept" and considering the data gathered from the questionnaires, it could be deducted that many Regional Locals claim familiarity with a place even when they only know its name and others if they have observed, visited, or passed by the place frequently. Furthermore, concerning the Visitors, it could be also deducted that they use a wider range of knowledge (information) on how to navigate in this unfamiliar (for them) environment in comparison to that used by the two other groups of participants. This finding could suggest that the wide range contributes to a more successful navigation (Visitors' Average Deviation is 529 m. against Regional Locals' Average Deviation which is 749m.). On the other hand, Regional Locals' half-familiarity entails confusion and error in self-location.
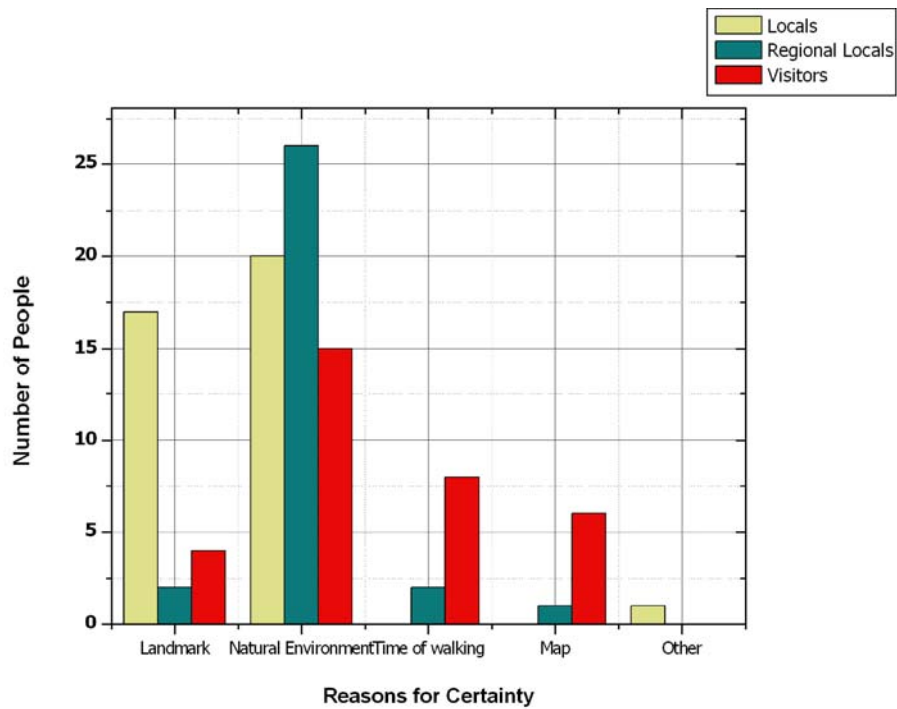
Fig. 12 Answers of all three groups.

An important part of the Experiment was the measurement of the *Displacement Error* (namely the incorrect encoding of the participants' location) and furthermore the *reasons* that these errors happen. Fig. 13 (Average Displacement Error) shows that *Landmarks* and *Maps* are used with almost the same accuracy as indicators of self-location (the Average Deviation is respectively 153.26 m. and 120.83 m.), while *Natural Environment* and *Time of Walking* contribute less to a good understanding of the spatial relations in the coastal zone (the Average Deviation is respectively 626.69 m. and 900.00 m.).[19] Fig.14 displays the Reasons for Certainty in relation to the Average Displacement Error that has been recorded in the overall sample of participants.

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[19] It should be mentioned that in the category "other" answers like "the route of the bus" are included. These answers are very few but there is great deviation in accuracy.

Average Displacement Error

Fig. 13 Average Displacement Error.
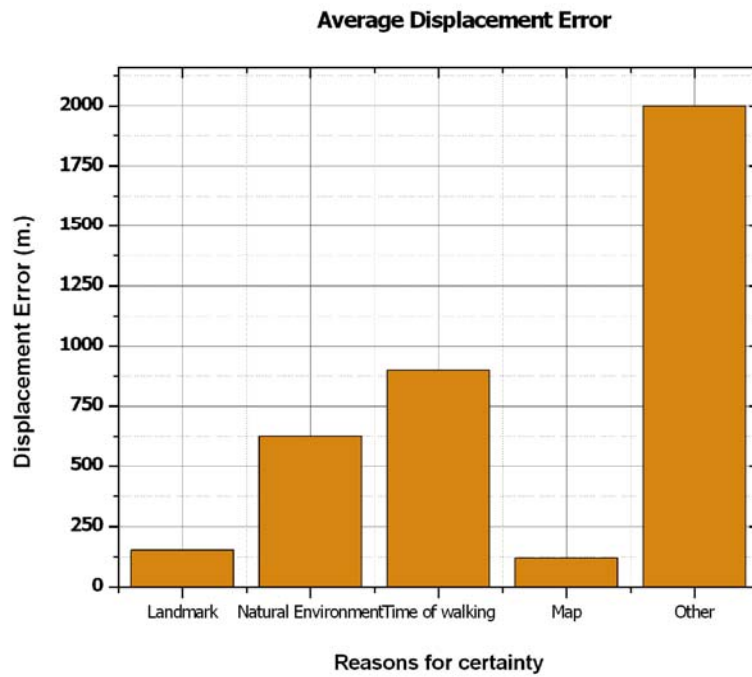
Reasons for certainty/Average Deviation (m)
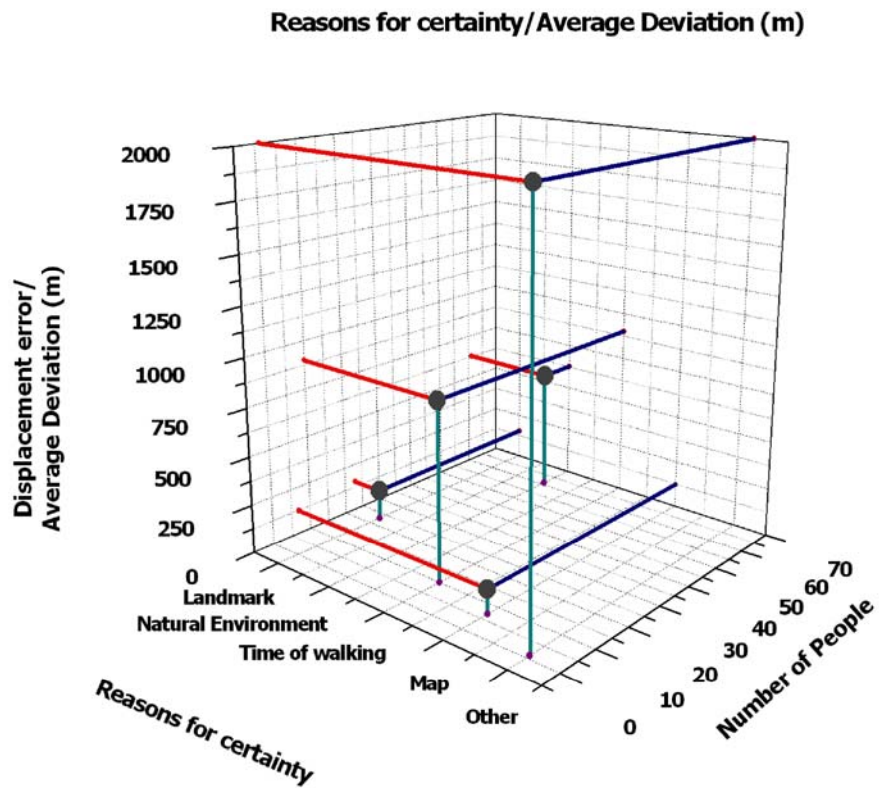
Fig. 14 Reasons for Certainty in relation to the Average Displacement Error.

As mentioned above, many researchers have attempted to understand how cognitive space is constructed and how it affects our decisions when navigating. The *Space Syntax* approach in terms of the relation between *cognition* and *spatial configurations* forms a strong basis for the methodology of this research. The concept of *spatial configuration* is fundamental in space syntax theory, as it is defined as "a set of spatial relationships where each relation affects and is affected by all others in the set" (Hillier, B. and Hanson, J. 1984). Furthermore, the availability of *visual* information about the environment is an important factor for decision making.

From the experiment conducted in the Coast, the results showed that there were some systematic errors (distortions) in participants' answers (Fig. 15). A great amount of participants, that actually appeared to invoke the *Natural Environment* as indicator of their location, tended to confuse certain locations. The most frequent confusions were between locations *D and E* (with a Frequency of 8 times), *B and D* (with a Frequency of 7 times), *B and E* (with a Frequency of 6 times) and *C and E* (with a Frequency of 6 times).
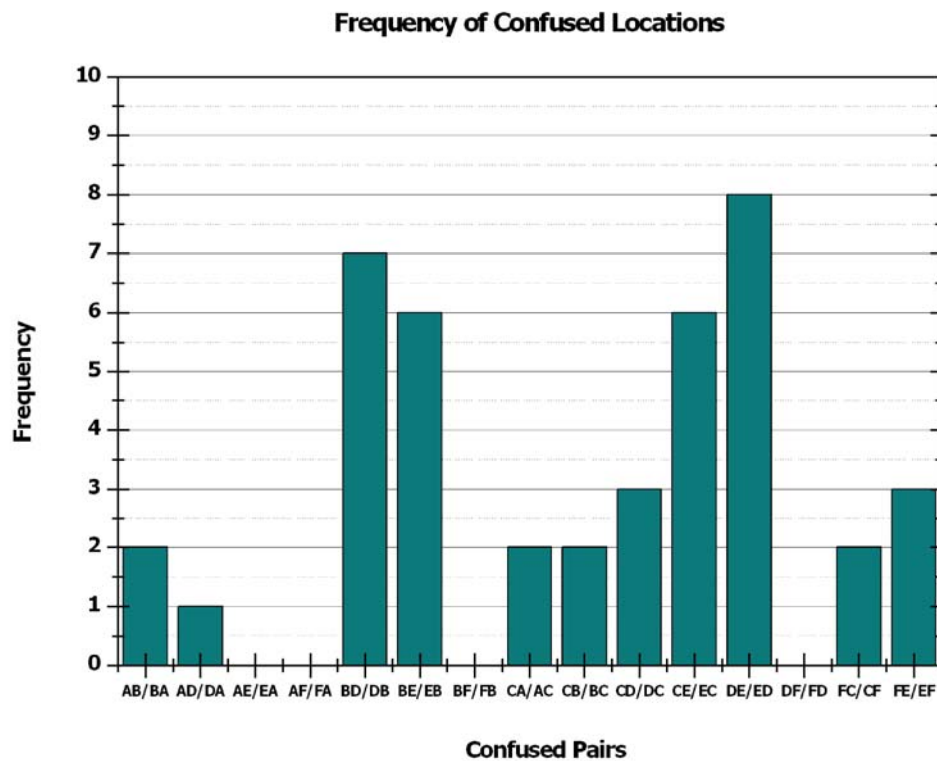
Fig. 15 Frequency of confused Pairs.

4.1.3   Further Analysis

In this research, the syntactic analysis that has been performed is based on two models of space syntax analysis – axial analysis[20] (Hillier, B. and Hanson, J. 1984) and Visibility Graph Analysis[21] (Turner et al., 2001). In order to analyse the *configurational (syntactic)* and the *geometrical* properties of Peraiki Coast, the coastline of the peninsula was divided into 6 segments, as mentioned before. In Fig.16 the axial break-up of the centre of Piraeus is displayed and in Fig.17 the axial lines of each of these segments (A, B, C, D, E and F) are demonstrated.

Fig. 16 Axial break-up of the centre of Piraeus.

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[20] Axial map is a method of representation composed of axial lines (implying meanings related to movement of a human body) of the continuous system of open space accessible to public, by the least and longest set of lines that traverse all the convex spaces. (Hillier and Hanson, 1984)

[21] Visibility Graph Analysis (Turner et al., 2001) is an analytic tool which analyses the extent to which any point in a spatial network is visible from any other.
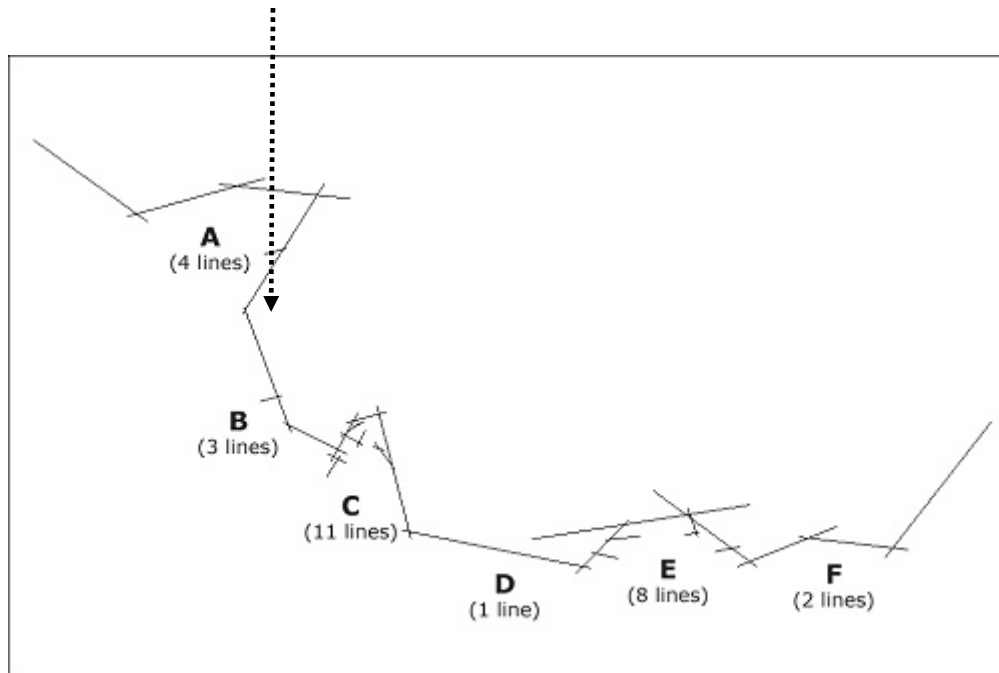
Fig. 17 The axial lines of each of the segments (A, B, C, D, E and F).

Analysing the *configurational (syntactic) values* of Connectivity, Integration Rn, and Integration R3 (Table 1 and Table 2), and considering the Average Values (ABS –Glossary of Statistical terms), it could be deducted that the most confused pairs *DE*, *BD*, *BE* and *CE*, have Differences in *Average IntRn* 0.225 (ABS), 0.955 (ABS), 0.106 (ABS) and 0.085 (ABS). Those values could explain the confusion between C and E and between B and D as the configurational similarities of the parts of the coastline entail error in the correct estimation of self-location (Fig. 18). Furthermore, the Differences in *Average Connectivity* for the aforementioned Pairs are 3.375 (ABS), 2 (ABS), 1.375 (ABS) and 0.806 (ABS); the latter difference is one of the lowest among all pairs, which suggest that the two locations (C and E) could cause disorientation and confusion during wayfinding.

	Line Ref No	Connectivity	IntRn	Int R3	Average IntRn	Average IntR3	Average Connectivity
A (4)	62	3	1.248	2.182	1.355	2.510	5
	1464	6	1.463	2.984			
	1499	10	1.466	3.012			
	1736	1	1.244	1.861			
B (3)	166	9	1.257	2.654	1.147	2.135	5
	97	5	1.094	2.137			
	1778	1	1.090	1.614			
C (11)	74	7	1.094	2.206	0.955	1.383	2.818
	67	3	0.977	1.997			
	134	7	1.103	2.290			
	1737	2	0.966	1.390			
	1738	1	0.864	0.682			
	1739	3	0.966	1.489			
	1740	1	0.864	0.785			
	1741	1	0.864	0.785			
	1742	3	0.966	1.489			
	1743	2	0.973	1.422			
	1744	1	0.870	0.682			
D (1)	165	7	1.266	2.784	1.266	2.784	7
E (8)	82	6	1.103	2.219	1.041	1.737	3.625
	163	9	1.158	2.519			
	91	6	1.148	2.278			
	1745	1	1.007	1.327			
	1746	3	1.015	1.762			
	1747	1	0.904	0.945			
	1748	2	1.017	1.584			
	1749	1	0.973	1.263			
F (2)	1361	6	1.322	2.629	1.237	2.431	5.5
	110	5	1.152	2.234			

Table 1 Configurational (syntactic) values

Pairs	Difference in Averages IntRn	Abs|Average| IntRn	Difference in Averages IntR3	Abs |Average| IntR3	Difference in Averages Connectivity	Abs |Average| Connectivity
AB	0.208	0.208	0.374	0.374	0	0
AD	0.088	0.088	-0.274	0.274	-2	2
AE	0.314	0.314	0.772	0.772	1.375	1.375
AF	0.118	0.118	0.078	0.078	-0.5	0.5
BD	-0.955	0.955	-1.383	1.383	-2	2
BE	0.106	0.106	0.397	0.397	1.375	1.375
BF	-0.089	0.089	-0.296	0.296	-0.5	0.5
CA	-0.400	0.400	-1.126	1.126	-2.181	2.181
CB	-0.192	0.192	-0.751	0.751	-2.181	2.181
CD	-0.311	0.311	-1.401	1.401	-4.181	4.181
CE	-0.085	0.085	-0.354	0.354	-0.806	0.806
DE	0.225	0.225	1.047	1.047	3.375	3.375
DF	0.029	0.029	0.353	0.353	1.5	1.5
FC	0.281	0.281	1.047	1.047	2.681	2.681
FE	0.196	0.196	0.693	0.693	-3.625	3.625

Table 2 Difference in Averages.
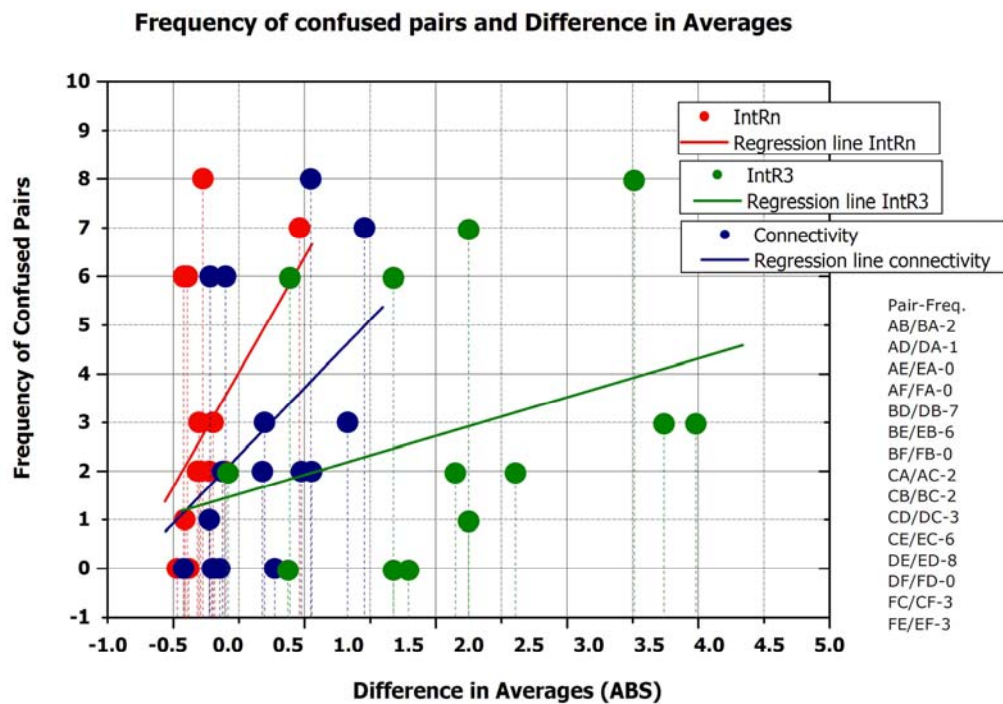
Fig. 18 Frequency of confused pairs and Differences in Averages.

However, the confusion that is caused when people navigate in locations *D/E* and *B/E* could be investigated through the *geometric properties* of the Coast. In order to

measure these properties, Visibility Graph Analysis was conducted and the *visual fields (isovists[22])* were analysed. Once the visibility graph has been generated, the geometric property of an array of isovists can therefore be illustrated by its own diagram. Each viewpoint (from which an isovist was generated) is represented by a point on plan. The colour of the point is assigned using the value of each measure. A rainbow spectrum is employed in which red denotes the maximum value and blue represents the minimum value of a measure. The colours orange, yellow and green are assigned respectively for the intermediate values. Fig.19 shows a graph of *Isovist Area*, namely how *much* of the environment is visible from this location. From Connectivity *graph* (Fig.20) it could be claimed that someone would expect the locations D and F to be confused, as they have similar connectivity values (red and yellow). Additionally, according to the values of the same graph, someone would also expect confusion between both C and E locations and A and E locations; however, none of the participants confused the location A with E, while the error [C instead of E] had frequently occurred.

Fig. 19 Isovist Area.

Concerning the correlation of *Connectivity Degree* with the geometric value of *Maximum radial length*, the relationship between *connectivity* and the *maximum radial length* of an isovist has an r-squared value of *0.121. Maximum radial length* (Fig. 21) is a

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[22] The definition of the isovist introduced by Benedikt in (Benedikt 1979) is that the entire field of view from a single point can be represented by a planar polygon, usually parallel to the ground plane.

measure of the "longest available line of sight from an isovist's viewpoint" (Ruth Conroy-Dalton, 2001, Ch. 8, p. 158). The longer the line of sight from a viewpoint, the more likely it is to connect with other isovist viewpoints; however, the poor correlation between connectivity and maximum radial length demonstrates that the lines of sight from an isovist's viewpoint are limited. Another week relationship is the relationship between isovist area and integration. The r-squared correlation coefficient for the relationship between isovist area and visual integration is *0.088* (Fig.22).

Looking at *Visual Integration* graph (Fig. 23), some interesting conclusions could be drawn. According to the values, someone would expect more confusion between A and D locations than between B and D locations. However, the pair that the subjects found most difficult to distinguish was the D/E locations.
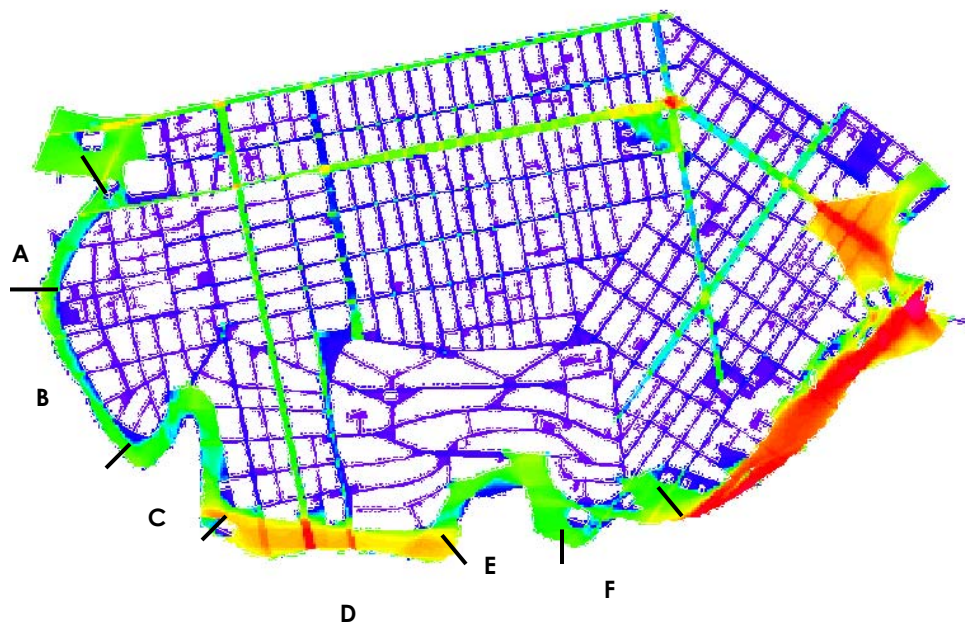
Fig. 20 Connectivity degree.
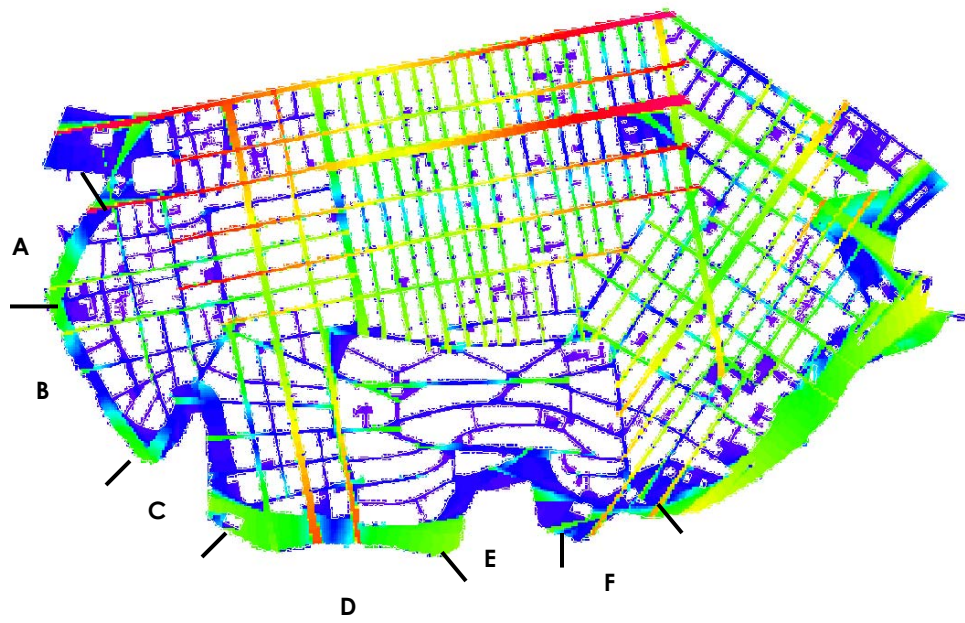
Fig. 21 Maximum radial length.
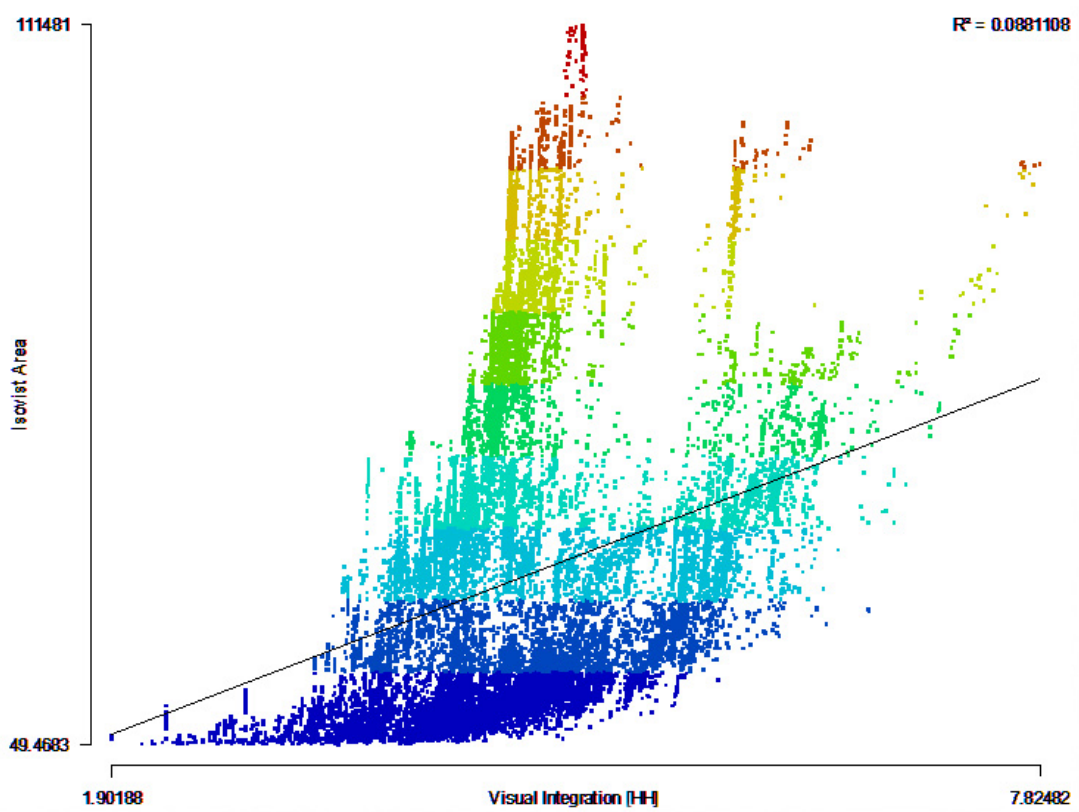
Fig. 22 Scattergram of isovist area and visual integration for Peraiki Coast with r²= 0.088.
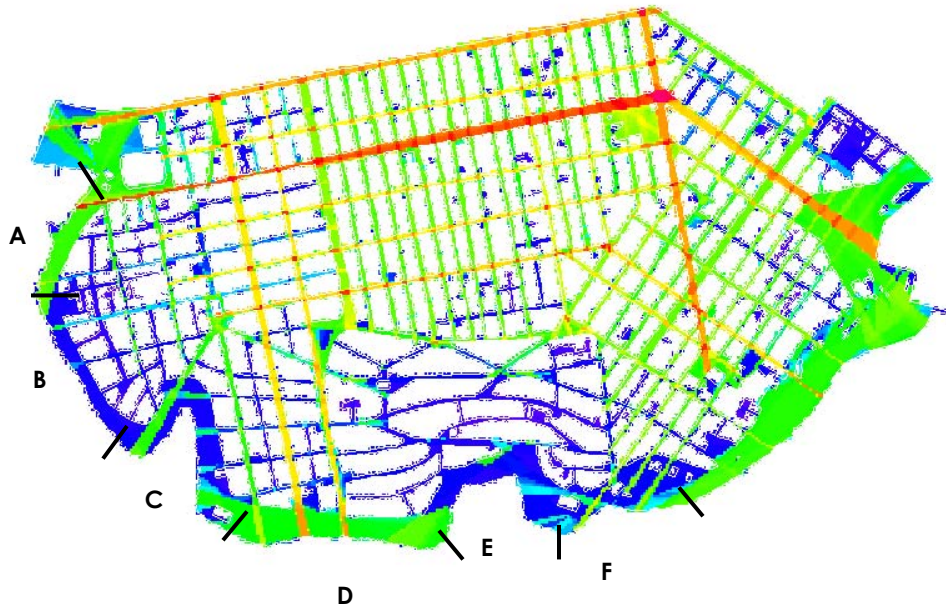
Fig. 23 Visual integration.

4.1.4   Key points

Taking everything into account, it could be argued that when people navigate along the Coast, they keep updating position and orientation over the course of their imagined movement, as is required when encoding from a verbal description. However, through the analysis was demonstrated that the wayfinding performance is not always successful as *errors* and *biases* when using memory or judgment could confuse. As Barbra Tversky in (Barbra Tversky, 2000b) suggests "people's mental representations of the space of navigation are not holistic or complete or accurate" (Barbra Tversky, 2000b, p.4).

From the analysis it was found that the relationship between *geometric measures* of isovists and *syntactic measures* of isovists (referring to the *overall structure* of the world), is highly significant. The fact that there are not strong correlations between certain geometric measures of isovists and syntactic measures (*connectivity/Maximum radial length and isovist area/visual integration*) implies the danger of error if we attempt to make global inferences from purely local information. This could probably explain the fact that the majority of subjects made wrong judgments about their position within *the whole system* based on visual information of the space that they are occupying. From the total sample, 36.27% almost correctly estimated their position (0-50m. displacement error), while

63.73% made wrong judgments (from 150m. to 2500m. displacement error) (Fig.24). Therefore, local (visual) information appears to be critical to navigation along the coast; to a large extent the local surrounds provide an *azimuthial reference*[23] (Loomis et al., 1999), i.e. information such as the location of the sea, the position of the sun, the position of the islands opposite the peninsula and the position of celestial bodies. However, no matter how crucial this information is, it was found to be misleading and confusing as the most of participants failed in a successful updating of their position.
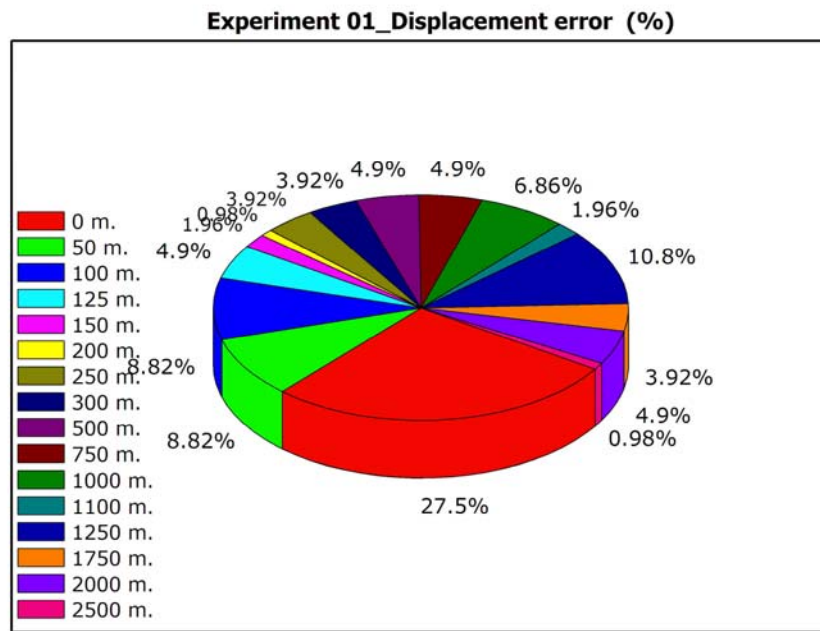
Fig. 24 Displacement error (%) for all participants.

4.2 Experiment_02 – Mikrolimano

4.2.1 The survey

The second experiment was conducted in the **harbour of Mikrolimano** (or Tourkolimano), in the area below the Hill of kastella (the Hill of Mounychia, the acropolis of ancient Piraeus, 403 B.C.), which has view to Faliro Bay and the Saronic Gulf (Fig.25). This area was selected not only because of the circular shape of the coast outline, but because the height of the hill above obstructs the visual information towards the centre of the city. In other words the experiment's destinations were out of sight.

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[23] Azimuthial reference captures the idea that the earth's surface is an unmoving and unchanging background for behaviour (Gallister, 1990; Loomis et al., 1999).

Fig. 25 The harbour of Mikrolimano, below the Hill of kastella.

The questionnaires (Appendix F) were given to a sample of 67 people (20 locals, 27 regional locals and 20 visitors) (Fig. 26) during a weekday (14/06/06). The participants were asked to ***point out*** certain features[24] of the city. It is important to mention that the notion of "Landmarks" as spatial reference points was developed (Sadalla et al., 1980) from the concept of "cognitive reference points" (Rosch, 1975). The Landmarks are cognitively distinct from other elements in spatial memory and central to the nature and organisation of spatial representation (Presson C.&Montello, D. R.,1988). Therefore, for this experiment three groups of *Landmarks* were chosen. Fig. 27 shows the layout that the researcher was holding during the experiment. On the map there was no indication of any requested location as there was the possibility that the map could be seen by the subjects. The requested features were grouped in a three-part classification with different types of features: **Antiquities** (Fig.28 – Archaeological Museum, Main Gate of Piraeus, and the Konon Walls near Porfuras Basketball Court), **Modern Piraeus** (Fig.29 – Municipal Theatre,

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[24] The features that were chosen are all *landmarks*. As we will show later in the third Experiment, landmarks are the dominant features in the mental maps of the pedestrians of Piraeus.

Train Station of Piraeus and Naval College) and **Leisure** (Fig.30 – Restaurant "Axinos", Fast food "Goody's" and Church of Prophet Ilias). In order to avoid any confusion and errors, a compass was used by the researcher during the experiment. The participants/subjects were also asked the frequency of their visits and the degree of certainty they accorded their answer. In Fig.31 the location of Mikrolimano (in a red dotted circle) and the nine locations are demonstrated.
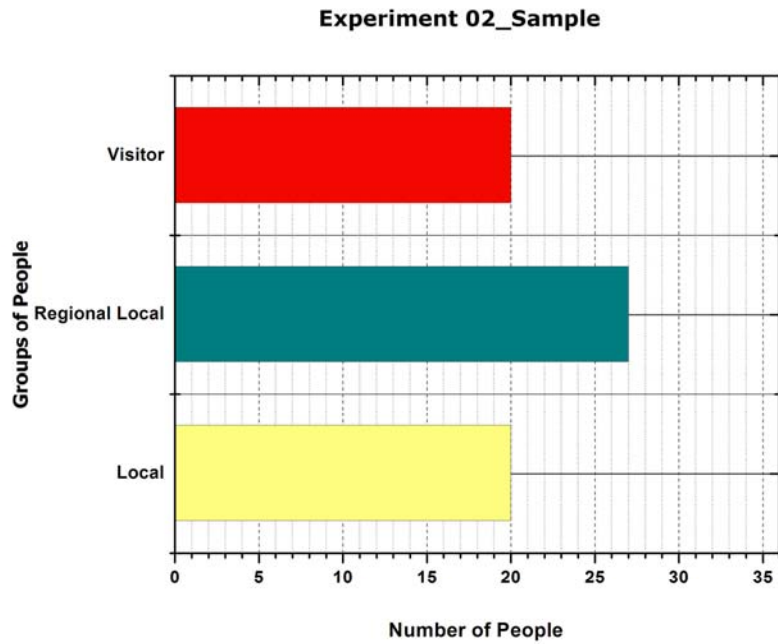
Fig. 26 The three groups of participants/subjects: Visitors, Regional Locals, Locals.

Fig. 27 The layout of Mirolimano that the researcher had during the experiment.
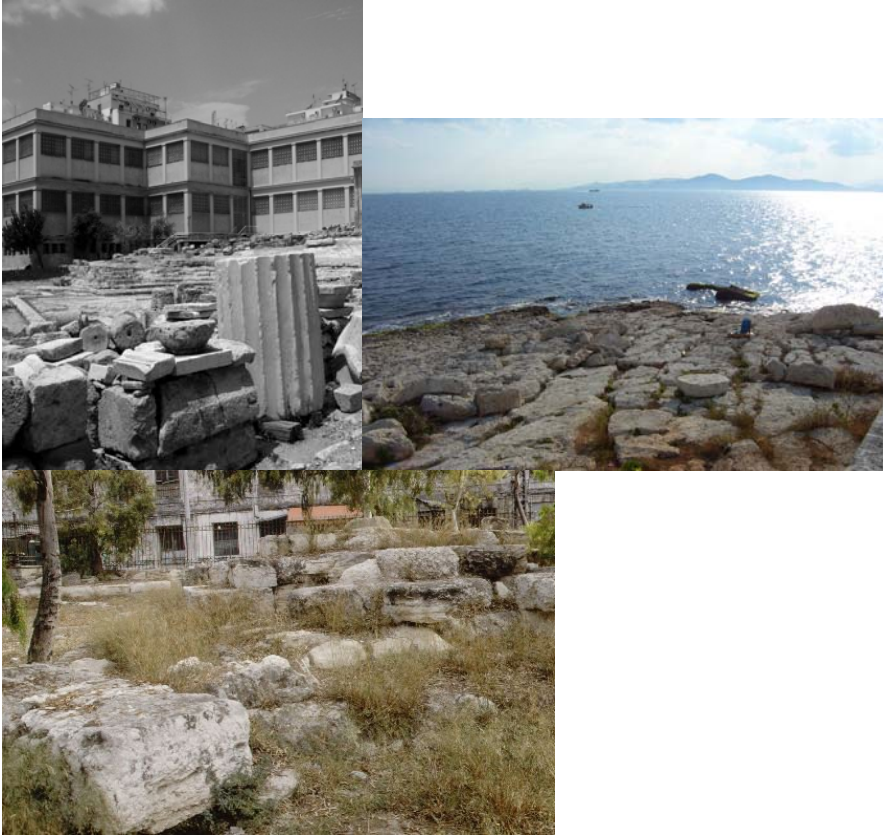
Fig. 28 Antiquities (right: Archaeological Museum, left: the Konon Walls near Porfuras Basketball Court and down: Main Gate of Piraeus).
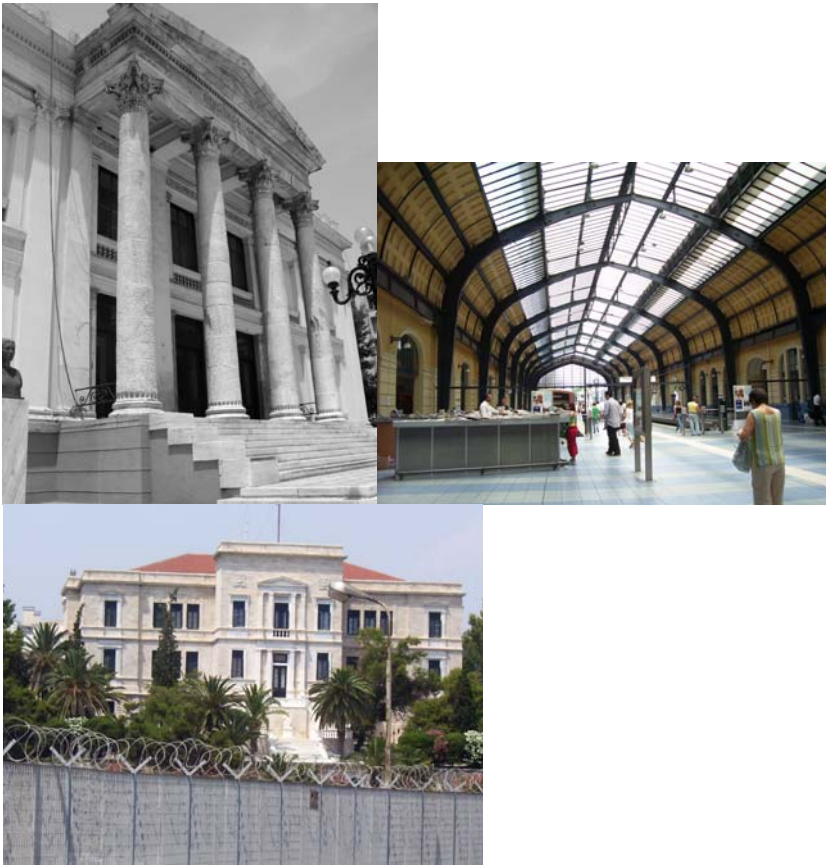
Fig. 29 Modern Piraeus (right: Municipal Theatre, left: Train Station of Piraeus and down: Naval College).

Fig. 30 Leisure (right: Restaurant "Axinos", left: Fast food "Goody's" and down: Church of Prophet Ilias).

Fig. 31 Mikrolimano (in a red dotted circle) and the nine locations.

This experiment had a binary character: the participants had to utilise *both* **egocentric** (body to object) and **allocentric** (object to object) representations in order to respond. The latter had to rely on egocentric information in order to point out from *their* location, but they had to use also allocentric information in order to solve this spatial task, as the target-locations were outside their visual field.

4.2.2 Data analysis/Observations

Performance is evaluated by comparing the collection of real and estimated angles and average angle error (especially the *absolute* difference between real and estimated direction for every particular location).[25] Statistical analysis has been carried out in order to measure the degree of accuracy (or deviation) and the degree of certainty (or uncertainty).

In all three categories of locations (**Antiquities**, **Modern Piraeus** and **Leisure**), the Regional Locals seem to give the least approximate location for the requested destination, while the most accurate is the pointing of the Visitors. The performance of the Locals is between the performances of the two aforementioned groups. More specifically, concerning **Antiquities** (Fig. 32), Locals' *locational accuracy* (ABS Average Deviation 34°) appears to be by far higher than Regional Locals' (ABS Average Deviation 59°). The least difficulty in "recognising"[26]a place had the Visitors (ABS Average Deviation 33°). For **Modern Piraeus** (Fig. 33), Locals' ABS Average Deviation is 37°, Regional Locals' is 53° while Visitors seem again to perform the task with better results (ABS Average Deviation 17°). Additionally, for the category of **Leisure** (Fig. 34), the Regional Locals' recognition task had the highest displacement (in degrees) error (ABS Average Deviation 46°) and the Visitors' the lowest (ABS Average Deviation 31°), while the Locals'performance has ABS Average Deviation 33°. In the following diagrams each group is represented with different colour; yellow for the Locals, dark cyan for the Regional Locals and red colour for the Visitors. In Fig. 35 all the requested places of all three categories are demonstrated; from the nine locations the Main Gate of Piraeus (Antiquities) is subject to greatest error (ABS Average

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[25] The task of "pointing to unseen targets" and the calculation of deviation is a common method used in cognitive experiments (Golledge, Ruggles, Pellegrino, & Gale, 1993; Montello & Pick, 1993; Sadalla & Montello, 1989).

[26] In the spatial domain "recognising" a place means being able to identify its location. (Golledge, R. ,1992).

Deviation 41°), while Train Station (ABS Average Deviation 28°)and Fast food "Goody's" (ABS Average Deviation 28°) the error seems to be substantially reduced.
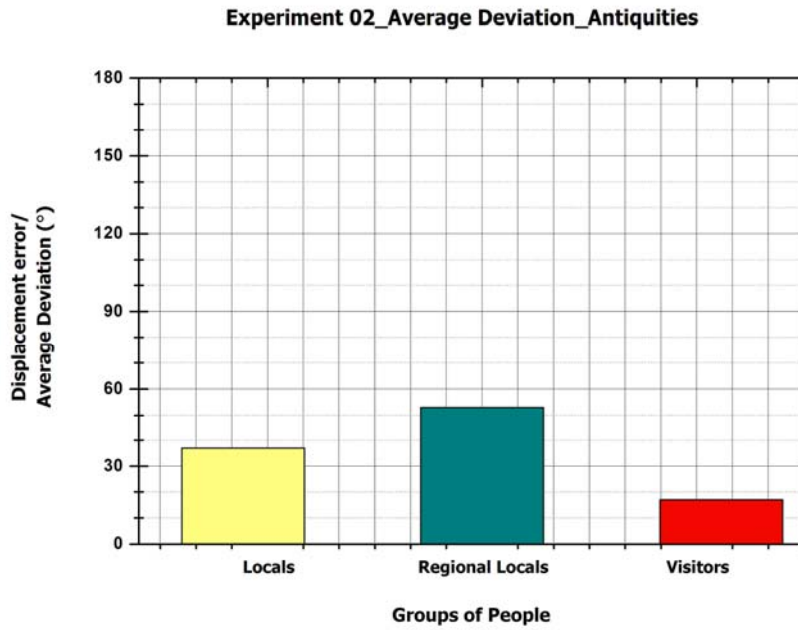
Fig. 32 Absolute Average Deviation (in degrees) for each group of participants/subjects – Antiquities.
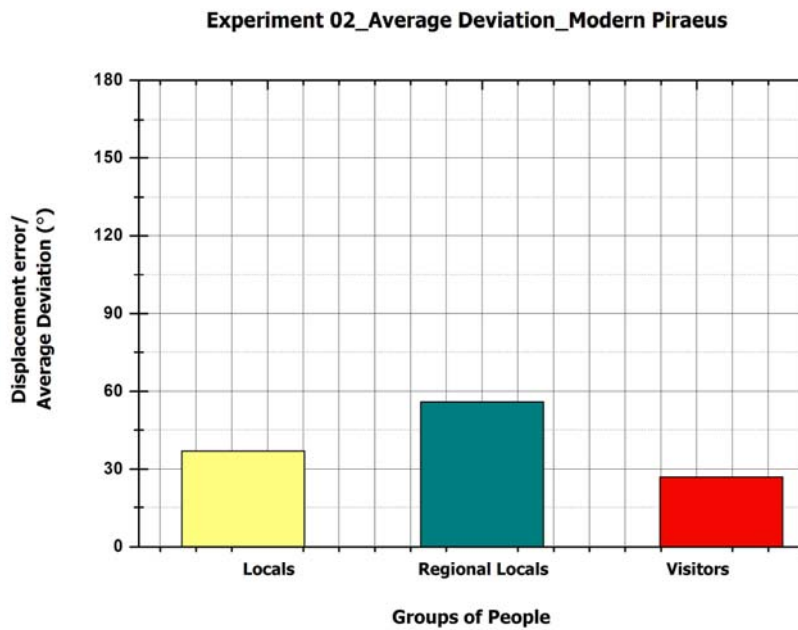
Fig. 33 Absolute Average Deviation (in degrees) for each group of participants/subjects – Modern Piraeus.
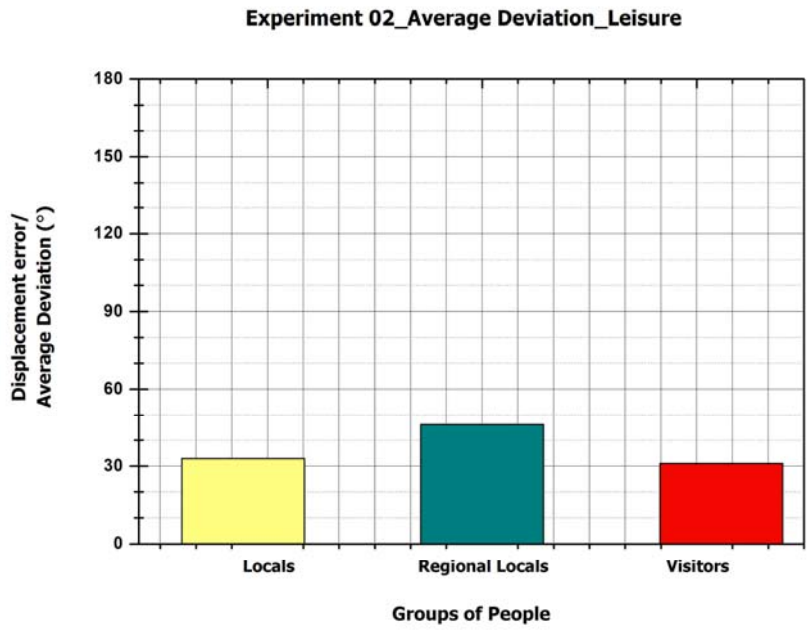
Fig. 34 Absolute Average Deviation (in degrees) for each group of participants/subjects – Leisure.
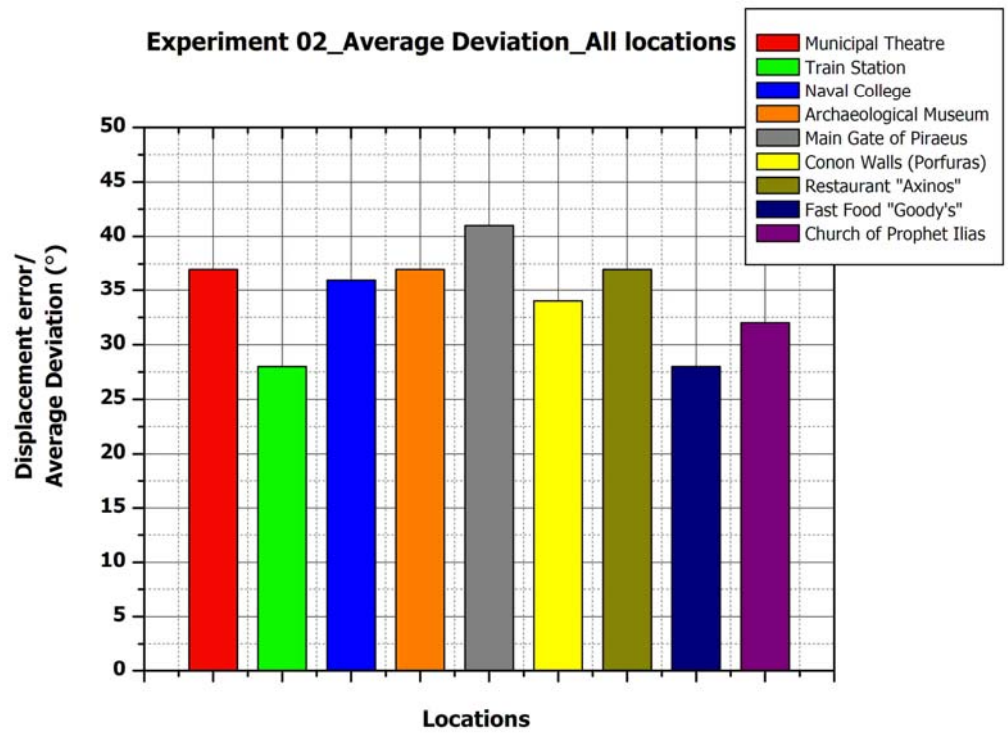
Fig. 35 Average Deviation for all locations.

4.2.3 Further Analysis

For an individual to determine a place's location includes the encoding of both *distance* and *direction* which are easily subject to great error. Through the observations, the majority of the Locals having a more complete mental map of the city, they were

emphatic about the location of the requested places. Often their mental representations were related to the cardinal compass directions: North, South, East, and West and therefore they were convenient labels to define the places. The degree of certainty about the position of a place was much greater than the equivalent certainty of the Regional Locals. Last but not least, the Visitors answered with high accuracy but the range of their knowledge regarding the requested locations was extremely limited. The following Polar Charts demonstrate the Directional error for Landmarks concerning Modern Piraeus with associated certainty for all three groups of participants. Fig.36 shows the Municipal Theatre, Fig.37 the Train Station of Piraeus and Fig.38 Naval College. Each Chart consists of two circles; the outer depicts the answers that were recorded as "certainty" and the inner the answers that were recorded as "uncertainty".
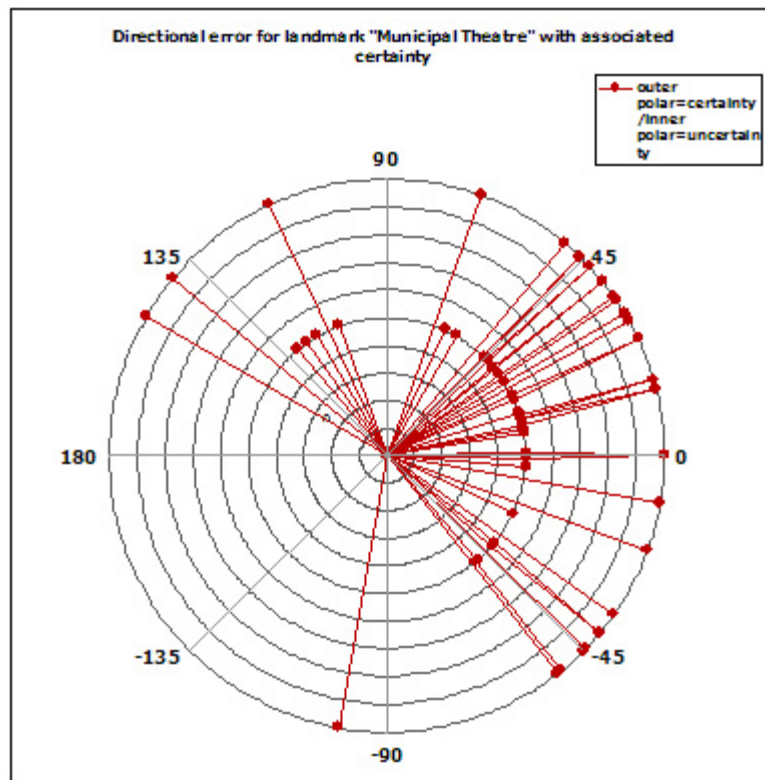
Fig. 36 All groups - Directional error for landmark "Municipal Theatre" with associated certainty (Modern Piraeus).
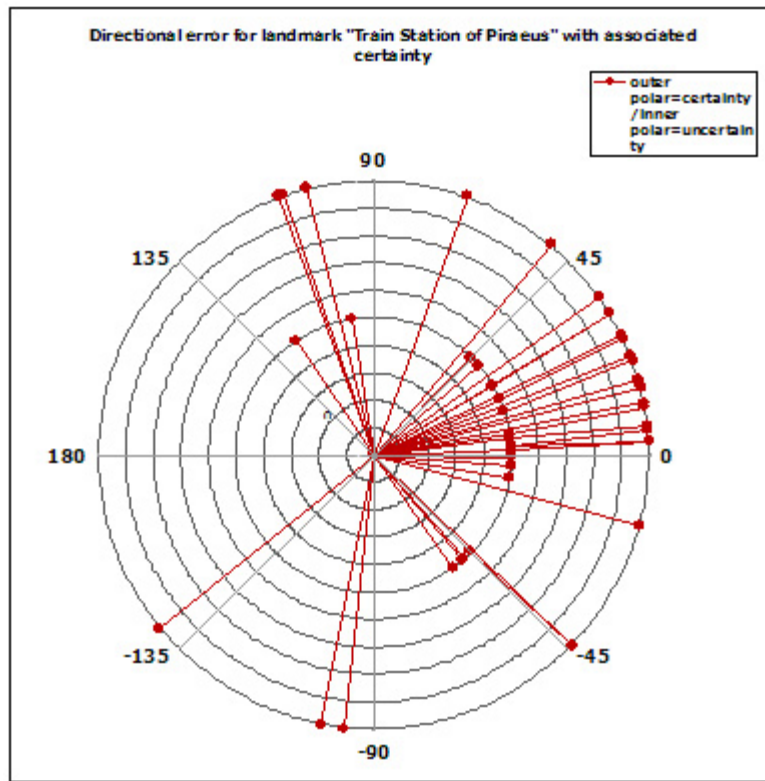
Fig. 37 All groups - Directional error for landmark "Train Station of Piraeus" with associated certainty (Modern Piraeus).
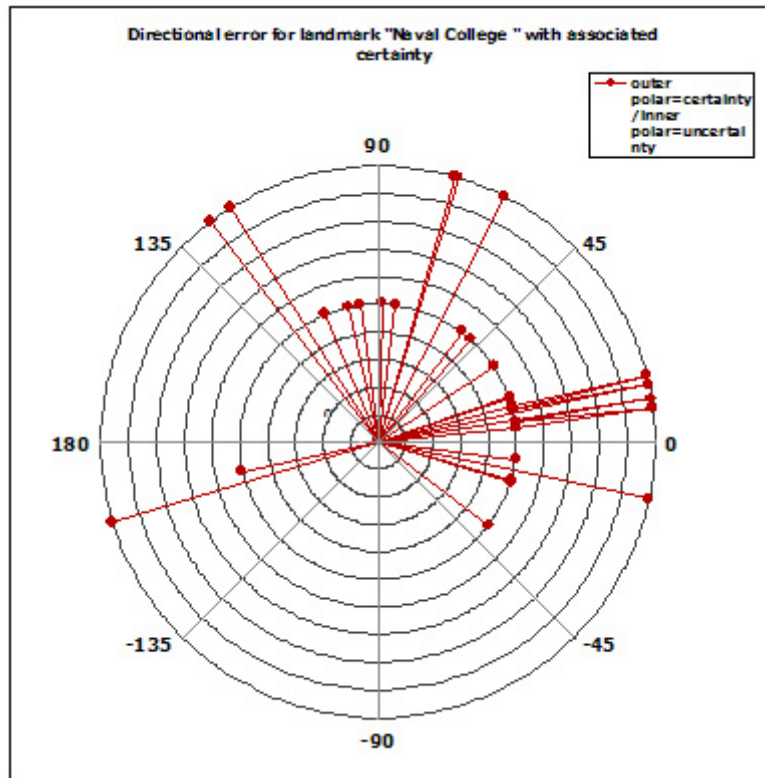
Fig. 38 All groups - Directional error for landmark "Naval College" with associated certainty (Modern Piraeus).

In a similar way, the following three Polar Charts demonstrate the Directional error for Landmarks concerning Antiquities with associated certainty for all groups of participants. Fig.39 shows the Archaeological Museum, Fig.40 the Main Gate of Piraeus, and Fig.41 the Konon Walls (Porfura).
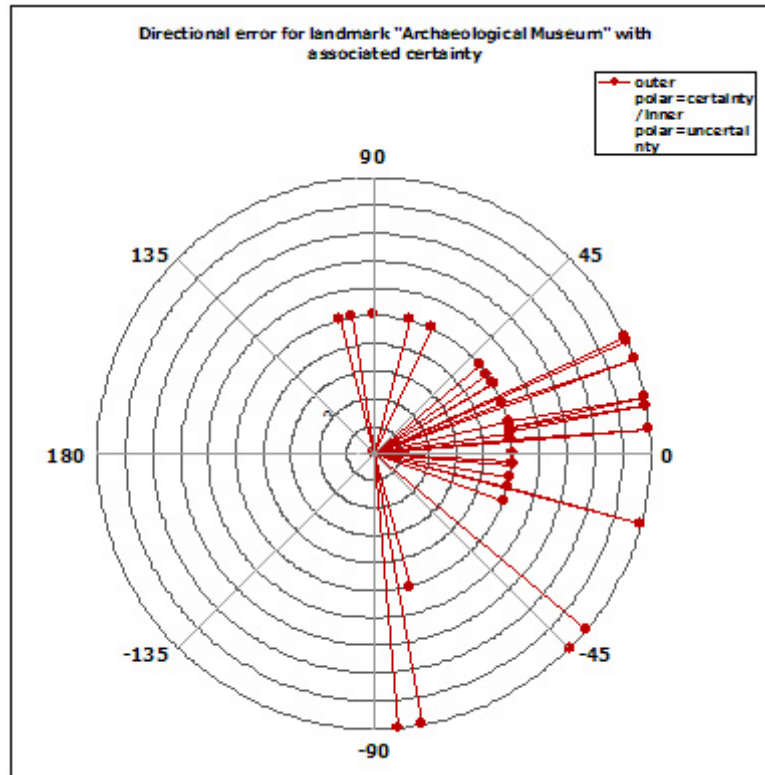
Fig. 39 All groups - Directional error for landmark "Archaeological Museum" with associated certainty (Antiquities).
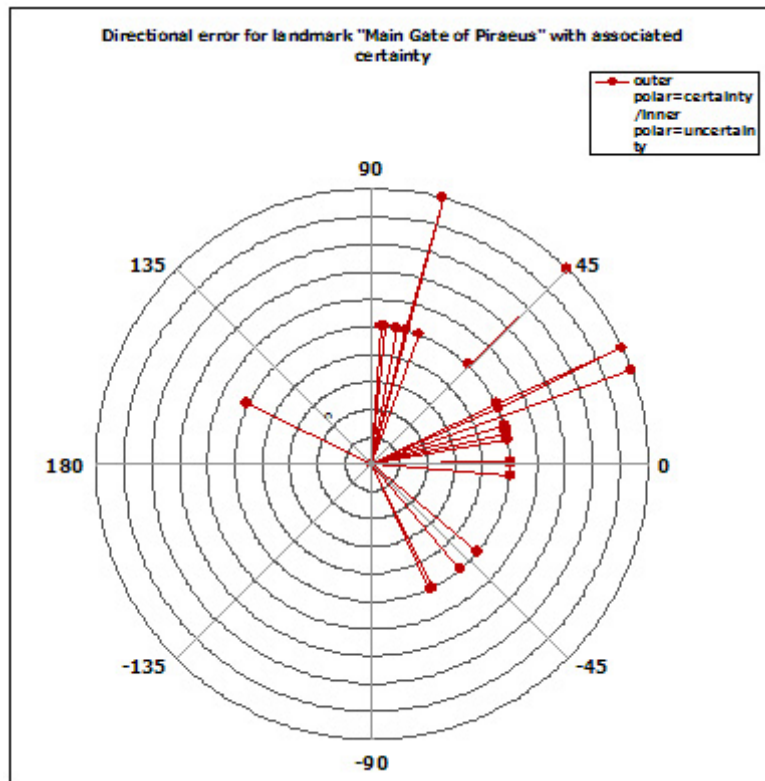
Fig. 40 All groups - Directional error for landmark "Main Gate of Piraeus" with associated certainty (Antiquities).
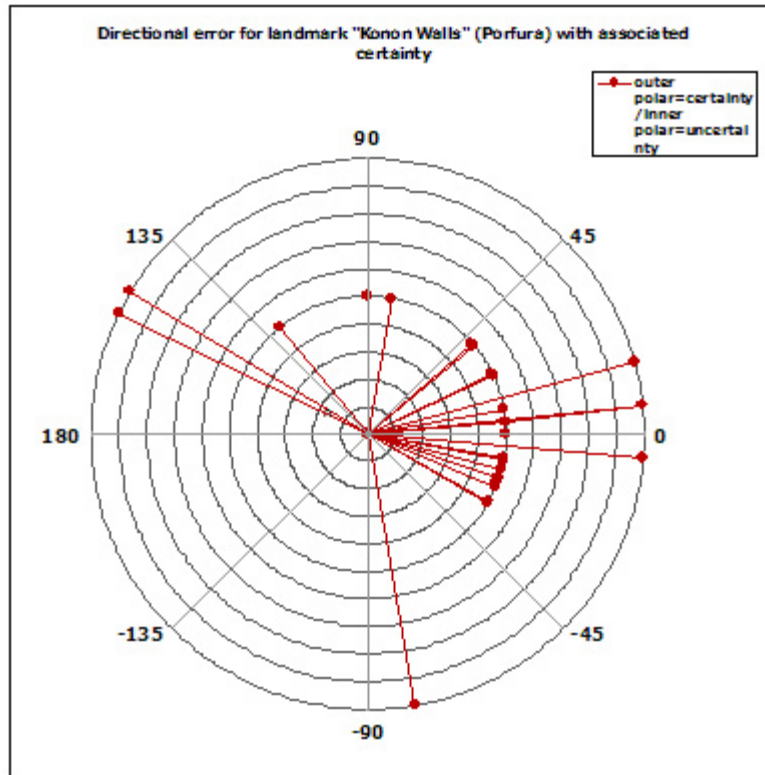
Fig. 41 All groups - Directional error for landmark "Konon Walls" (Porfura) with associated certainty (Antiquities).

Last but not least, there are the polar charts that represent the Directional error for Landmarks concerning Leisure activities with associated certainty for all three groups of participants. Fig.42 shows the Municipal Theatre, Fig.43 the Train Station of Piraeus and Fig.44 Naval College.

Fig. 42 All groups - Directional error for landmark "Restaurant "Axinos" with associated certainty (Leisure).
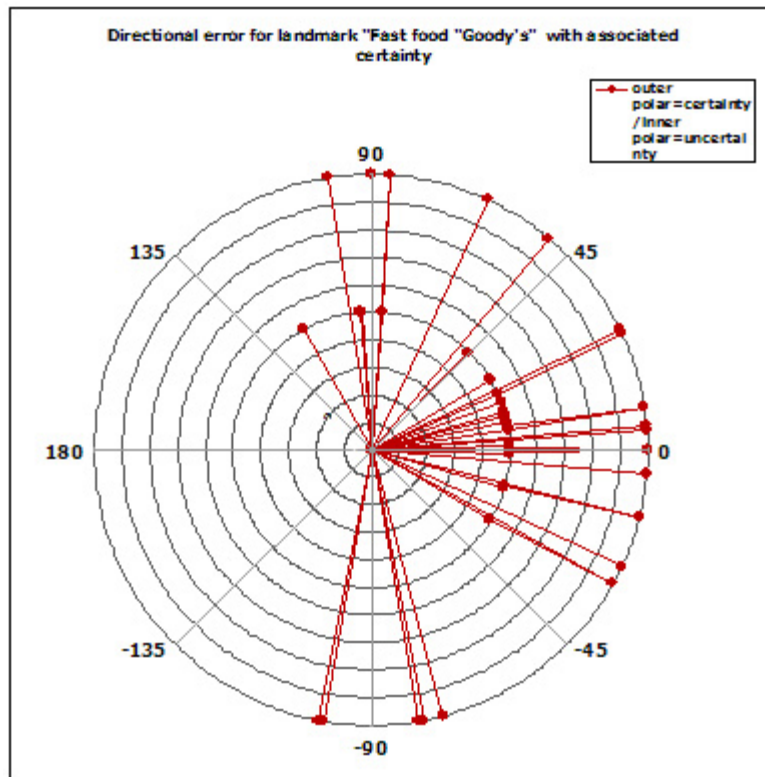
Fig. 43 All groups - Directional error for landmark "Fast food "Goody's" with associated certainty (Leisure).

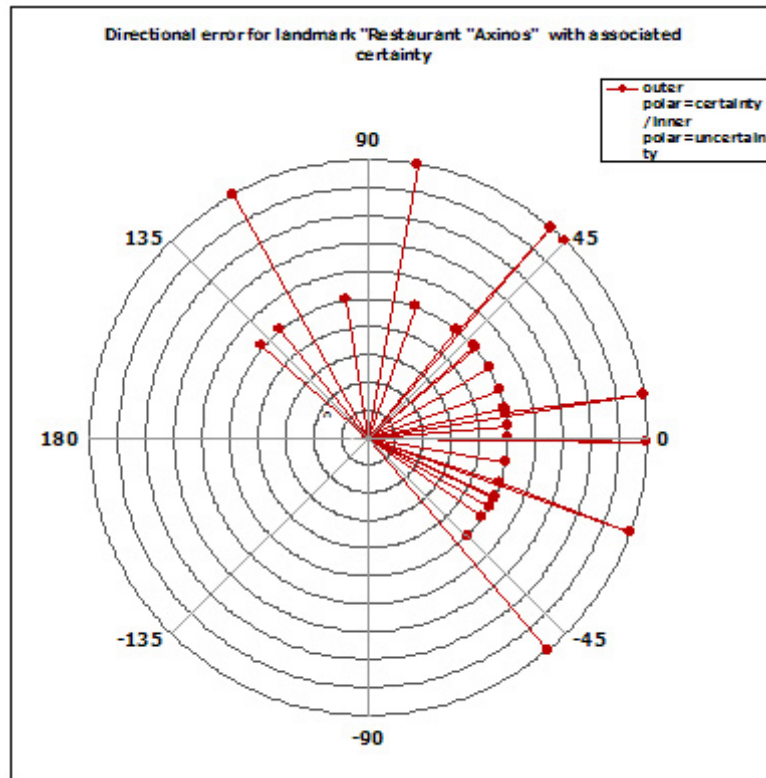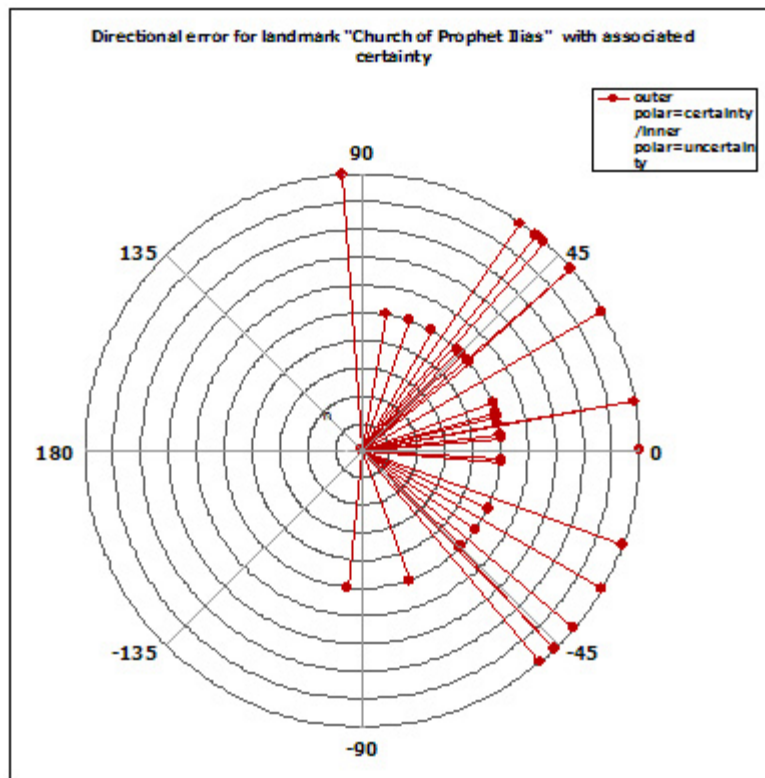**Fig. 44** All groups - Directional error for landmark "Church of Prophet Ilias" with associated certainty (Leisure).

4.2.4   Key points

The participants of this experiment had to use a cognitive map of the environment, by locating each of the nine places by pointing at the estimated each time destination. The Regional Locals claimed familiarity with the place and the requested locations. However, it cannot be discounted that places have many characteristics, including a name or identity, physical features such as color, shape, size, and so on. Therefore, although "place" is a dimensionless spatial term, conventionally it is interpreted as a *multidimensional phenomenon* (Golledge, R., 1992). As found in the previous experiment in Peraiki Coast, Regional Locals claimed familiarity with a landmark or a district even when they only knew its name and others if they had observed, visited, or pass by that feature frequently. Importance accrues to the place because of this common knowledge. Therefore this "common knowledge" would be interpreted as "certainty" to them.

The Locals, in order to point towards a direction tend to use both global and local scale as frame of reference. Being familiar with the city, and having the landmarks (that we will reveal in the third Experiment) as the dominating directional and orientation key to transmit spatial information, the recognition task was considered by the majority of the Locals as a "simple" task.

The regression analysis reveals that from all three categories of locations (**Antiquities**, **Modern Piraeus** and **Leisure**), the *Antiquities*, although they are dispersed within the whole city spatial scale (global and local scale), the geometric content (metric distances, topological relations) appear to be distorted and biased. Less fuzziness (less average displacement error) appears to have the *Leisure*. People use a least erroneous or biased representation concerning the leisure activities, even if the reference frame (egocentric/view-dependent vs. allocentric/view-independent) is the same for all locations. Another conclusion that can be draw from the analysis is that when the subjects were asked to point a Landmark from "Modern Piraeus" or "Antiquities", they showed a linear trend towards *right side* in their pointing error, while when they were asked to point a Landmark from "Leisure", they showed a linear trend equally towards both sides, and the least pointing error (Fig.35). Such a finding could imply that the targets associated with leisure activities are better specified in the mental representations of the pedestrian's of Piraeus. One explanation could be that pointing accuracy is positively associated with the geographical adjacency; the Leisure's targets were closer to the experiment's location (Mikrolimano) than Modern Piraeus' and Antiquities' targets.

4.3   Experiment_03 – Sotiros Dios St.

4.3.1   Part One_ Mental Maps

4.3.1.1   The survey

The third Experiment was conducted in **Sotiros Dios Street** with a sample of 76 people (17 locals, 19 regional locals and 15 visitors) and it took place during two weekdays and a weekend (15/06/06, 18/06/06 and 21/06/06) and consists of *two parts*. The first part concerns the construction of mental maps and it is an **allocentric** type of representation (not dependent on the body's position in space or direction of regard). The participants were given a map of the centre of Piraeus (in blue and grey colours), on which no elements were indicated and they were asked to draw a sketch map of the spatial layout of the centre, including every kind of element such as streets, buildings, areas and open spaces. As through the experiment the frequency of the occurrence of the city elements was substantial to be measured, no instructions or guidance was provided to the sample. A wide range of competence in drawing maps was found among the participants. Fig.45, Fig.46 and Fig.47 show two relatively well drawn (one by a Local and one by a Regional Local) and a poorly drawn sketch map (by a Visitor) side by side[27].

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[27] In Appendix G all the mental maps are presented.
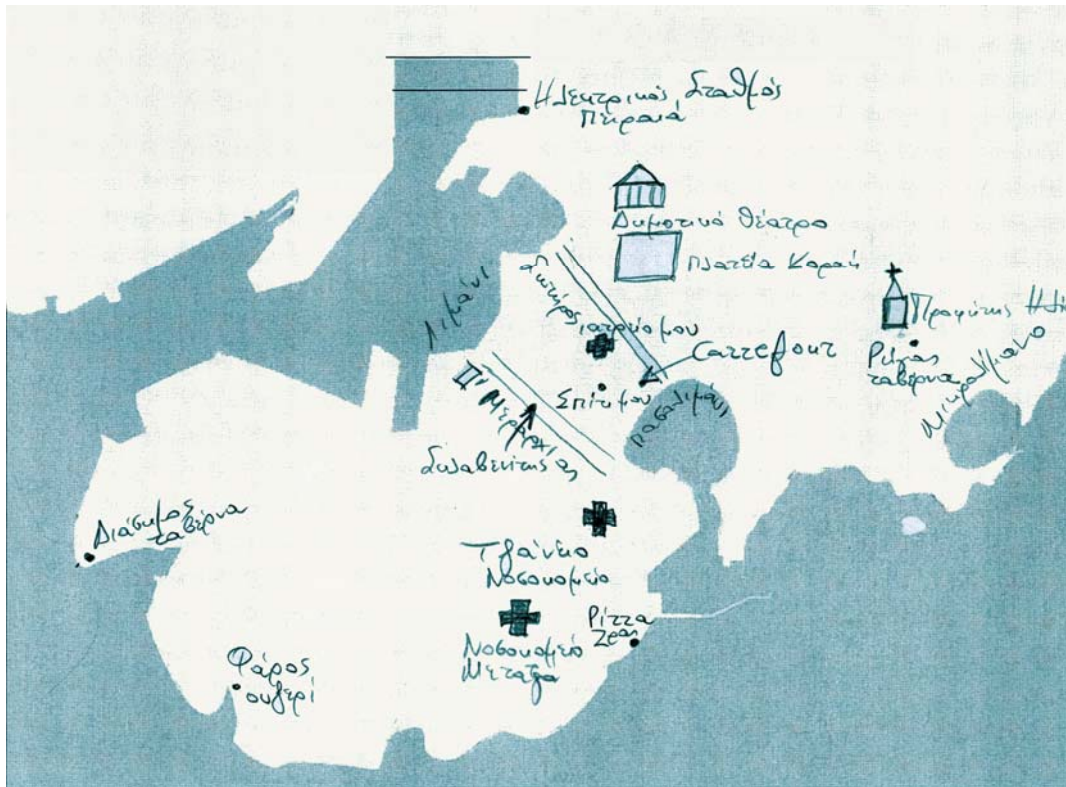
Fig. 45 Mental map drawn by a Local.
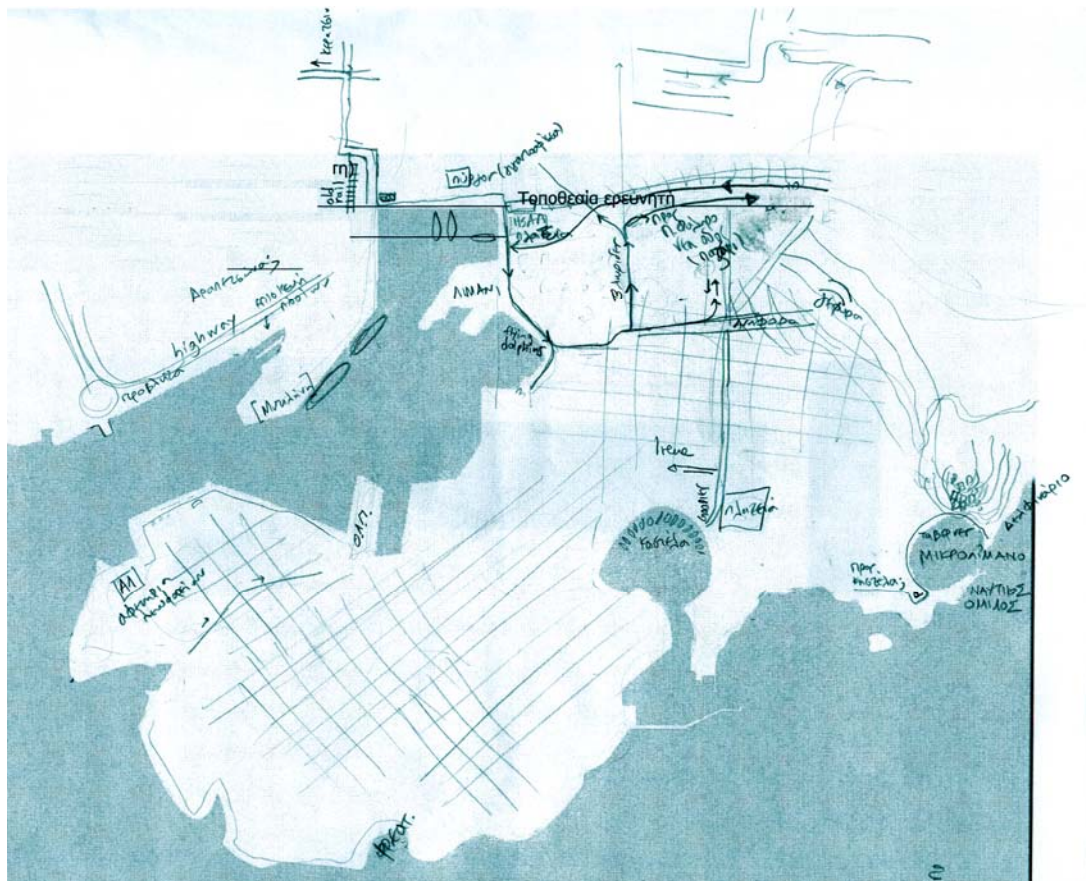
Fig. 46 Mental map drawn by a Regional Local.
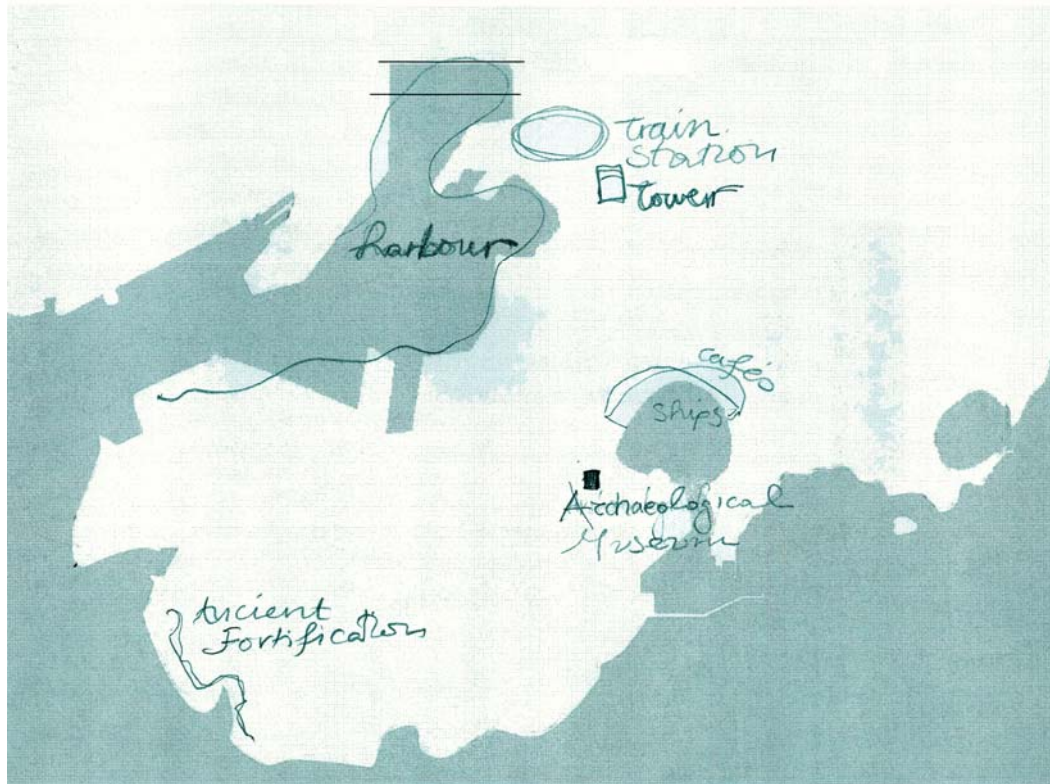
Fig. 47 Mental map drawn by a Visitor.

4.3.1.2   Data analysis/Observations

From the analysis of the maps, it was found that there are a number of typical errors, including incompleteness, variations in scale across the area, roads being drawn too wide, possible straightening of roads and use of single lines to represent streets. The maps are also sometimes very simple, highly selective, distorted, and augmented. These typical errors are valuable in this study because they may allow us to understand the syntactic characteristics of sketch maps that reflect how people perceive and represent the real environment.

In this part of the research, three techniques are used to elicit cognitive information from the maps. First, a conventional analysis is performed by disaggregating depicted elements. The *Lynch-defined environmental components (landmarks, paths, edges, nodes and districts)* are invoked in order to classify the elements of Piraeus. The number of times each element was drawn is counted. Fig.48 illustrates the number of participants that represented the city Elements in their maps. The Landmarks tend to be depicted more often in the maps – 237 times – while Districts were represented 144 times, Edges 34 times,

Paths 30 times and Nodes 20 times. This result suggests that the **visual descriptor** of Landmark (Conroy Dalton, R. and Bafna, S., 2003) plays the primary role in the acquisition and transmission of knowledge of the environment (and not the *visual descriptor* of Edge). Additionally, the **spatial** **descriptor** of District (the other two are the Nodes and the Paths) is utilised as anchor for location in the process of wayfinding.

The hierarchical difference between the *spatial* and *visual* elements has been demonstrated by recent studies in wayfinding, such in the research of Benjamin's Kuipers (Kuipers, B., 1996). According to Kuipers, the mental maps are primary structured by the spatial elements ("first order elements"), which then may be elaborated, or fine-tuned by the addition of visual elements ("second order elements"). However, in the mental maps that the pedestrians of Piraeus drawn, the inverse finding seems to be observed; the visual elements seem to play a more crucial role than the spatial ones. Fig.49 shows the total number of the elements (in groups) and their frequency of occurrence in the maps.

Lynchian Elements in the centre of Piraeus
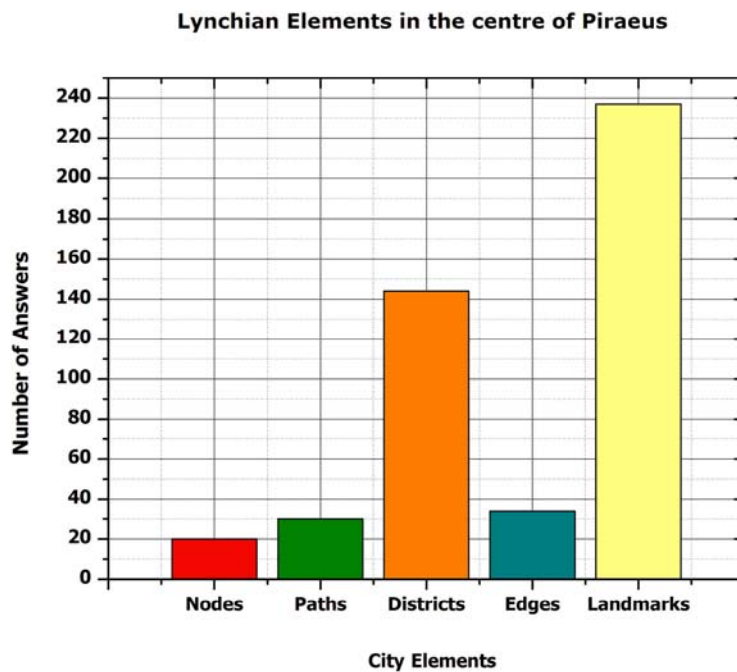
Fig. 48 The Lynchian Elements in the centre of Piraeus depicted by the subjects.
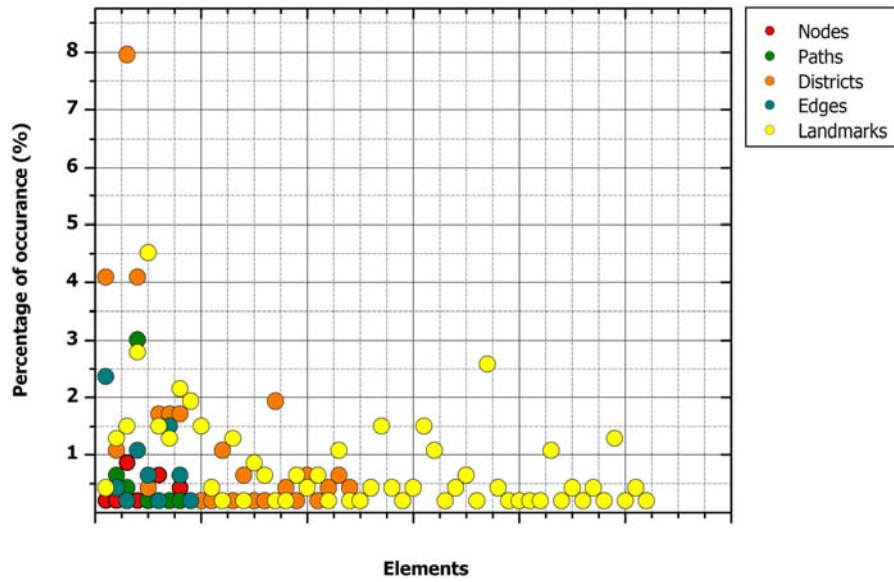
Fig. 49 Occurrence of Elements of the city centre divided in 5 groups.

In more detail, the analysis looked at the frequency with which each element is represented in the maps (Fig.50, Fig. 51, Fig.52, Fig. 53, and Fig. 54).

Fig. 50 Frequency of Landmarks occurring.

Fig. 51 Frequency of Districts occurring.

Fig. 52 Frequency of Edges occurring.

Frequency of Paths occurring
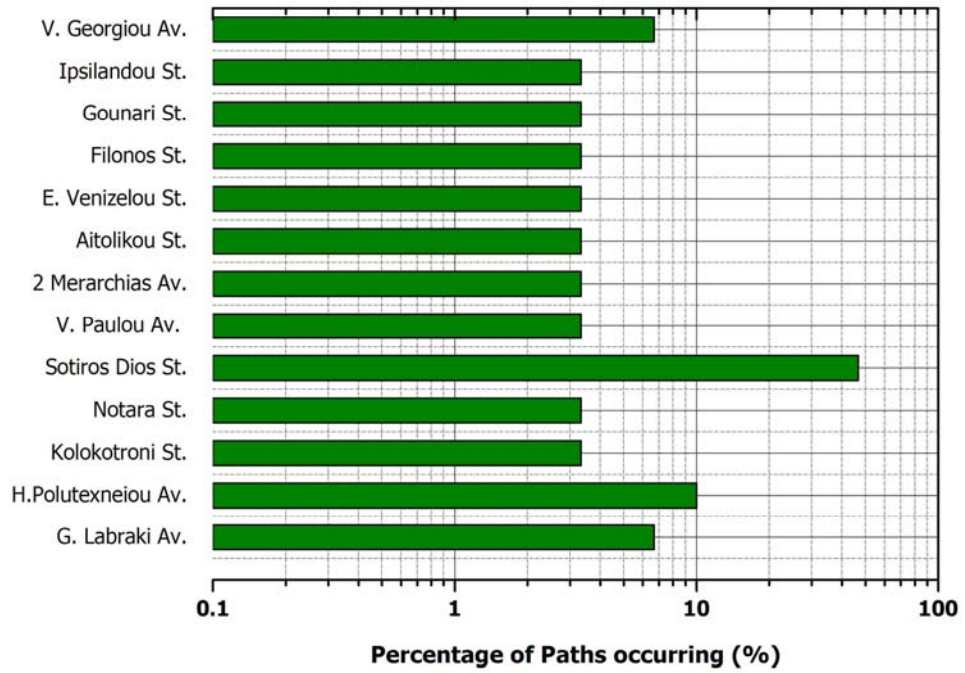
Fig. 53 Frequency of Paths occurring.

Frequency of Nodes occurring
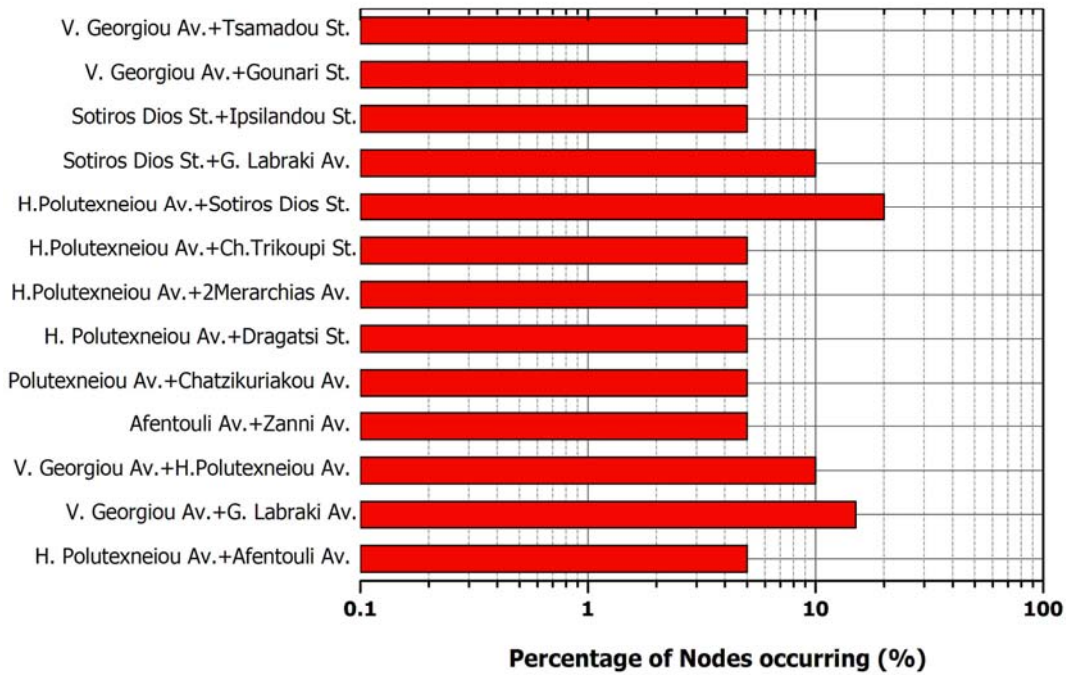
Fig. 54 Frequency of Nodes occurring.

4.3.1.3   Further Analysis

In further analysis, Space-syntax analysis is applied and an axial break–up that contains all the axial lines which enclose, or are adjacent to, the aforementioned elements was drawn. Therefore, the resultant "set" of the axial lines is held, in statistical terms, to be a "population" (Glossary of Statistical terms). This population consists of 963 *axial lines*. Furthermore, the ten most frequently occurring elements are chosen and in statistical terms these are held to be a **"sample"** (Glossary of Statistical terms) of the wider **"population"**.[28] The sample consists of *91 axial lines* (1 line is common for Main Harbour and Train Station and one line is common for Municipal Theatre and Korai Sq.*). Fig.55 illustrates the percentages of the most often represented elements that indicate the "sample" and Fig.55 shows the 10 locations.
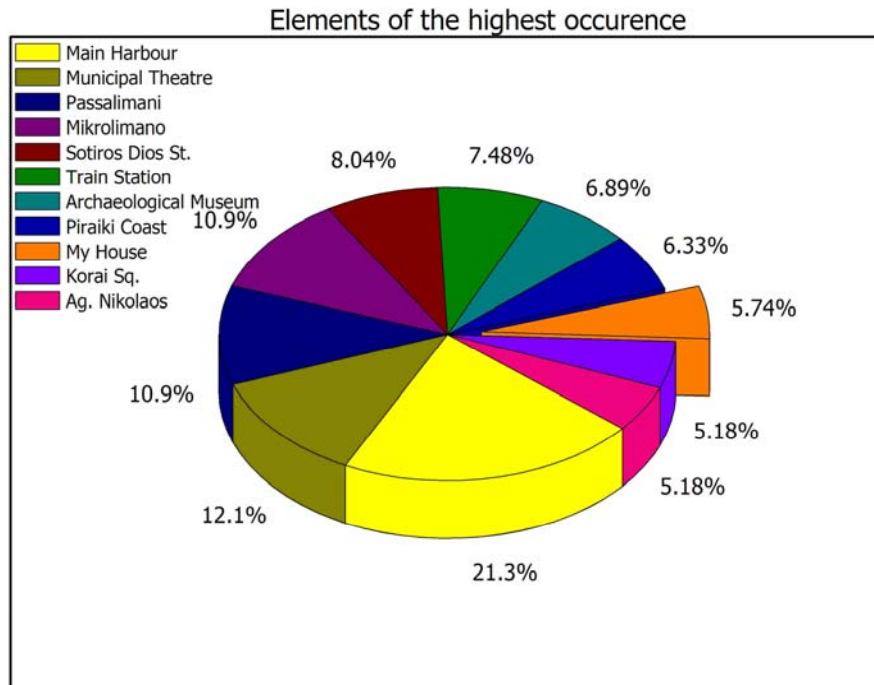
Fig. 55 Percentages of the most often represented elements of the sample.

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[28] The way the axial lines of the sample were selected is described in Appendix H.
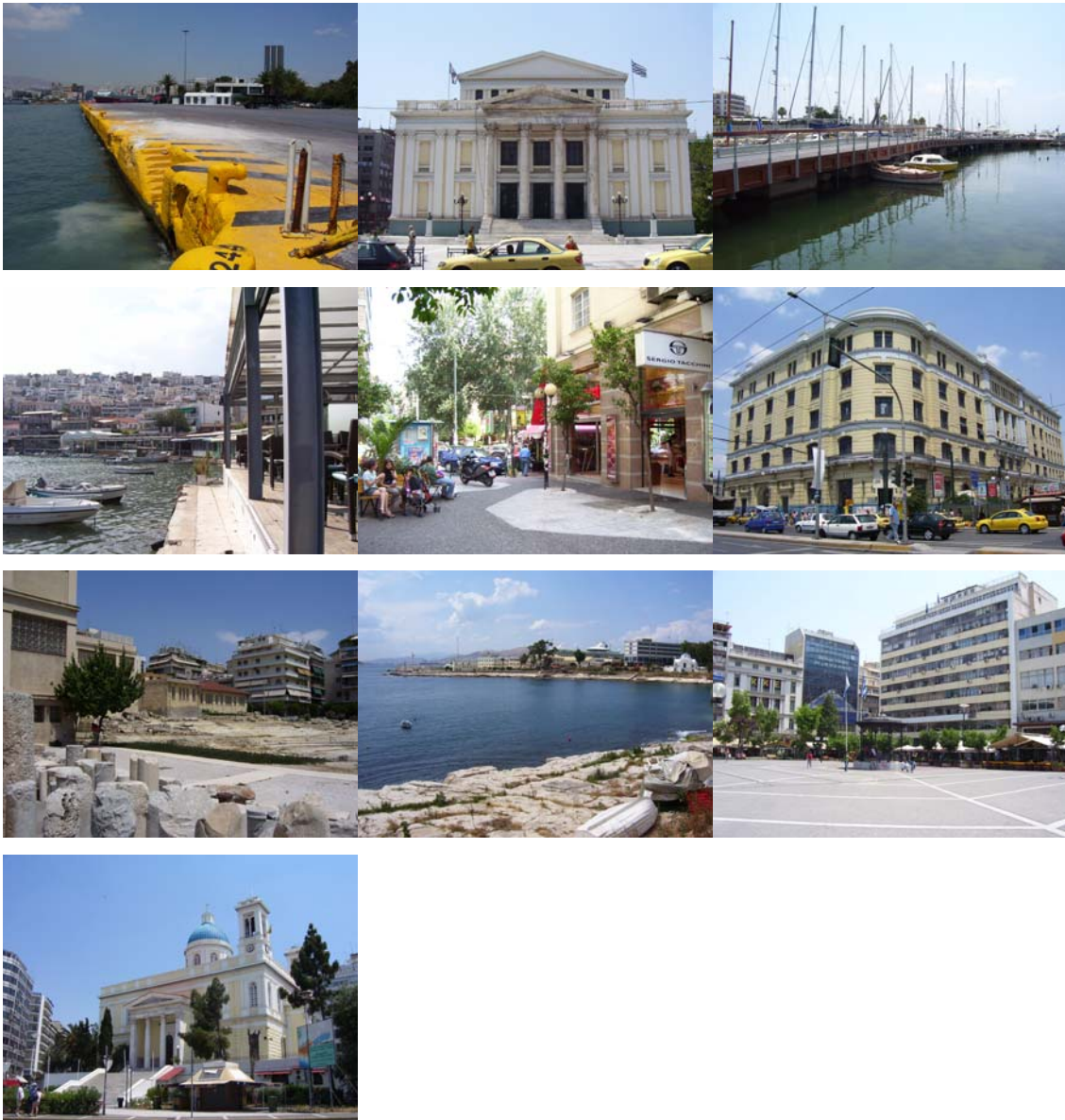
Fig. 56 The ten most frequently depicted elements: (from right to left) Main Harbour, Municipal Theatre, Passalimani, Mikrolimano, Sotiros Dios St., Train Station, Archaeological Museum, Peraiki Coast, Korai Sq. and Ag. Nikolaos.

Through space syntax analysis the characteristics of the configuration of spaces and features could be quantified and the syntactic values of the lines that describe the elements could be measured. Not only were the values of global integration and of local integration R3 calculated, but the connectivity values for each element as well. On the maps, the location of the participants' residents *("My House")* is frequently depicted, at 5.74%. Although this observation is included in the statistical analysis, for the purpose of this study is excluded from the "sample" (Table 3).

	Most frequent in occurrence Elements	Classification	Percentage of occurrence (%)	No of subjects
1	**Main Harbour**	District	7.96	37 people
2	**Municipal Theatre**	Landmark	4.52	21 people
3	**Passalimani**	District	4.09	19 people
4	**Mikrolimano**	District	4.09	19 people
5	**Sotiros Dios St.**	Path	3.01	14 people
6	**Train Station**	Landmark	2.80	13 people
7	**Archaeological Museum**	Landmark	2.58	12 people
8	**Peraiki Coast**	Edge	2.37	11 people
9	*My House*	*Landmark*	*2.15*	*10 people*
10	**Korai Sq.**	District	1.94	9 people
11	**Ag. Nikolaos**	Landmark	1.94	9 people

Table 3 Most frequent in occurrence elements.

The syntactic values of the elements of the "sample" are measured (Table 4).

City Elements	Number of axial lines	Average Int Rn	Average Int R3	Average Connectivity
Main Harbour	28	1.5837	0.5885	0.2015
Municipal Theatre	4	0.801	0.8348	0.4345
Passalimani	10	0.5207	2.5276	0.0976
Mikrolimano	6	1.0535	0.3677	0.0793
Sotiros Dios St.	1	2.3881	3.7086	28
Train Station	4	0.6318	0.7403	0.2916
Archaeological Museum	4	0.6665	0.8265	18.5
Peraiki Coast	28	0.1968	0.3809	0.0697
Korai Sq.	4	0.8043	0.8326	19.25
Ag. Nikolaos	4	0.6008	0.7795	0.3511
Total	93	1.5602		

Table 4 Averages of syntactic values (IntRn, Int R3, Connectivity).

Descriptive statistics - **central limit theorem and z-test**

As one of the main objectives of the research is to investigate the association between configurational features and cognitive representations and thus throw light on how configurational aspects of the built environment may affect the cognitive knowledge, descriptive statistics were again applied. Using a couple of statistical tests, the **central limit theorem** and the **z-test**, it is possible to compare the sample of the selected axial lines to its population and determine how likely it is that the sample was drawn at random from that population.

The central limit theorem states that for any sample population drawn from a population (which need not be normally distributed) then as long as the sample size is relatively large (n>10) then the distribution of the sample will be approximately normal. The

larger the size of the sample the better the approximation. The sample size of most frequent in occurrence elements used in this part of the research is 91 (very large), which means that uses this definition.

The value of the random variable z using the central limit theorem is shown below (Logan B.F., Mallows CL, Rice SO and Shepp LA, 1973):

$$Z = \frac{\sum_{i=1}^{n} X_i - n\mu}{\sigma\sqrt{n}} \square\, N(0,1)$$

Where X_1, X_2, ... are a sequence of independent random variables (the selected elements), μ is the mean of the population and σ^2 its standard deviation.

Approximately normal distributions occur in many situations, as a result of the central limit theorem. Using the statistical method of z-test, we tested the initial hypothesis which assumed that the pedestrians of Piraeus *don't* randomly select the 10 aforementioned elements to represent in their mental maps. The test requires stating a hypothesised mean difference, which in the hypothesis has a value of 0.7031. A confidence level is also required for this test and the standard 95% confidence level has been used. Essentially, if the resultant value of z is less than a specified value (listed on a statistical look-up table), then the sample (the most often depicted elements) *could have been drawn at random* from the population. If the value of z is larger, then it implies that participants were not depicting certain elements randomly.

The two tests were made three times. In the first case (**Case 1**) the values of all lines of the sample were calculated. In the second case (**Case 2**) the three elements that consist of the greatest number of lines were excluded (the Main Harbour, Passalimani and Peraiki Coast). However, those lines were *not* excluded from the total number of lines of the Sample (it remained 91 lines). In the third case (**Case 3**) not only the three aforementioned elements were excluded but their lines as well (therefore the Sample consists of 26 lines).

The results of the two statistical tests, the z-test and the central limit theorem, for the three cases are presented in the following Table 5.

	Measure	No of lines -Sample	Populati on Av.	Populati on Stand ard Dev.	Populati on Varianc e	Sample Av.	Sample Standa rd Dev.	Sample Varia nce	" Z " from c. l. t.	" Z " from Z-test
Case1	lnRn	91	1.5579	0.3080	0.0949	1.5602	0.5255	0.2762	-22.8363	0.00001
Case2	lnRn	91	1.5579	0.3080	0.0949	1.8647	0.5295	0.2804	-41.5767	0.00001
Case3	lnRn	26	1.5579	0.3080	0.0949	1.8647	0.5295	0.2804	-77.7825	0.00001

Table 5 The results of the two statistical tests, the z-test and the central limit theorem, for the three cases.

According to the results of the z-tests, z_1, z_2 and z_3 have a value of 0.00001, with z_1 from central limit theorem being -22.8363, z_2 -41.5767 and z_3 -77.7825 (the sign of z, i.e. whether it is a positive or negative number is not important in this case). The fact that it is less than a specified value (1.65 for a one-tailed distribution and 1.96 for a two-tailed distribution), implies that in all cases the sample of the elements was *not* drawn randomly from the population and especially the third value (z_3 -77.7825 – which is the highest –) indicates that the 26 selected lines have been selected for certain reasons.

The table of results also indicates that the average value of global Integration for the sample of 91 lines is 1.5602, lower than the average of the sample of 26 lines which is 1.8647, while both of the averages are higher than the average value of the population (1.5579). This result demonstrates that the cognitive model of Piraeus that people have in their minds is constructed in relation to the closeness or accessibility of spaces from all others – in other words the measure of integration.

Furthermore, the values of Standard Deviation for the two samples are quite similar. For the sample of 91 lines is 0.5255 and for the sample of 26 lines is 0.5295 and they are both higher than the value of the population (which is 0.3080). This result indicates that the second sample that includes the most integrated lines also contains lines of greater range in integration.

Analysing the syntactic properties of the population with a respect to the syntactic variables of the spaces represented in the maps using axial-analysis methods, it could be suggested that not all the depicted elements are located in areas of high connectivity or high integration. Fig.57 shows Global Integration Rn of axial analysis of the "population" and the locations of the "sample" (91 lines). Fig.58 shows Connectivity of the "population".
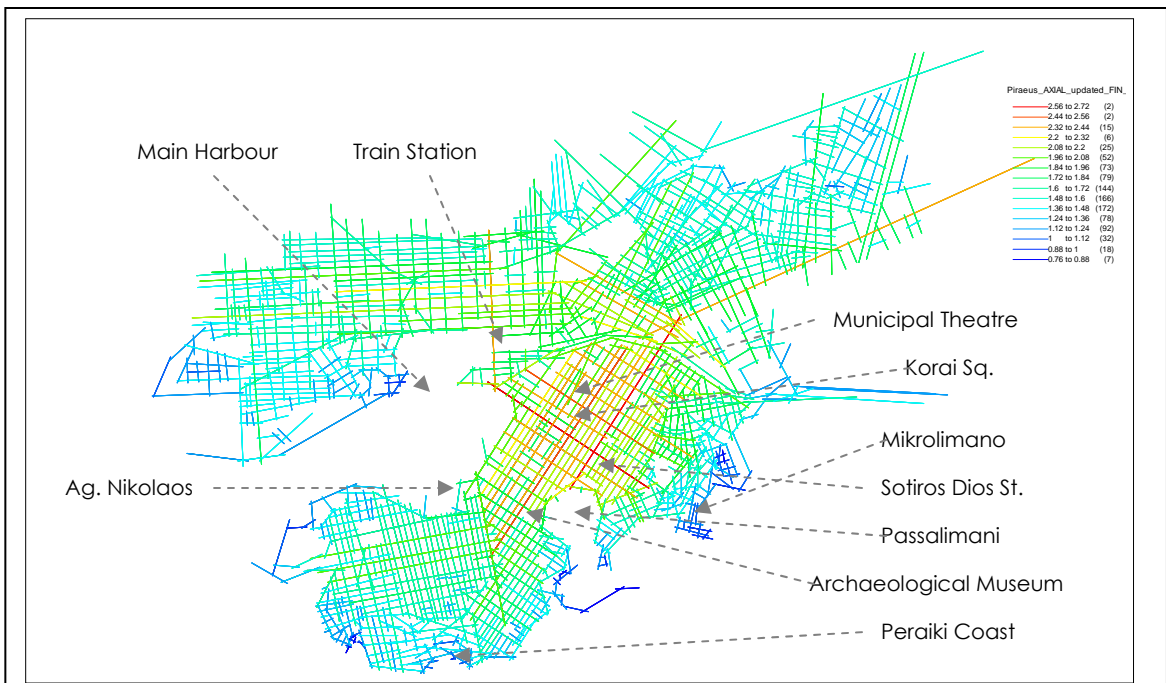
Fig. 57 Global Integration Rn of axial analysis of the "population" and the locations of the "sample" (91 lines).
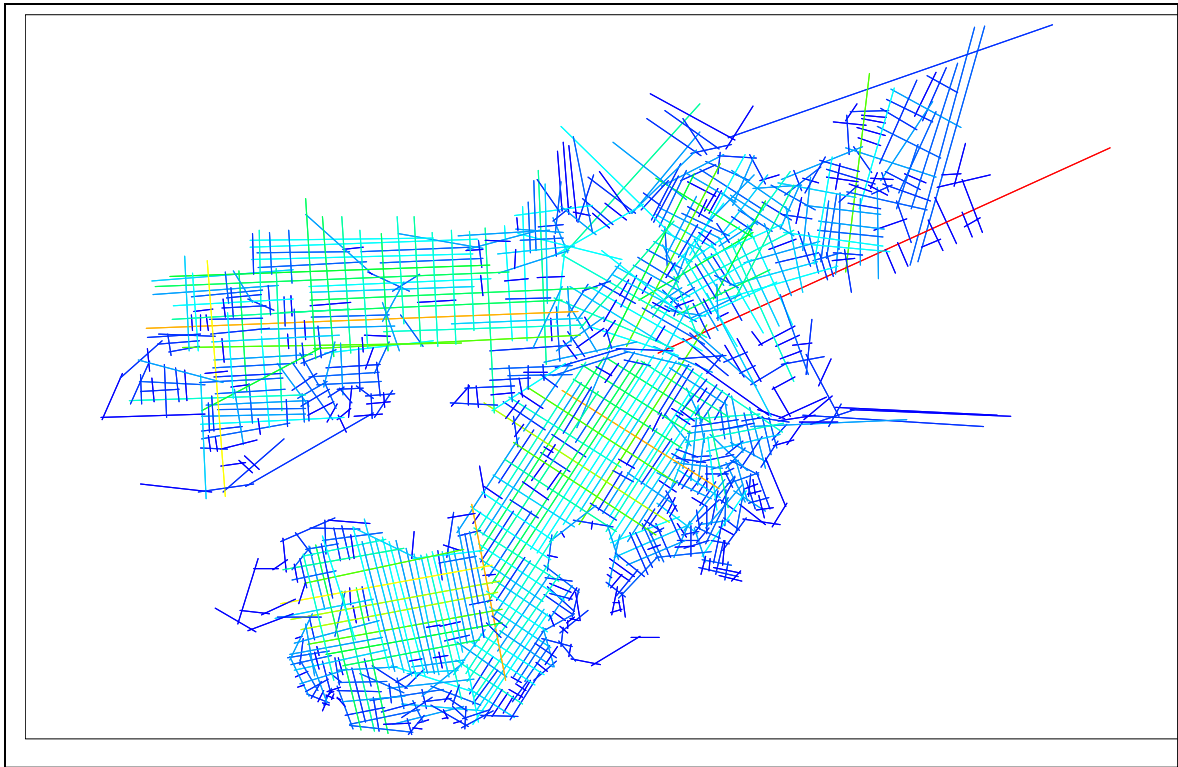
Fig. 58 Connectivity of the "population".

In order to construct a picture of the ease or difficulty with which we come to understand the shape of this complex space by seeing a part of it at a time through movement within it, the concept of **"intelligibility"** (Hillier et al., 1987, Hillier, 1996a) is built

on this relation. The scattergram demonstrating the systematic relation between grid structure and movement, namely the correlation between the connectivity and integration values of the lines making up the axial map of the grid (intelligibility), reveals that the "sample" has an ambiguous performance within the whole system. The adjusted r-square value 0.5066 (Fig.59) implies that the sample is oscillating between intelligibility and unintelligibility. The ten lines that seem to have the best performance (marked in a red dotted ellipse) are those that "grasp" the three grids of the city and especially the oldest of all grids; that of the centre (Fig.60).
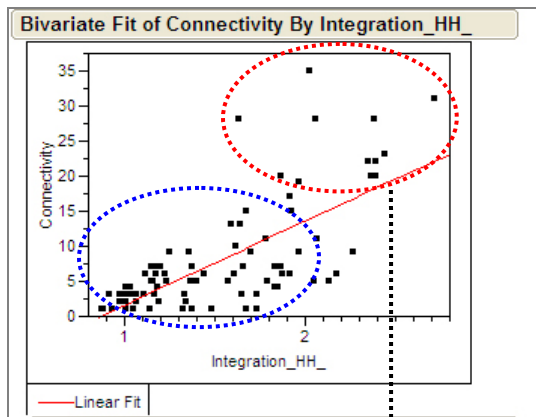
Fig. 59 Intelligibility of the "Sample".
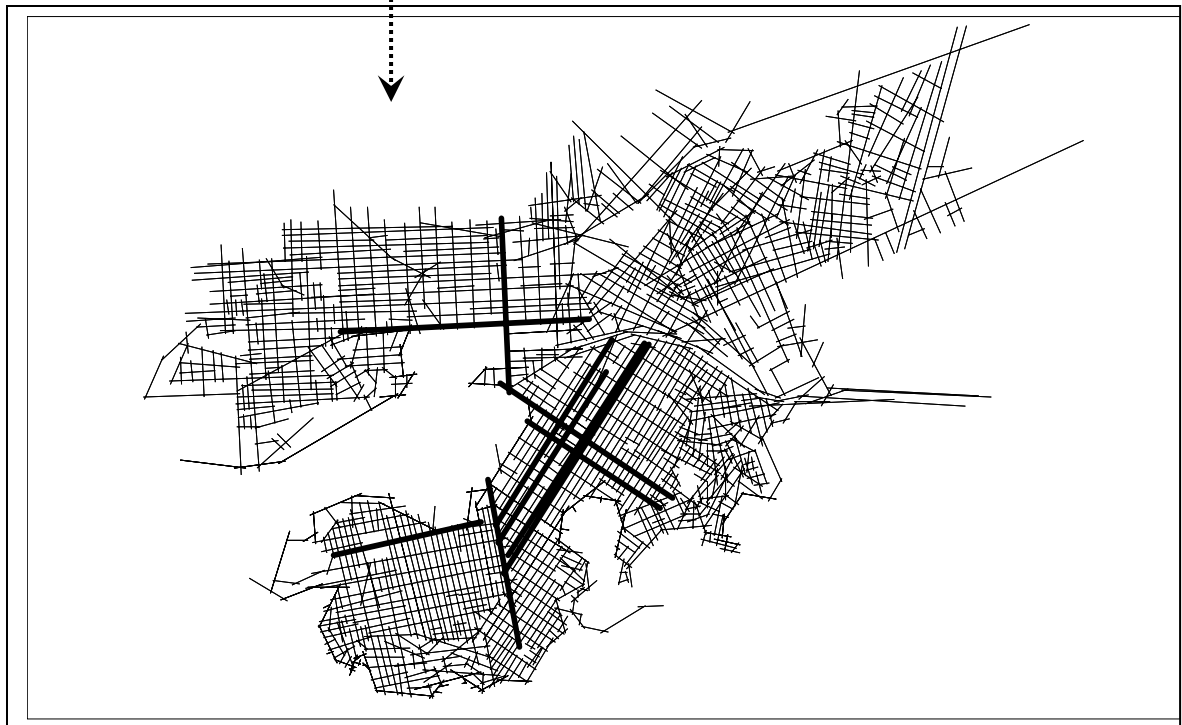
Fig. 60 Axial Map of the selected "Population". The most intelligible lines of the "sample" are highlighted. The three grids of the city of Piraeus are clearly demonstrated.

Fig. 61 Axial Map of the selected "Population". The least intelligible lines of the "sample" are highlighted. They are four of the most frequent in occurrence elements of the city: the District of Main Harbour, of Passalimani, of

The regression analysis reveals two outlier groups, one in the upper right part, marked in a red dotted ellipse, and another in the lower left, marked in a blue dotted ellipse (Fig.59). The first outlier group (Fig.60) consists of spaces that enclose Landmarks and the Path and the second group (Fig.61) consists of spaces that are mostly Districts and Edges. The Landmarks have high global integration values, and indeed these spaces are the most frequently represented on the mental maps, as shown in Fig.48. However, considering the ten most often in occurrence (Fig.55), it is certain Districts that play the crucial role in the cognitive knowledge of the pedestrians of Piraeus (the representation is 21.3% for the Main Harbour, 10.9% for Passalimani and 10.9% for Mikrolimano).

From the results above, it can be concluded that there is a clear pattern of association between the syntactic properties of the real environment and those of the mental maps, suggesting that the measure of global integration is a good predictor of cognitive representations of spatial configuration. Taken alongside the finding that global integration is closely related to the frequency of elements drawn on the maps, this suggests that global integration is strongly related not only with simple information referring to the occurrence of elements in mental maps but also with the more complex information referring to relational knowledge of spatial configuration.

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However, the measures of global integration and Connectivity cannot fully reveal the cognitive mechanisms that are being considered while navigating through the city. As mentioned in Chapter 4.1.4 there are other aspects such as geometrical properties of a space and topological relations that should be also considered. These aspects are analysed thought the second part of the Third Experiment.

4.3.2   Part Two_ Origins-Destinations

4.3.2.1   The survey

In the second part of the Experiment, route-choice decisions are made by the participants while being at the same location (Sotiros Dios Street) as they were in the first part. As the routes are built up by connecting a series of landmarks, this strategy is egocentric (dependent on the body's location and direction of pointing in space). The subjects were requested to name the route that they would choose going from a certain origin to a certain destination. This question was made for four pairs of origins-destinations. The four pairs were chosen in that way that the elements are distributed within the centre. Fig.62 demonstrates the four pairs.

The four pairs are the following:

- From **Korai Sq.** (in the city centre) **to Marina Zeas** (in Freatida Coast)
- From **Kanari Sq.** (in Passalimani) **to Naval College** (in Peraiki Coast)
- From **Yacht club of Greece** (in Mikrolimano) **to Sotiros Dios St.** (in the city centre)
- From **Kanari Sq. to the Train Station of Piraeus** (in the Main Harbour)

Fig. 62 The four pairs of origins-destinations.
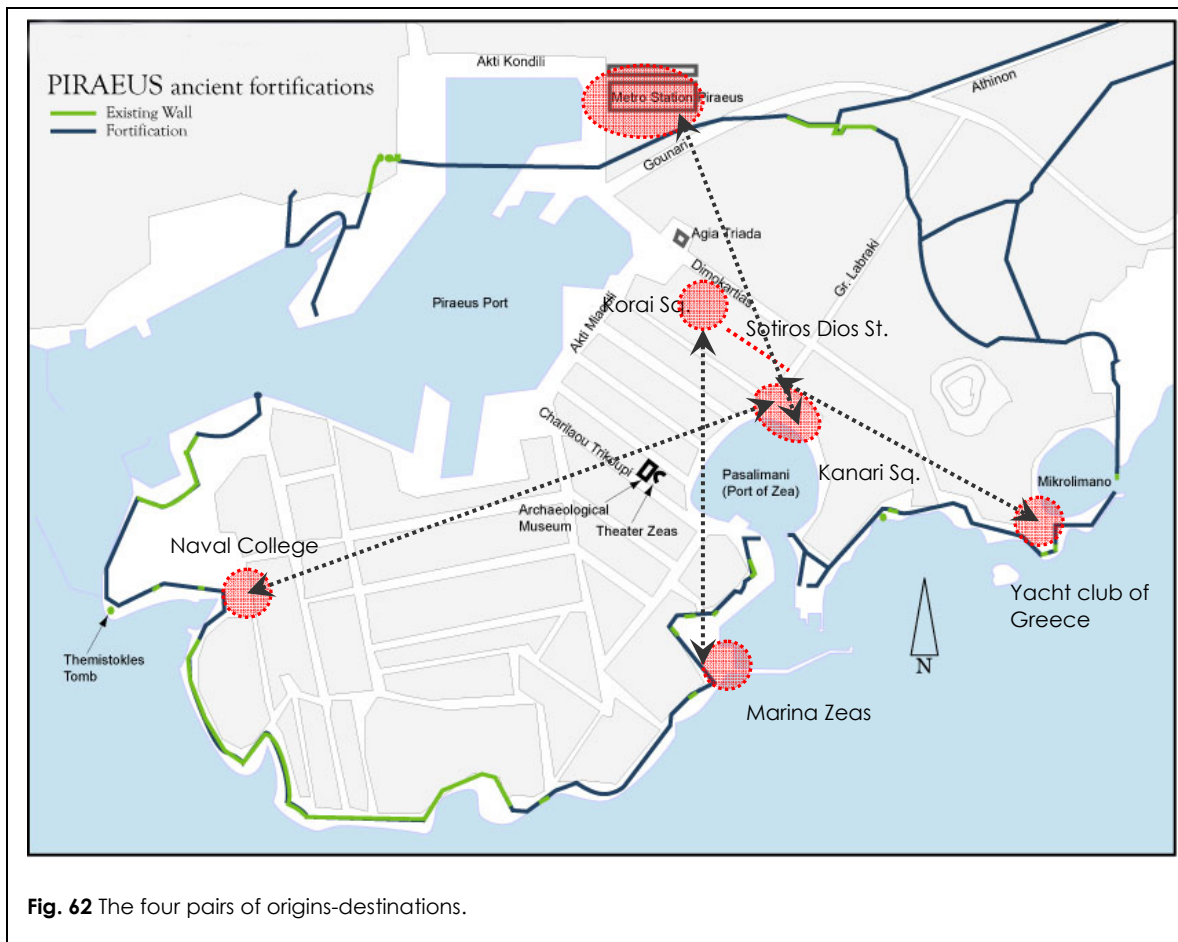
4.3.2.2   Data analysis/Observations

Recent studies have shown (Golledge, 1995, Conroy, 2001) that the most popular routes from a sample also appeared to be more "linear". However, Golledge (Golledge, 1995) in his experiments he surmises that the desire to reduce complexity can only be present if subjects have been told explicitly that they will be required to retrace their route. He states that the factors that are most influential in route choice selection are shortest path, simplest (fewest number of changes of direction) route and following the longest-leg first (i.e. starting the journey by selecting the longest line of sight). In the experiment the participants were not required to retrace their route. The hypothesis is that the three different groups would follow different routes, as every group has different kind of **spatial knowledge**, related to the degree of familiarity they already had with the place they were walking. The application of the **landmark knowledge** for the Visitors, of the **route knowledge** for the Regional Locals and of the **survey knowledge** for the Locals is actually for each group a competition among the desire to select the simplest route in angular

terms (fewest angle changes), in topological terms (fewest turn changes) and in metric terms (fewest length of route).

For the research, the route of each subject is represented and analysed individually. The degree of knowledge of the two given locations and the degree of knowledge of the street network, determined the number of answers. For the pair Korai Sq.-Marina Zeas, from the 76 subjects (17 locals, 19 regional locals and 15 visitors) 100% of the Locals were able to answer, while almost half of the Regional Locals (57.89%) had constraints in defining the route. The Visitors had the least knowledge of all groups (20% answered) (Fig.63). Some of the most interesting cases, from a cognitive point of view, were those in which a participant had to provide the description of a route for the first time, thus having to solve a novel problem. Unfortunately, these cases were very few as in case of ignorance, the route directional request was not granted.

Fig. 63 The knowledge of the route Korai Sq.-Marina Zeas.
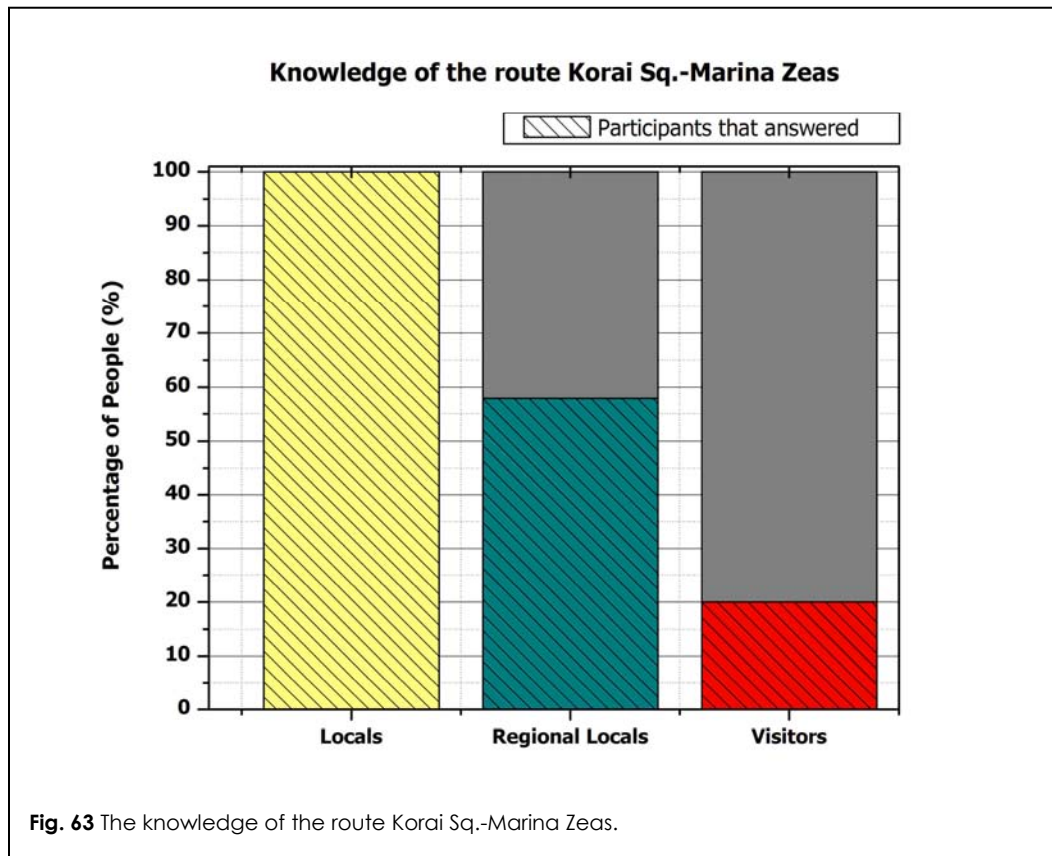
The locations of the origin (Korai Sq.) and the destination (Marina Zeas) for the first pair are illustrated in Fig.64 and Fig.65 show the route decisions made by all three groups (yellow colour for the route decisions of the Locals, dark cyan for the Regional Locals and red colour for the Visitors). Fig.66 and Fig.67 show the origin, the destination and the route

decisions concerning the second pair, Fig.68 and Fig.69 of the third pair and Fig.70 and Fig.71 of the fourth pair respectively.
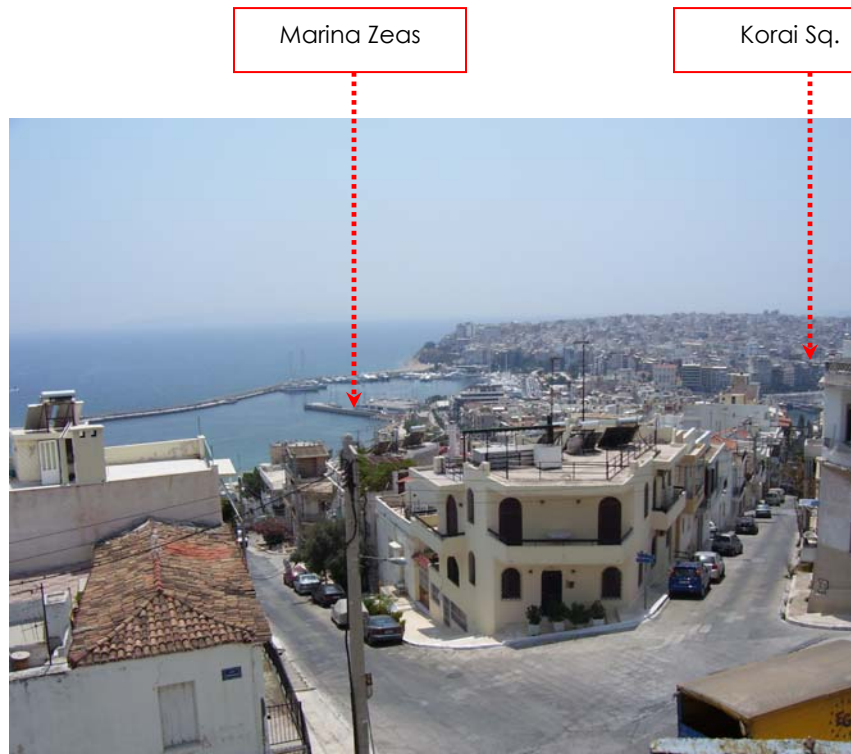
Fig. 64 Origin (Korai Sq.) - Destination (Marina Zeas).
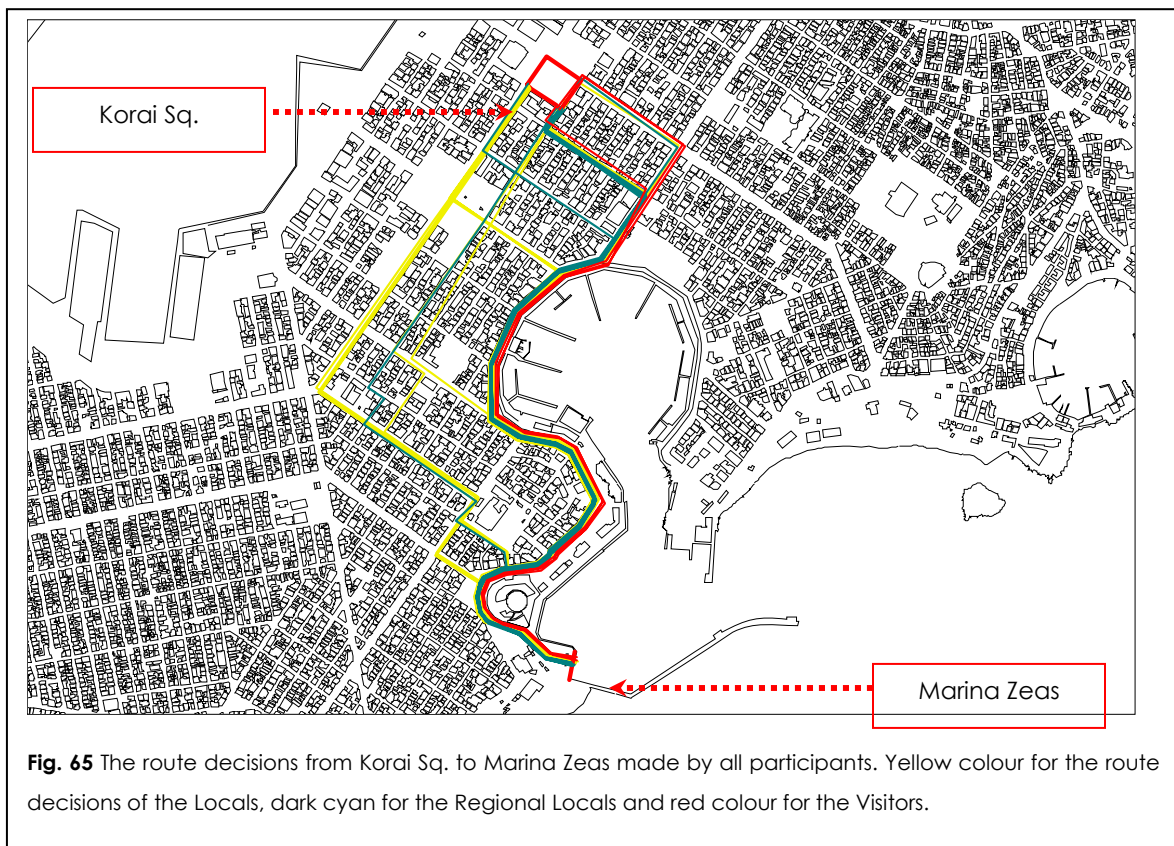
Fig. 65 The route decisions from Korai Sq. to Marina Zeas made by all participants. Yellow colour for the route decisions of the Locals, dark cyan for the Regional Locals and red colour for the Visitors.

Fig. 66 Origin (Kanari Sq.) - Destination (Naval College).
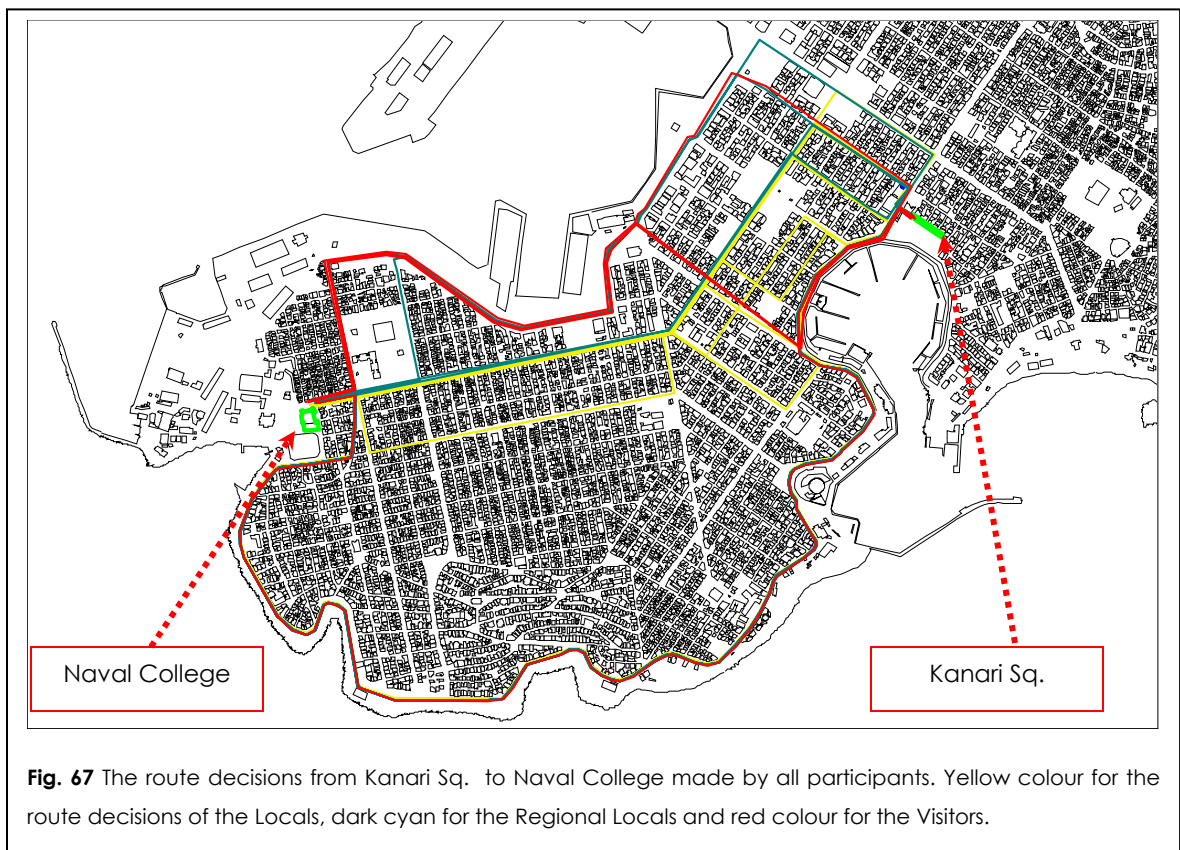
Fig. 67 The route decisions from Kanari Sq. to Naval College made by all participants. Yellow colour for the route decisions of the Locals, dark cyan for the Regional Locals and red colour for the Visitors.
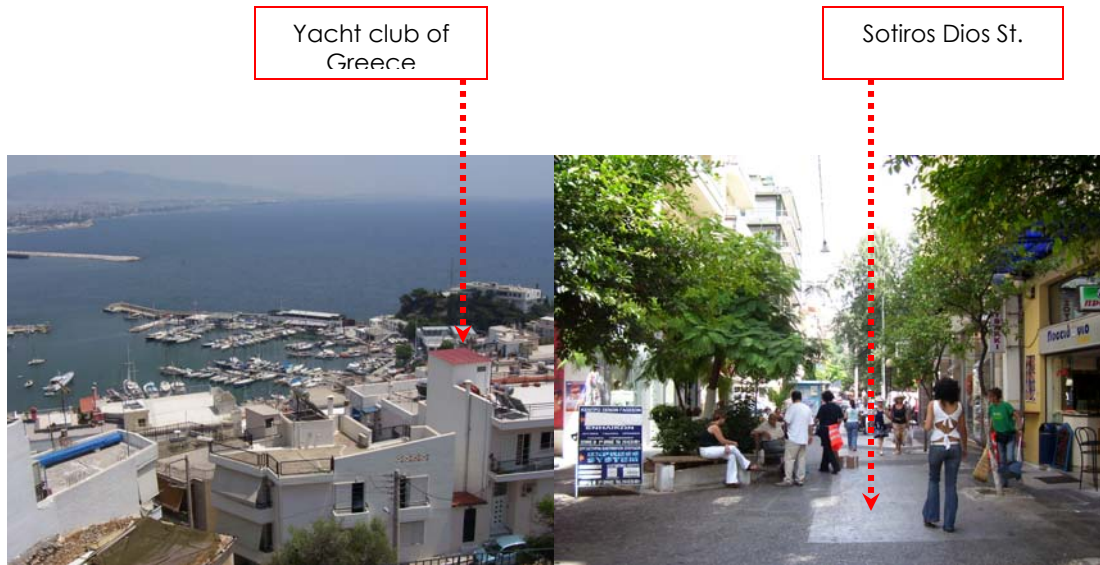
Fig. 68 Origin (Yacht club of Greece in Mikrolimano) - Destination (Sotiros Dios St.).
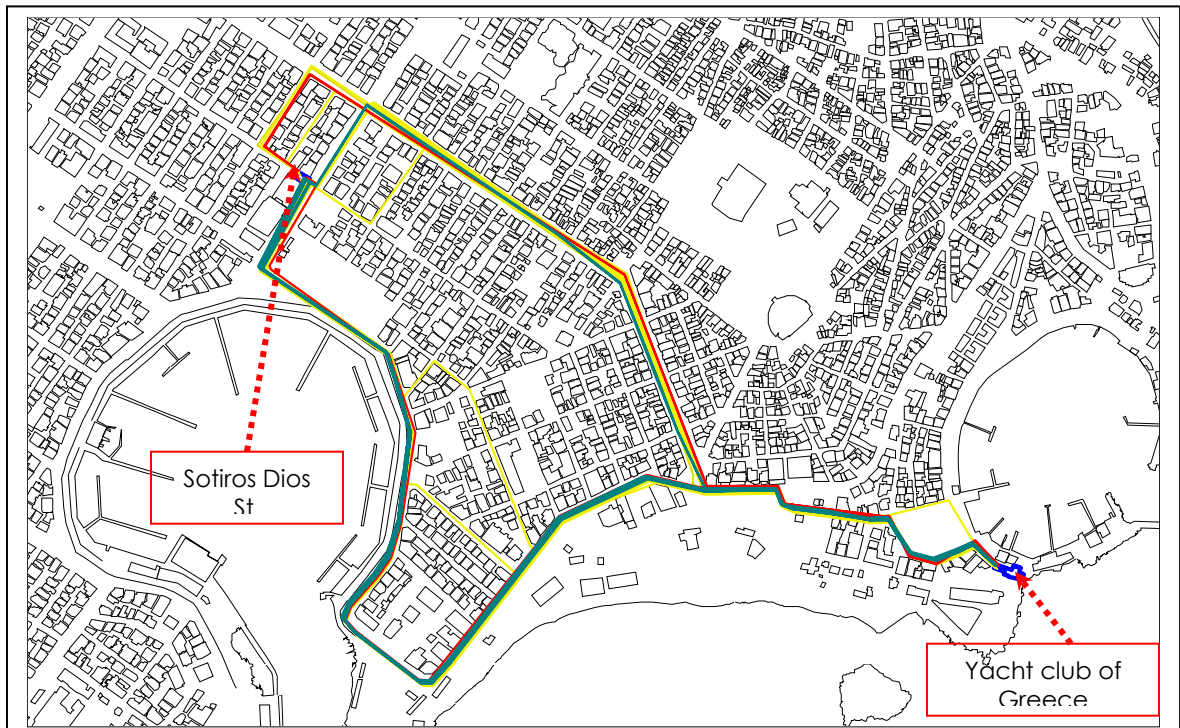
Fig. 69 The route decisions from Yacht club of Greece (in Mikrolimano) to Sotiros Dios St. made by all participants. Yellow colour for the route decisions of the Locals, dark cyan for the Regional Locals and red colour for the Visitors.

Fig. 70 Origin (Kanari Sq.) - Destination (Train Station of Piraeus).
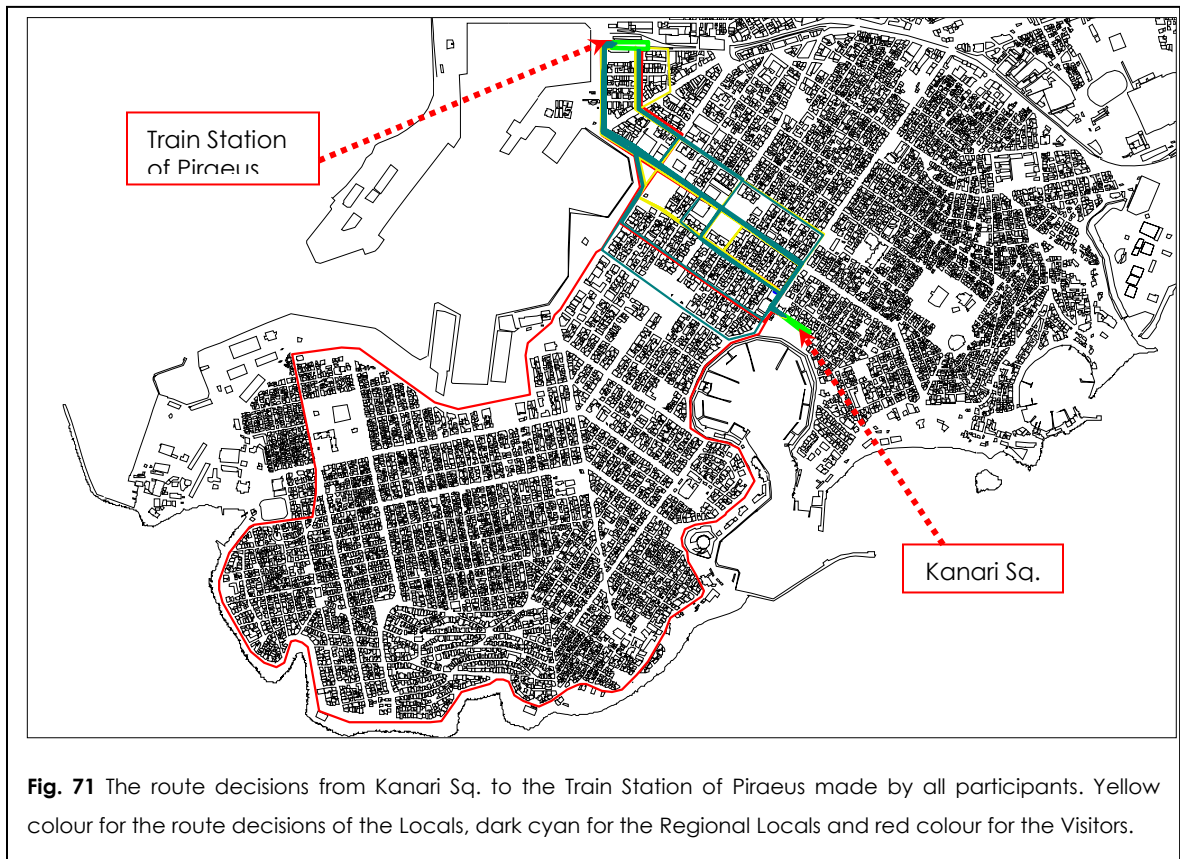
Fig. 71 The route decisions from Kanari Sq. to the Train Station of Piraeus made by all participants. Yellow colour for the route decisions of the Locals, dark cyan for the Regional Locals and red colour for the Visitors.

As all the four pairs of origin-destination are within the centre of Piraeus, it implies that the syntactic analysis should be conducted using an axial break – up that mainly includes

the peninsula. In other case, the values of the syntactic measures would be affected by the great number of lines of the rest of the city. Therefore, for the purpose of this part of the research an axial break-up was also drawn according to natural boundaries, the railways and the ruins of the main Gate of the ancient surrounding wall of Piraeus.

### 4.3.2.3   Further Analysis

a. SEGMEN_ "Get route"

The **"Distance"** between lines is conceptualised differently in human navigation, as suggested by Hillier and Iida in (Hillier B. and Iida S., 2005). It could imply **least length** (**metric**) where the *distance* cost of routes in measured as the sum of segment lengths, defining length as the metric distance along the lines between the mid-points of two adjacent segments, **fewest turns** (**topological**) where the *distance* cost is measured as the number of changes of direction have to be taken on a route and **least angle change** (**geometric**) where *distance* cost is measured as the sum of angular changes that are made on a route.

Iida S. developed a Common Lisp application (the **SEGMEN** model) (Appendix J) which does graph computation for space syntax analysis (Iida Shinichi, 2004, p.1). The analysis that is performed is *simple*, *constant* and *metric* (*angular*, *topological* and *metric* respectively). Using the aforementioned application, *certain* *routes* may be calculated by assigning three different weights to relations between adjacent segments: metric length, directional change, and degree of angular change. In this way, taking the urban street network of Piraeus and subject it to different mathematical interpretations according to how distance is defined, we could be able to explore how well the different interpretations correlate with the real movement patterns taken from the experiment.

b. Axial and Segment Analysis

As the human trip is made up of two elements: a. an origin-destination pair every trip is from an origin space to a destination space (to-movement component) and b. the spaces passed through on the way from origin to destination (through-movement component) (Hillier, 2006), both of integration and choice values should be measured. Having drawn the least line map, we divide each line into its segments. Then, we assign **integration** (closeness in mathematic terms) and **choice** (betweenness in mathematic terms) measures using least angle change (geometric), fewest turns (topological) and shortest path (metric), weightings to relations between each segment and all others, and

we apply them at different radii from each segment, also defining radii metrically, geometrically and topologically[29].

Route _01 – From Korai Sq. to Marina Zeas

The routes of the participants are represented individually (Fig.65, Fig.67, Fig.69, and Fig.71). Allocentric relations comprise both distance and directional information (Klatzky, 1998), where *allocentric interpoint distances* refer to the distances between pairs of objects, and *allocentric interpoint bearings* to the angles formed by a line from one object to another, relative to an axis of reference. Therefore a more rigorous examination of the recorded answers would reveal that people's ability to make an allocentric judgment involves various processes. For the Locals, there are several distinct routes between the two locations, primarily through the centre of the city. The Regional Locals and the Visitors in that case perform similar attribute; the majority of the sample of both groups choose the coastal zone in order to reach Marina Zeas.

Global Integration Rn of Axial analysis that was carried out in the axial break – up in order to measure the syntactic characteristics of the participants' routes is shown in Fig.72. In Fig.73, Fig.74 and Fig.75, the axial map is overlaid with the route choices of Locals, Regional Locals and Visitors respectively[30]. Locals would find their way *through* the most integrated lines of the system, while Regional Locals and Visitors would perform wayfinding following the coastal line of Passalimani and Freatida.

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[29] The two kind of segment analysis, the "topological" and "metric" were carried out using plug-ins in the latest version of Depthmap (Depthmap60505b) that Alasdair Turner recently developed in Space Syntax Laboratory, Bartlett, UCL.

[30] In Appendix I the route choices for the other three pairs are presented.
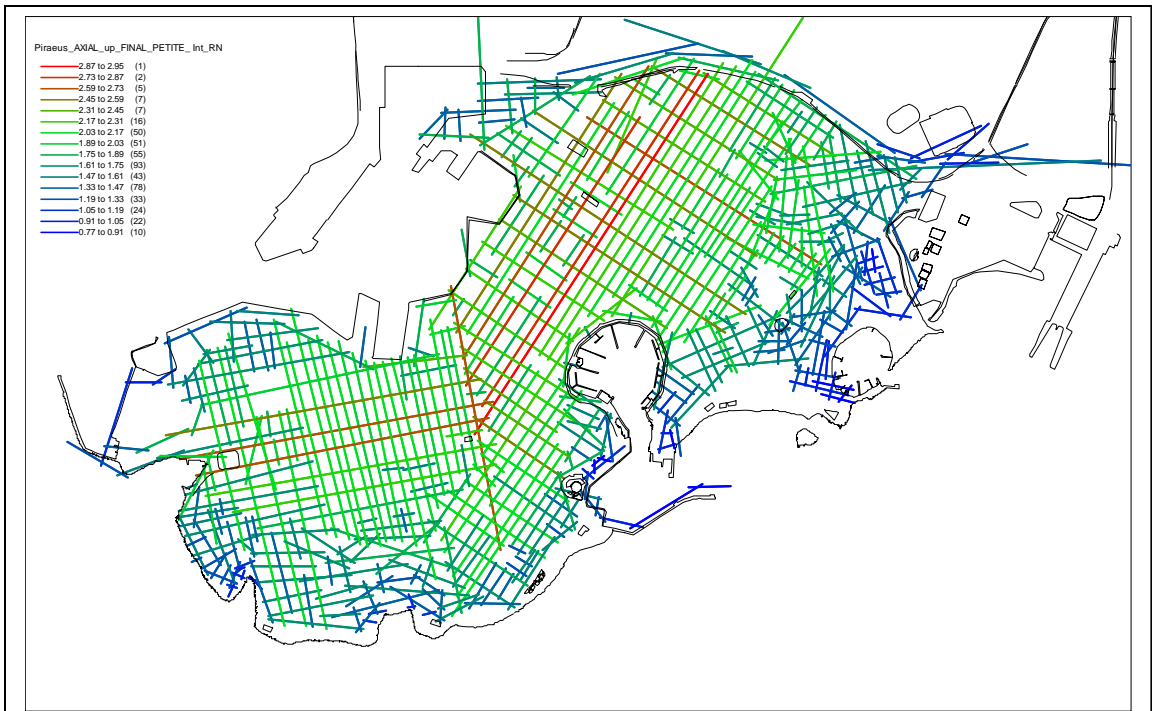
Fig. 72 Axial break–up showing InRn of Piraeus.

Origin: Korai Sq.

Destination: Marina Zeas
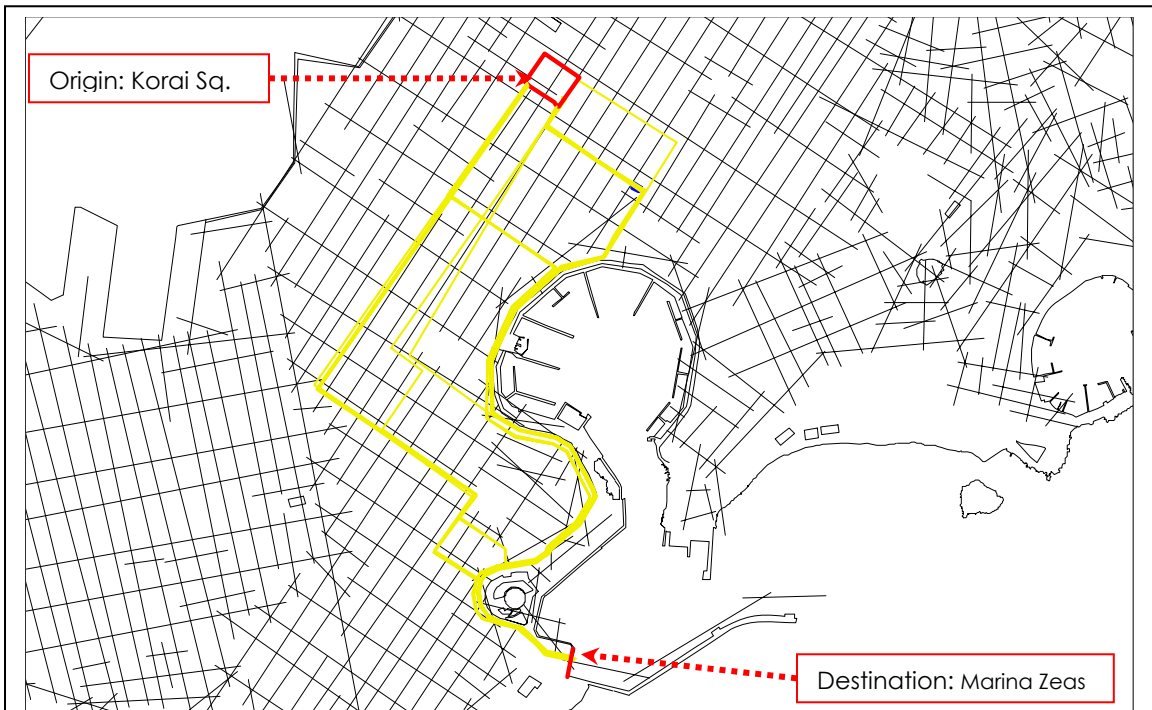
Fig. 73 Axial map overlaid with Locals' route choice from Korai Sq. to Marina Zeas.
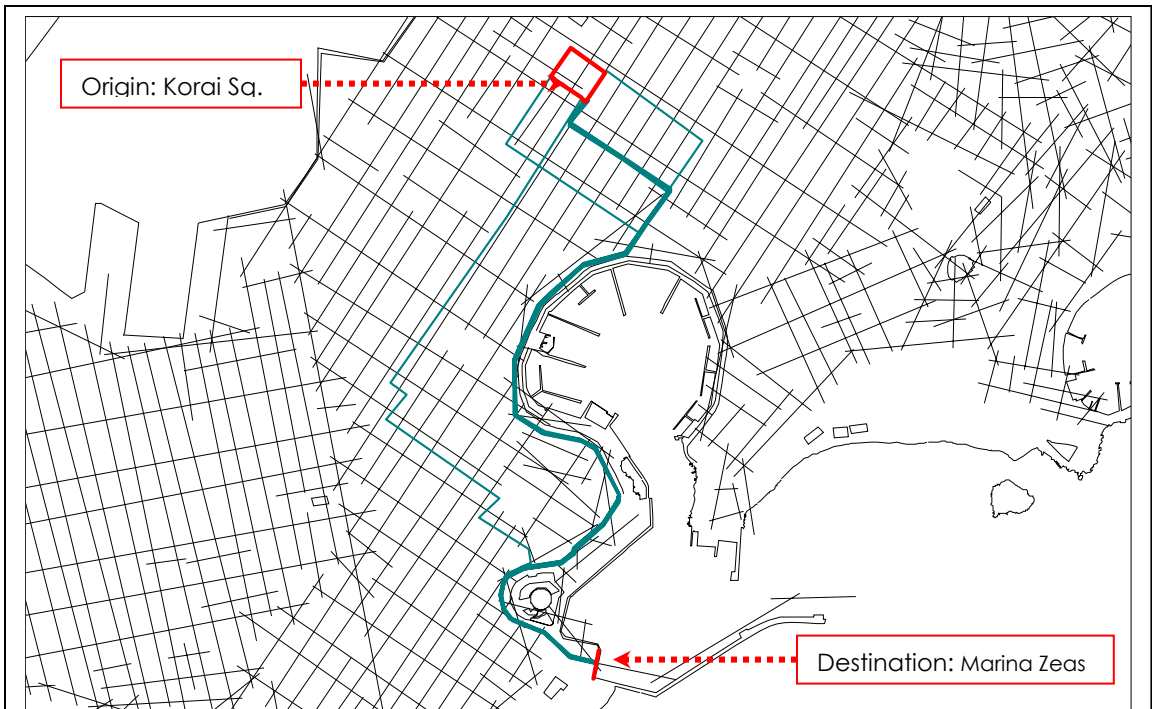
Fig. 74 Axial map overlaid with Regional Locals' route choice from Korai Sq. to Marina Zeas.
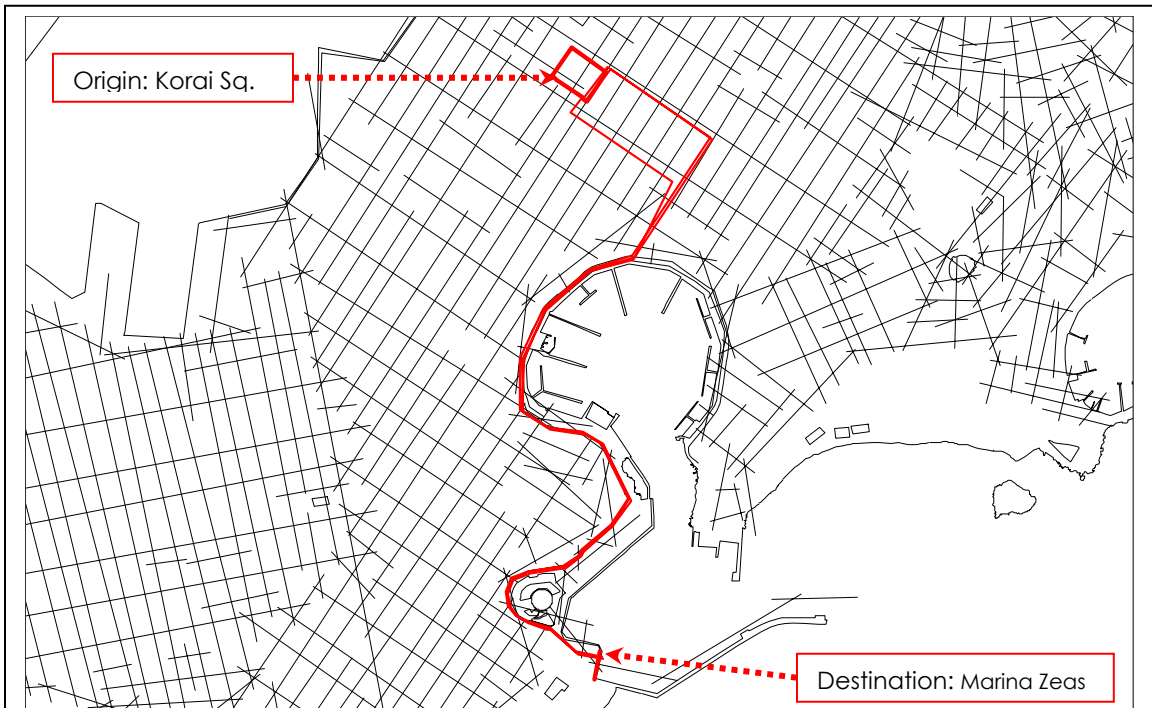
Fig. 75 Axial map overlaid with Visitors' route choice from Korai Sq. to Marina Zeas.

For the route Korai Sq. – Marina Zeas, the **SEGMEN** model calculated[31] a single route with the least degree of angular change, a single route as the shortest one and 39 different routes with directional change. The table below (Table 6) shows the results from SEGMEN graph computation for this particular route:

Analysis	Number of routes	Depth	Radius	Minimum steps	Maximum steps
Simple	1	4.0684	17	34	34
Metric	1	1527.4465	16	29	29
Constant	39	6	17	30	35

Table 6 Results from SEGMEN application for the route Korai Sq. – Marina Zeas.

The method of analysis that is developed in this part of the research is being used to seek patterns within a sample of different routes. Using this SEGMEN tool, we are able to measure the shortest, least angle change and fewest turns route against the sample of all observed routes in a *qualitative* manner.

Fig.76, Fig.77 and Fig.78 demonstrate the routes from Korai Sq. to Marina Zeas with the least angle change paths (simple), with the shortest paths (metric) and fewest turns paths (constant) respectively.

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[31] The argument "get-route" of *SEGMEN* model was applied (Iida S. 2004).
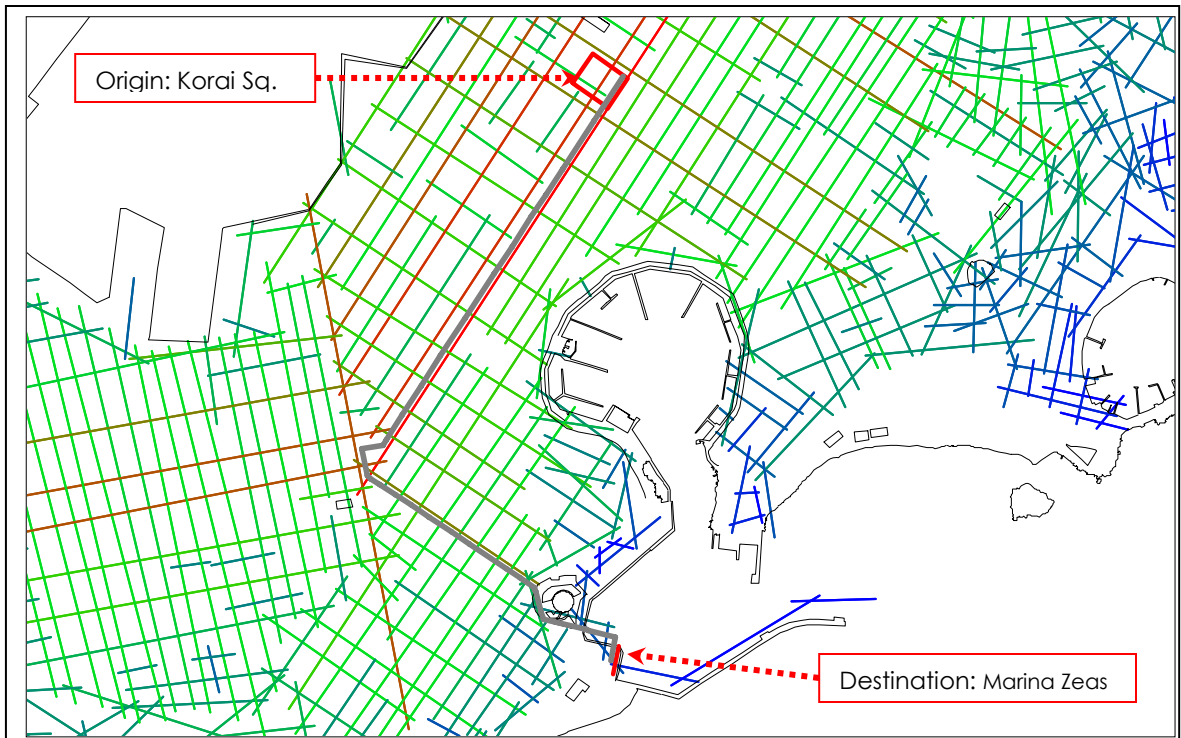
Fig. 76 Axial Map (InRn) of Piraeus which highlights the simplest route (in grey colour) from Korai Sq. to Marina Zeas weighted by the degree of angular change ("simple").
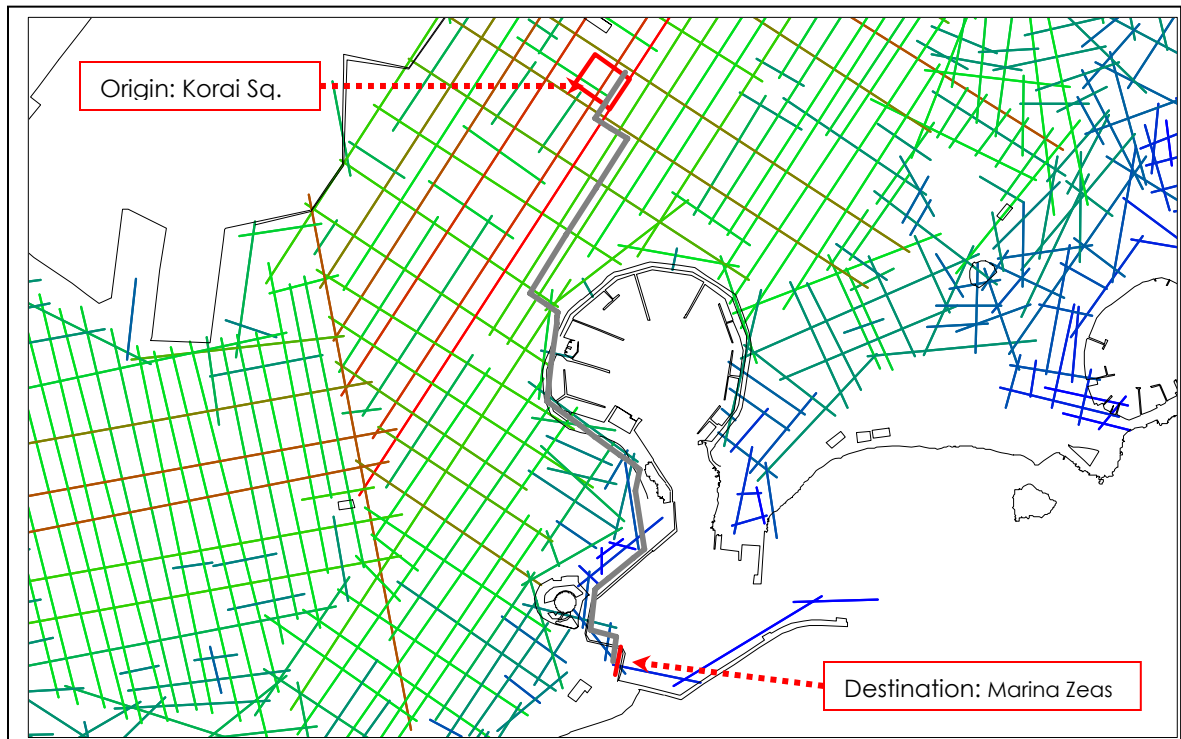
Fig. 77 Axial Map (InRn) of Piraeus which highlights the shortest path (in grey colour) from Korai Sq. to Marina Zeas ("metric").

Fig. 78 Axial Map (InRn) of Piraeus which highlights the fewest turns paths (in grey colour) from Korai Sq. to Marina Zeas ("constant").
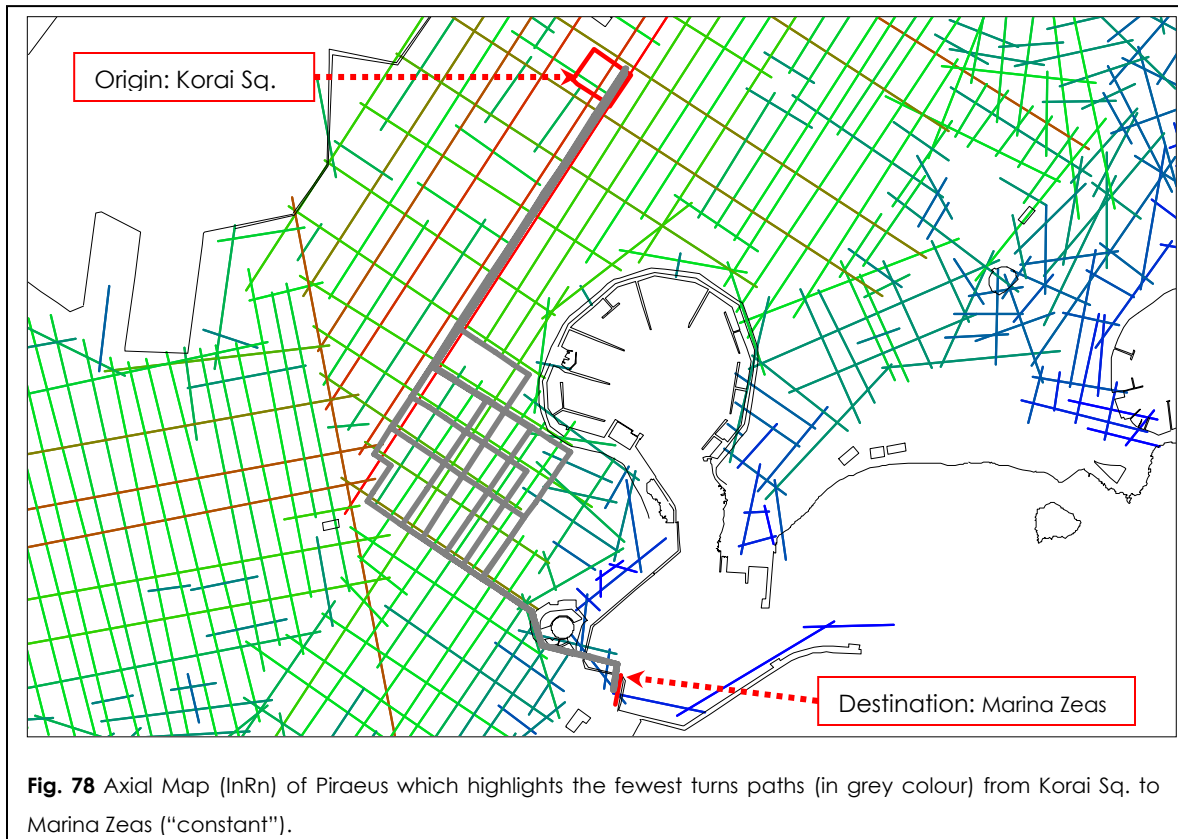
Considering both the regression analysis and the route choices of the participants, it could be stated that of Locals would almost evenly chose to walk from Korai Sq. to Marina Zeas through a metric weighted route (22.63%), a topologically[32] weighted route (19.78%) or an angular weighted route (19.78%), with a slight preference to the first one (Fig.79). The Regional Locals' behaviour is similar to the Locals'; they would walk primarily through a metric weighted route (25.88%) and then through a topologically weighted (21.34%) and an angular weighted route (21.34%). (Fig.80). Additionally, 34.13% of the Visitors would travel choosing also the shortest path (Fig.81), 16.78% choosing fewest turns route and 13.91% making the least angle change. Measuring the **metric deviation** (m.) (Fig.82), the Locals' route appears to be longer 284.25 m., while for Regional Locals and for Visitors deviation is slightly higher (299.73 m. and 305.48 m. respectively).

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[32] Although the analysis has been done for all 39 topological routes, because of time constraints and word limitations only the three topological routes are demonstrated in this paper.
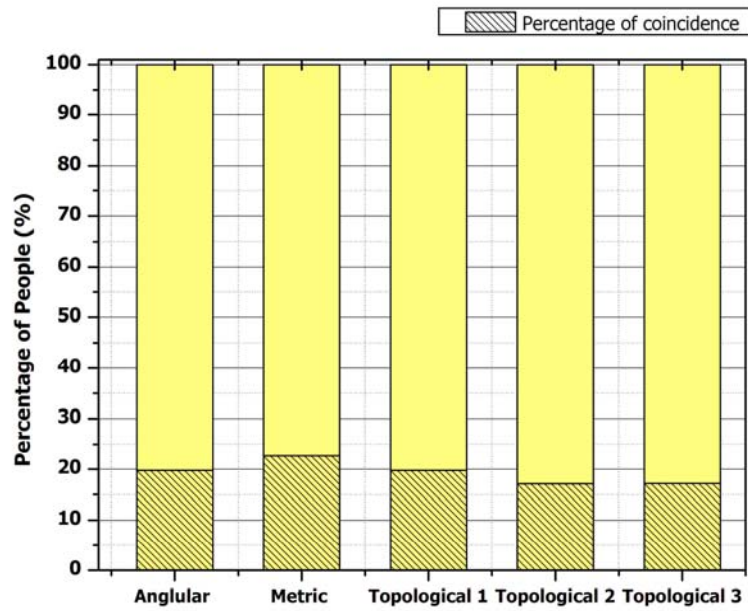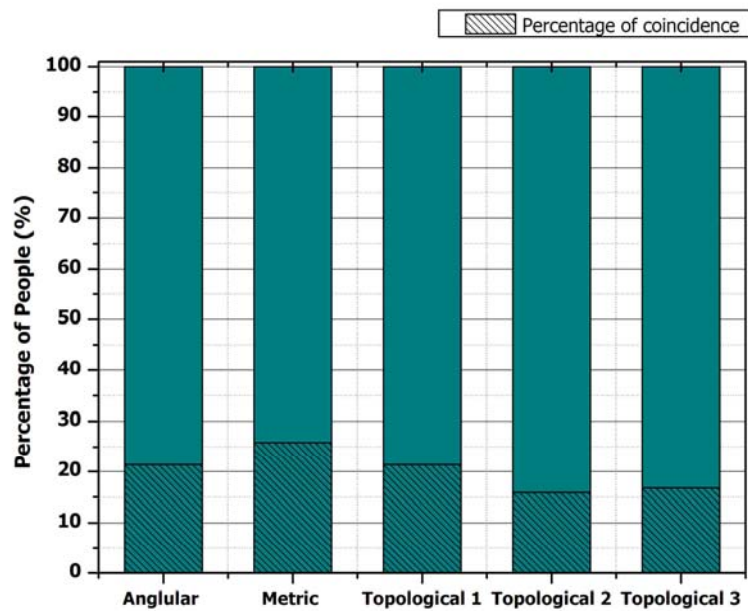
Fig. 79 Locals' route choices from Korai Sq. to Mairna Zeas.

Fig. 80 Regional Locals' route choices from Korai Sq. to Mairna Zeas.
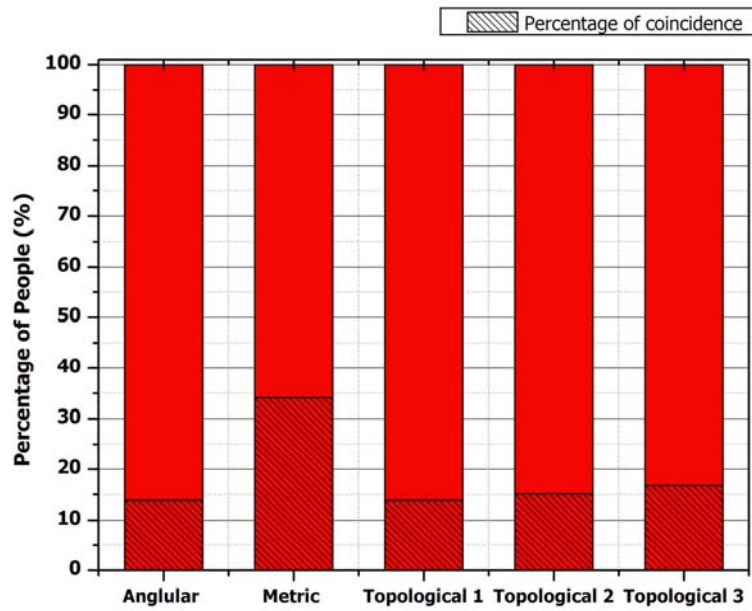
Fig. 81 Visitor's route choices from Korai Sq. to Mairna Zeas.

Fig. 82 Metric deviation (m.) for all groups (Korai Sq.-Marina Zeas)

Measuring *integration* – the to-movement – and *choice* – the through-movement measure – setting the three different weighting (Fig.83, Fig.84, Fig.85), we could investigate how consistent the correlations with one or other weighting are. The better correlations would inevitably reveal people's movement choices, since everything else about the system is identical.

1000m

Fig. 83 Axial Map of Piraeus showing Metric Mean Depth.
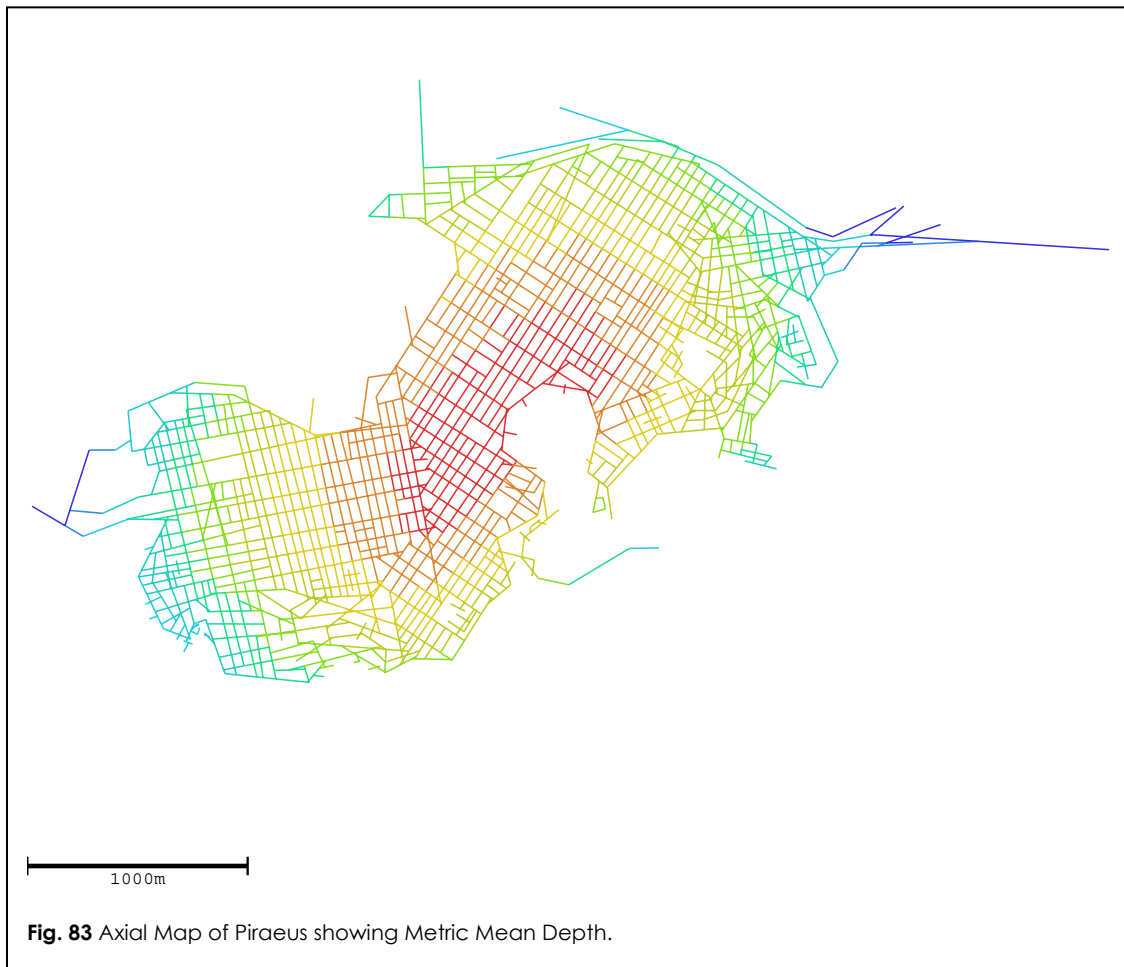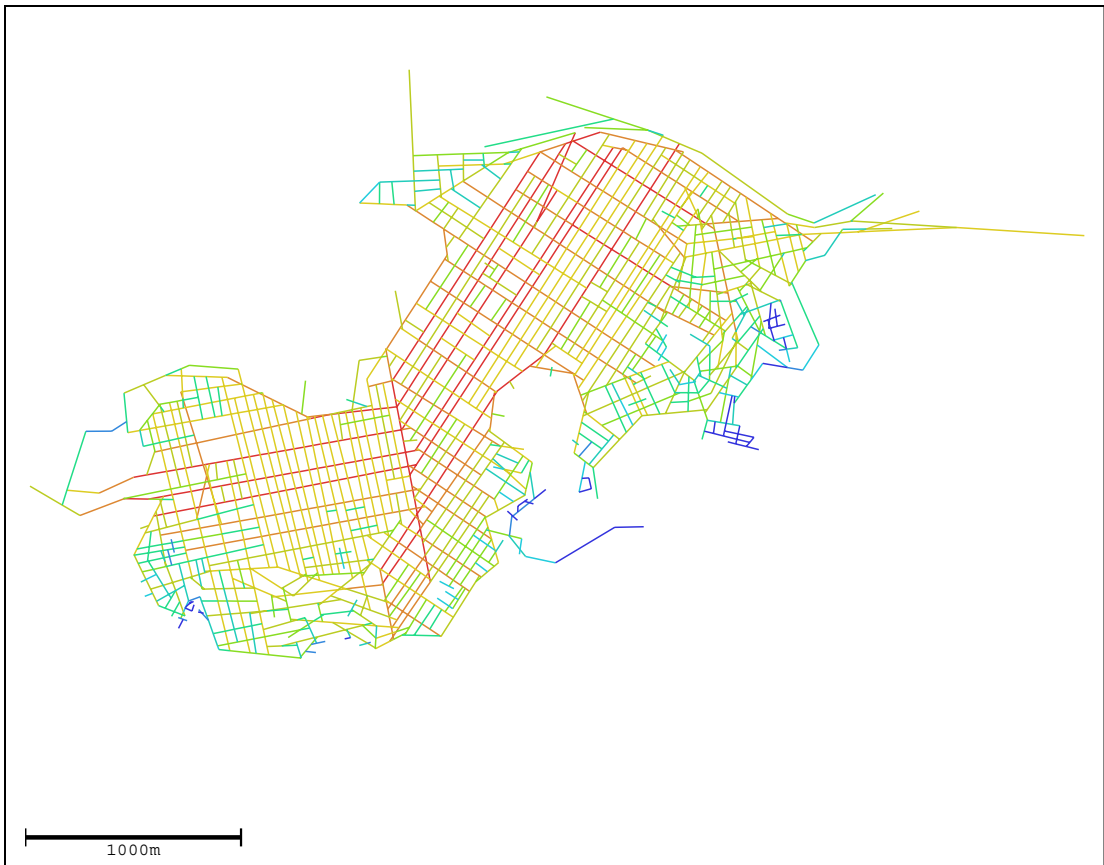
Fig. 84 Axial Map of Piraeus showing Angular Mean Depth.
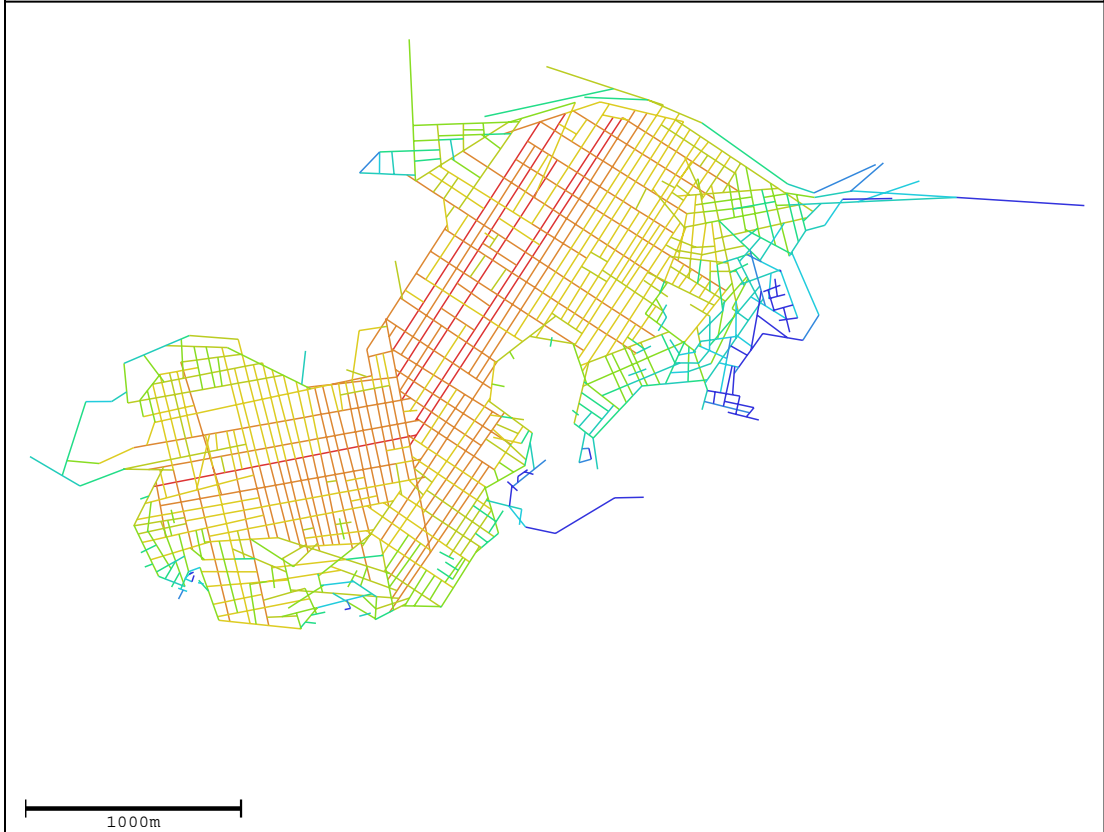
Fig. 85 Axial Map of Piraeus showing Topological Mean Depth.

In order to conduct **Segment** analysis (even if it is angular, metric or topological) it is essential to define the different radii. In this way we will be able to capture much more detail of the local structure. As people move locally, they tend to choose routes which are not necessarily part of the global route but they are important in a local scale. If we apply choice measures at different radii from each segment, (also defining radii metrically, geometrically and topologically), we could have a series of configurational measures which could describe the relation between the structure of the city and the way it functions. Therefore, segment analysis was conducted, but not any significant conclusion could be drawn. From Segment analysis the topologically weighted analysis had the most interesting results[33]. The choice in all radii tends to "pick up" routes that are parts of the two interrelated, orthogonal grids of the city. The regularity and the linearity seem to affect route choice decisions in the way that it seems that the people will not get lost in the unintelligible parts of the city.

4.3.3 Key points

Taking everything into account, it might be stated that the route choices made by subjects appear not to be random, as there is a series of cognitive mechanisms that is involved in producing directions. First, the participants had to activate an internal representation of Piraeus in which the imaginary routes was to be executed. These representations included topographical information and visual aspects of the environment. Afterwards, the participants had to define the route that best fitted the request within the subspace of the currently activated mental representation. The optimal route (in terms of economy of movement) is a *straight* line (Denis, 1997). Indeed from the observations, many of the most popular routes are very "linear" and many of the least popular routes appear to be very undulating. What is highly interesting is that most of the participants (especially Regional Locals and Visitors that have low degree of familiarity with the place) didn't follow straight routes to the wayfinding goal as segment analysis highlighted. Only Locals tend to find their way through as a straight a route as possible with minimal angular deviation (from a straight line on condition that this choice always approximates the direction of their final destination. This implies that not only the regularity of the grid contributes to route choice decisions, but the presence of physical obstacles in

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[33] For the analysis the radius is gradually reduced (2000 m., 1600 m., 1200 m., 1000 m., 800 m., 600 m., 400 m., 200 m.); lines of the local network are more or less highlighted as they become more or less important during a local journey.

the environment plays a crucial role. The greater "obstacle" in Piraeus is its topography which is rich in height variation, especially in the peninsula. The participants had to consider both the aforementioned factor and the physical constraints (for instance, urban routes must follow the network of streets).

Chapter 5: Limitations and Conclusions

5.1   Limitations

As with every research, the present one has also a number of limitations. First, although the overall number of people that participated in the three experiments is 228 (85 people in the first, 67 people in the second and 76 people in the third experiment respectively), which is quite consistent in terms of the restricted time available, the sample of participants is not evenly distributed as a result of the different level of difficulty of the experiments.

Another limitation is the time and the extent of the analysis of the thesis. Especially in the third experiment, in part two (Origins-Destinations), the research has been conducted for four pairs of Origins-Destinations (*a.* from Korai Sq. to Marina Zeas *b.* from Kanari Sq. to Naval College *c.* from Yacht club of Greece to Sotiros Dios St. *d.* from Kanari Sq. to the Train Station of Piraeus), but only the first one is discussed in the body of the thesis.

Furthermore, because of time limitations the second part of the third experiment could be ideally conducted by getting participants to walk instead of asking them to imagine the route.

Last but not least, because of the limitations on the length of the thesis, the research based on the movement traces recorded through "people following" (Glossary of terms) in the Train Station (Main Harbour) was not presented. It would be also interesting to discuss the results from agent-based modeling analysis (Turner, A. and Penn, A., 2002) that has been applied to the certain area.

5.2   Conclusions

The aim of this paper was to examine wayfinding performance and navigation processes in the centre of Piraeus, or to investigate how the different elements of an old city affect the spatial cognition of its users. The elements of the city of Piraeus affect movement behaviour in different ways, as the three experiments and the analysis showed.

It became evident that the **spatial knowledge** of the individuals passes through stages: from egocentric to allocentric frames of reference and from topological to fully metric comprehension of space. Defining primary in the body to object relation (egocentric) and then the object to object relation (allocentric), the users construct

different models of cognition. First, observed/recorded data from **Recognition Tasks in Peraiki Coast** that was analysed showed that although people navigating on foot receive multiple cues for updating their position and orientation (the remains of the Konon Walls, the landmark of the Cross), it is the knowledge of both the syntactic and geometrical properties of the coast that have to be subconsciously considered in order to find their way.

Secondly, the findings from the experiment **in Mikrolimano**, confirmed Moar and Carleton's suggestion in (Moar and Carleton, 1982) which claims that when people are quite familiar with an environment (as the Locals), their pointing accuracy increases enough to allow projective convergence to give an approximate location for the object being pointed to. As pointing is the externalisation of cognised directions, the experiment revealed the degree of individuals' ability to integrate lists and procedures into a configurational knowledge structure. The greatest pointing errors have been compiled by Regional Locals, as their over-confidence entails wrong estimations. In their case, it could be said that "a little knowledge is a dangerous thing"[34]. However, is not so clear whether the errors that were made were a result of incorrect distance estimation, incorrect direction estimation, or a combination of both.

Thirdly, the conclusion drawn from the **Cognitive Maps** was that the depicted features appeared not to be randomly made. These subjective structures that encode the spatial relations "confirmed" the identity of Piraeus as being the "Main Port" with the **three natural harbors** (Passalimani/Zea and Mikfrolimano/Munychia on the East and Kantharos/Main Harbour on the West). It cannot be discounted that all participants started constructing their maps in relation to the distinguishing geomorphology of the three harbours. It has been already suggested that the depicted features appeared not to be randomly made. It can be further suggested that there is not only a close relationship between the spatial configuration in the real world and its representation in spatial cognition (as that can be elicited through cognitive mapping), but also between the spatial component and its significance as part of the "common sense spatial knowledge" which is the knowledge base for most people. This could explain why the frequency with which elements are identified on the cognitive maps is not necessarily highly correlated with all the syntactic measures. Furthermore, the findings from the maps can be linked to

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[34] It is an English idiom, meaning that a small amount of knowledge can cause people to think they are more expert than they really are. It was first used by Alexander Pope (1688-1744) - An Essay on Criticism, 1709:"A little learning is a dangerous thing; drink deep, or taste not the Pierian spring: there shallow draughts intoxicate the brain, and drinking largely sobers us again." Source: http://www.phrases.org.uk/meanings/10400.html, [Accessed 08/09/2006].

the previous experiment's conclusion, since in both experiments the degree of knowledge of various elements from the different grids of the "palimpsest" was measured.

It is suggested that the most ancient grid although it contains the elements that have shaped the city's contemporary urban space, are not easily recognisable by "strangers"; they are mostly found in *inhabitants'*" mental representations. The elements from the neoclassical and the modern period of Piraeus are more frequently cited. As the latter two grids contain features that have still a crucial role in the city's social activities (Train Station, Municipal Theatre, Town Hall), they appear to be better situated and framed in the cognitive models of Piraeus' pedestrians.

Fourthly, it can be also noted that **Route Choice Decisions (Imagined Movement)** made by the pedestrians are also not to be randomly made. People choose strategically certain routes. The route-choice decisions involve a variety of criteria, such as the shortest route, or the route with the smallest angular discrepancy with respect to the goal at each intersection and so forth. The **least length** (metric distance) the **fewest turns** (topological relations) and the **least angle change** (geometric properties) are being taking into consideration (individually or in combinations) when someone tries to find his/her way from an origin to a destination. These route choice decisions that need to be made are related to the kind of cognitive knowledge that a person has.

In conclusion, in the research it was found that the elements which tend to play an important role in people's cognitive scheme are the ones that either have the greatest values in terms of isovists geometrical properties and visibility access or the ones that have the greatest values in terms of axial lines syntactical properties and are located in critical areas which can be considered as landmarks, such as the Municipal Theatre the church of Ag. Nikolaos in the Main Harbour or the church of Prophet Ilias in Kastella. This research was an attempt to correlate spatial configurations and cognition of the urban environment of the centre of Piraeus so as to investigate the *knowledge* that urges human behaviour and shapes movement. And that *knowledge* is a combination of sensation, perception, belief, attitude, reasoning, intentionality, information processing, learning, image, affect, personality, language...

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Glossary of Terms

Half-familiar places

Almost every day, people have to make geographic decisions about places and areas that they have been to, but don't know well. Of course this is an issue in wayfinding and journey planning, both for consumer and professional travelers. But also, local service providers sit in offices looking at a GIS covering the whole of their home area, although they could mentally picture only parts of it (and not always clearly). These places that people have been to but don't know well could be called "half-familiar" places (Clare Davies, Ordnance Survey).

Imageability

It is that quality in a physical object which gives it a high probability of evoking a strong image in any given observer. It is that shape, color, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment. It might also be called *legibility*, or perhaps *visibility* in a heightened sense, where objects are not only able to be seen, but are presented sharply to their senses (Lynch, K. 1960).

Legibility

The ease with which the parts of a city may be recognised and can be organised into a coherent pattern. (Lynch, K. 1960).

Palimpsest

A. *n.* **1.** Paper, parchment, or other writing material designed to be reusable after any writing on it has been erased. *Obs. .* **a.** A parchment or other writing surface on which the original text has been effaced or partially erased, and then overwritten by another; a manuscript in which later writing has been superimposed on earlier (effaced) writing. Cf. sense B. 1. **b.** In extended use: a thing likened to such a writing surface, esp. in having been reused or altered while still retaining traces of its earlier form; a multi-layered record. **3.** A monumental brass plate turned and re-engraved on the reverse side. Cf. PALIMPSEST *a.* 2. *Obs.* **4.** *Physical Geogr.* and *Geol.* A structure characterized by superimposed features produced at two or more distinct periods. **B.** *adj.* **1.** Of a manuscript or writing surface: written over again; having the original writing effaced and overlaid by later writing. Also *fig.* **2.** Of a monumental brass: turned over and re-engraved on the reverse.

Now *rare*. **3.** *Petrogr.* Of a rock structure: partially preserving the texture that existed prior to metamorphism. **4. a.** *Physical Geogr.* Of a landscape or landform, esp. a glaciated topography or a drainage pattern: exhibiting superimposed features produced at two or more distinct periods. **b.** *Geol.* Of a sediment or deposit: that has been reworked since it was first laid down. Source: Oxford English Dictionary online, Second Edition 1989, Copyright © Oxford University Press 2006.
<http://dictionary.oed.com/cgi/entry/50169691?query_type=word&queryword=palimpses t&first=1&max_to_show=10&sort_type=alpha&result_place=1&search_id=Q1jh-HyVgH0-1910&hilite=50169691> [Accessed 04/06/2006].

People Following

We observe in order to see how much we can learn about the environment without taking account of people's intentions. Space syntax approach suggests that an important and valuable means of representing the prevailing conditions in an urban area is a survey of the movement behaviour. "People following" is one of the methods that Space syntax suggests (Gate method, static snapshots, directional splits, people following, movement traces, questionnaires are all such methods).

(Applicability of "people following")

This is an increasingly important technique for observing movement that disperses from a specific 'movement distributor' – for example, a train station or a shopping mall. It can be used to investigate three specific issues:

1. the pattern of movement from a specific location,

2. the relationship of a route to other routes in the area, and

3. the average distance people walk from the specific location (this can help determine the pedestrian catchment area of a retail facility or public square).

Skeuotheke, Armamentarium

Armamentarium (skeuotheke, hoplotheke), a place where armamenta were kept; an armoury or, more frequently, a naval arsenal where tackling, &c., as well as munitions of war, were housed. In primitive times the acropolis of a city was the usual place for the storage of arms; but the fortifying of larger areas, and especially of ports like the Piraeus, gave rise to a special class of buildings designed for their safe custody. In Aeschylus (fragm. 273) and Aeschines (c. Ctes. 25) skeuothekai are mentioned in connexion with naval matters. They must, however, be distinguished from neoria, dockyards, and neosoikoi, slips or docks. There was a celebrated armamentarium in the Piraeus, built by the architect Philo under the financial administration of the orator Lycurgus, about B.C.

342-330 (Cic. de Or. i. 1. 4, 62; Plin. H. N. vii. 125; Strab. ix.; Plut. Sull. 14). The expression of Pliny, armamentarium CD (another reading is mille) navium, has been wrongly explained as a basin in which 1000 ships could lie. The corrected number comes from the passage in Strabo, where naustathmon tais tetrakosiais nausin is distinguished from hoplotheke Philonos ergon. This was destroyed at the capture of Athens by Sulla. A hoplotheke of the elder Dionysius at Syracuse is described by Aelian (V. H. vi. 12) as well filled with arms, armour, and engines; the naustathmon at Rhodes included thesauroi hoplon, as did those of Massalia and Cyzicus; and, as in modern times, strangers were wholly or partially excluded (Strab. xiv.).

Among the Romans the armamentaria were places for the manufacture as well as the storage of arms (Liv. xxvi. 51; xxix. 22 and 35); and arms might be served out from them in times of public danger (Cic. Rab. Perd. 7, 20). We also find them under the empire, organised with the usual thoroughness of the Romans in military matters.

Source: A Dictionary of Greek and Roman Antiquities (1890) (eds. William Smith, LLD, William Wayte, G. E. Marindin). Cited Aug 2005 from The Perseus Project URL below, <http://www.perseus.tufts.edu> [Accessed 28/08/2006].

Shipsheds

Stoa-like boathouse; several located on the shores of the harbors at Piraeus. 480 B.C. - 390 B.C.

Plan:

Floors, with slotted slipways cut to accommodate trireme keels, that sloped and descended into the water between rows of tall columns alternating with rows of shorter columns. Parallel roofs supported by taller columns at the ridges and the shorter columns at the valleys.

History:

Slipways cradled and protected the keel and undersides of ship when it was hauled from the water.

Dimensions:

Average breadth: 6.75 m
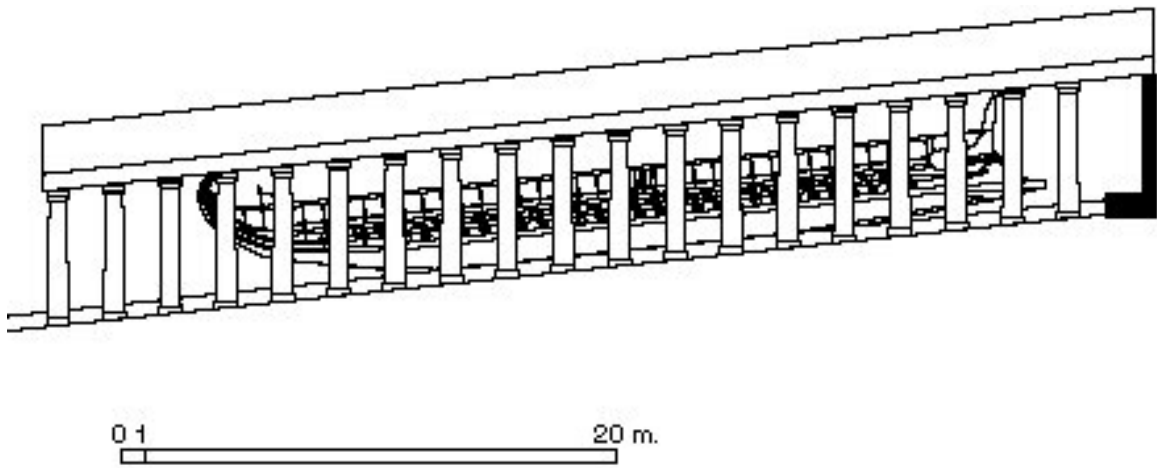
Piraeus, Shipsheds: Reconstructed section of slips at the harbor of Zea. *copyright D. Neel Smith 1989, drawn by M. W. Cutler and C. H. Smith based on Dörpfeld (artist) for excavations of the Greek Archaeological Society 1885, in N.D. Papachadzi 1974 106 fig. 33 Trireme section based on J.F. Coates 1985*

Source: *This text is cited Nov 2002 from* <u>The Perseus Project</u> *URL below,* <u>http://www.perseus.tufts.edu</u> [Accessed 28/08/2006].

Glossary of Statistical Terms

Absolute Average Deviation (ABS)

The absolute value of a real number x is denoted $|x|$ and defined as the "unsigned" portion of x,

$$|x| = x \operatorname{sgn}(x)$$
$$= \begin{cases} -x & \text{for } x \leq 0 \\ x & \text{for } x \geq 0, \end{cases}$$

where $\operatorname{sgn}(x)$ is the sign function. The absolute value is therefore always greater than or equal to 0.

Average Deviation (AVEDEV)

The average deviation (or Mean Deviation) is one of several indices of variability that statisticians use to characterise the dispersion among the measures in a given population. To calculate the average deviation of a set of scores it is first necessary to compute their mean and then specify the distance between each score and that mean without regard to whether the score is above or below the mean. The average deviation is defined as the mean of these absolute values.

For a sample size N, the mean deviation is defined by

$$MD \equiv \frac{1}{N} \sum_{i=1}^{N} |x_i - \overline{x}|,$$

Normal Distribution

A normal distribution in a variate X with mean μ and variance σ^2 is a statistic distribution with probability function

$$P(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-(x-\mu)^2/(2\sigma^2)}$$

on the domain $x \in (-\infty, \infty)$. While statisticians and mathematicians uniformly use the term "normal distribution" for this distribution, physicists sometimes call it a Gaussian distribution and, because of its curved flaring shape, social scientists refer to it as the "bell curve." Feller

(1968) uses the symbol $\varphi(x)$ for $P(x)$ in the above equation, but then switches to $n(x)$ in Feller (1971).

Central Limit Theorem

Let $X_1, X_2, ..., X_N$ be a set of N independent random variates and each X_i have an *arbitrary* probability distribution $P(x_1, ..., x_N)$ with mean μ_i and a finite variance σ_i^2. Then the normal form variate

$$X_{\text{norm}} \equiv \frac{\sum_{i=1}^{N} x_i - \sum_{i=1}^{N} \mu_i}{\sqrt{\sum_{i=1}^{N} \sigma_i^2}}$$

has a limiting cumulative distribution function which approaches a normal distribution.

Under additional conditions on the distribution of the addend, the probability density itself is also normal (Feller 1971) with mean $\mu = 0$ and variance $\sigma^2 = 1$. If conversion to normal form is not performed, then the variate

$$X \equiv \frac{1}{N} \sum_{i=1}^{N} x_i$$

is normally distributed with $\mu_X = \mu_x$ and $\sigma_X = \sigma_x / \sqrt{N}$.

Population

The word population has a number of distinct but closely related meanings in statistics.

1. A finite and actually existing group of objects which, although possibly large, can be enumerated in theory (e.g., people living in the United States).

2. A generalization from experience which is indefinitely large (e.g., the total number of throws that might conceivably by made in unlimited time with a particular pair of dice). Any actual set of throws can then be regarded as a sample drawn from this practically infinite population.

3. A purely hypothetically population which can be completely described mathematically.

Sample

A sample is a subset of a population that is obtained through some process, possibly random selection or selection based on a certain set of criteria, for the purposes of investigating the properties of the underlying parent population. In particular, statistical

quantities determined directly from the sample (such as sample central moments, sample raw moments, sample mean, sample variance, etc.) can be used as estimators for the corresponding properties of the underlying distribution.

The process of obtaining a sample is known as sampling, and the number of members in a sample is called the sample size.

Appendices

Appendix A_ Hippodamus of Miletus

Hippodamus of Miletus was the most famous Greek urban theorist, and the earliest of whom we have any real knowledge. If he wrote treatises they are long gone, and we know of his personality and thoughts primarily from Aristotle's brief description in the 1267b-1269a; also 1330b. Hippodamus thus seems to have come to city planning from the theoretical, rather than the practical side of things; he was concerned not solely with the physical layout of cities, but in the ordering of an ideal society, and he designed his ideal city to accommodate such a community. A number of ancient sources describe Hippodamus as an architect, such as Strabo (14.2.9), Harpocration, the, Photius, and the Suda (see Falciai, p. 28). But these sources are all far removed in time from Hippodamus and may reflect later evaluations of his role in the planning of actual cities, rather than as a theorist. Most modern scholars allow that he planned the newly synoikized city of Rhodes in 408/7 B.C., although Strabo says only that the new city was "founded" by the same architect who did the Piraeus (Strabo 14.2.9). Hippodamus used to be credited with the replanning of his home town, Miletus, when it was rebuilt in 479 B.C., or at least with taking part in the replanning (as von Gerkan, 45-46; followed by Hoepfner and Schwandner, 17-22, 302).

Aristotle tells us that Hippodamus "discovered the division of poleis". This could refer to the physical planning of the city—not the invention of the grid plan, which was already ancient when Hippodamus was born, but some other aspect of the city's organization—as well as to the division of the polis as a community of citizens. It very probably refers to both, and to the correspondence between physical and social planning. Gorman, "Aristotle's Hippodamus". Hippodamus organized his ideal state in a **tripartite** system. The polis, of 10,000 citizens, was divided into three sections based **on occupation**: one section of artisans, one of farmers, and the third soldiers. Likewise the land was to be divided into three parts, religious, public, and private sections; the laws were organized into three classes, wanton assault, damage, and homicide; and the magistrates were to attend to three subjects, public matters, matters relating to aliens, and matters relating to orphans. Such an attention to numerology is sometimes attributed to either Hippodamus 's background in Ionian natural science or to Pythagorean influence, but it is encountered in other political and architectural works, for instance in the of Plato, and could be seen as characteristic of general Greek ideas about city and social planning rather than of Ionian thought in particular. Martin, 16, Hoepfner and Schwandner, 301-10, and others attribute

to Hippodamus a strong Pythagorean influence; cf. also Lévêque and Vidal-Naquet, 128 and n. 2. But ideas about numerology and harmony were neither exclusively Pythagorean nor Milesian. They were more widely held, and it seems to me fruitless to attempt to trace Hippodamus's philosophical background from such meager evidence.

Aristotle further tells us that he "cut up" (KATE/TEMEN) the Piraeus, and refers to cities planned "according to the newer and according to the Hippodamian manner" (1330b). Hippodamus was a practicing planner, and aspects of his thought can be understood through how it was carried into practice. Hesychius and Photius provide glosses on *(IPPODA/MOU NE/MHSIS, "the nemesis of Hippodamus," explaining it as "Hippodamus, son of Euryboön and a meteorologos, divided (or distributed) the Piraeus for the Athenians."Hesychius makes Hippodamus divide (DIEI=LEN) the Piraeus; Photius makes him distribute (DIE/NEIMEN) it. The different terminology used by these authors is interesting: all three words, "cut up," "divide" and "distribute" are commonly used in other contexts to describe different stages in the process of organizing a city and its territory. These nemeses thus seem to be related to the "division of cities," at least of the Piraeus.

The boundary stones themselves directly attest only one lang="greek">nemesis, the Mounichia, a hill in the eastern part of the city. This stone was found in situ just northwest of the hill. The other two stones, reading A)/XRI TE=S [EPIG-ROUGH]ODO= TE=SDE TO\ A)/STU TE=IDE NENE/METAI, were not found in situ. I3 1111 is said to have been found in Odos Makra Stoa, in the northern part of the city near the city wall. McCredie translates the inscriptions "Here, up to this street, the City has been planned," suggesting that the A)/STU, as distinct from the Mounichia and other regions, formed one nemesis.McCredie, "Hippodamos" 97. But the different phrasing of the two inscriptions might suggest a different meaning, and the second text might just as easily be translated "Here, up to this street, the City has been divided into nemeses." The City would then not be a single nemesis, but a series of nemeses of which the Mounichia is one.

Unfortunately the actual plan of the Piraeus is rather poorly known, since the Sullan destruction left the city in ruins and the modern port has destroyed or buried what was left. The little that is known, primarily from nineteenth-century observations, suggests that the hills of Mounichia and Akte were laid out without a true grid plan. Since the Mounichia formed *one nemesis* it is possible that the Akte formed *another*. The flatter central part of the Piraeus, in contrast, was laid out in a regular grid, with four main streets oriented northeast-southwest, and a number of main streets (five?) oriented northwest-southeast. These seem to define a series of large parcels of land, about 250 x 275 m, which were subdivided by smaller streets into house blocks. (Von Eickstedt, ; Hoepfner and Schwandner, 22-50; Garland, 1987, p.144-45). This type of hierarchical divisive planning, with wide streets defining "major rectangles" which are then subdivided into blocks, is a

method quite different from that of cities like Olynthus, where streets of equal width divide the city into blocks, without larger arteries or clearly divided sectors.

Hippodamus's most significant contribution to city planning is probably the special method of division of land and territory. Although Aristotle describes only three broad functional categories of land in Hippodamus's ideal state, his "division of cities" seems to be more complex, flexible, and generally applicable than a simple division of land by function. As McCredie points out, it is this aspect of Hippodamus's planning, rather than any innovations in orthogonal street patterns, which established his position as the father of Greek city planning.

Appendix B_ Fortifications

The whole peninsula of Peiraeeus, including of course Munychia, was surrounded by Themistocles with a strong line of fortifications. The wall, which was 60 stadia in circumference (Thuc. ii. 13), was intended to be impregnable, and was far stronger than that of the Asty. It was carried up only half the height which Themistocles had originally contemplated (Thuc. i. 93); and if Appian (Mithr. 30) is correct in stating that its actual height was 40 cubits, or about 60 feet, a height which was always found sufficient, we perceive how vast was the project of Themistocles. In respect to thickness, however, his ideas were exactly followed: two carts meeting one another brought stones, which were laid together right and left on the outer side of each, and thus formed two primary parallel walls, between which the interior space (of course at least as broad as the joint breadth of the two carts) was filled up, not with rubble, in the usual manner of the Greeks, but constructed, through the whole thickness, of squared stones, cramped together with metal. The result was a solid wall probably not less than 14 or 15 feet thick, since it was intended to carry so very unusual a height. (Grote, vol. v. p. 335; comp. Thuc. i. 93.) The existing remains of the wall described by Leake confirm this account. The wall surrounded not only the whole peninsula, but also the small rocky promontory of Etioneia, from which it ran between the great harbour and the salt marsh called Halae. These fortifications were connected with those of the Asty by means of the Long Walls, which have been already described. It is usually stated that the architect employed by Themistocles in his erection of these fortifications, and in the building of the town of Peiraeeus, was Hippodamus of Miletus; but C. F. Hermann has brought forward good reasons for believing that, though the fortifications of Peiraeeus were erected by Themistocles, it was formed into a regularly planned town by Pericles, who employed Hippodamus for this purpose.
*This extract is from: Dictionary of Greek and Roman Geography (1854) (ed. William Smith, LLD). Cited June 2004 from **The Perseus Project** URL below*

Appendix C _ The "settlers"

In the newly established Greek city of Piraeus, the government of the newly established Greek state (1834) provided land to two different social groups: the **Hydriots** (from the island Hydra) and the residents of the island **Chios.** Furthermore, there was a group of "settlers" from other places in Greece and other countries (most of them from Turkey). Therefore, the group from the island Chios occupied the right side of Kantharos (**Chiotic district**), the "settlers" from other places occupied the left side of Kantharos (**General district**) and the Hydriots occupied the area south of the Chiotic district (**Hydriot district**) (today the area is called "Hydraika") (Malikouti Stamatina, 2004).

Appendix D _ The spatial components

- The ruins of the **Main Gate** of the ancient surrounding wall of Piraeus (built by Themistokles in 493 B.C. before the building of the town had ever begun), at the entrance to the modern city, at the district of "Gouva tou Vavoula"

- The ruins of the **Eetioneia Gate**, on the north side of the Kantharos Harbour (built by Themistokles in 411 B.C.)

- The ruins of the **ancient Wall of Piraeus** in the peninsula of Piraeus (**Konon Walls**, built in 394 B.C.) and in other spots of the beach

- The **Hellinistic Theater at Zea,** (constructed in the beginning of the 3rd century BC) next to the building of the Archaeological Museum,

- Section of the **shipsheds of Zea** (today it is called "Passalimani"), in the basement of an apartment block at Sirangeiou St.1, from the 4th century B.C.

- Remains of the **Arsenal (Skeuotheke) of Philo** (built between 347/6 and 323/2 B.C.) at Ipsilandou Str. at Zea

Also:

- The **Municipal Theatre** that dominates one of the city's central squares (Korai Sq.) built in 1880's (1884-1885) is example of the neoclassical architecture of Piraeus

- The **Train Station** in the Main Harbour (Kantharos) which was completed in 1882 is also one of the best preserved neoclassical buildings of Piraeus

- The **Tower** (the skyscraper) of Piraeus in the Main Harbour which is the only high-rise building of the city (84 m height, 24 floors) and it is considered as one of the most representative landmarks of the modern city

- The **KERANIS Tobacco Factory** in the Main Harbour, which was founded in 1927. The building which is located at 39 Athinon Ave. was erected in 1939-1940, and the new building in 1969-1972 (Belavilas N., 2002)
- **Elais olive oil Factory** in Piraios St. which was founded in 1920 from Arist. Makri and his partners. The innovative, modernistic design of the building introduced a way to describe the new architectural identity of "Industrial" Piraios St (Belavilas N., 2002).

Fig. 86 KERANIS Tobacco Factory. Photograph: N. Belavilas.

Fig. 87 Elais olive oil Factory. Photograph: N. Belavilas.

Appendix E _ Space Syntax

Space Syntax is a set of theories and techniques that have been developed from Hillier and Hanson at University College London since the mid 1970s. According to them, the "logic" that a spatial pattern creates, is closely related to its social use, cultural significance and behavioural implications of layouts, in contemporary and historical contexts (Hillier B. and Hanson J., 1984). Space Syntax explains the substantial proportion of the variance between aggregate human movement rates in different locations in both urban and building interior space. The concept of **"spatial configuration"** is very important in this theory, as it concerns relations which take into account other relations in a complex (Hillier, 1996). In recent studies linking *space syntax* with *cognitive science*, it has been claimed that the spatial configuration encourages or impedes aspects of human activity through spatial cognition and subsequent movement behaviour (Hillier B., 1996a; Kim, Y. O., & Penn, A. 2004).

The spatial analysis that has proved to be consistently better at predicting pedestrian movement is he **"axial analysis".** The "axial map" presents "the least set of straight axial lines which passes through each convex space and makes all axial links" (Hillier B. and Hanson J., 1984, p.92). The representation of the overall spatial structure of an environment by means of axial lines is the "axial map". Each axial line is further represented as a node in a *graph*. When any two axial lines cross, this is indicated by a link between the two nodes representing those lines. This graph is purely topological and we can measure the relative position of each axial line within the whole system. Calculating the number of *steps* in the graph, we find this relative position. The lines that are short distances (in graph terms) from the rest of the system are termed *"integrated",* while those which are, on average, a greater distance (in graph terms) from all other lines are termed to be *"segregated"* within the environment.

The way the configuration is being understood and the way the information about configuration is organised, is expressed by the concept of **"intelligibility"**, which Bill Hillier describes in "Space is the Machine" (1996). According to Hillier, "between function and structure is the notion of *intelligibility*, defined as the degree to which what can *be seen* and experienced locally in the system allows the large-scale system to be learnt without conscious effort" (Hillier, 1996, p.215). In an *intelligible* world (where the relationship between local and global properties of space is strong), "this relationship assists subjects in navigating efficiently. In *unintelligible* worlds, this approach fails to assist them, as the relationship between the local and the global is less strong, even misleading. In these worlds, people become lost and disorientated" (Conroy Dalton, R., 2002).

The method involves taking a selection of points across a space, and forming graph edges between those points if they are mutually visible, to form a **visibility graph**. **The Visibility Graph Analysis** (**VGA** or **Isovist Grid Analysis**) is a method of graph based analysis introduced by Turner et al. in (Turner et al., 2001). Following Benedikt (Benedikt 1979; Benedikt and Burnham 1985; Benedikt 1992), Turner et al., attempt to build graphs of isovists (i.e., as the title of Turner et al, 2001 suggests, moving from isovists to visibility graphs). Benedikt in (Benedikt 1979) defines the "isovist" as the entire field of view from a single point can be represented by a planar polygon, usually parallel to the ground plane. In VGA, a grid of points is overlaid on the plan. A graph is then made of the points, where each point is connected to every other point that it can see. Having constructed the visibility graph, we then take measures of various features of the graph. Taking into account Hillier and Hanson's (1984) work, we have concentrated on the "*integration*" of a point in the graph. The integration is a normalised (inverse) measure of the mean shortest path from the point to all other points in the system.

Appendix F_ Questionnaires

Experiment_01 – Peraiki Coast

E x p e r i m e n t 1

Location of Experiment 1/ Τόπος διεξαγωγής πειράματος 1:_____

Date /Ημερομηνία:_____ **Time /Ώρα:**_____

Subject/ Κατηγορία Ερωτηθέντος:_____

1. Are you inhabitant of Piraeus? (Είστε κάτοικος Πειραιά;)

☐ Yes ☐ No

☐ Ναι ☐ Όχι

For Visitors or Regional Locals)

(Αν είναι τουρίστας ή από την ευρύτερη περιοχή της Αθήνας και του Πειραιά)

2. How often do you visit Piraeus? (Πόσο συχνά επικέπτεστε τον Πειραιά;)

☐ once a week (μία φορά τη βδομαδα)

☐ more often than once a week (συχνότερα από μία φορά τη βδομαδα)

☐ once a month (μία φορά τον μήνα)

☐ more than twice a year (συχνότερα από δύο φορές τον χρόνο)

☐ once a year or less (μία φορά τον χρόνο ή λιγότερο)

☐ it is the first time I come (είναι η πρώτη φορά που έρχομαι)

3. In which part of the coast do you think you are now? Could you show your location on the map? (Σε ποιο σημείο της ακτής πιστεύετε ότι βρίσκεστε αυτή τη στιγμή; Μπορείτε να το δείξετε στον χάρτη;)

4. How do you know? (Πώς το συμπεράνατε;)

E x p e r i m e n t   1 _____

Location of Experiment 1/Τόπος διεξαγωγής πειράματος 1: _____   **Location of Researcher/Τοποθεσία ερευνητή** _____

Date /Ημερομηνία: _____   **Time /Ώρα:** _____
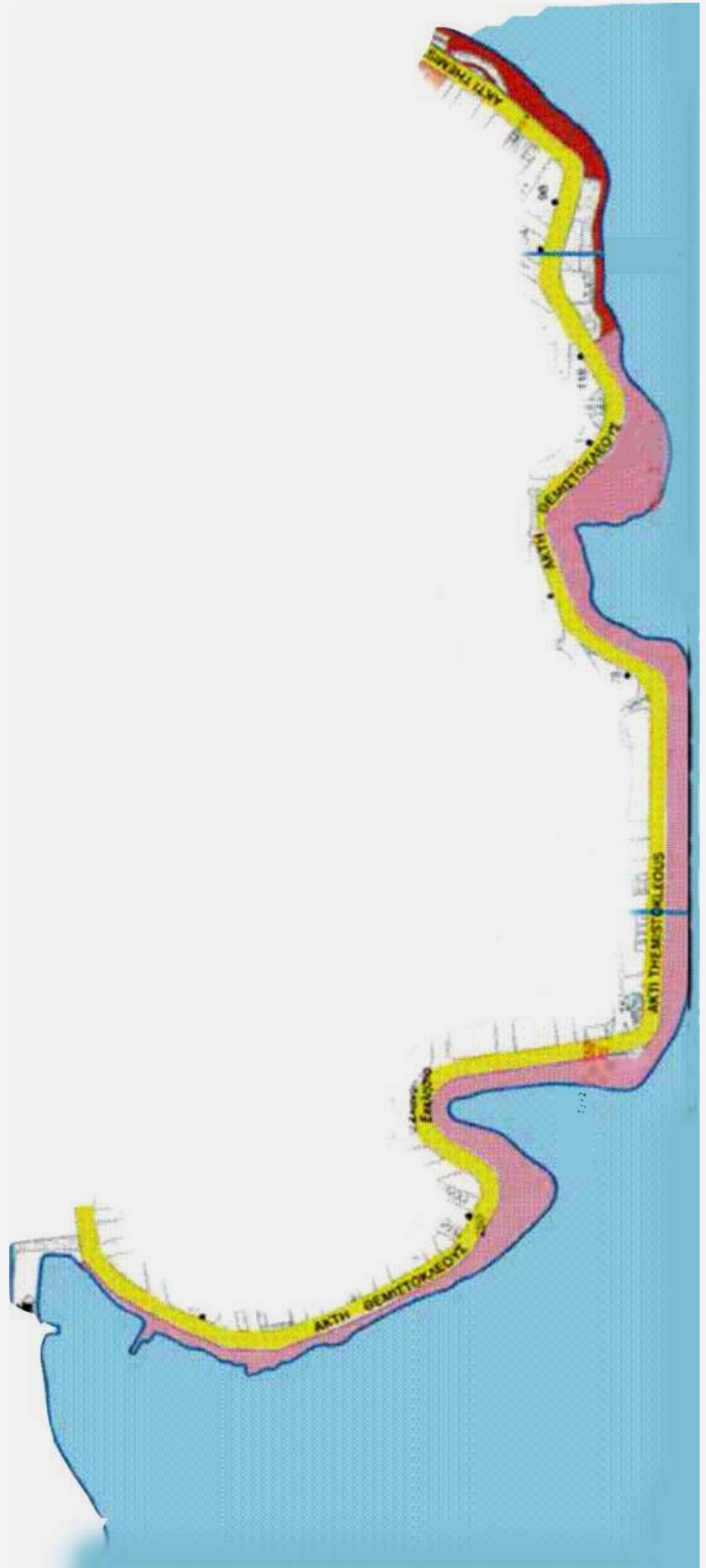
Subject/ Κατηγορία Ερωτηθέντος: _____

E x p e r i m e n t 2

Location of Experiment 1/ Τόπος διεξαγωγής πειράματος 2:_____

Date /Ημερομηνία:_____ **Time /Ώρα:**_____

Subject/ Κατηγορία Ερωτηθέντος:_____

1. Are you inhabitant of Piraeus? (Είστε κάτοικος Πειραιά;)

☐ Yes ☐ No

☐ Ναι ☐ Όχι

For Visitors or Regional Locals)

(Αν είναι τουρίστας ή από την ευρύτερη περιοχή της Αθήνας και του Πειραιά)

2. How often do you visit Piraeus? (Πόσο συχνά επικέπτεστε τον Πειραιά;)

☐ once a week (μία φορά τη βδομαδα)

☐ more often than once a week (συχνότερα από μία φορά τη βδομαδα)

☐ once a month (μία φορά τον μήνα)

☐ more than twice a year (συχνότερα από δύο φορές τον χρόνο)

☐ once a year or less (μία φορά τον χρόνο ή λιγότερο)

☐ it is the first time I come (είναι η πρώτη φορά που έρχομαι)

3. Could you point out the Municipal Theatre? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκετε το Δημοτικό Θέατρο;)

4. Could you point out the Train Station of Piraeus? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκετε ο ηλεκτρικός σταθμός Πειραιά;)

5. Could you point out the Naval College at the end of Peiraiki coast? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκετε η Σχολή Ναυτικών Δοκίμων στο τέλος της Πειραϊκής;)

6. Could you point out the Archaeological Museum of Piraeus? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκετε το Αρχαιολογικό Μουσείο Πειραιά;)

7. Could you point out the Main Gate of Piraeus at the district of "Gouva tou Vavoula"? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκονται τα αρχαία της Πύλης του Πειραιά (στον Λάκκο του Βάβουλα;

8. Could you point out the Konon Walls (Porfuras basketball court)? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκονται τα Κονώνεια τείχη – Γήπεδο πορφύρα;)

9. Could you point out the Restaurant "Axinos"? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκετε το μεζεδοπωλείο «Αχινός»;)

10. Could you point out the Fast food "Goody's"? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκονται τα Goody's στο Πασαλιμάνι;)

11. Could you point out the Church of Prophet Ilias? (Μπορείτε να δείξετε που πιστεύετε ότι βρίσκεται το καφέ η εκκλησία στον Προφήτη Ηλία;)

E x p e r i m e n t   2

Location of Experiment 1/ Τόπος διεξαγωγής πειράματος 1:_____

Date /Ημερομηνία:_____ **Time /Ώρα:**_____

Subject/ Κατηγορία Ερωτηθέντος:_____

Experiment_03 – Sotiros Dios St.

E x p e r i m e n t   3

Location of Experiment 1/ Τόπος διεξαγωγής πειράματος 1:_____
Date /Ημερομηνία:_____ **Time /Ώρα:**_____
Subject/ Κατηγορία Ερωτηθέντος:_____

1. Are you inhabitant of Piraeus? (Είστε κάτοικος Πειραιά;)

☐ Yes ☐ No

☐ Ναι ☐ Όχι

For Visitors or Regional Locals)
(Αν είναι τουρίστας ή από την ευρύτερη περιοχή της Αθήνας και του Πειραιά)
2. How often do you visit Piraeus? (Πόσο συχνά επικέπτεστε τον Πειραιά;)

☐ once a week (μία φορά τη βδομαδα)

☐ more often than once a week (συχνότερα από μία φορά τη βδομαδα)

☐ once a month (μία φορά τον μήνα)

☐ more than twice a year (συχνότερα από δύο φορές τον χρόνο)

☐ once a year or less (μία φορά τον χρόνο ή λιγότερο)

☐ it is the first time I come (είναι η πρώτη φορά που έρχομαι)

A Part/Α φάση:

3. Could you draw on the map spatial elements of the city of Piraeus? (Μπορείτε να τοποθετήσετε μερικά στοιχεία στον χάρτη; (κάποιο κτίριο, πλατεία, δρόμο, οτιδήποτε)

B Part/Β φάση:

4. How would you go from Korai Square to Marina Zeas? (flying dolphins)
(Πώς θα πηγαίνατε από την πλατεία Κοραή στην Μαρίνα Ζέας – δελφίνια);
5. How would you go from Mikrolimano (Yacht Club of Greece) to Sotiros Dios Street (Pedestrian Street)?

(Πώς θα πηγαίνατε από το Μικρολίμανο (Ναυτικός όμιλος ελλάδος) στον πεζόδρομο της Σωτήρως;)

6. How would you go from Pasalimani (kanari square) to Piraeus Train Station?

(Πώς θα πηγαίνατε από το Πασαλιμάνι (πλατεία κανάρη-πασαρέλα) στον Ηλεκτρικό Σταθμό Πειραιά;)

7.(How would you go from Pasalimani (kanari square) to Naval College at the end of the coast where Themistoklis Tomb is located?

(Πώς θα πηγαίνατε από το Πασαλιμάνι (πλατεία κανάρη-πασαρέλα) στη Σχολή Δοκίμων στο τέρμα της Πειραϊκής;)

E x p e r i m e n t   3   (B   P a r t) _____

Location of Experiment 1/Τόπος διεξαγωγής πειράματος 1: _____

Date /Ημερομηνία: _____ **Time /Ώρα:** _____

Subject/ Κατηγορία Ερωτηθέντος: _____

Appendix G_ Mental Maps
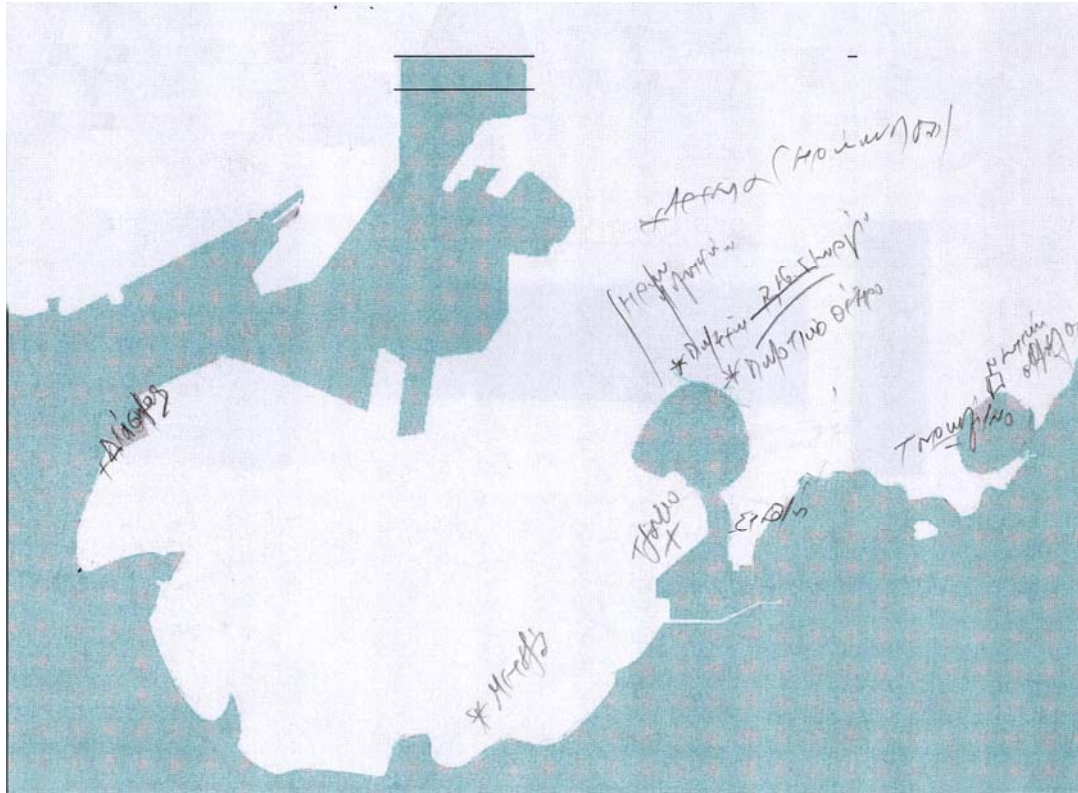
Fig. 88 Mental map drawn by a Local (01).
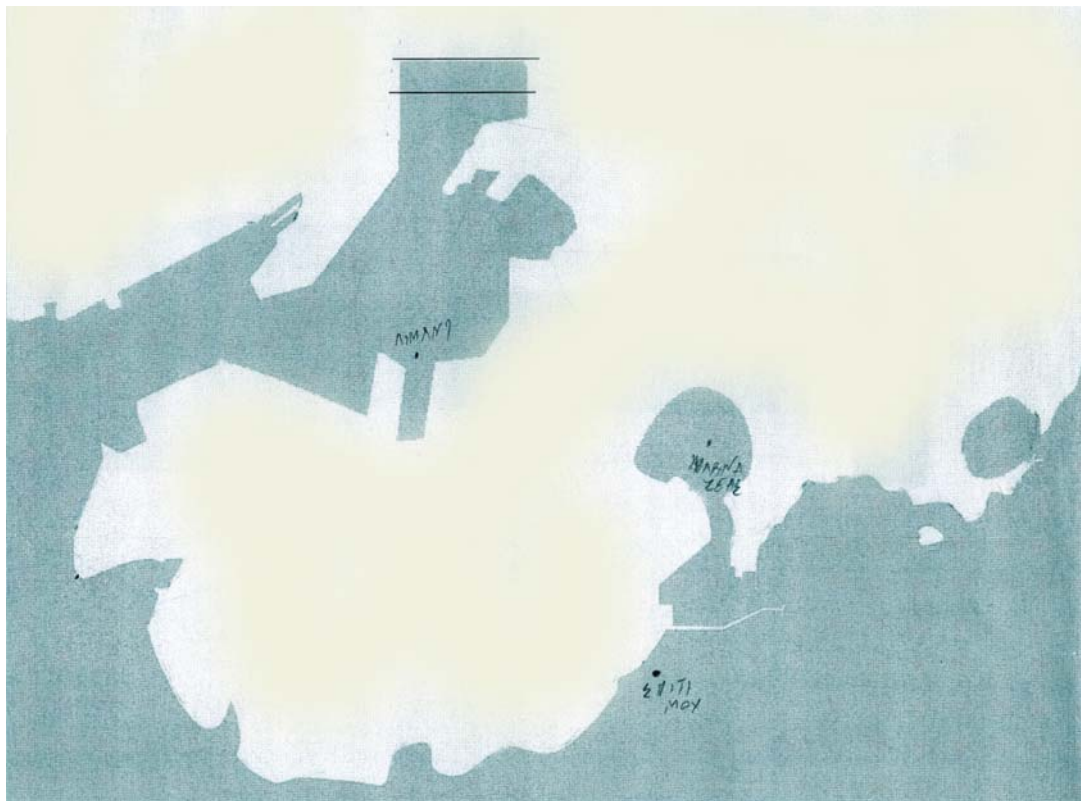
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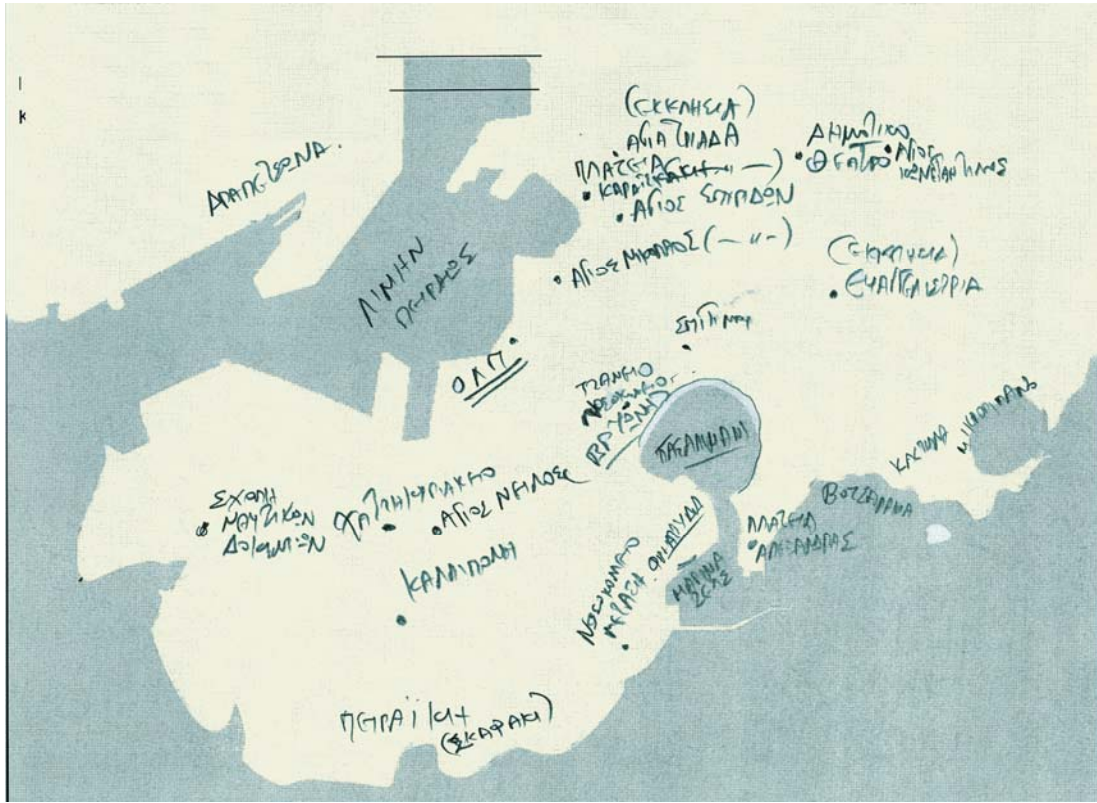
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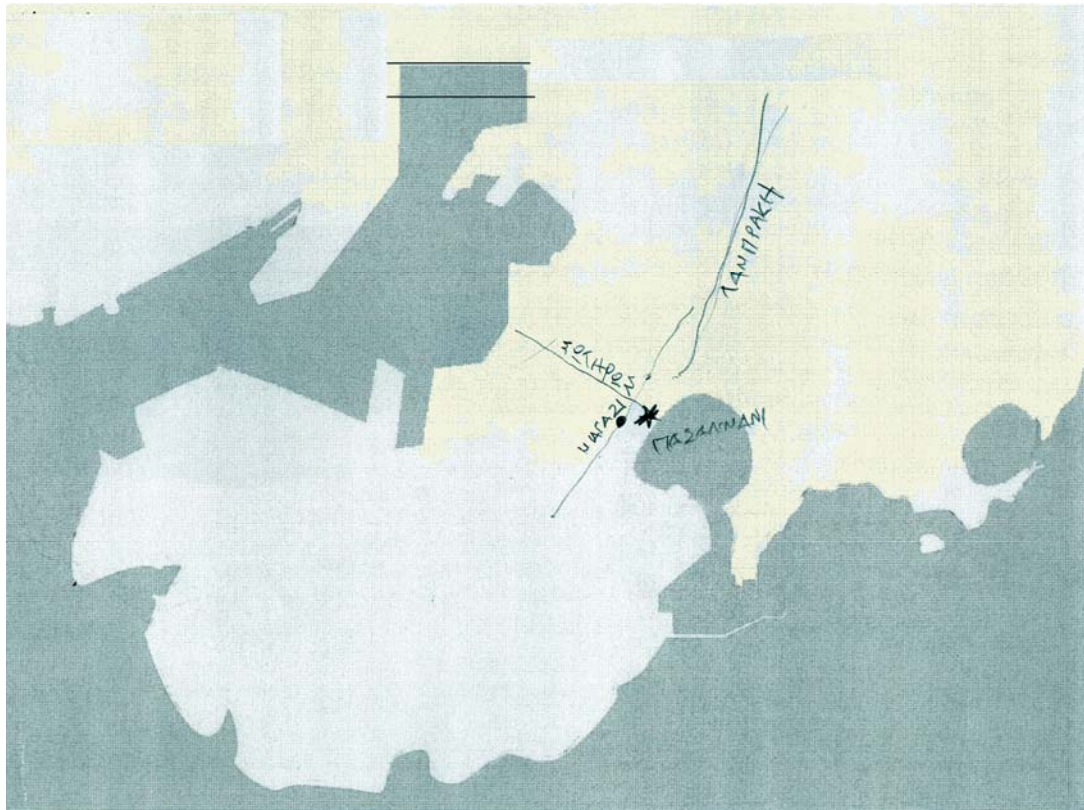
Fig. 91 Mental map drawn by a Local (04).
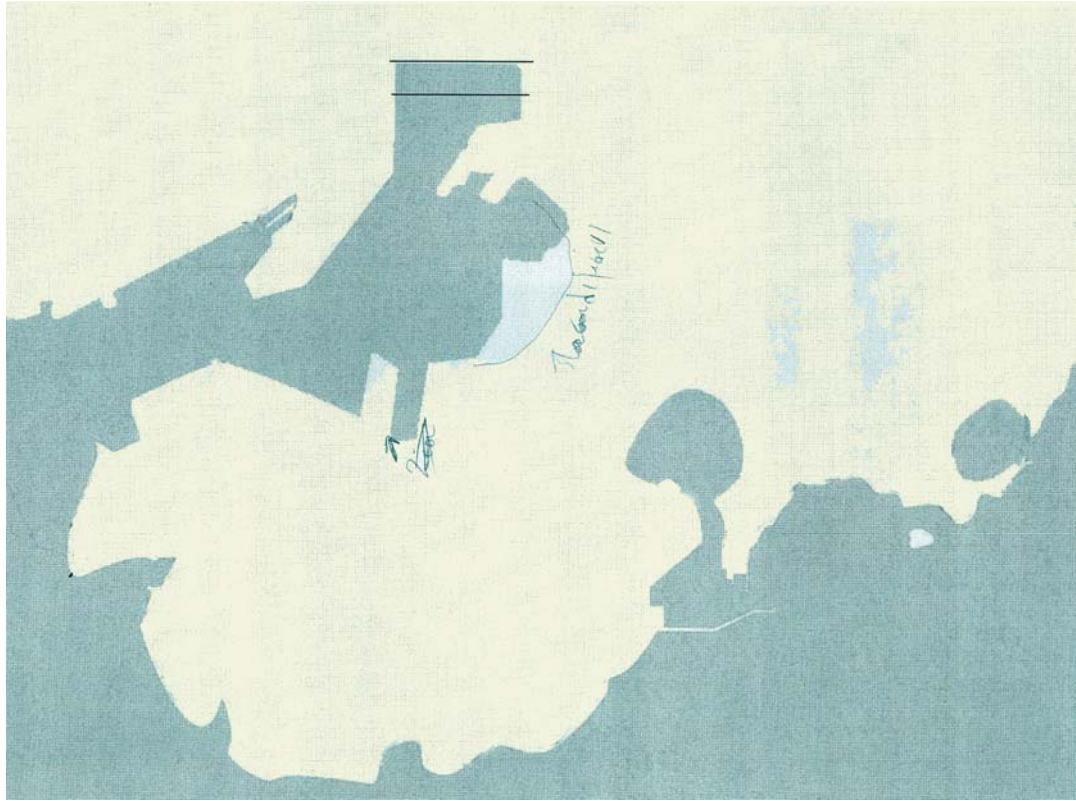
Fig. 92 Mental map drawn by a Local (05).
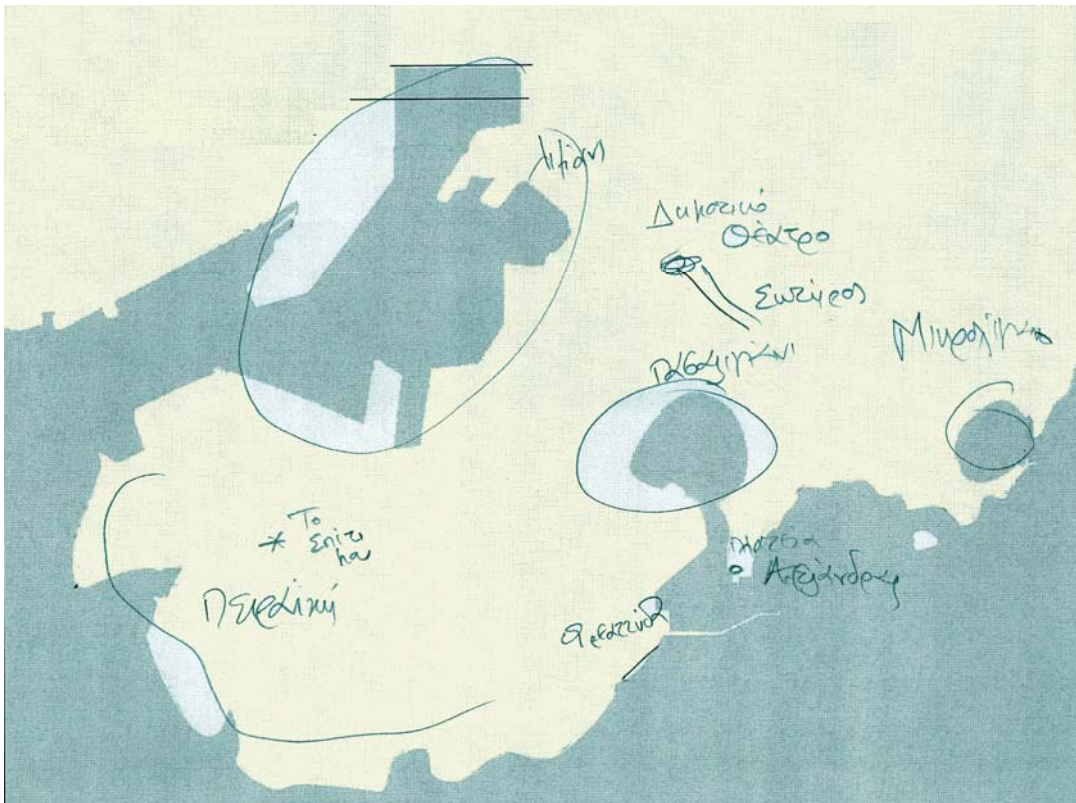
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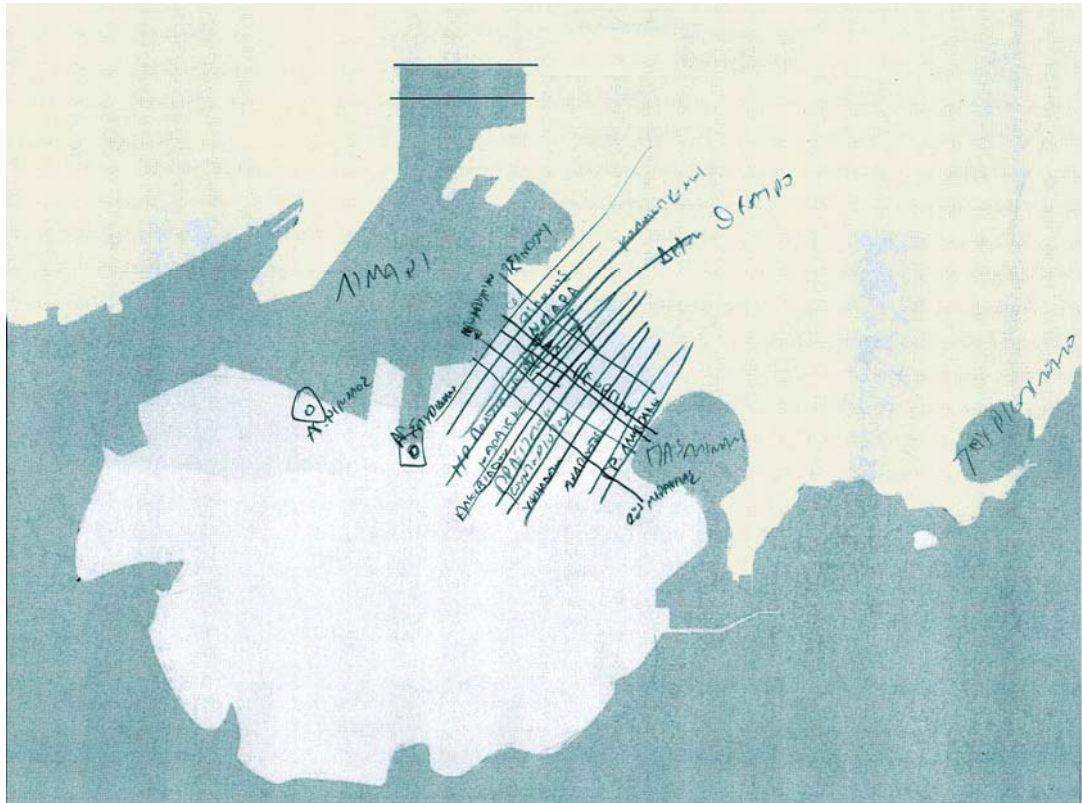
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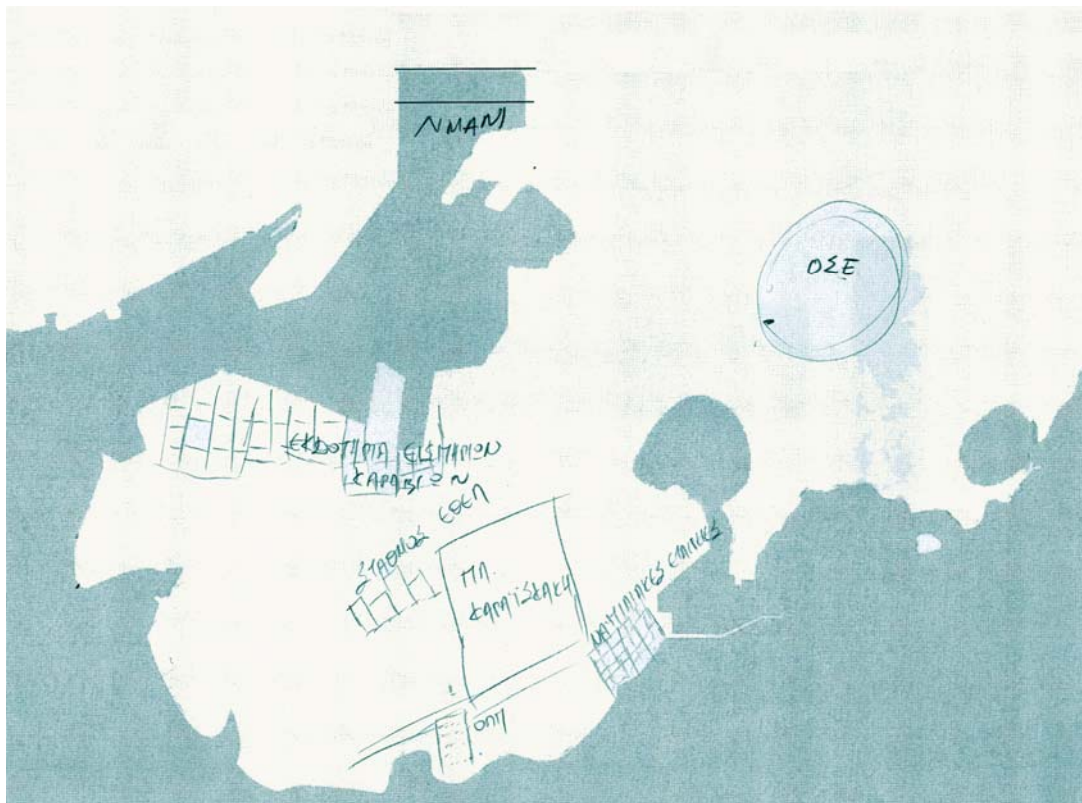
Fig. 95 Mental map drawn by a Local (08).
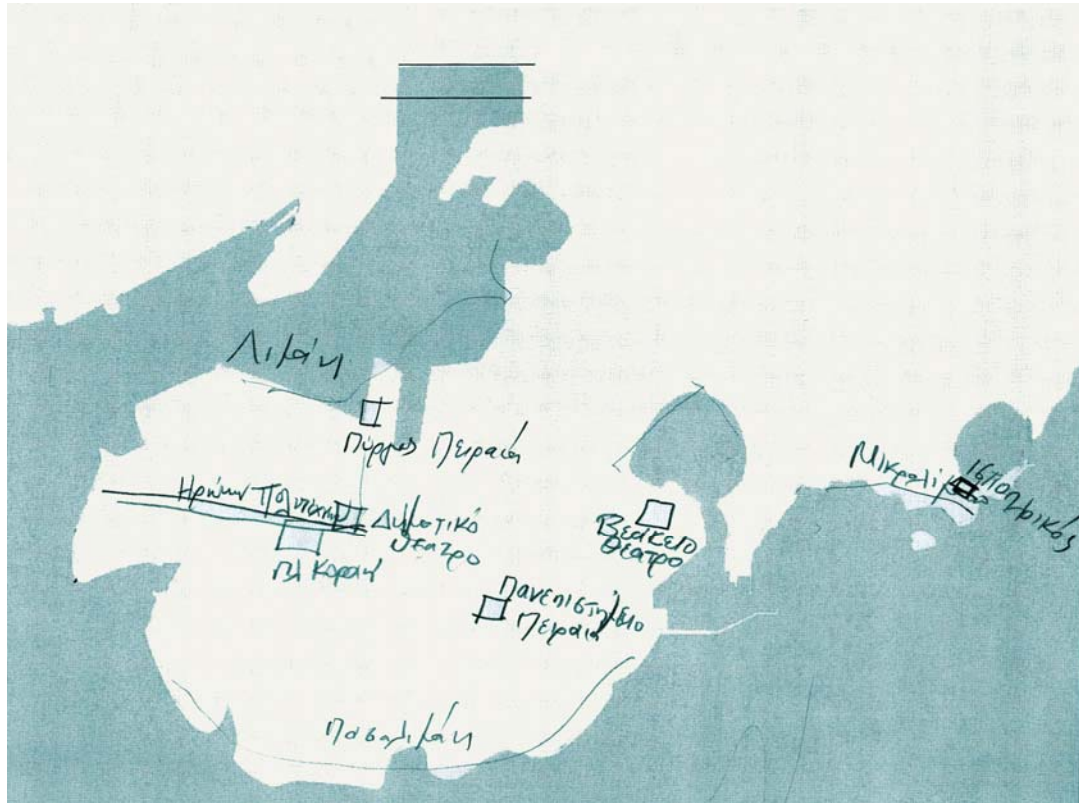
Fig. 96 Mental map drawn by a Local (09).
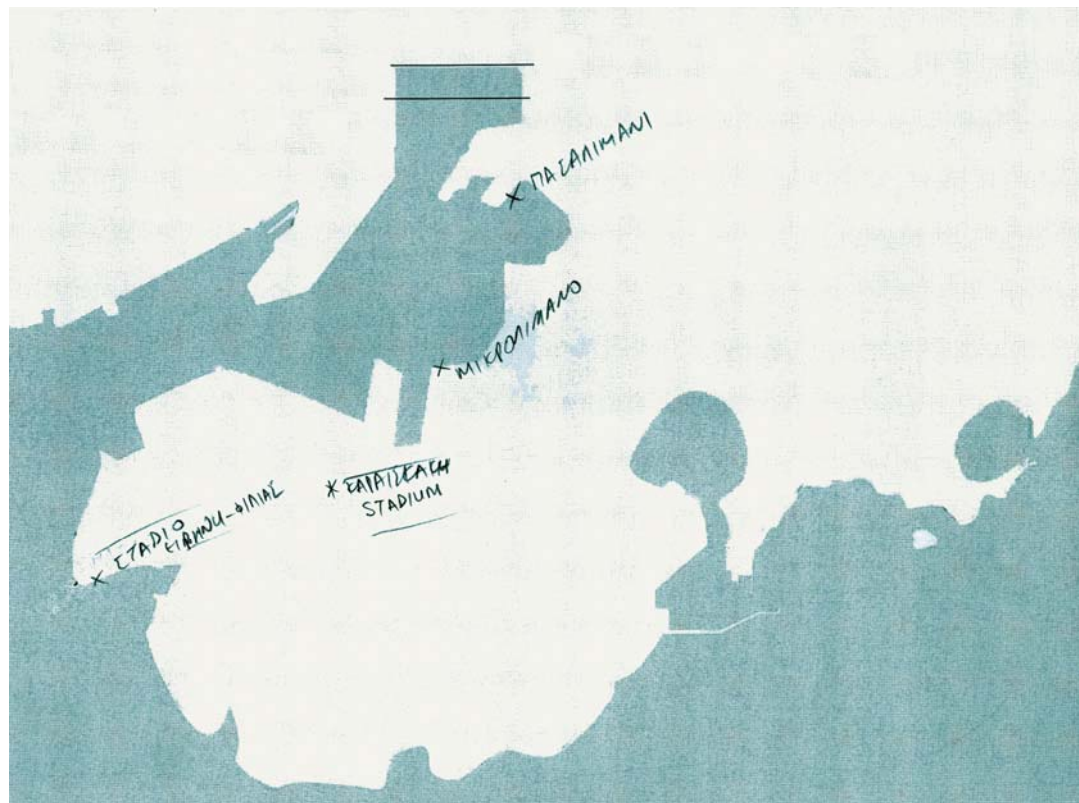
Fig. 97 Mental map drawn by a Local (10).
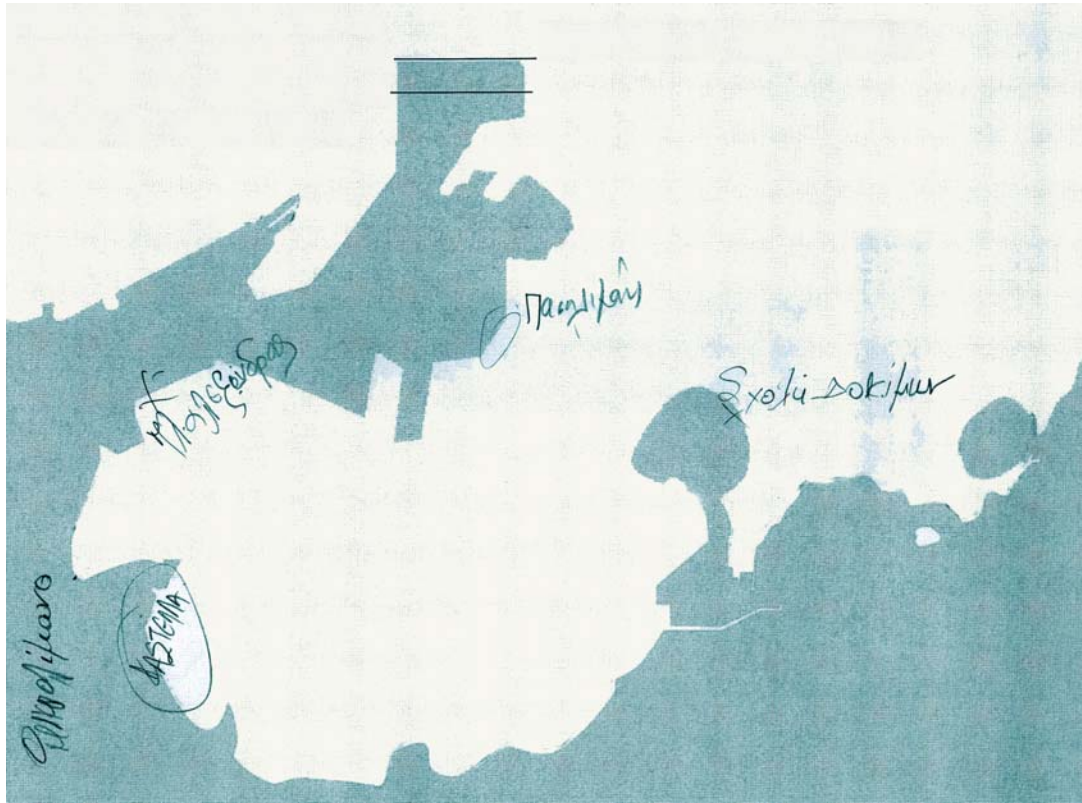
Fig. 98 Mental map drawn by a Local (11).
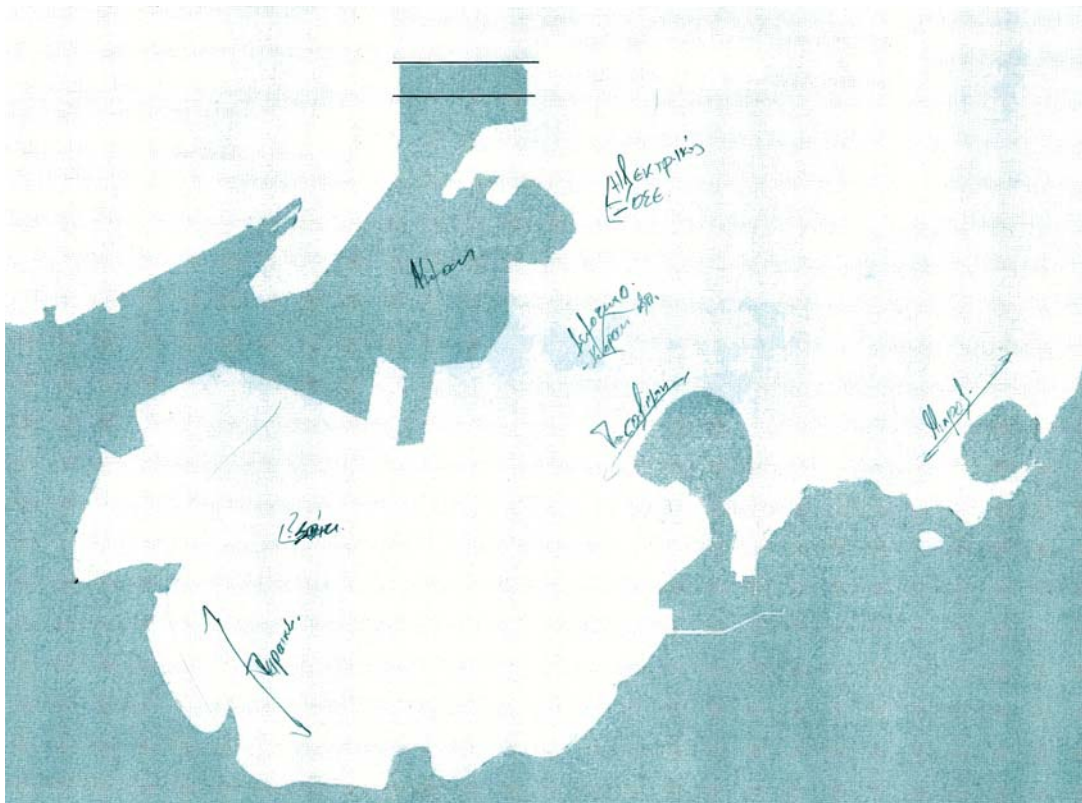
Fig. 99 Mental map drawn by a Local (12).
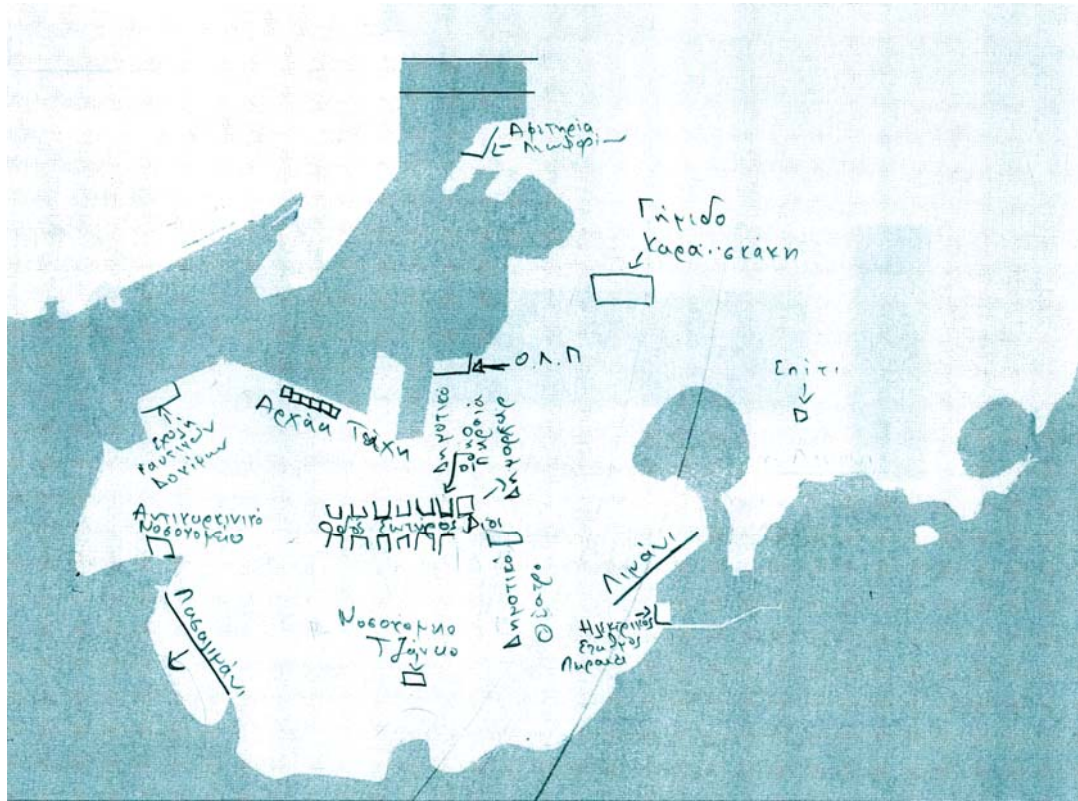
Fig. 100 Mental map drawn by a Local (14).
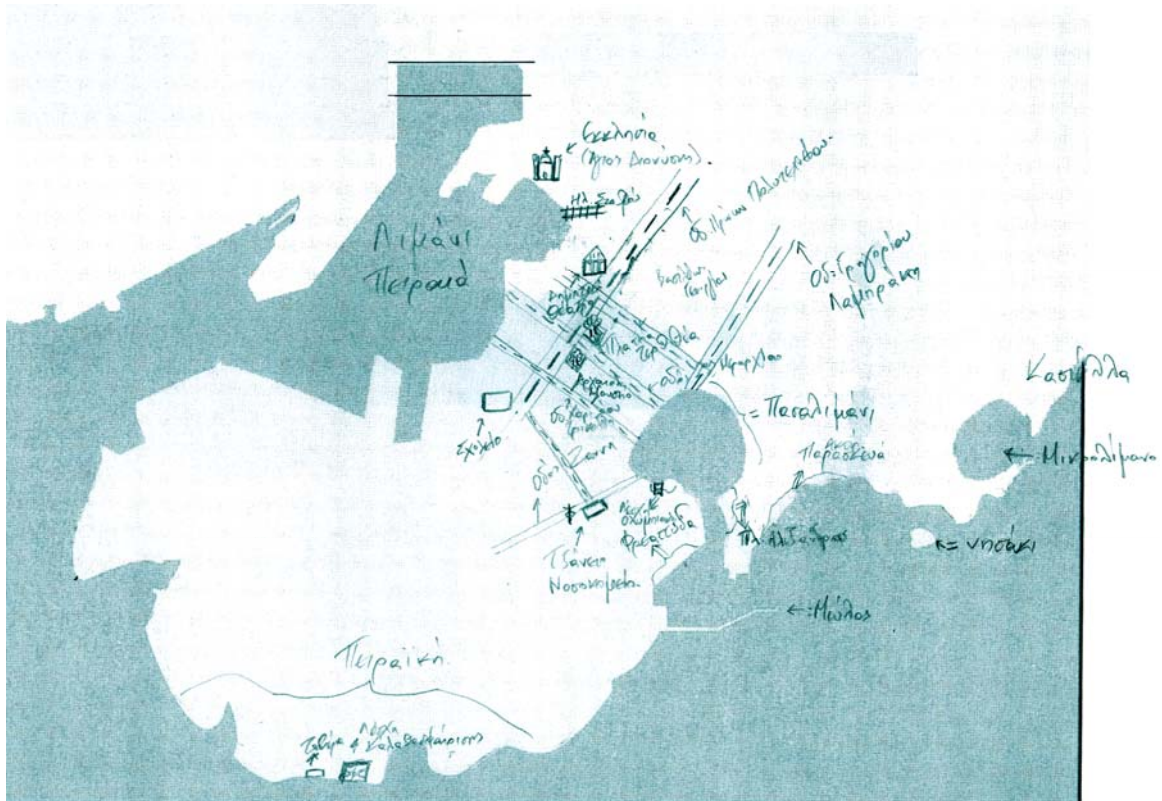
Fig. 101 Mental map drawn by a Local (15).
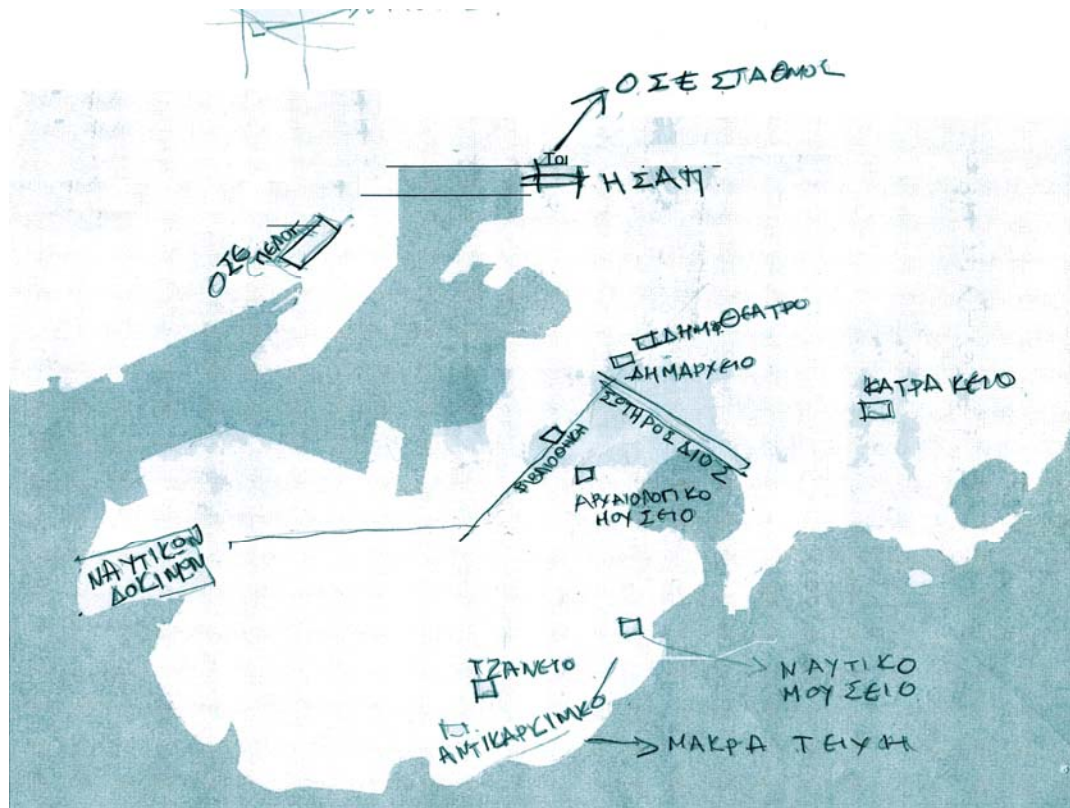
Fig. 102 Mental map drawn by a Local (16).
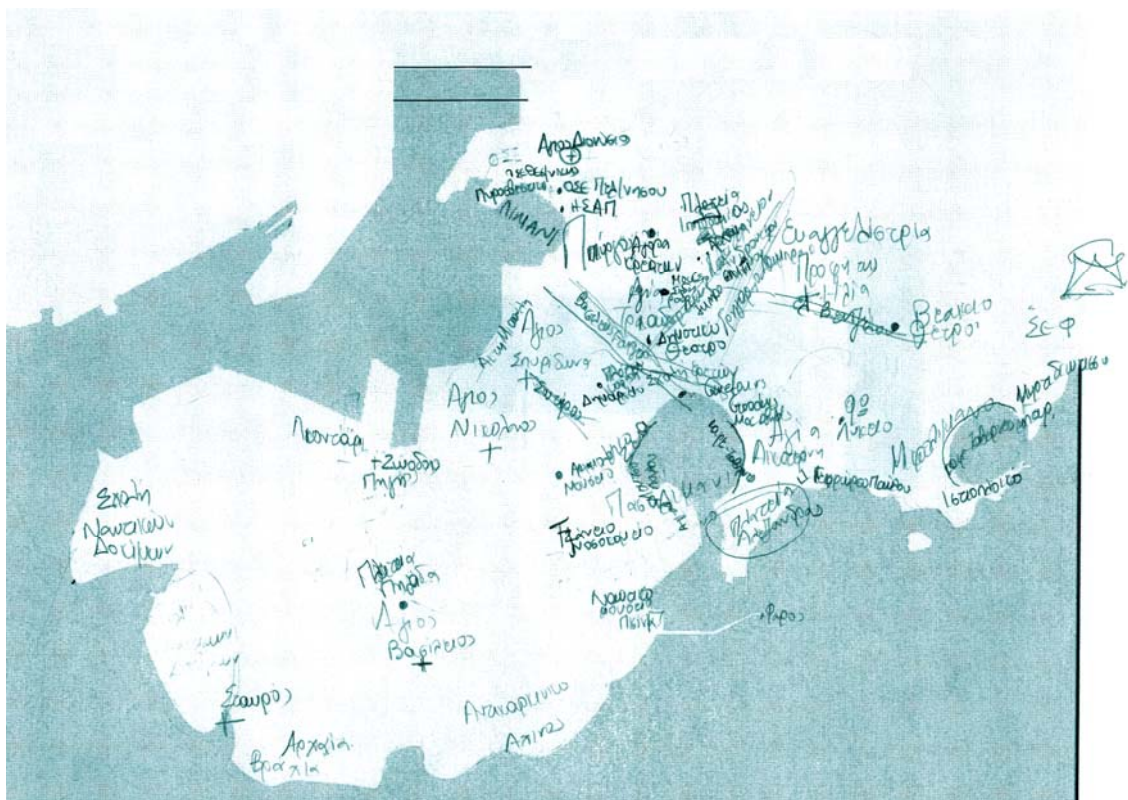
Fig. 103 Mental map drawn by a Local (17).
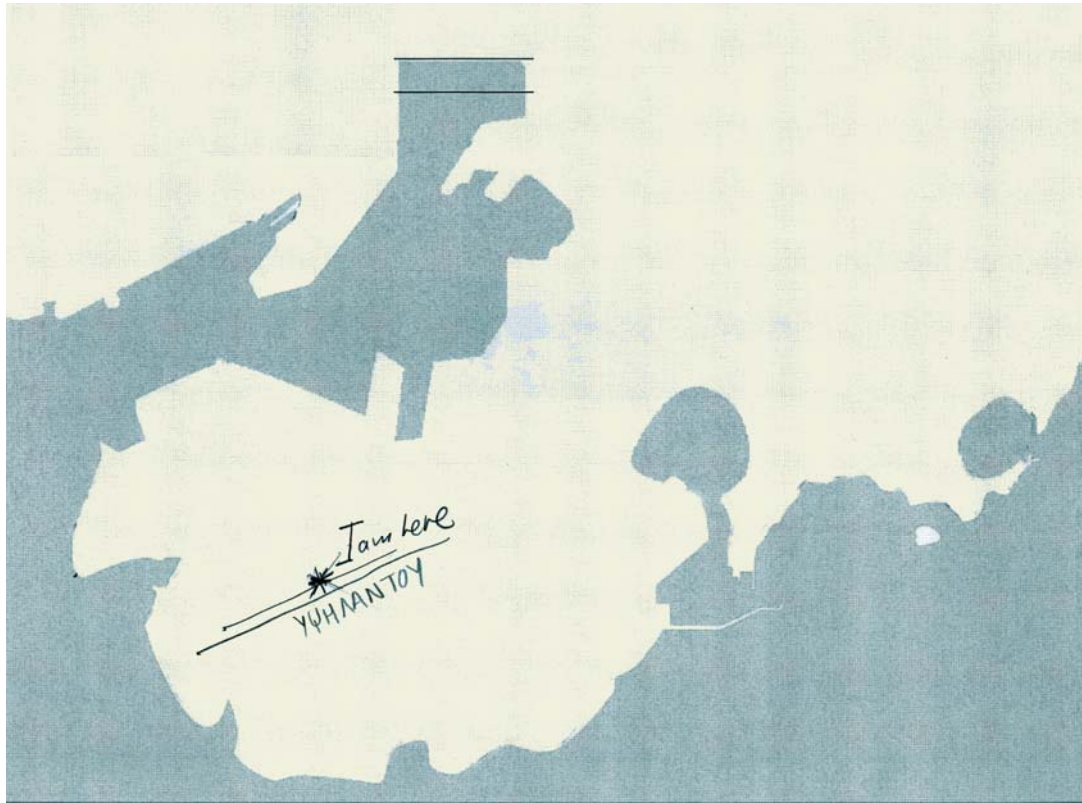
Fig. 104 Mental map drawn by a Regional Local (01).
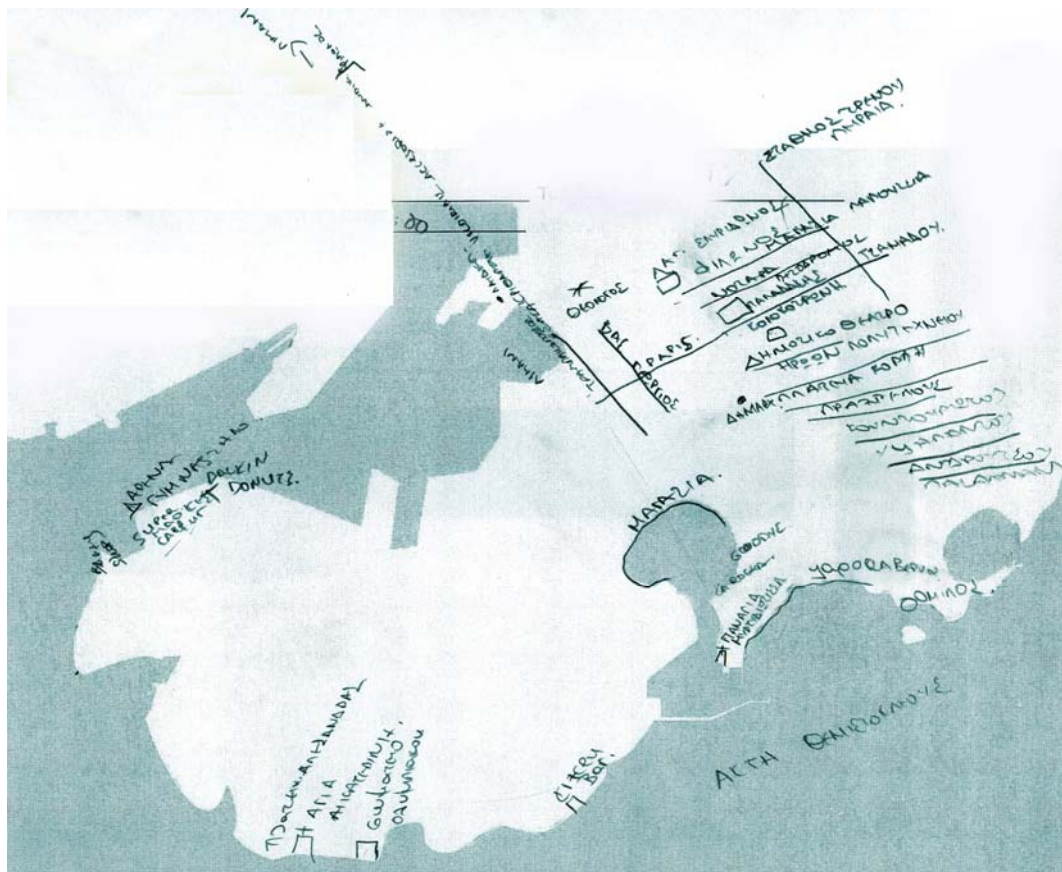
Fig. 105 Mental map drawn by a Regional Local (02).
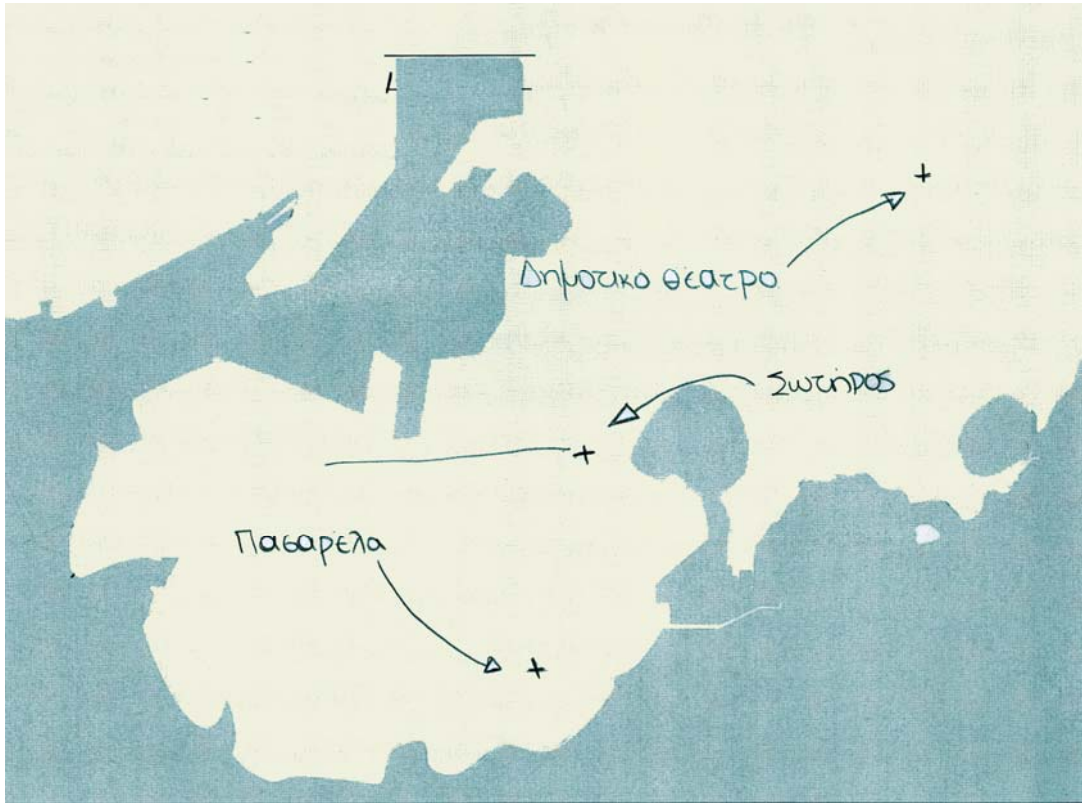
Fig. 106 Mental map drawn by a Regional Local (03).

Fig. 107 Mental map drawn by a Regional Local (04).
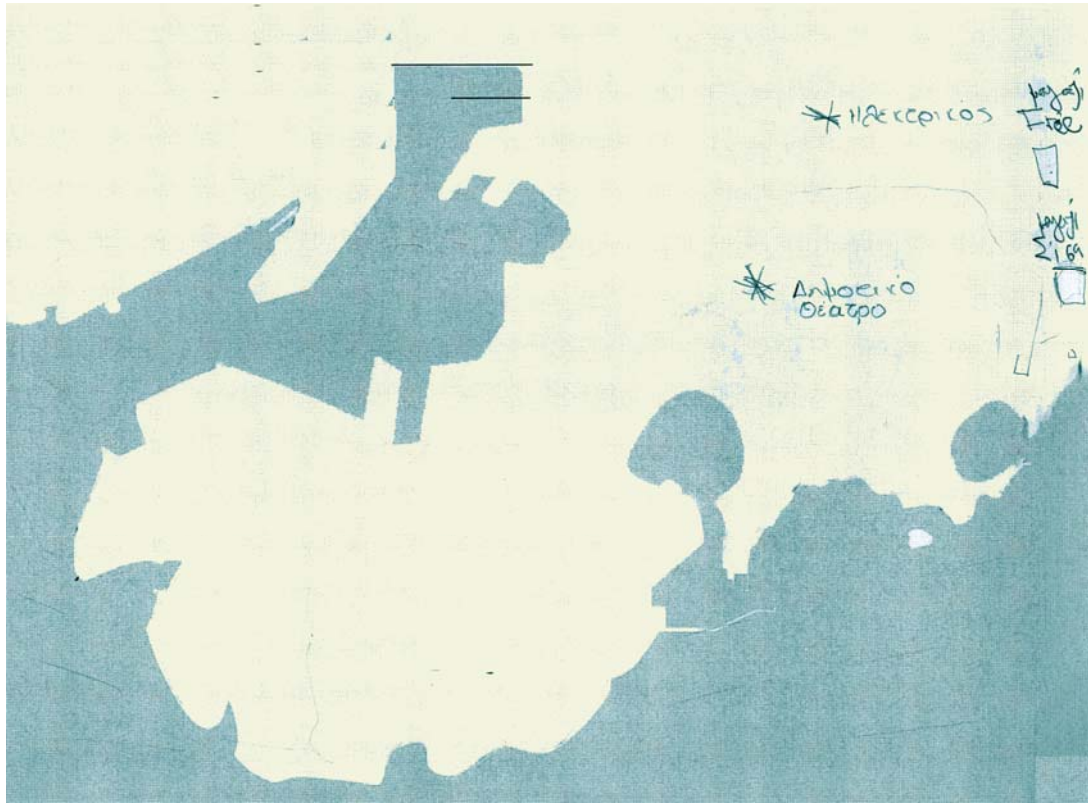
Fig. 108 Mental map drawn by a Regional Local (05).
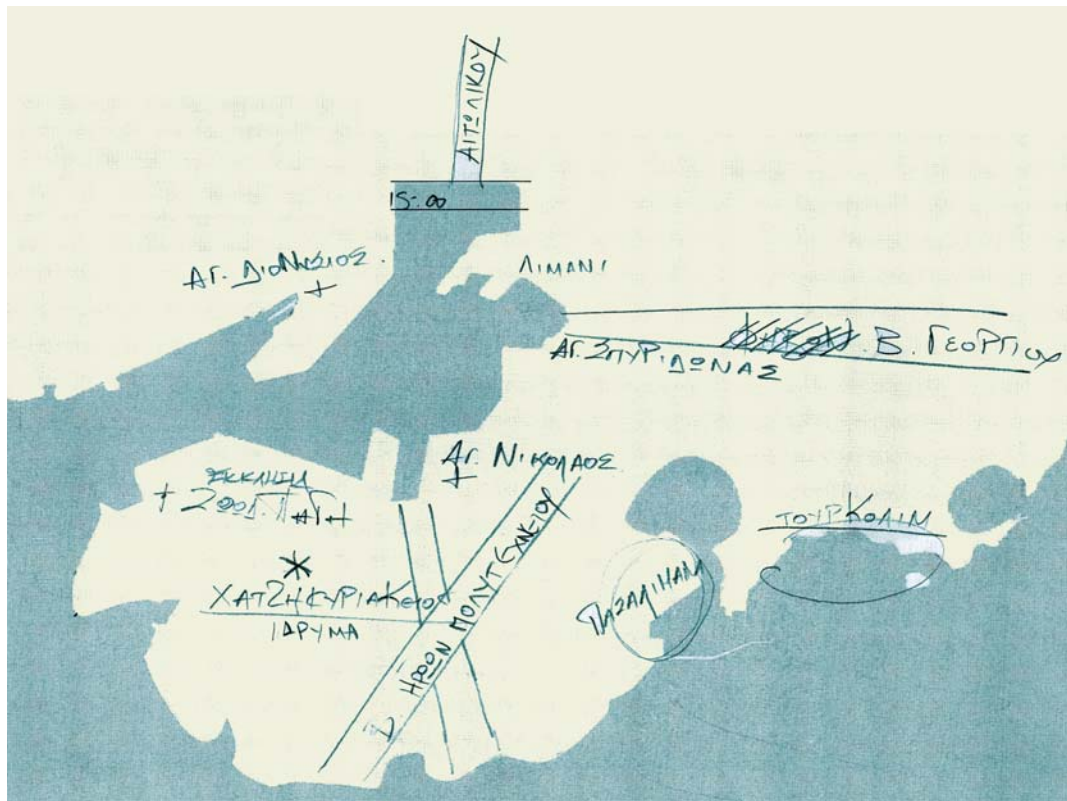
Fig. 109 Mental map drawn by a Regional Local (06).
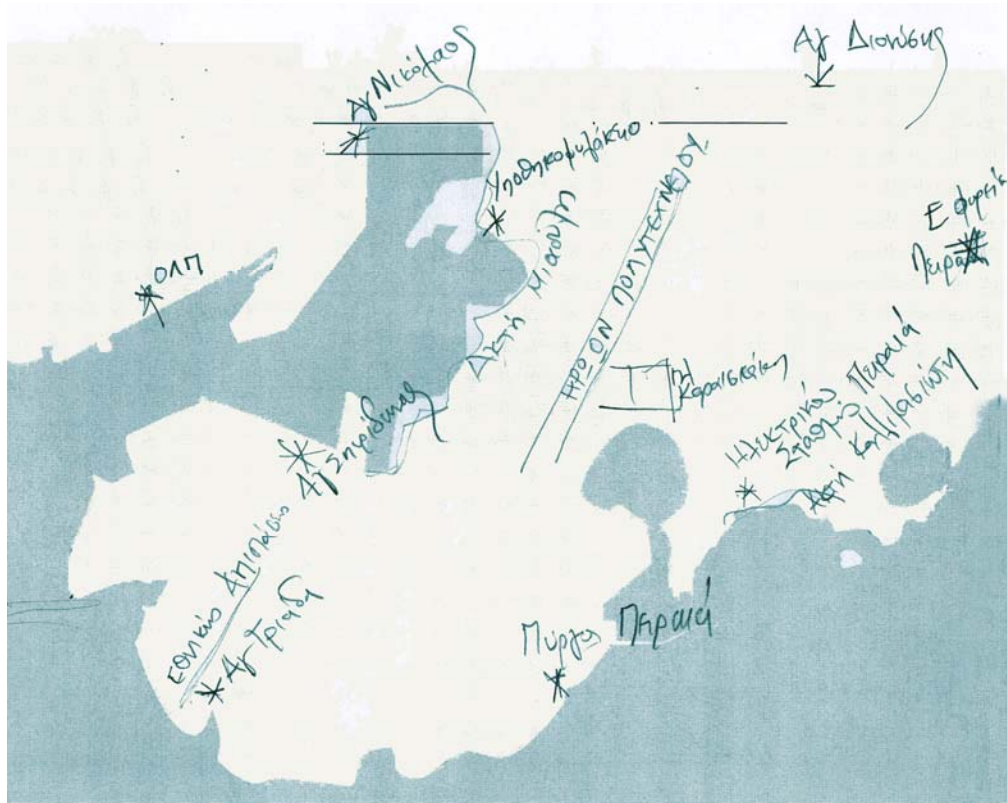
Fig. 110 Mental map drawn by a Regional Local (07).
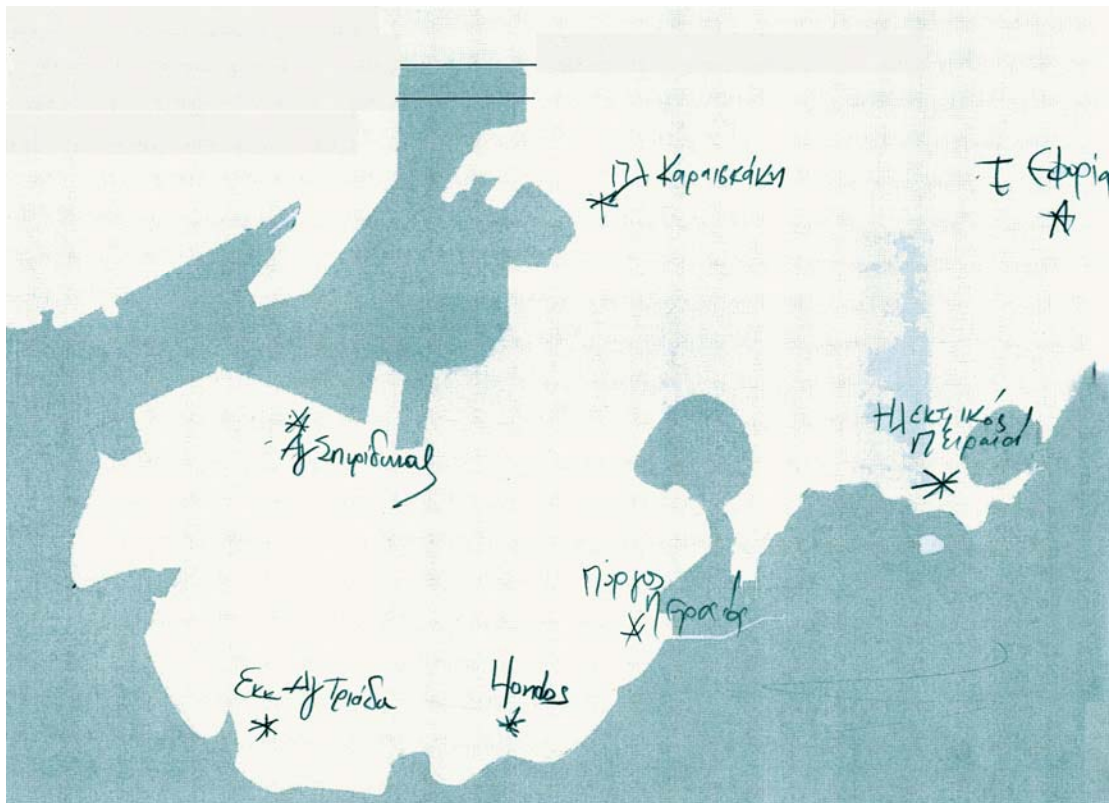
Fig. 111 Mental map drawn by a Regional Local (08).
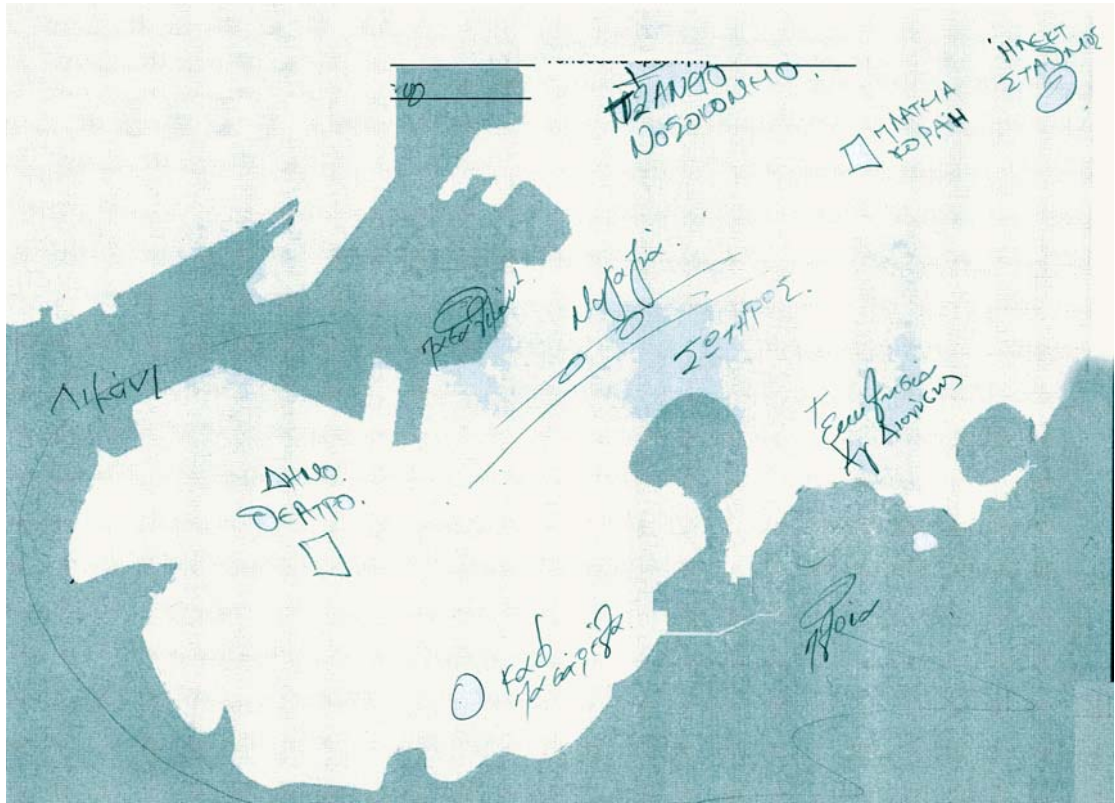
Fig. 112 Mental map drawn by a Regional Local (09).
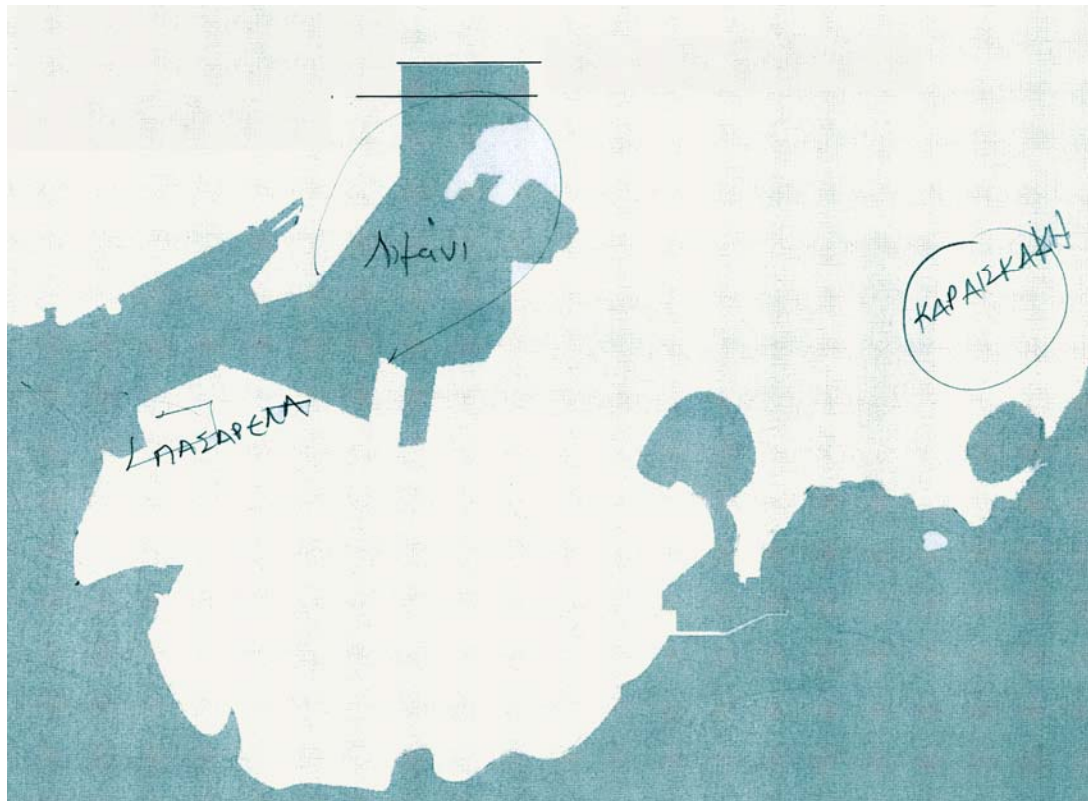
Fig. 113 Mental map drawn by a Regional Local (10).
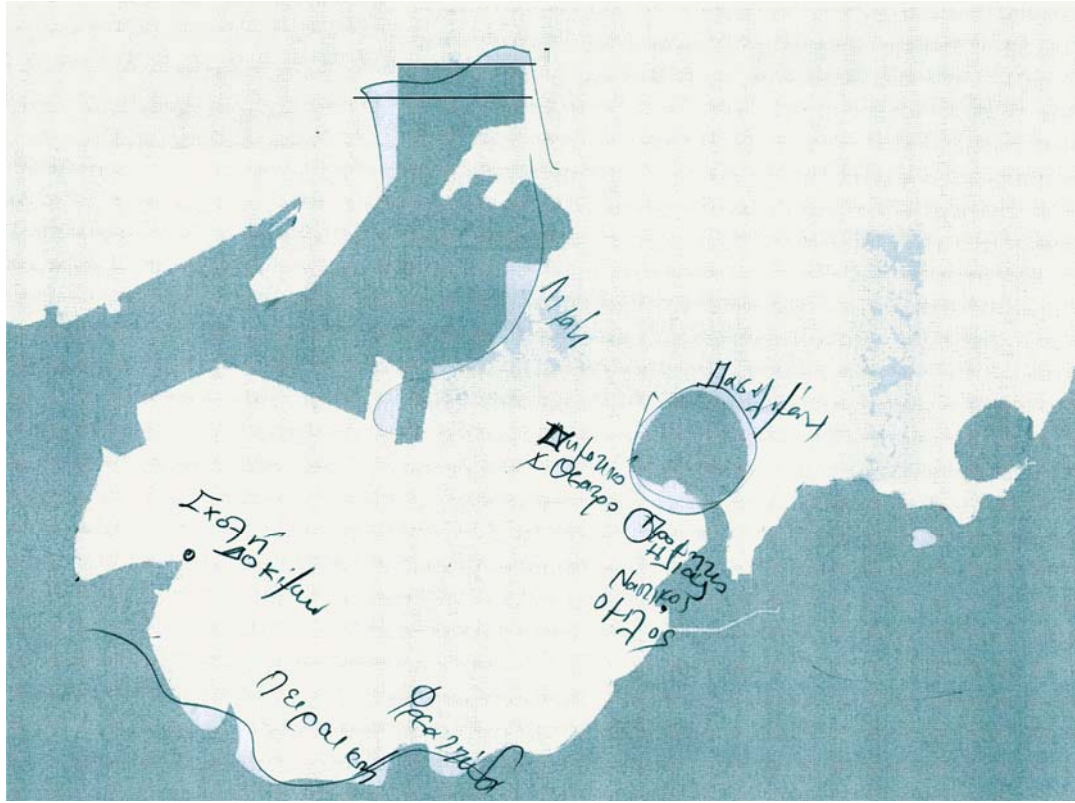
Fig. 114 Mental map drawn by a Regional Local (11).

Fig. 115 Mental map drawn by a Regional Local (12).
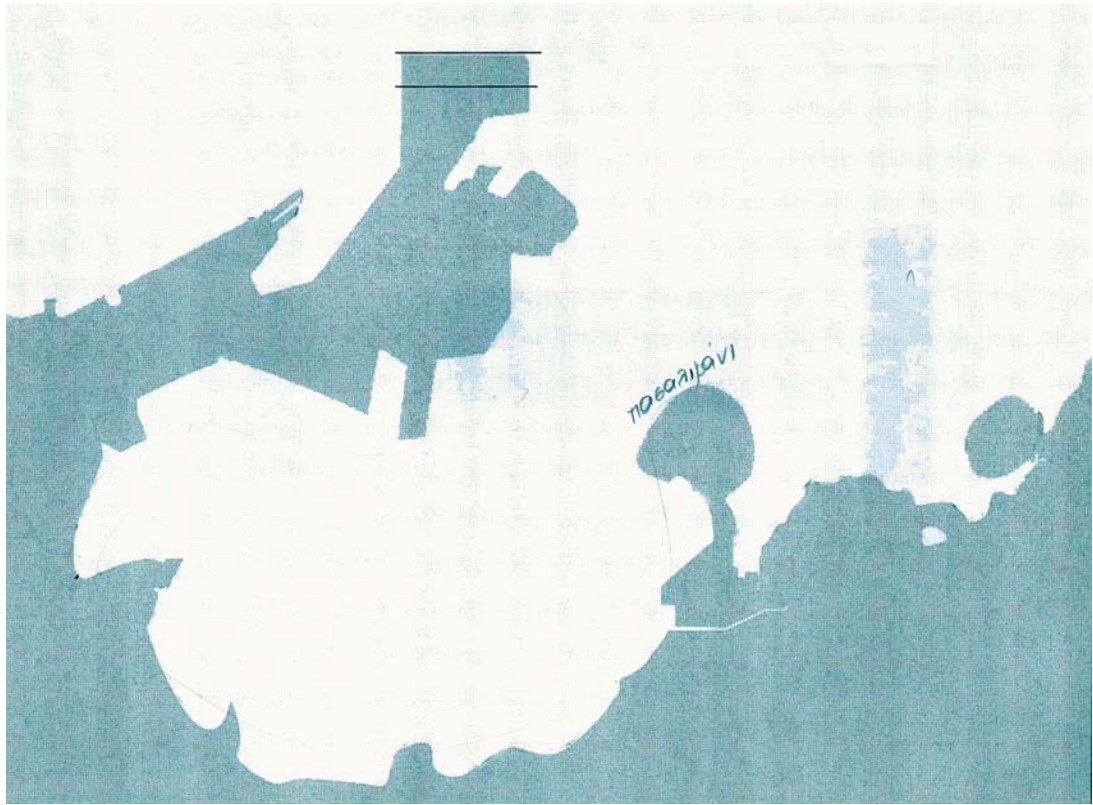
Fig. 116 Mental map drawn by a Regional Local (13).
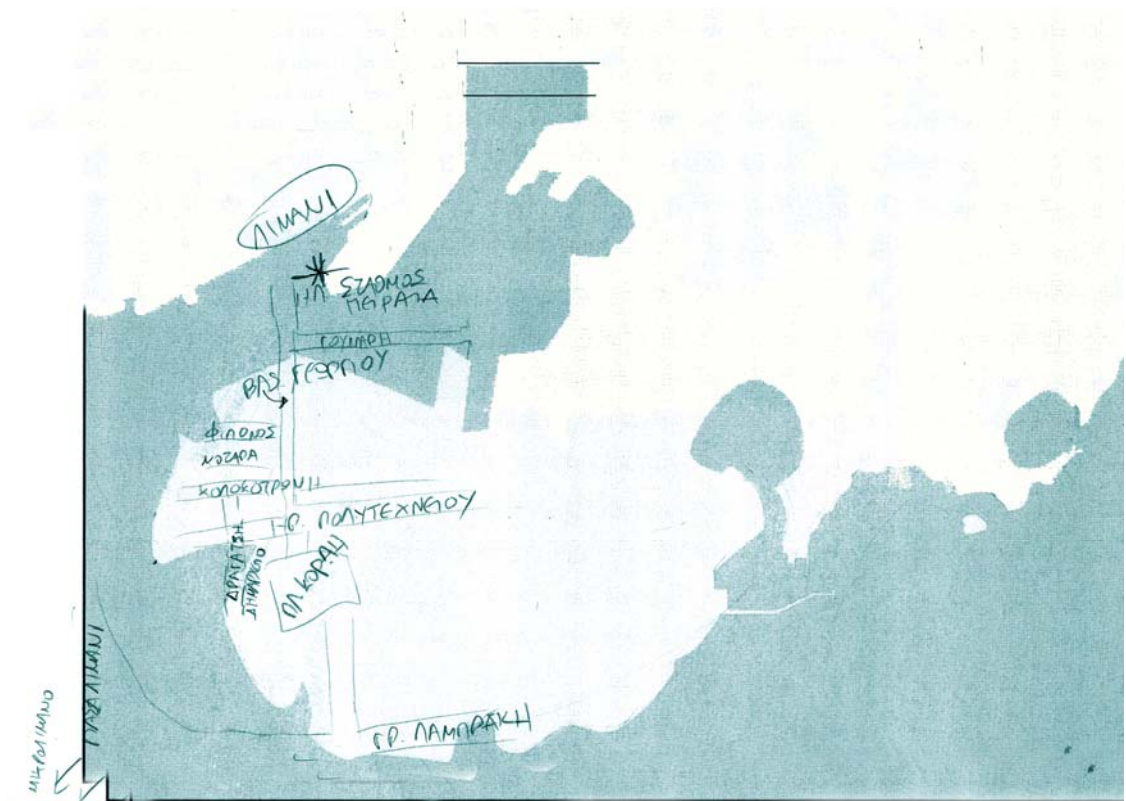
Fig. 117 Mental map drawn by a Regional Local (14).
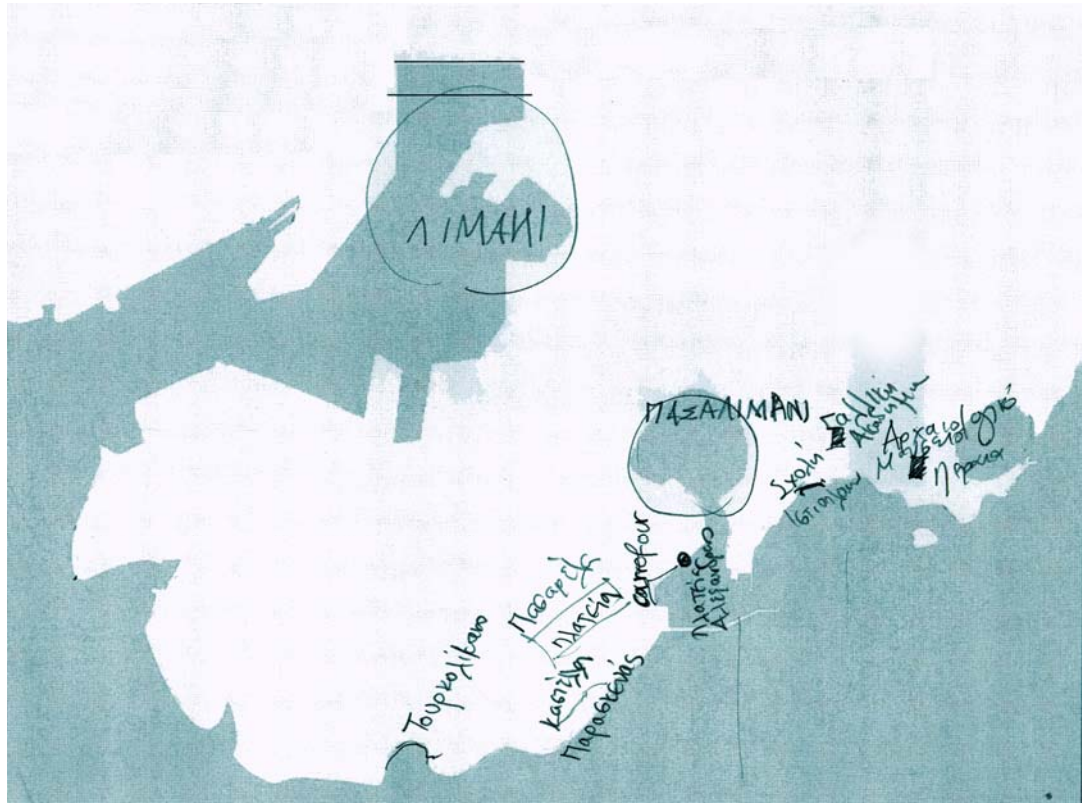
Fig. 118 Mental map drawn by a Regional Local (15).
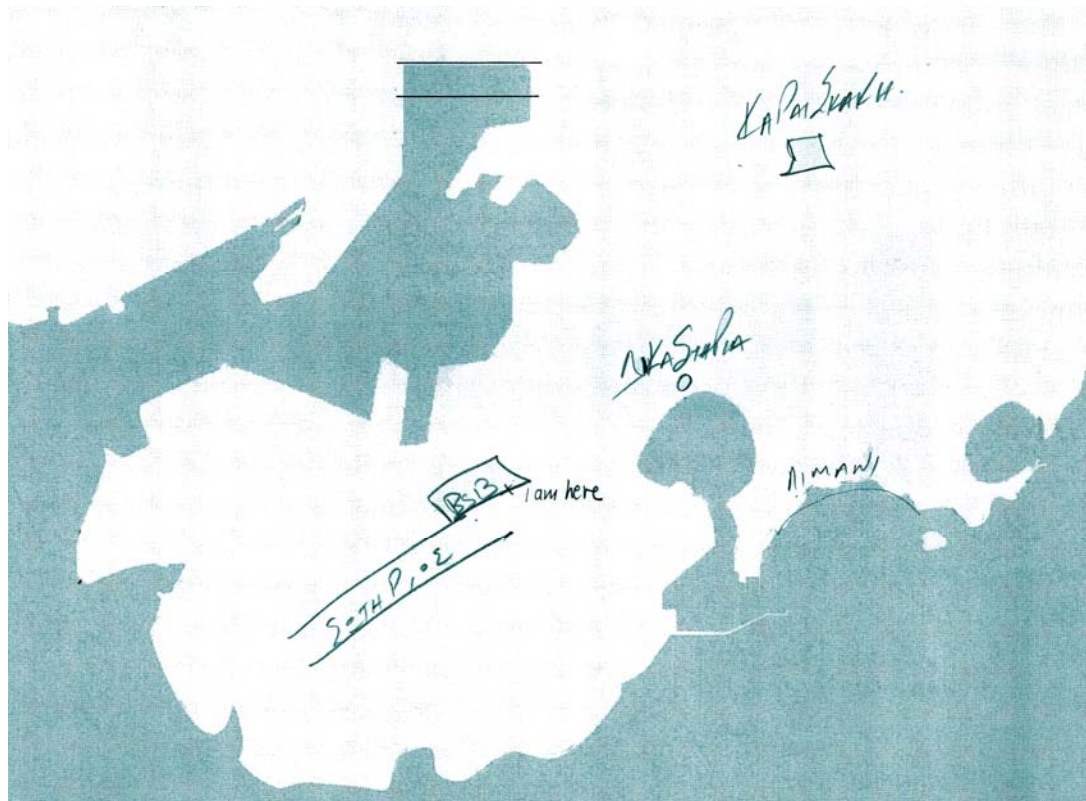
Fig. 119 Mental map drawn by a Regional Local (16).

Fig. 120 Mental map drawn by a Regional Local (17).

**Fig. 121** Mental map drawn by a Regional Local (18).
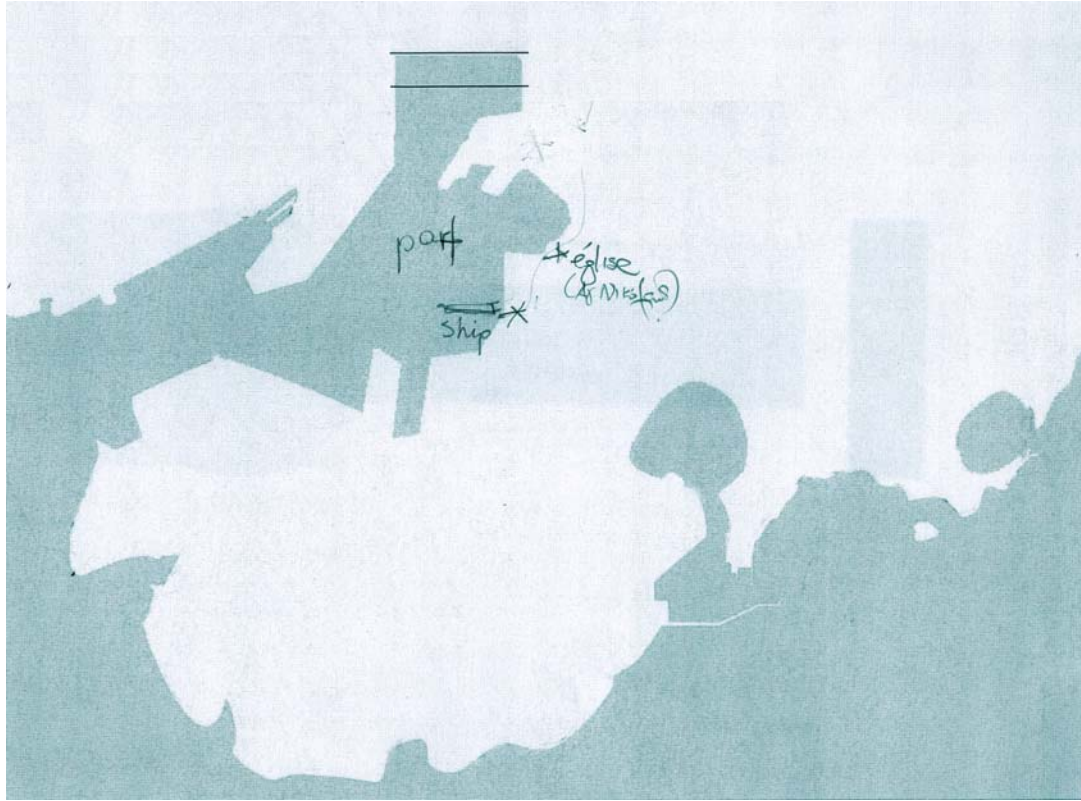
Fig. 122 Mental map drawn by a Visitor (01).
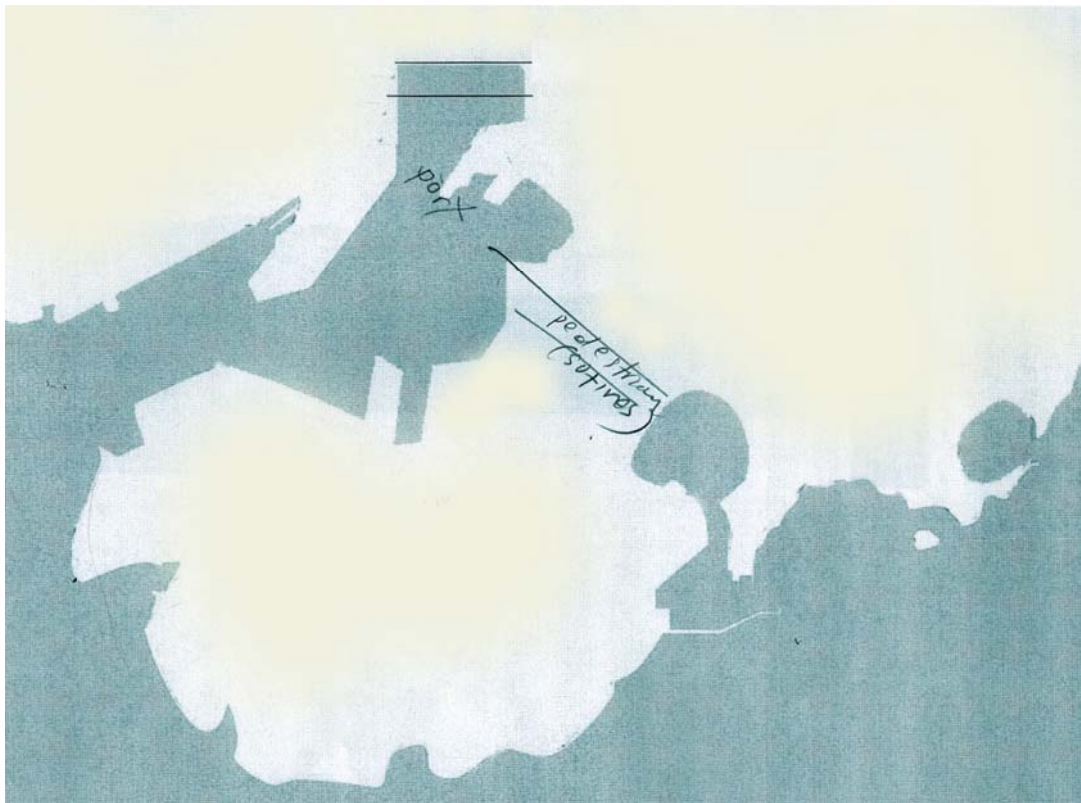
Fig. 123 Mental map drawn by a Visitor (02).
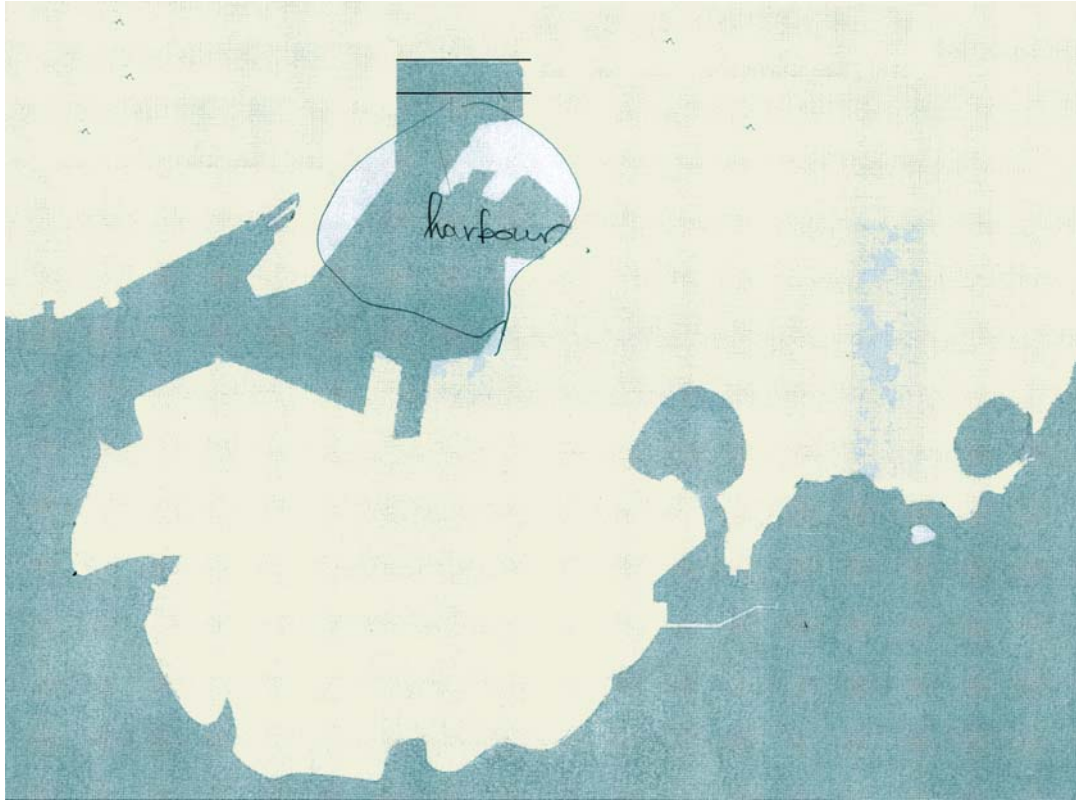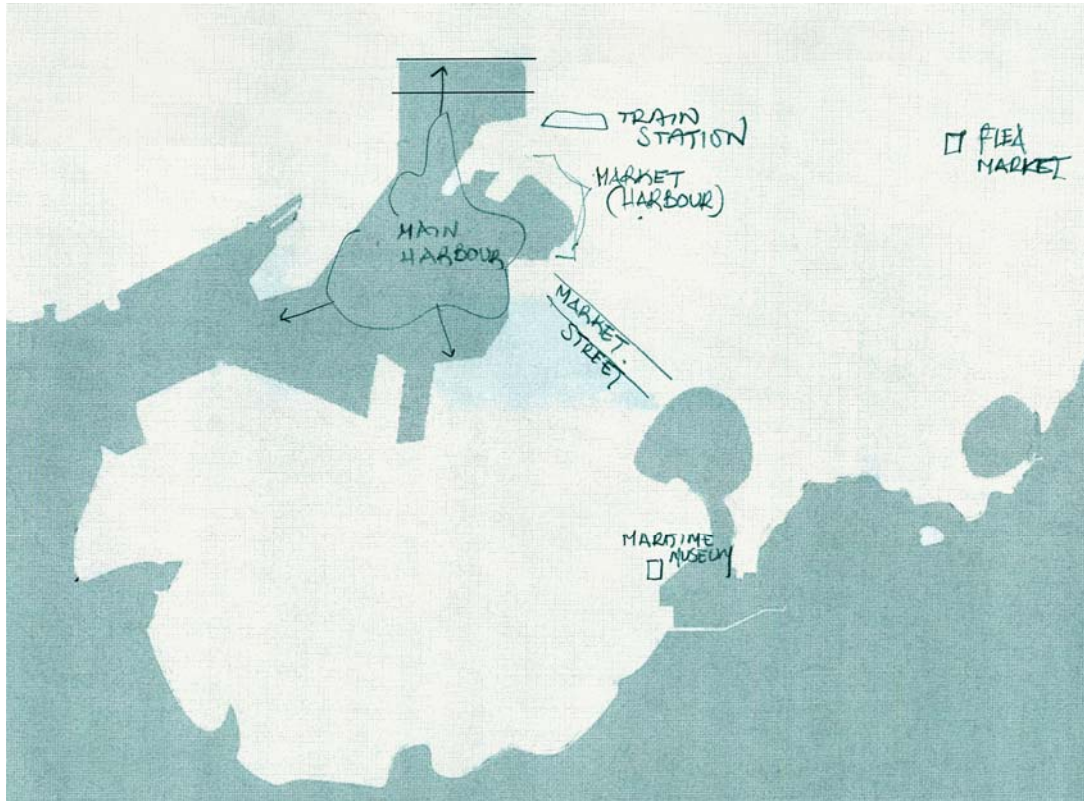
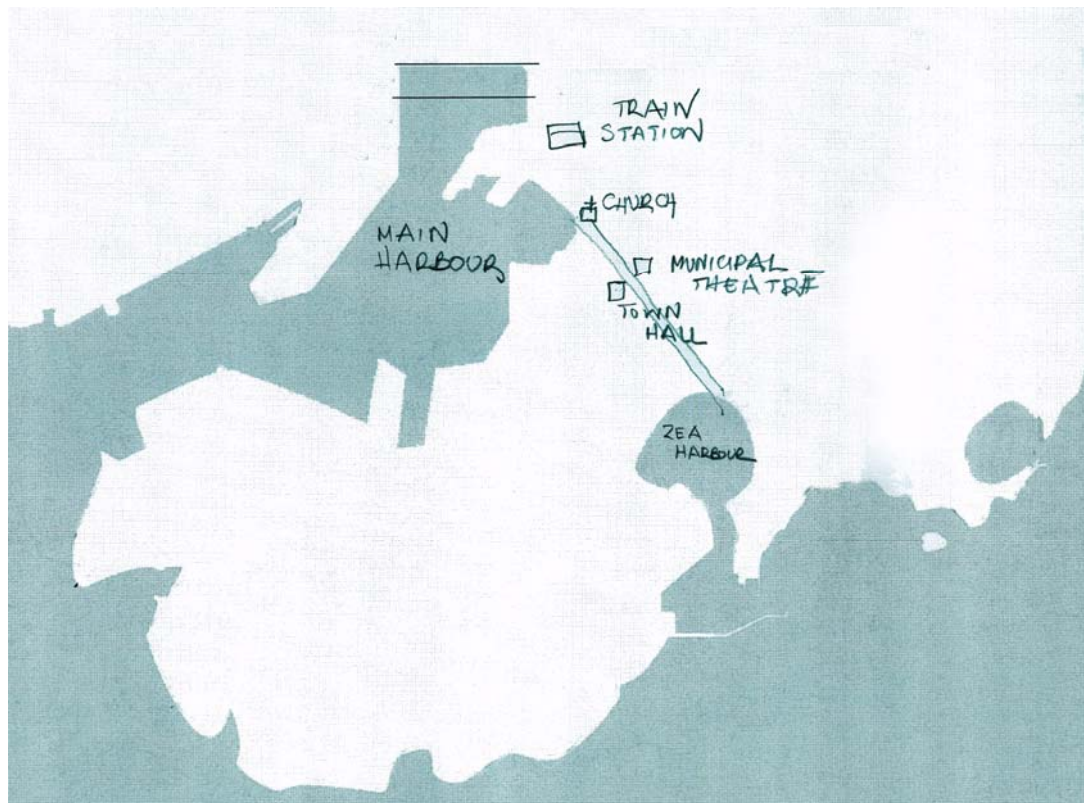**Fig. 124** Mental map drawn by a Visitor (03).
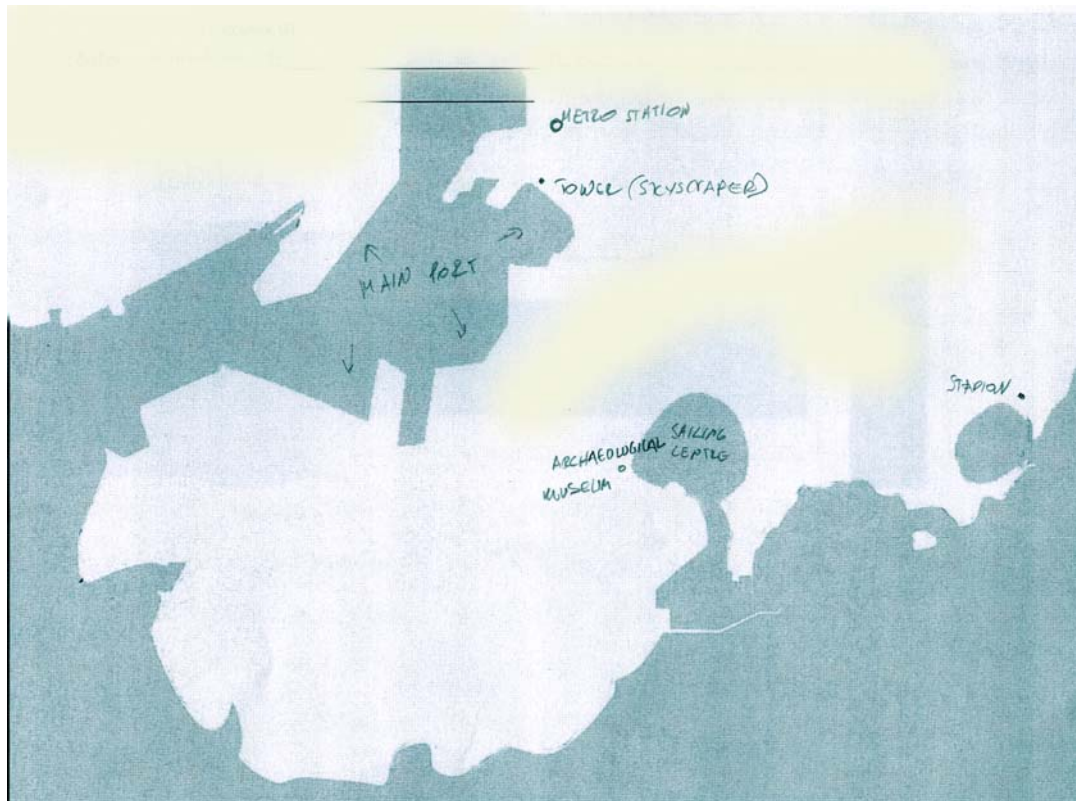
Fig. 125 Mental map drawn by a Visitor (04).
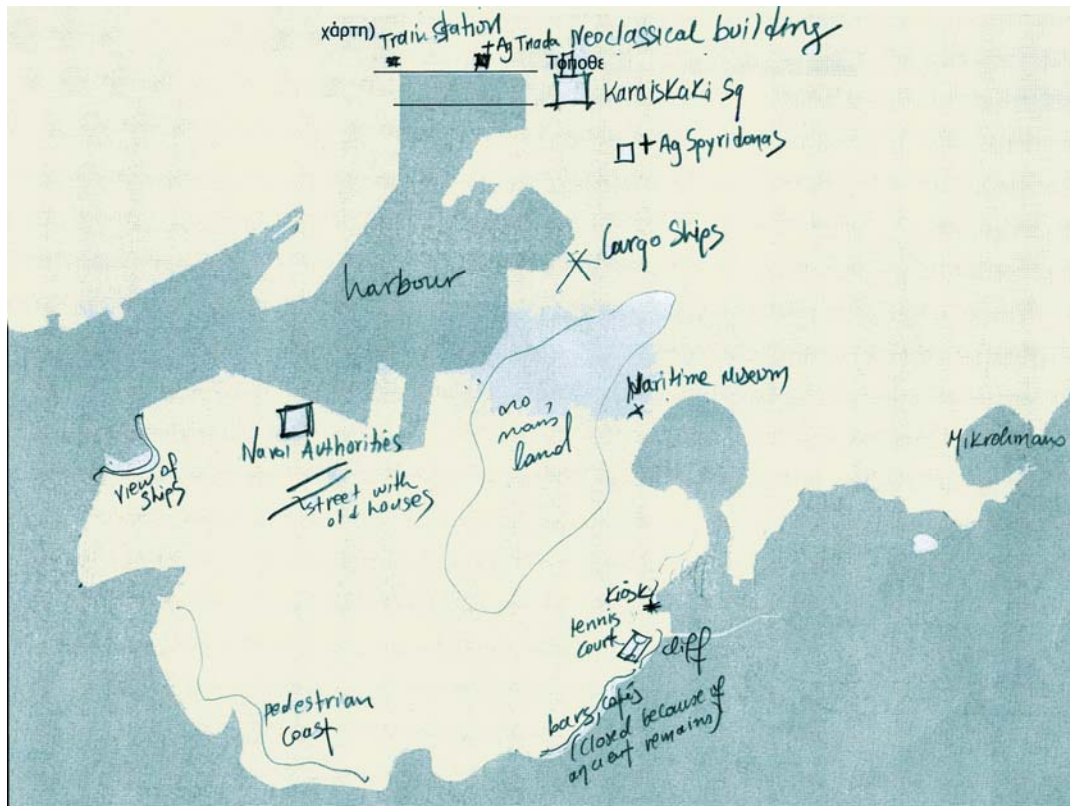
Fig. 126 Mental map drawn by a Visitor (05).
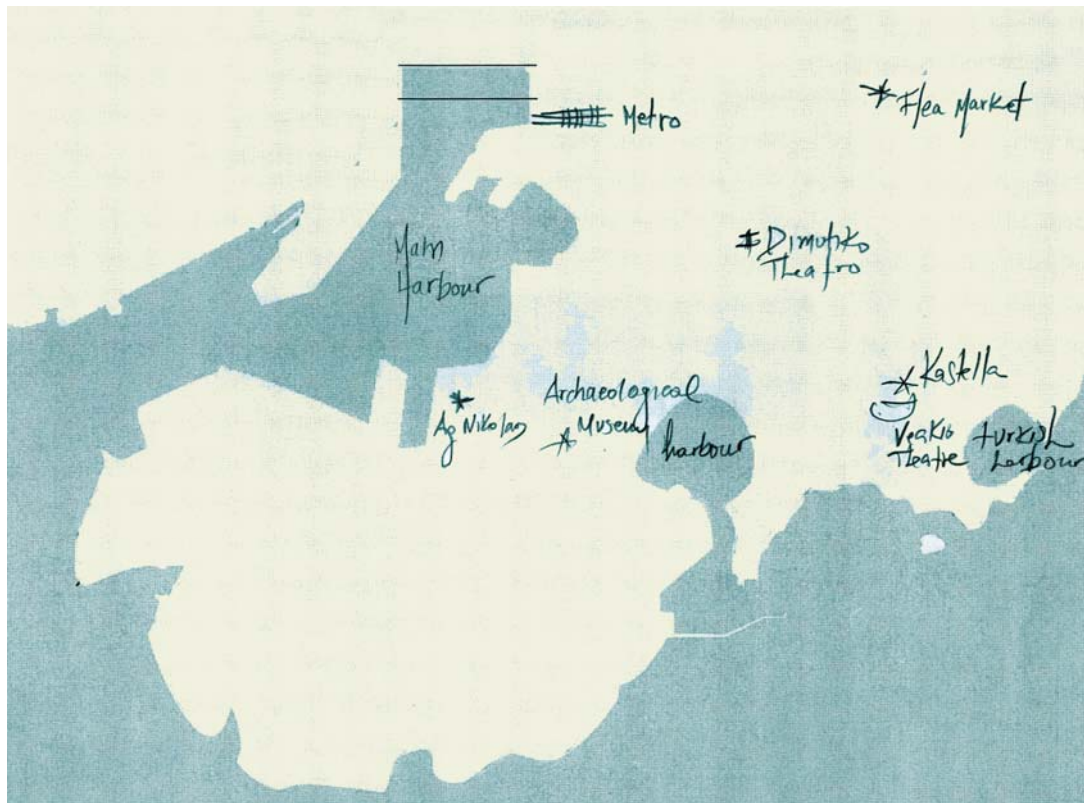
Fig. 127 Mental map drawn by a Visitor (06).
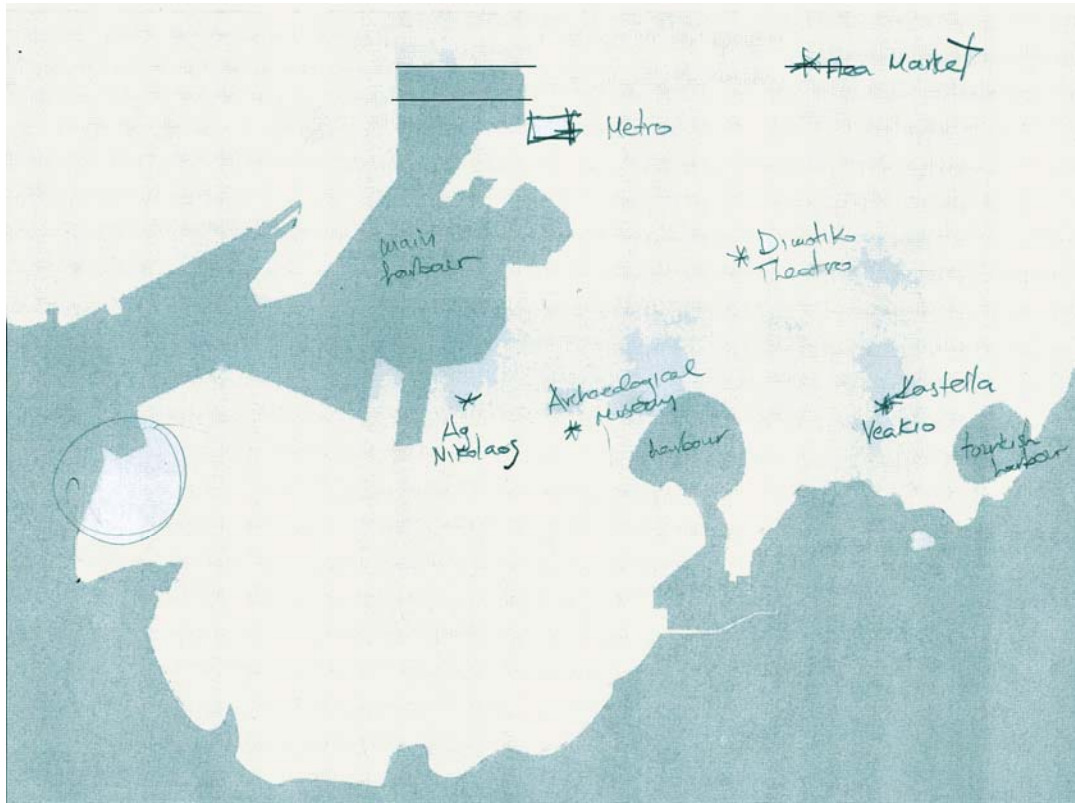
Fig. 128 Mental map drawn by a Visitor (07).
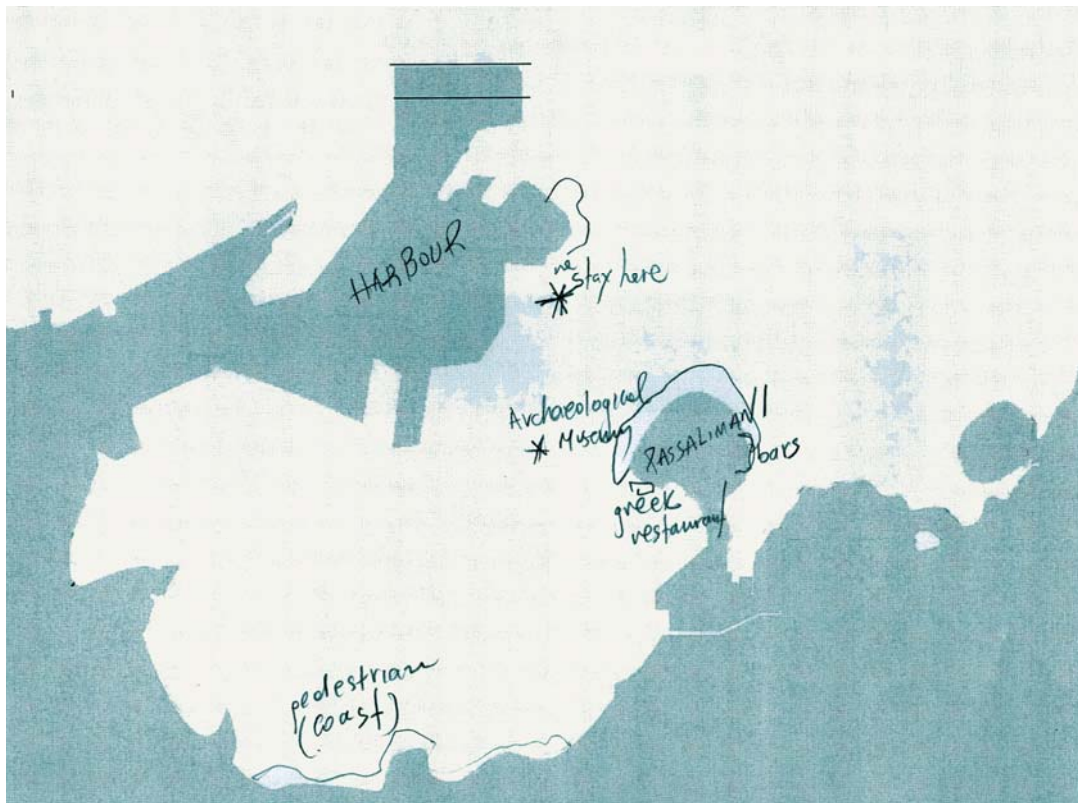
Fig. 129 Mental map drawn by a Visitor (08).
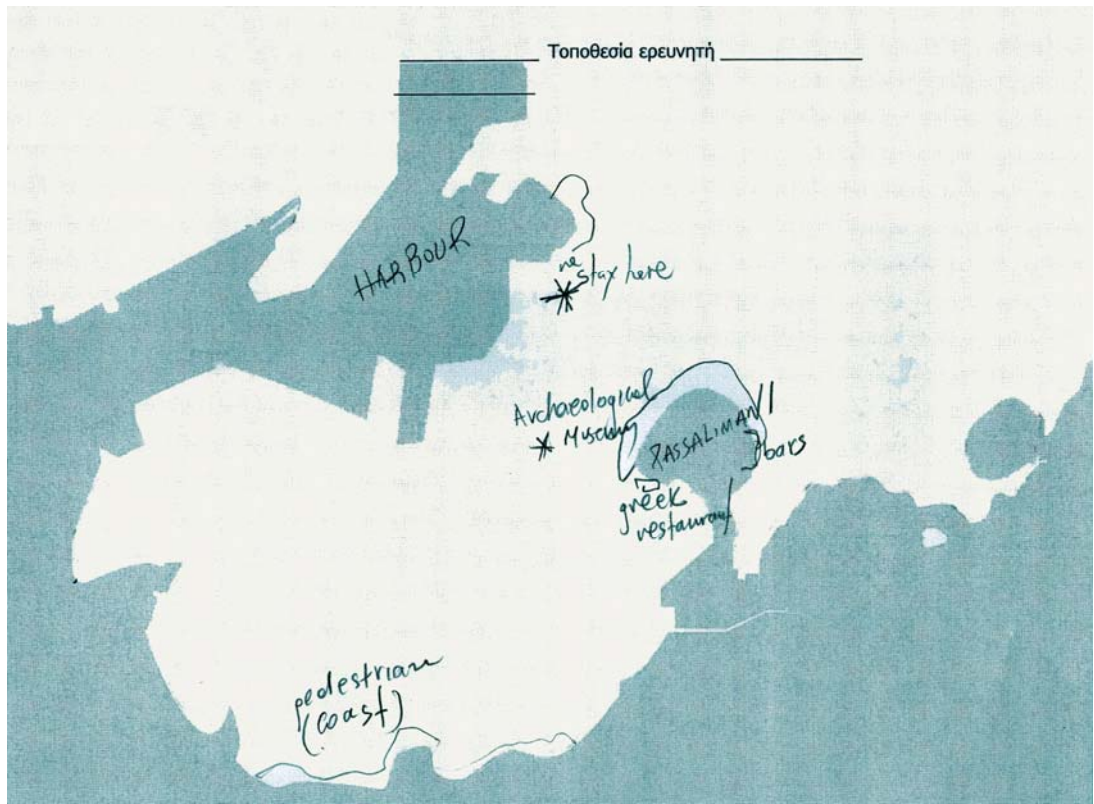
Fig. 130 Mental map drawn by a Visitor (09).
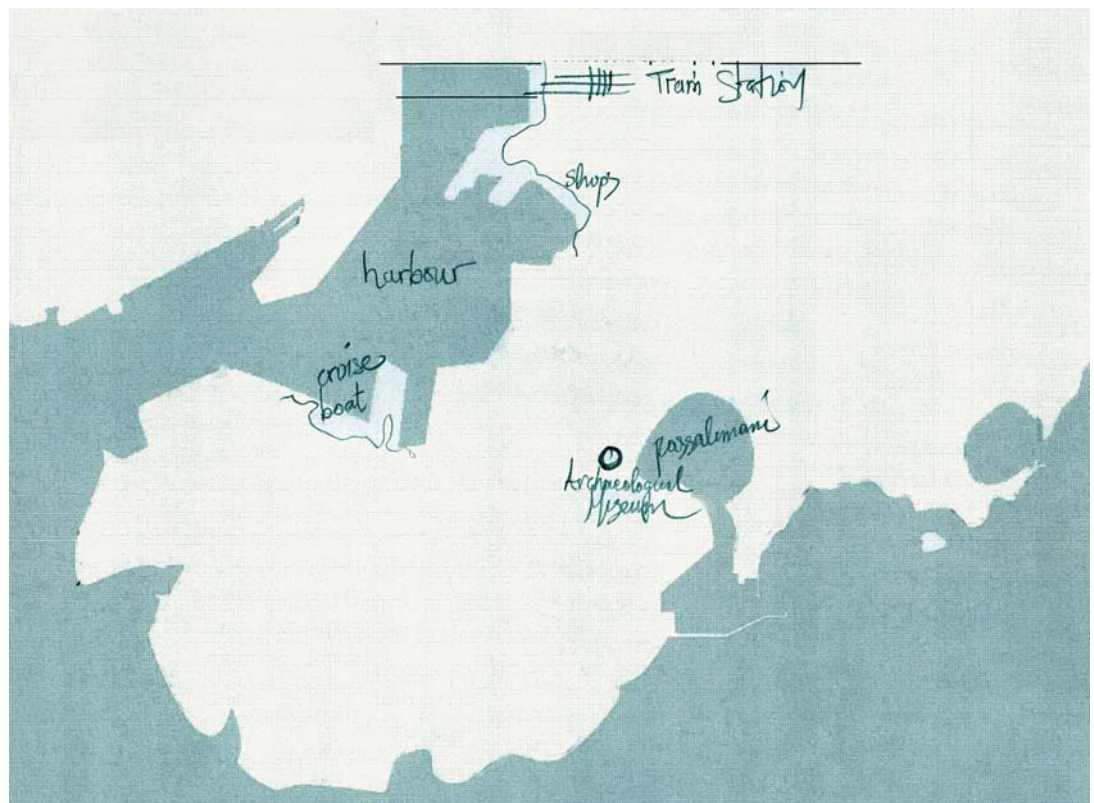
Fig. 131 Mental map drawn by a Visitor (10).
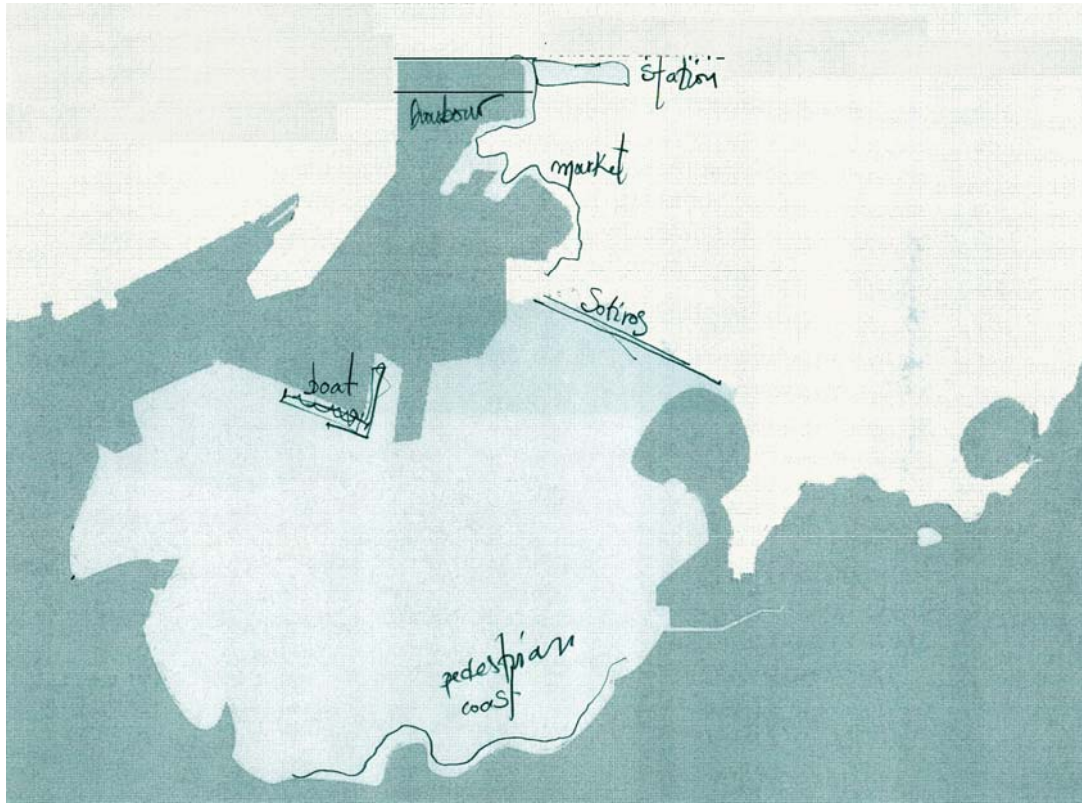
Fig. 132 Mental map drawn by a Visitor (11).
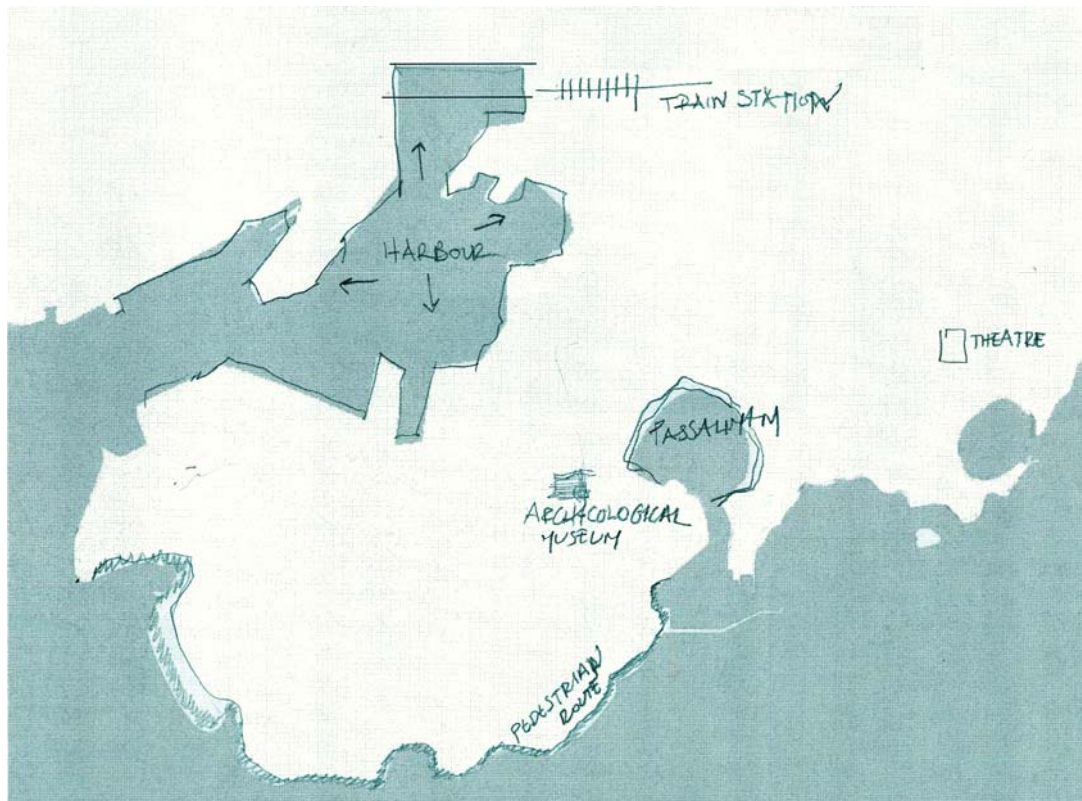
Fig. 133 Mental map drawn by a Visitor (13).

Fig. 134 Mental map drawn by a Visitor (14).

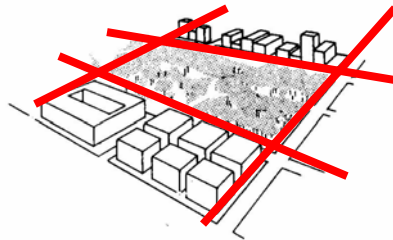**Fig. 135** Mental map drawn by a Visitor (15).

Appendix H_ Sample

The "sample" of 91 axial lines was selected according to the number of lines that describe each one of the ten most frequent in occurrence elements. The following diagrams show examples of this description (the axial lines in red colour overlay the five lyncial elements).
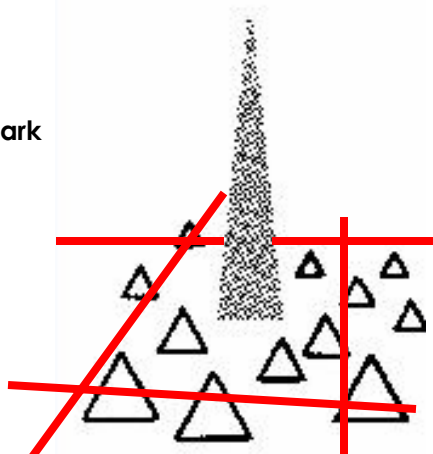
Path
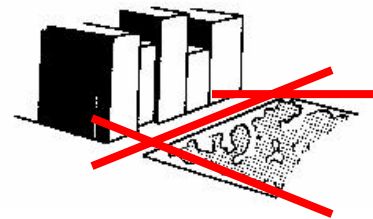
Edge

District

Node

Landmark

Appendix I_ Routes

Fig. 136 Axial Map overlaid with Locals' route choice from Konari Sq. to Naval College.

Fig. 137 Axial Map overlaid with Regional Locals' route choice from Konari Sq. to Naval College.
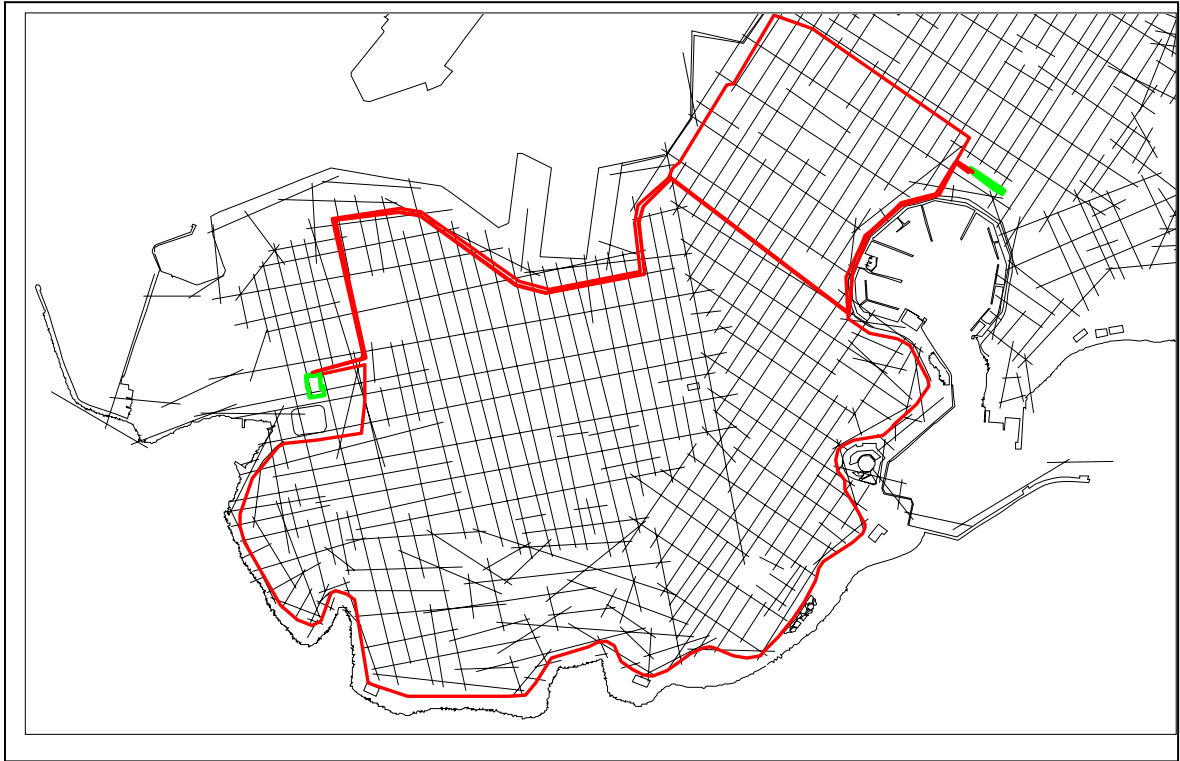
Fig. 138 Axial Map overlaid with Visitor's route choice from Konari Sq. to Naval College.
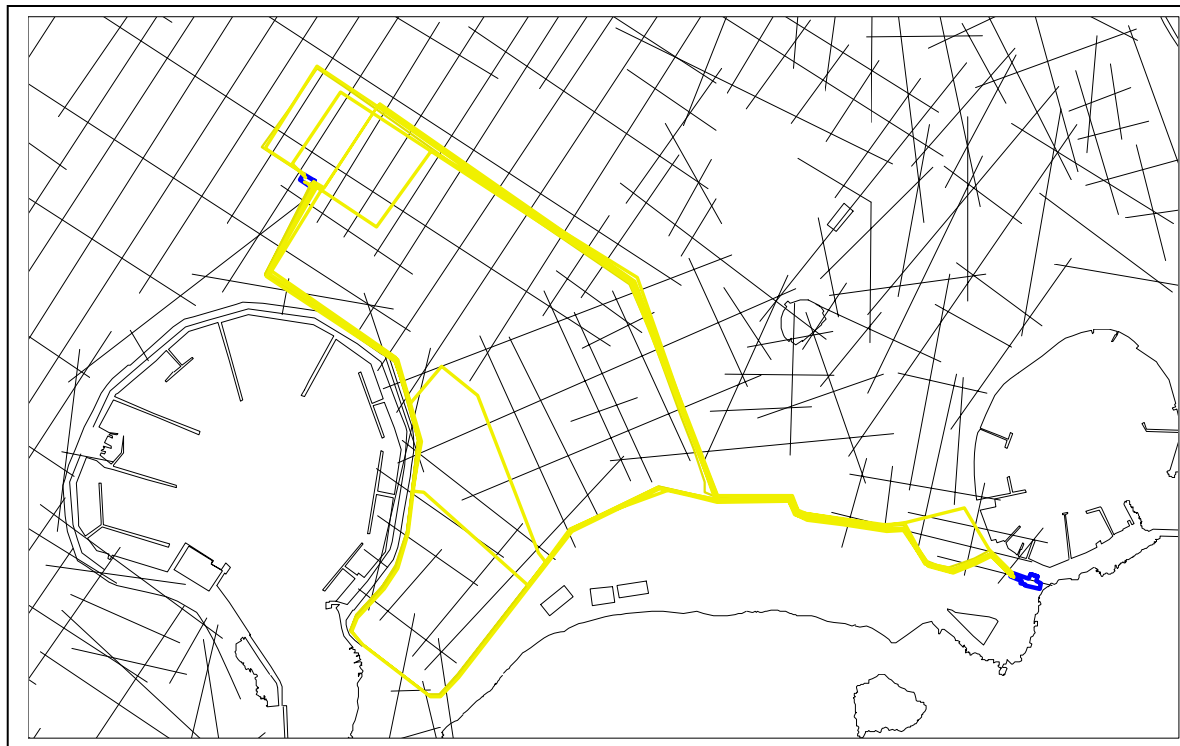

Fig. 139 Axial Map overlaid with Local's route choice from Yacht club of Greece (in Mikrolimano) to Sotiros Dios St.
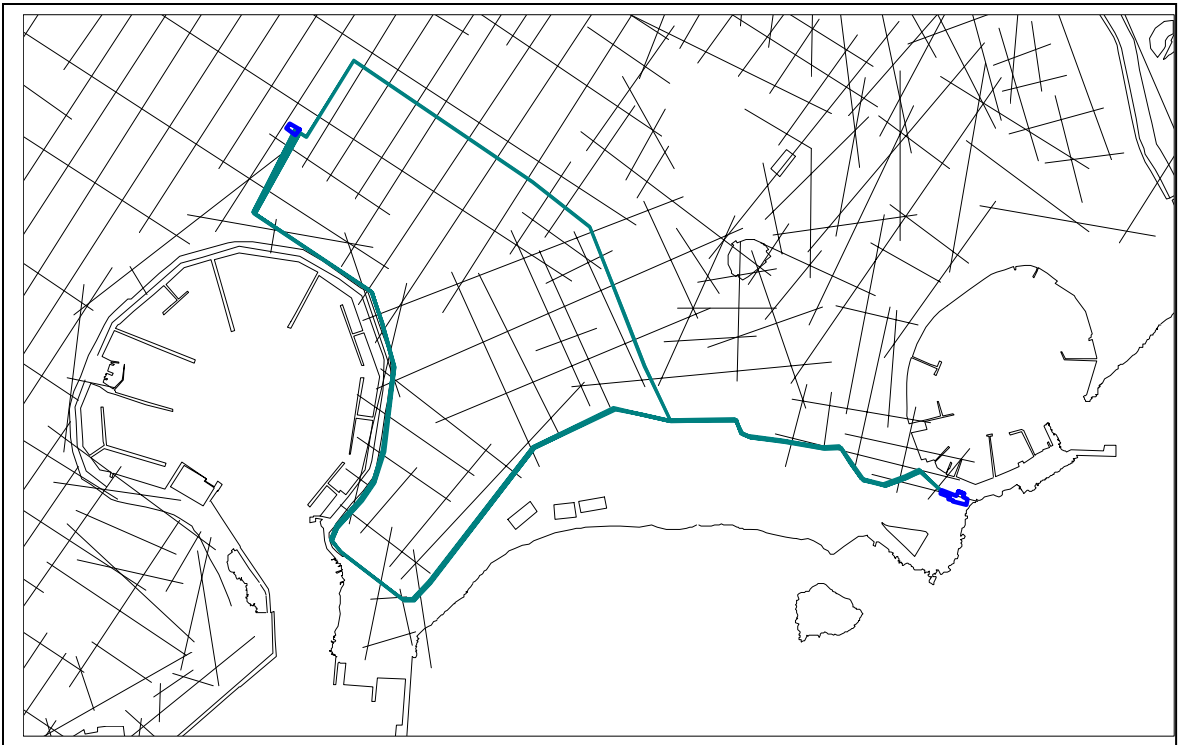
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Fig. 140 Axial Map overlaid with Regional Local's route choice from Yacht club of Greece (in Mikrolimano) to Sotiros Dios St.
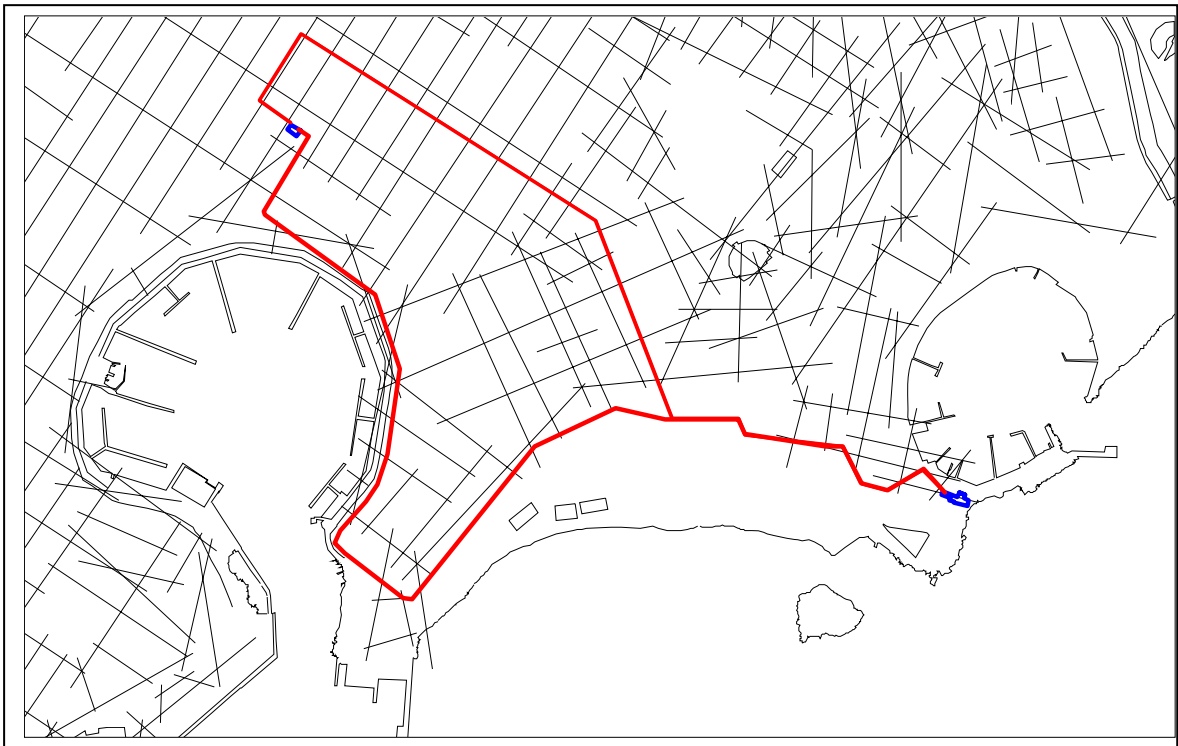

Fig. 141 Axial Map overlaid with Visitor's route choice from Yacht club of Greece (in Mikrolimano) to Sotiros Dios St.

Fig. 142 Axial Map overlaid with Local's route choice from Kanari Sq. to the Train Station of Piraeus.
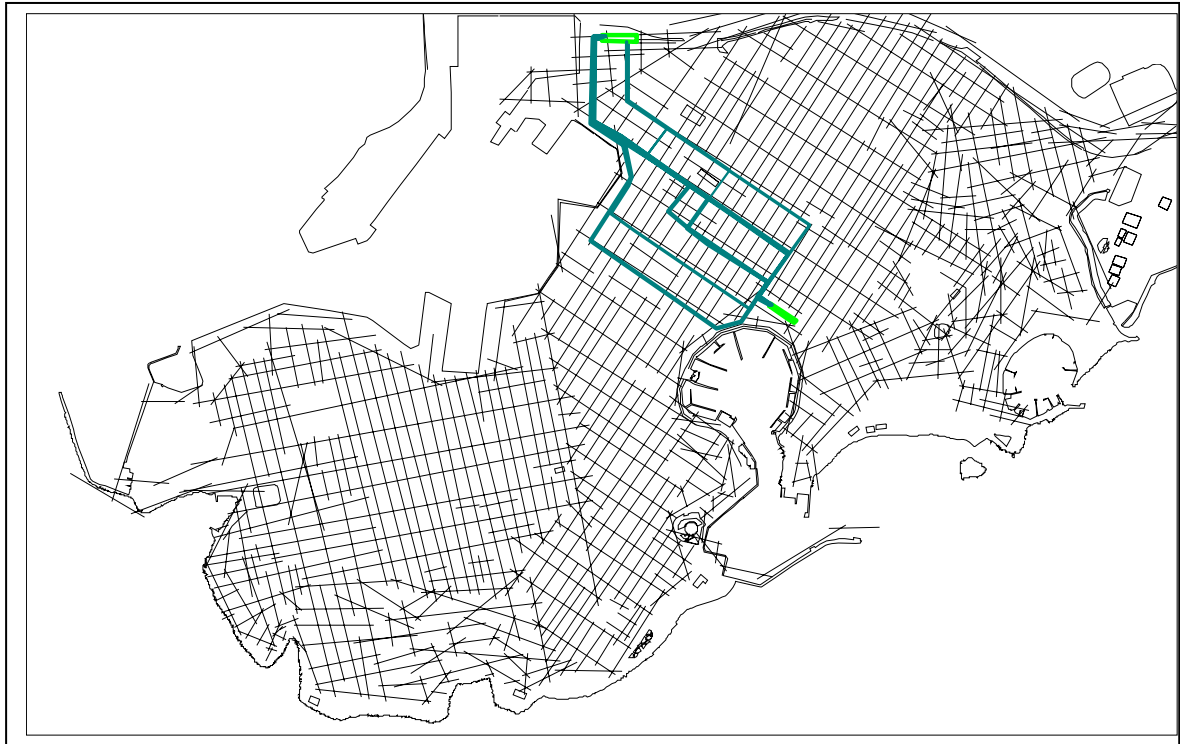

Fig. 143 Axial Map overlaid with Regional Local's route choice from Kanari Sq. to the Train Station of Piraeus.
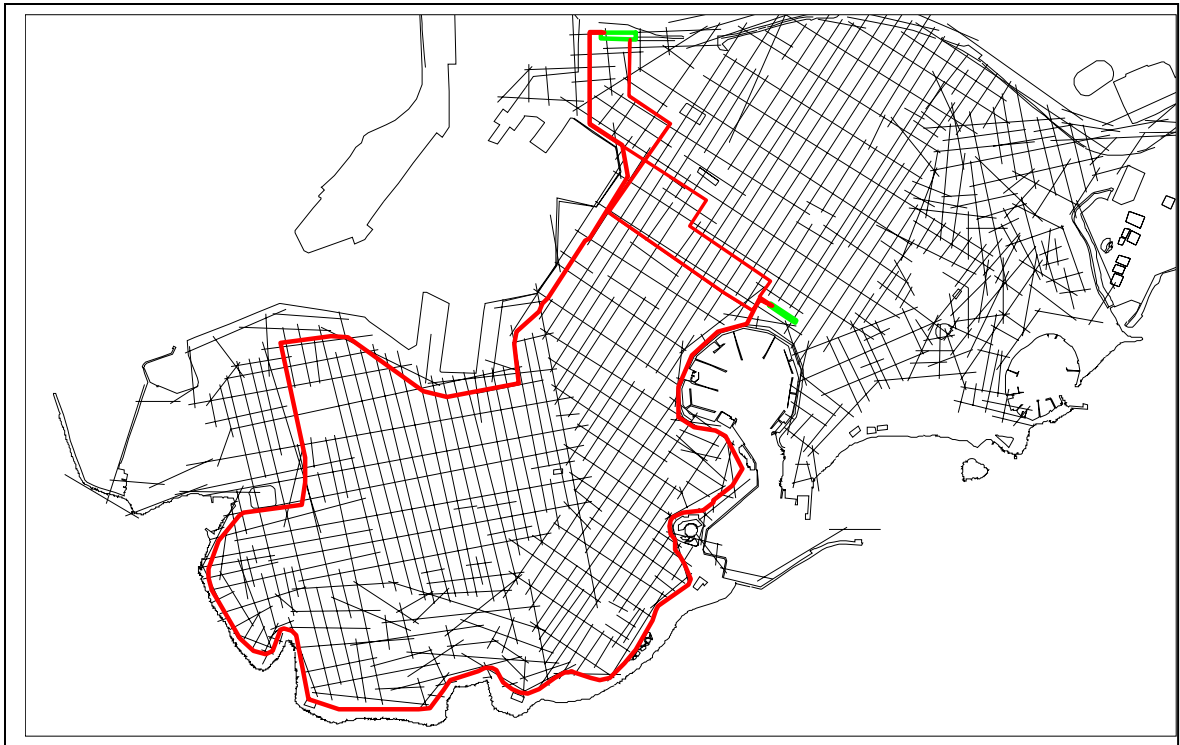
Fig. 144 Axial Map overlaid with Visitor's route choice from Kanari Sq. to the Train Station of Piraeus.

Appendix J_ SEGMEN

Segmen (written by Shinichi Iida) is a Common Lisp application which does graph computation for space syntax analysis (Iida Shinichi, (2004), p. 1). The analysis that is performed is *simple*, *constant* and *metric*. "**Simple**" is a 'simple' angular segment analysis in which the degree of angle of incident at the intersection of two lines is taken as a weight (it is calibrated so that the right angle turn will be. **"Constant"** is a 'topological' segment analysis in which the weight gains by 1 when the change of direction of any sort happens. "**Metric**" is a segment analysis in which the shortest path computation takes into account the metric length of each segment.

This program offers several different filtering criteria so that choosing different option for a particular condition of the map, movement choice from an origin to a destination could be calculated; it could give us the routes taking into account the angle changes (**simple**), the turn changes (**constant**) and the length of the route (**metric**).

In the following diagram **Figure a** is an unweighted line network with three lines. **Figure b** shows how the line network is disaggregated at intersections to form a segment network. **Figure c** shows its graph representation. Each line segment is represented as a node in the graph and links between nodes are intersections. The distance cost between two line segments is measured by taking a `shortest' path from one to the other, so the

cost of travel between S and a can be given as $w(\frac{1}{4}\,¡\mu)+w(')$, while the cost between S and b can be $w(\mu)+w(\frac{1}{4}\,¡')$. The following weight definitions are used to represent different notions of distance: Least length (metric): The distance cost of routes in measured as the sum of segment lengths, defining length as the metric distance along the lines between the mid-points of two adjacent segments. The distance of two adjacent line segments in thus calculated as half the sum of their lengths. Fewest turns (topological): Distance cost is measured as the number of changes of direction has to be taken on a route. In the example shown in Figure b and c, $w(\mu) = w(\frac{1}{4}\,¡\,\mu) = w(') = w(\frac{1}{4}\,¡\,') = 1$ (however, $w(0) = 0$). Least angle change (geometric): Distance cost is measured as the sum of angular changes that are made on a route, by assigning a weight to each intersection proportionate to the angle of incidence of two line segments at the intersection. The weight is defined so that the distance gain will be 1 when the turn is a right angle. In other words, $w(\mu)\_\mu; (0 \cdot \mu < \frac{1}{4}; w(0) = 0; w(\frac{1}{4}=2) = 1$
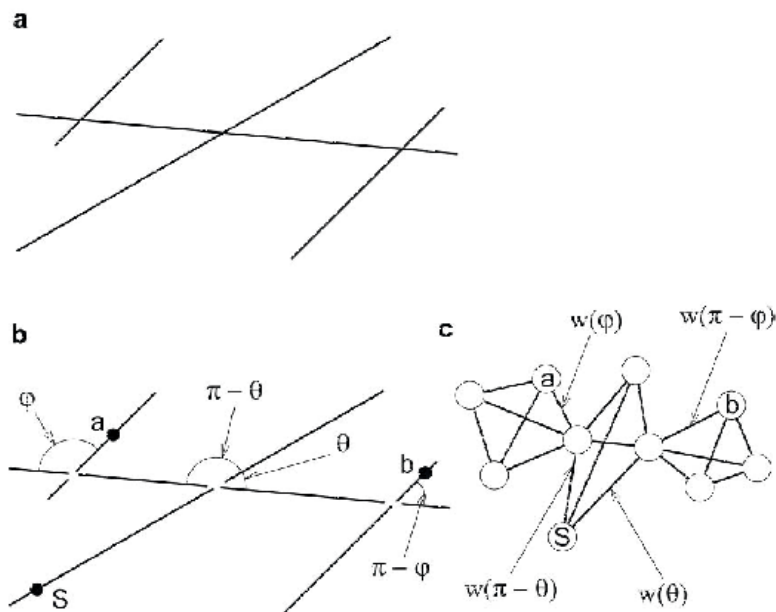

Fig. 145 Line networks.

SEGMEN FUNCTION REFERENCE

Get-route

Syntax:

```
(get-route :start userid :end userid :weight nil :use-vlinks t
 :radius t :rad-mode 'steps
 :resolution t :cut-off-threshold nil
 :check-loop t :to-file nil)
```

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Description:

This is a description of the function.

Arguments:

`dummy arg`   Possible values are explained here.

Keywords:

`dummy key`   Possible values are explained here.

Return values:

If there are any, the values are listed here.