"Think Globally, Act Locally":
A regionalistic approach to the selection of building materials in Greece

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ABSTRACT: This paper proposes the methodology for the development of a practical system for the assessment of the environmental impact of local materials. It focuses on the evaluation of materials that are produced in a region, both the contemporary, which are currently produced, and the traditional, which have been widely used and have shaped regional architecture in the past, and which today tend to be used less or excluded from building construction. Departing from the concept "think globally, act locally", and having in mind regional vernacular building tradition, past and present, this system applies the issues of the sustainable choice of materials on those, which are available in the different regions of the country. It is a flexible system, which draws data from all existing methods, but its starting point is the use of, as far as possible, local materials, in a way similar to traditional construction.
Keywords: local materials, local construction methods, environmental impact

INTRODUCTION
The building sector is, among all human activities, one of the biggest consumers of energy and material resources. Furthermore, buildings produce large quantities of waste in terms of solid, liquid and air pollution. According to Boonstra [1] 50% of the raw materials, which are extracted from nature are related to building construction, 40% of the energy consumed in the E.U. is related to the building sector, from which also originates 50% of national waste. During the last decades, it has become evident that the energy consumed by a building is not limited to its period of use, but extends throughout its construction, use, and demolition. While, a lot is being said on energy consumption and the ways of minimising it, the environmental impact of building materials has only recently started to gain a rising importance.

Nowadays, there is an extensive literature available for the qualitative and quantitative estimation of the environmental impact of a large number of building materials, which are used in building construction. [2, 3, 4, 5, 6, 7, 8] While some parameters (e.g. energy consumption, air pollutants emissions, etc.) can be accurately calculated, the issues connected with material transportation depend, every time, on the site of a specific project.

This paper focuses on a regionalistic approach to the environmental impact of building materials, with Greek traditional architecture used as the main departure point for the development of a methodology for a relevant, practical evaluation system. This approach is based on the fact that the vernacular architecture of every country is characterised by a wise and appropriate use of building materials, both in building construction, and in urban open spaces. The proposed system combines principles of material selection, which characterised traditional architecture, with the contemporary issues concerning the environmental impact of building materials.

The starting point and the aim of this research is to address a paradox, which is very frequently seen all over Greece, and probably, in other countries: in regions with abundant stone and slate availability, stone and slate from other distant areas of the country or even from abroad, is transported and used. Obviously, the answer to this paradox can be easily attributed to matters of cost and, possibly, aesthetics of designers and clients. Nevertheless, this fact poses a series of questions that range from aesthetic issues of contradiction with the surrounding landscape, which is distinguished by the colours and the texture of local stone, to the environmental issues of energy consumption and air pollution caused by the transportation of heavy-weight materials.

MATERIAL SELECTION IN GREEK VERNACULAR ARCHITECTURE
Use of natural materials In many cases the use of natural materials in traditional construction resulted from the under-development of industrially manufactured materials, their scarcity and extremely high cost. [9, 10, 11] Nevertheless, natural materials are used with great efficiency enforcing both the bioclimatic function of the

buildings, as well as their aesthetic integration to their natural surroundings.

Use of local materials It must be acknowledged that the use of local materials in traditional architecture is mainly due to the lack of transportation means and economic resources. [9] People had no other choice but to use materials, which were available within close distances from their towns or villages. Those materials were used in the buildings according to their physical properties and their durability.

Greek traditional architecture of every region is distinguished by the use of the available local materials. It is those different materials that give to both public open spaces, and private houses their distinct character and beauty. Settlements situated in valleys or plains are built with adobe, with adobe bricks made on site, using the earth from the excavation. On the other hand, settlements in the mountains or on the islands, where there is an abundance of stone, are characterised by the extensive use of local stone in all of the parts of the construction. The combination of this, with the fact that every area has its own different local stone, marble and slate, give every settlement a strong regional character and an almost complete blending with the surrounding environment.

The same applies to all the parts of the construction. An interesting example is the case of the different flat roof configurations, which can be found on the Aegean islands, and especially the Cyclades (Fig. 2). The generalised use of flat roofs is mainly due to the scarcity of rainwater, and the need for its efficient collection. But the use of materials in the construction differs according to the island. In islands with wood availability the flat roof substructure is constructed from wood, whereas in islands without trees able to provide structural wood, the wooden elements are minimised and are replaced by built elements, such as stone arcs (*volta*) in the middle of the spaces, and slate. Layers of reed and seaweed are used as insulation and vapour barriers, while the main roof material is common earth.

Figure 1: Houses built mostly with (a) adobe and (b) stone in settlements of the Korestia area, near Kastoria, NW Greece.

The need for special skills The construction methods, which are used in vernacular architecture, demand specialised building skills. This is essential in order to construct building elements with the ability to withstand and modify climatic conditions, and static and dynamic forces of earthquakes that are endemic in the country, with the available local materials. Furthermore, these skills keep local building tradition alive and give each place its aesthetic and unique building character. The construction methods, which are used in traditional architecture, comprise of lean mortars, which help the easy separation of the materials (stone, adobe, and bricks) during demolition, and promote their reuse. (Fig. 3)

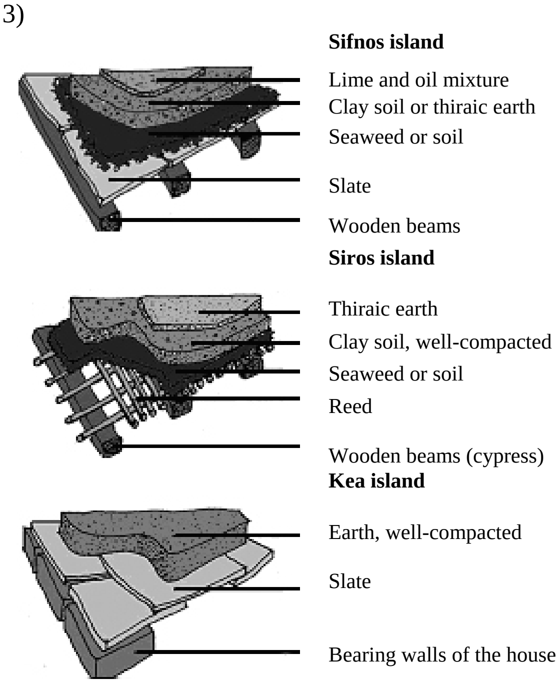


Figure 2: Sections of typical flat roof construction in islands of the Cyclades complex.
Source: Drawn after descriptions given in [12].

Figure 3: Stone wall construction in Sifnos (a) with local stone and earth mortar and (b) with slate and cement mortar.

Reuse and recycling of materials The materials, which come from demolished buildings, are very frequently integrated in new constructions, e.g. structural stone from demolished buildings is often used for new ones. The same applies sometimes to adobe bricks, according to their preparation, size and condition. When adobe is not reused, it is left on site, where, in time, it returns to its primary natural state, i.e. earth. The structural parts of the buildings are reused in new buildings, whenever it is suitable. Otherwise, they are used for other purposes, or burned as firewood. Natural organic material, such as reed and seaweed, which are often used in flat roof construction in the Cyclades are fully biodegradable and recyclable by nature.

CONTEMPORARY ENVIRONMENTAL ISSUES CONCERNING MATERIAL SELECTION

The choice of building materials is usually based on economic and aesthetic criteria. Nevertheless, a holistic and environmentally conscious approach, should also take into consideration parameters such as their thermal behaviour and their environmental impact. The environmental impact of building materials involves both quantitative parameters and qualitative parameters. (Table 1)

Table 1: Quantitative and qualitative parameters of the environmental impact of building materials.
Source: Adapted from [6, 8].

Quantitative Parameters
Energy consumption (embodied energy). Air pollution (CO_2, SO_2 and NO_x emissions). Water consumption.
Qualitative Parameters
Ecological degradation (e.g. resource consumption, landscape and ecosystems destruction, production of dust, noise and vibrations, and possible cause of environmental disasters). Toxic substances (affecting the environment, human health or both. End-of-life-cycle issues (possibility to repair/restore, reuse or recycle, and waste).

The overall energy consumption of a given building material also depends on the energy, which is consumed for its transportation from the place of manufacture to the construction site that, in turn, results in air pollutants emissions (Table 2). The transportation energy consumption can be significant and may, in the case of heavy-weight (high density) materials, surpass the energy, which is consumed for the extraction of raw materials and the manufacture of the building materials. [8]

The close relationship, which existed between use of materials in an area and their distance from it, was evident from very early on. Vitruvius (Book 2, Chapter 8, Paragraphs 3-5) [13] mentions the stone from quarries on the borders of the Tarquinienses, called the Anician quarries, noting, "(...) if these quarries were closer to the City (Rome), it would be well-worth for all the buildings to be made of this stone. (…) But, since the City is closely situated to the quarries of Palla and others, the need forces the use of their product. (...)". Furthermore, he mentions [13] (Book 2, Chapter 9, Paragraphs 14-16) larch timber (Larix europea, a coniferous, deciduous tree with heavy, hard and very durable wood), which is “(…) transported down the Po to Ravenna, and is available at the provinces Fano, Pesaro, Ancona and other cities in the area. Had its transportation to the City been possible, this wood would much contribute to building construction. (…)”.

Furthermore, as mentioned in the previous paragraph, the difficulties and the elevated cost of transport were the main reasons why local materials were predominantly used in traditional architecture. In Greece, this attitude was maintained even during the first half of the 20th century and even in large cities, like Athens. At this point, it is interesting to quote Papatheodorou [14], who in 1939 mentions that “even if the marbles from the Mani area (distance from Athens: approximately 300 km) are of excellent quality, their use in the (Athens) market is limited due to the increased cost of transportation (…)”.

Table 2: Energy consumption and air pollution values for different means of transportation.
Source: Adapted from [8].

Energy and Means of Transportation	kWh /ton km	g CO_2 / ton km	g SO_2 / ton km	g NOx / ton km
Diesel: Road	0.445	120	0.1	1.9
Diesel: Sea	0.167	50	0.3	0.7
Diesel: Rail	0.167	50	0.05	0.75
Electrical: Rail	0.056	-	-	-

REUNITING PAST AND PRESENT. THE PROPOSED EVALUATING SYSTEM

General description The aim of the system is the selection of local materials, both natural and manufactured, for building construction in every given area of the country. The system does not ignore the contemporary production of building materials, but aims at integrating it in the process of local material selection.

Methodology of development The materials, which are available for building construction, are categorised according to their position in the building shell (exterior wall, internal partition, flat or sloped roof, etc.) or the urban fabric (road, sidewalk, square, pedestrian street, etc.). This constitutes the starting point of the system. Its further development is based on both bibliographical and in-situ research.

Bibliographical research is necessary for the gathering of data concerning not only the thermophysical, optical and acoustic properties of the various building materials, but also the quantitative parameters of their environmental impact. It is obvious that the values of embodied energy and water consumption, and of air pollution may differ from country to country and from industry to industry because of the differences in manufacturing processes, energy efficiency of equipment, available raw materials, cost-efficiency, etc. Nevertheless, in the absence of detailed, industry-specific data, the necessary data can be provided from the available bibliography.

The in-situ research involves the recording of the materials, which are available or produced in every region of the country, as well as in its nearby regions. This is actually an inventory of the available suppliers and industries of building materials, and their location.

The assembled data can be recorded in the form of tables or other documents (see Figs. 4 and 5). All the available information can be integrated in a computer-based tool in the form of an .html document, in which architects, planners and designers can, from a series of consecutive steps / choices, gather information on the different available materials and reach an environmentally friendly and bioclimatically suitable solution. It goes without saying that aesthetic and economic issues also influence this decision.

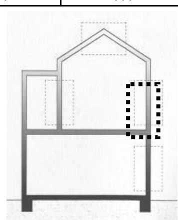
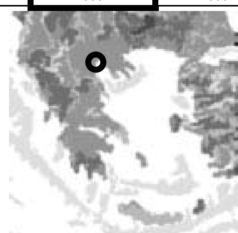
AVAILABLE MATERIALS				
ROOF	FLOOR	INTERIOR WALLS	EXTERIOR WALLS	OPEN SPACES
…	…	…	…	…
				
POSITION ON THE BUILDING SHELL			LOCATION DATA (CITY, LATITUDE, LONGITUDE, ALTITUDE)	

Figure 4: Example of table concerning the position on the building shell and available building materials.

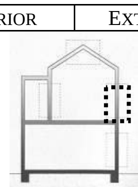
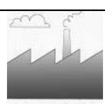
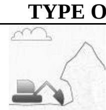
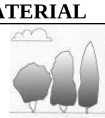
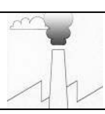
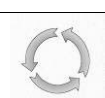
Table No	MATERIAL : USE :	…	
		INTERIOR	EXTERIOR
POSITION ON BUILDING SHELL :			
GENERAL DATA			
PLACE OF ORIGIN OF RESOURCE	ENVIRONMENTAL LOCAL RESTRICTIONS	PHYSICAL PROPERTIES	OPTICAL PROPERTIES
	Yes … / No …	Thermal conductivity Density Specific heat	Reflectivity / Absorptivity Transmittance Emissivity
TYPE OF MATERIAL			
			
MANUFACTURED	NATURAL NON-RENEWABLE	NATURAL RENEWABLE	
EVALUATION PARAMETERS			
			
ENERGY / EMISSIONS	TRANSPORT	HEALTH	RECYCLING
kWh/kg - m^3 – item	Density (kg/m^3)	No known health risk	Yes / No
Emissions:	Weight:	Health risks during:	Possibilities:
Emissions to soil Emissions to water Emissions to air : CO_2, SO_2, NO_x	Light weight Medium weight Heavy weight	Production Construction Use Demolition	Reuse Recycling Energy recycling

Figure 5: Example of table concerning material description.

Evaluation parameters The evaluation system seeks to make designers reflect on the environmental impact of building materials concerning two different levels: first their transportation process from the place of production to the construction site and then their production / manufacturing process. The evaluation of the transportation process follows the logic that was presented above, according to which local materials are preferable to transported or imported ones. For a given area, the materials that are necessary for the different parts of the construction of e.g. a house should be provided from the nearest possible locations. This principle mainly involves heavy-weight materials.

The evaluation of the production / manufacturing process follows the logic according to which the natural materials are preferable to manufactured ones and should be as close to their natural state as possible. From those the renewable ones should be checked for sustainability of their source and of course (something that stands for all building materials) should always be used sparingly. The non-renewable ones should follow the check of recyclability, which means that they should comply with the need to be as fully recyclable as possible after their use in the building and of course with longevity as a paramount need in the life of the building they have been used. If the material is manufactured, the (non-renewable) energy used in all processes should be scrutinised and recorded as a measure of the materials environmental behaviour. It is obvious that in order to improve the overall environmental performance of manufactured materials, these should be as fully. If the material is used in the interior of a building or if it can cause with its presence any kind of health problem to the inhabitants, then this should be noted and the specific material should be avoided.

The concurrent consideration of the above-mentioned, two processes leads to a final evaluation, which does not provide a single best solution for the parts of the building structure, which are of interest, but a range of choices, according to the available local materials. It should be noted, though, that there may be exceptions to this procedure, i.e. in few -and extreme- cases where the production embodied-energy is of such magnitude that it may be more preferable to transport materials from a more distant location than to use the locally manufactured ones (see Table 3).

The process of evaluation also raises many questions concerning the building techniques, as well as the fads and fashions that are currently in frequent use in any given place. The consideration of the environmental impact of the production and transportation of building materials may affect these established practices, leading to their abandonment or enforcement. In this way, the environmental dimension of a building is set forward and, through that architects and other professionals that are involved in building construction, increase their environmental conscience and face up to their local problems.

Table 3: Example of energy consumption caused by the production and the transportation of different materials for ventilated façade construction. Source: Quantitative data adapted from [8].

	Density		Production	Road transportation			
	p kg/m^3	p kg/m^2	E. E. kWh/m^2	E. E. $kWh/m^2.km$	Origin	Distance [km]	E. E. kWh/m^2
Granite slabs (2 cm)	2800	56	34.5	0.0249	PO	4120	102.7
Ceramic panels (0,7 cm)	2250	15.75	31.25	0.007	DE	2890	20.6
Compos. ALU panels (0,4 cm)	1375	5.5	217	0.0022	GR	100	0.3
Compos. wooden panels (1 cm)	1400	14	305	0.0062	ES	3470	21.6

CONCLUSION

The urban design and the architecture of traditional settlements and buildings is an inexhaustible source of ideas, a huge reservoir of "condensed" knowledge concerning climatic and environmentally friendly design. This paper focussed on one of the many aspects of traditional architecture, its concern for material selection and construction, using it as the basis and the starting point for the creation of a regionalist system for the evaluation of the environmental impact of building materials. For this reason, the principles of traditional architecture concerning material selection are combined with the corresponding contemporary principles to provide a methodology for the development of an evaluation system. A full-scale research is indispensable in order to mark out local and manufactured materials of every area and to assess their environmental impact.

It should be noted that the system does not propose the abandonment of all the available technology and the return to the strenuous construction practices of the centuries preceding the industrial revolution. It merely exploits the basic principles of vernacular tradition and applies them to all contemporary available technology and industry. In a way, it is consistent with the term “New Vernacular”, introduced by Smith, et al. [11]. Nevertheless, the priorities fluctuate according to the size of villages and cities. While its application logical to all construction in villages and small towns, it is practically impossible to try to impose this system on large city areas. There, the intensity of the building activity and the material consumption is such that it could overbalance every local ecosystem or landscape. In all cases, arise issues of over-exploitation of local materials and further degradation of the landscape. Or maybe not, because by confining the use of a certain material in its immediate vicinity, its depletion can also be confined, or even reduced.

Finally, it is evident that the proposed system significantly limits the possible choices of materials, and in this way may constrain architectural imagination. Nevertheless, it is strongly believed that "desperate situations call for drastic measures" and that in a world of serious inequalities, the sacrifice to be made is of minor importance. To choose the most environmentally benign material between those, which are locally available, is far too low a price to pay for the restoration of balance and equity in our planet.

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