ARTICLE IN PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

Building and Environment ▮ (▮▮▮▮) ▮▮▮–▮▮▮

BUILDING AND ENVIRONMENT

www.elsevier.com/locate/buildenv

Urban environmental impact matrices development: assessment indices incorporation

Carlos A. Discoli*

Instituto de Estudios del Hábitat, IDEHAB, U.I. N°2, FAU, UNLP, Consejo Nacional de Investigaciones Científicas y Téchnicas, CONICET, Calle 47 N°162. CC 478 (1900) La Plata, Buenos Aires, Argentina

Received 13 May 2003; received in revised form 10 December 2003; accepted 5 August 2004

Abstract

A methodology which can be applied to the environmental impact study (EIS) and which facilitates to analyse the urban variables as a whole is explained. The work can be done in different scales (urban sectors and areas) which depend on the analysis complexity degree. This would allow to qualify and to quantify the local and regional environmental impact. Different concepts, methods and techniques have been considered and conveniently integrated. A body of relational decision matrices has been developed, in which the *magnitude*, *sign*, *significance* and *temporality impact* concepts are included. Different indices levels have also been developed.

1. Introduction

This article deals with a subject promoted by the World Conferences on Environment and the Conventions on Climate Change and which has begun to be unavoidable in urban undertakings in Latin America. Consequently, and considering the environmental impact assessment (EIA), a useful methodology for the environmental impact studies (EIS) has been developed. The EIS is part of the EIA procedure and integrates a wide diversity of urban-regional variables. In this article, the EIA is considered as a legal, administrative and scientific-technologic procedure and it is a useful instrument to work on the metropolitan areas complexity and their region as a whole or in sectors. The urban dynamics originates constant interventions, causing different intensity environmental distortions This situation deepens the imbalance in the natural–artificial environmental relationship. An efficient urban management, aiming at bringing closer the sustainability concept and the development patterns, requires: (1) To know and put into practice procedures enabling to visualise the situation condition; (2) To obtain truthful information; (3) To formulate accurate diagnoses; and (4) To develop and implement coherent and coordinated policies.

In our continent, the local and regional environmental crisis is immersed in the economy globalisation framework, in the development patterns consolidation and expansion and unsustainable life styles, and in the habitat impoverishment, reaching unbearable levels in some cases [1].

In this current situation, the risk awareness of the population is increasing, being the consequences little foreseeable. In all nations and social classes, an incipient, though uneven, idea is being conceived with the purpose to build a sustainable habitat [2], thus considering that the environmental subject goes beyond the ecological dimension. As regards the term sustainable, and knowing the different conceptions, it this work it is referred to the space modified by the man, on regional, urban and building scales, to inhabit it with an endogenous development pattern to fulfil the fundamental needs and improve life quality. This requires a model minimising the damage on the production and

*Tel./fax: +54-0221-4236587/90.
E-mail address: discoli@rocketmail.com (C.A. Discoli).

0360-1323/$ - see front matter
doi:10.1016/j.buildenv.2004.08.014

habitability ecological bases by means of a technological pluralism, within a democratic, justice and solidarity framework.

Within the international context, these processes have been known for approximately three decades and have allowed the development of technical-normative containment instruments. In general, different aspects of the problem, specific to each discipline, have been considered, producing incipient though still highly fragmented and little encouraging results in this century. Meetings like the World Conference on Environment and Development (Stockholm '72 and Rio '92) and the United Nations Convention on Climate Change (UNCCC, Parties Conferences: COP-1, Berlin '95; COP-2, Geneva '96; COP-3, Kyoto '97 and COP-4, Buenos Aires '98) have allowed the environmental subject to be politically recognised and some serious procedures aiming at sustainability to be put into action [3,4].

On the other hand, socio-economic and environmental conditions produced by the present development style together with historical and cultural reasons have originated "Healthy Cities" movements [5] in Europe since the Lisbon Conference (1986) in order to apply the World Health Organization (WHO) "Health for All" objectives. This movement integrates more than thirty European cities and seventeen networks with hundreds of cities and it has originated the "Healthy Counties" movement and later "Counties for the Health" in Latin America [6].

In Argentina, actions within this subject are mainly centred in a discursive rather than in an active field. Whereas the subject is present within the society, there are incipient, and greatly isolated undertakings, though their implementations present major deficiencies. Locally speaking, there are regulations which are, in most cases, fragmented. Some examples are the Environmental Aptitude Certificate within the Law N°11459/93 from Buenos Aires Province, mainly related to industrial plants which become inevitable the environmental impact study (EIS) for *building-energetic-productive undertakings*; as the Law 11347 aimed at regulating pathogenic waste; and the Law 25018 concerning radioactive waste, co-ordinated by the Atomic Energy National Commission. In the urban context specifically, the Law N°123 of Ciudad Autónoma de Buenos Aires considers the Environment Impact Study from an integral point of view, though with serious judicial difficulties as the urban setting is restricted and surrounded by another state like the Buenos Aires Province, with serious environmental and legal problems.

2. Precedents and methodology

The first EIA precedents go back to 1969 in the USA, where institutions like the National Environmental Police Activity (NEPA) have established systematic guidelines for private and government activities. Since then, methodologies and working protocols [7] have been introduced and specified in different countries as an answer to the presented needs and problems. Nowadays, there are several EIS techniques, for example, Check list, Lists with temporal threshold, Data Matrices, Sign Matrices, Thematic Maps, Battelle–Columbus Method and Holling Method among others. The first ones are the most widely known and they present certain restrictions for the urban area; the others are more specific and, in some cases, more complex.

Among the urban EÍS precedents in Argentina, the following can be mentioned: (1) The work carried out by the Environmental Architectural Area from San Juan Research Centre (CISAJ), in San Juan Province [8]. The methodology is based on the formulation of ten impact tables, one per each "area" of the ecosystem (economic, political, environmental, etc.); (2) Buenos Aires city environmental plan [9]; (3) The projects developed by Bariloche Foundation (BF) and the Energetic Economic Institute (EEI), together with the United Nations Program for the Environment (UNPE) [10]. In general, these projects have tried to provide solutions, some of them descriptive, some comprehensive, in which the natural and landscape resources of a region or country are considered.

At a local scale, the urban council laws have started to incorporate in their texts the environmental aspects and the need to assess every major urban undertaking. These laws require and enable professionals, in general without training, to carry out the environmental impact assessment reports from a list of basic points. None of these cases foresees a methodology or protocol which allow to systematise, qualify, quantify or establish comparable backgrounds supporting and identifying the impacts as well as differentiating the alternatives. In this way, our research group has started to develop methodologies to provide specific answers to the mentioned requirements [11,12].

Within this situation condition, it is necessary to formulate a flexible and instrumental methodology in accordance with our context needs and as part of the technical-administrative procedure of environmental impact assessment (EIA). The proposed methodology shows the analysis of several urban variables as a whole or in sectors and with different complexity degrees. It facilitates to qualify and quantify the way small and big projects will impact in the environment both locally and regionally. Different techniques have been studied and some have been rearranged and conveniently integrated in the decision matrices. *Natural and artificial elements* of the area to be analysed and the *actions* planned in the undertaking are incorporated in the matrices as variables.

In each matrix intersection, the *magnitude* and *sign impact*, its *significance* and *temporality* are conceptually analysed. The *magnitude* concept refers to the intervention extent or relevance, and its *sign*, to the positive or negative aspect of such intervention. In both cases, the type of landscape to be intervened and the land to be affected by the interventions (local, sectional, regional) are considered for the impact value. The *significance* shows how important the intervention is according to the context in which it will be done. And the *temporality* estimates the permanency or reversibility degree of the distortion produced by each intervention in relation to the affected element.

Different indicators levels have been developed and each intersection impact is represented graphically in order to obtain comparable diagnoses in short periods of time. The indicators will: (1) Qualify and identify the relevant positive or negative intersections; (2) Select the most critical *elements* and *actions*; (3) Identify areas requiring a more detailed assessment; (4) Search alternative actions to minimise the original impact value. We think that the current actions, methods, technologies, materials, etc., must be considered among the alternative actions. If new alternative settings appear, the greatest number of positive values must be preserved, except in those opposed situations which would be required to make a choice.

The matrices can be applied in new or recyclable urban undertakings. Variables can be analysed as a whole or, the most critical ones, individually. The aspects to be considered are, among others, the building one, the habitability, the technology, the transport, the energy flows, the emissions, the working aspects and the economic ones. Their choice depends on the planned intervention type. A good variables selection will allow to formulate good diagnoses and to provide possible alternative stages.

3. Decision matrices formulation

Four associated matrices have been formulated. Three of them represent the *magnitude*, *significance* and *temporality* concepts. The fourth matrix summarises the results of the transversal intersections of the first three and calculates the partial and total indicators representing the impact magnitude of the analysed intervention. In every case, the matrices keep the original structure in which the main *natural and artificial components* as well as the planned *actions* are included. In order to enhance the comprehension of the resulting numerical matrix (matrix 4) and to stand out the relevant intersections, a 3D diagram showing the maximums and their sign is provided (Figs. 1 and 2).

The lines and columns identification, corresponding to *the components and the actions* of the *magnitude* matrix 1, is typical of the qualitative and semiquantitative analyses developed by Leopold. An action (columns) impact extent or relevance on every component (lines) is subjectively quantified. Each intersection is qualified from 0 to 10 and a positive or negative sign is incorporated depending on the variable intersection type (actions and elements). If such intersection has a function calculating its value, as for example the quality indices used by the Battelle–Columbus System [13], it can be included in the matrix or calculated previously and standardised in accordance to the qualification rank. (from 0 to 10) In this way, a map of intersections with impact magnitude values is obtained.

In matrix 2, the impact *significance* is assessed if produced. The significance concept shows how important the impact is on certain element. For this decision, the affected element must be considered, its condition in relation to its existence fragility and the local and regional stage in question. It is not the same to assess elements outside an area of close risks, than stages connected to areas which are degraded or have a certain protection level. The impact significance on the element can be substantially modified according to the alternatives. The qualification ranges from 0 to 1.

Matrix 3 assesses the impact *temporality* and it must show the impact short, medium or long term in general. In this decision, the recovery degree of an element affected by a certain action is assessed. If any function evaluating the temporality or the element recovery period exist, it can be incorporated with the corresponding calculus normalisation. The qualification ranges from 0 to 1.

In order to enrich the methodology, Matrix 4, of *results*, has been developed keeping the original elements and actions structure. This matrix concentrates information about the *magnitude*, *sign*, *significance and temporality*. In Matrix 4, an indicator (Index 1) transversally relating each intersection field (in Matrices 1, 2 and 3) is incorporated; and a synthesis result for each intersection is calculated. *Index 1* ($\pm \boldsymbol{I}_1$) shows the participation degree that each intersection (action-element-temporality) has in the result matrix. The following Eq. (1) summarises Index 1 ($\boldsymbol{I}_1$):

$$(\pm)\boldsymbol{I}_1 = \text{Intensity} \times \text{Significance} \times \text{Temporality} = \pm 10. \quad (1)$$

To determine some actions relevance (columns) and elements (lines) within the entire project, Index 2 ($\pm \boldsymbol{I}_2$) is incorporated for each line and column. *Index 2* aims at integrating each line (action) and each column (element) of matrix 4. $\boldsymbol{I}_2$ relates each $\boldsymbol{I}_1$ value with the number of cases of similar sign (*n cases*) giving a relative weight in relation to the total number of intersections (*N of actions and N of elements* at work). As an exercise, an intervention hypothesis has been suggested consisting of 33 actions and 29 elements capable of being affected.

Hypothesis 1. Extension with traditional technology. Matrix 1.

Matrix 1 (Impact Extent)		**Actions to be considered in the new or recyclable undertaking**																																
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions			
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGeneració		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste
Inorganic	Construction elements	-1																-1	-1		-1						-3				-2			
	Soils																				-1												-1	-1
	Water quality																															-5		-1
	Atmospheric quality(Emis.)																									-1	-1		-1		-1		-1	
Organic	Microfauna																				-6										-1	-5		-1
	Fauna						-5																								-2			
	Flora																				-5										-4	-6		-3
	Open spaces																				-1										-8	-8	-8	-3
Urban activities	Undertaking building																				-3										-8	-8	-8	-3
	Residence	-4					-8					-4									-5	-3				-6	-9				-8	-8	-8	-3
	Commercial	-4					-8					-4									-4	5				5	5				-8	-8	-8	-3
Recreation	Recreation	-5					-10					-4									-7					-6	-6				-10	-8	-10	-4
	Lamdscape	7					-10		4												-7	-9				-9	-9				-8	-8	-10	-2
	Open spaces quality	-5					-10		4												-7	-9				-9	-9				-10	-8	-10	-4
Services/ work	Health and security	-4					-8		-4			-4									-5					-2	-3				-10	-10	-10	-10
	Employment								8			4									1					3	2			4				
	Transport network																					-6				-6	-7		1		-4		-4	
Industrial sector	Service provision								3			4																		7				
	Micro industries											2														4	2							
	Industries																	1	1															
Infrastructure	Utilities netwoks infr.											2																		6				
	Garbage collector								-2																							-8	-8	-8
	Architectural barriers																																	
	Accesses and corridors								-2																	-6	-7		-2		-8		-9	

Hypothesis 1. Extension with traditional technology. Matrix 2.

Matrix 2 (Impact Extent)		Actions to be considered in the new or recyclable undertaking																																
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions			
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGeneració		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste
Inorganic	Construction elements	0.1																0.1	0.1		0.1						0.1				0.1			
	Soils																				0.2												0.2	0.1
	Water quality																															0.8		1.0
	Atmospheric quality(Emis.)																									0.4	0.5		1.0		0.6		0.4	
Organic	Microfauna																				0.1										0.1	1.0		1.0
	Fauna						0.7																								0.3			
	Flora																				0.1										0.2	1.0		1.0
	Open spaces																				0.1										1.0	1.0	1.0	1.0
Urban activities	Undertaking building																				0.8										0.8	1.0	0.8	1.0
	Residence	0.1					1.0					0.2									0.6	0.9				0.9	0.6				1.0	0.4	1.0	0.4
	Commercial	0.1					0.1					0.2									0.6	0.9				0.9	0.6				1.0	0.4	1.0	0.4
Recreation	Recreation	0.1					1.0					0.2									0.7					0.8	0.7				1.0	1.0	1.0	1.0
	Lamdscape	0.2					1.0		0.5												1.0	1.0				0.8	1.0				1.0	1.0	1.0	1.0
	Open spaces quality	0.7					1.0		0.6												1.0	1.0				1.0	1.0				1.0	1.0	1.0	1.0
Services/ work	Health and security	0.1					0.2		0.1			0.2									0.6					0.8	1.0				1.0	1.0	1.0	1.0
	Employment								1.0			0.1									0.1					0.3	0.1			0.3				
	Transport network																					0.6				0.8	1.0		1.0		1.0		1.0	
Industrial sector	Service provision								0.6			0.1																		0.4				
	Micro industries											0.1														0.1	0.1							
	Industries																	0.1	0.1															
Infrastructure	Utilities netwoks infr.											0.1																						
	Garbage collector								0.6																							1.0	0.5	1.0
	Architectural barriers																																	
	Accesses and corridors								0.2																	0.8	1.0		1.0		1.0		1.0	

Hypothesis 1. Extension with traditional technology. Matrix 3.

Matrix 3 (Impact Extent)		Actions to be considered in the new or recyclable undertaking																																
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions			
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGener		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste
Inorganic	Construction elements	0.1															1.0	0.2		0.1						0.1				0.1			
	Soils																			0.1												1.0	1.0
	Water quality																														1.0		1.0
	Atmospheric quality(Emis.)																								1.0	1.0		1.0		1.0		1.0	
Organic	Microfauna																			1.0										1.0	1.0	1.0	1.0
	Fauna						0.1																							1.0			
	Flora																			1.0										1.0	1.0	1.0	1.0
	Open spaces																			1.0										1.0	1.0	1.0	1.0
Urban activities	Undertaking building																			1.0										1.0	1.0	1.0	1.0
	Residence	1.0					0.1					1.0									1.0	1.0				1.0	0.1				1.0	1.0	1.0	1.0
	Commercial	1.0					0.1					1.0									1.0	1.0				1.0	1.0				1.0	1.0	1.0	1.0
Recreation	Recreation	1.0					0.1					1.0									1.0					1.0	0.1				1.0	1.0	1.0	1.0
	Lamdscape	1.0					0.1		1.0												1.0	1.0				1.0	0.1				1.0	1.0	1.0	1.0
	Open spaces quality	1.0					0.1		1.0												1.0	1.0				1.0	0.1				1.0	1.0	1.0	1.0
Services/ work	Health and security	1.0					0.1		1.0			1.0									1.0					1.0	0.1				1.0	1.0	1.0	1.0
	Employment								1.0												1.0					1.0	0.1			1.0				
	Transport network																					1.0				1.0	1.0		1.0		1.0		1.0	
Industrial sector	Service provision								1.0			1.0																		1.0				
	Micro industries											0.1														1.0	0.1							
	Industries																0.1	0.1																
Infrastructure	Utilities netwoks infr.											1.0																		1.0				
	Garbage collector								1.0																							1.0	1.0	1.0
	Architectural barriers																																	
	Accesses and corridors								1.0																	1.0	0.1		1.0		1.0		1.0	

Hypothesis 1. Extension with traditional technology. Matrix 4.

Matrix 4 (Impact Extent)		Actions to be considered in the new or recyclable undertaking: Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions				I_{2E}=(Sum. I_1/n) x n/N ;			I_{2E}=(Sum. I_1/n) x n/N ; I_1>0		
Natural and Artificial Elements		Habitat		Pattern modification in			Noise and vibrations		Urbanization			Trasmission on lines						Quarries	Energy generation Generació		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste	Suma I_1; I_1<0	(-)n campos	(-) I_{2E}	Suma I_1; I_1>0	(+)n campos	(+) I_{2E}
Inorganic	Construction elements	-0.01																-0.10	-0.02		-0.01						-0.03				-0.02				-0.19	6.00	-0.01	0.00	0.00	0.00
	Soils																				-0.02												-0.20	-0.10	-0.32	3.00	-0.02	0.00	0.00	0.00
	Water quality																															-4.00		-1.00	-5.00	2.00	-0.31	0.00	0.00	0.00
	Atmospheric quality(Emis.)																									-0.40	-0.50		-1.00		-0.60		-0.40		-2.90	5.00	-0.18	0.00	0.00	0.00
Organic	Microfauna																														-0.20				-0.20	1.00	-0.01	0.00	0.00	0.00
	Fauna																														-1.20				-1.20	1.00	-0.08	0.00	0.00	0.00
	Flora																				-0.10										-1.60	-8.00		-3.00	-12.70	4.00	-0.79	0.00	0.00	0.00
	Open spaces																				-0.10										-8.00	-8.00	-8.00	-3.00	-27.10	5.00	-1.69	0.00	0.00	0.00
Urban activities	Undertaking building																				-2.40										-6.40	-8.00	-6.40	-3.00	-26.20	5.00	-1.64	0.00	0.00	0.00
	Residence	-0.40					-0.80					-0.80									-3.00	-2.70				-5.40	-0.54				-8.00	-3.20	-8.00	-1.20	-34.04	11.00	-2.13	0.00	0.00	0.00
	Commercial	-0.40					-0.08					-0.80									-2.40	4.50				4.50	3.00				-8.00	-3.20	-8.00	-1.20	-24.08	8.00	-1.51	12.00	3.00	0.75
Recreatio	Recreation	-0.50					-1.00					-0.80									-4.90					-4.80	-0.42				-10.00	-8.00	-10.00	-4.00	-44.42	10.00	-2.78	0.00	0.00	0.00
	Lamdscape	1.40					-1.00		2.00												-7.00	-9.00				-7.20	-0.90				-8.00	-8.00	-10.00	-2.00	-53.10	9.00	-3.32	3.40	2.00	0.21
	Open spaces quality	-3.50					-1.00		2.40												-7.00	-9.00				-9.00	-0.90				-10.00	-8.00	-10.00	-4.00	-62.40	10.00	-3.90	2.40	1.00	0.15
Services/ work	Health and security	-0.40					-0.16		-0.40			-0.80									-3.00					-1.60	-0.30				-10.00	-10.00	-10.00	-10.00	-46.66	11.00	-2.92	0.00	0.00	0.00
	Employment								8.00												0.10					0.90	0.02			1.20					0.00	0.00	0.00	10.22	5.00	0.64
	Transport network																					-3.60				-4.80	-7.00		1.00		-4.00		-4.00		-23.40	5.00	-1.46	1.00	1.00	0.06
Industrial sector	Service provision								1.80			0.40																		2.80					0.00	0.00	0.00	5.00	3.00	0.31
	Micro industries											0.02														0.40	0.02								0.00	0.00	0.00	0.44	3.00	0.03
	Industries																	0.01	0.01																0.00	0.00	0.00	0.02	2.00	0.00
Infrastructure	Utilities netwoks infr.											0.20																							0.00	0.00	0.00	0.20	1.00	0.01
	Garbage collector								-1.20																							-8.00	-4.00	-8.00	-21.20	4.00	-1.33	0.00	0.00	0.00
	Architectural barriers																																		0.00	0.00	0.00	0.00	0.00	0.00
	Accesses and corridors								-0.40																	-4.80	-0.70		-2.00		-8.00		-9.00		-24.90	6.00	-1.56	0.00	0.00	0.00
	Sum. I_1; I_1<0	-5.21	0.00	0.00	0.00	0.00	-4.04	0.00	-2.00	0.00	0.00	-3.20	0.00	0.00	0.00	0.00	0.00	-0.10	-0.02	0.00	-29.93	-24.30	0.00	0.00	0.00	-38.00	-11.29	0.00	-3.00	0.00	-84.02	-76.40	-88.00	-40.50						
	(-) n Acciones	6.00	0.00	0.00	0.00	0.00	6.00	0.00	3.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	11.00	4.00	0.00	0.00	0.00	8.00	9.00	0.00	2.00	0.00	15.00	11.00	13.00	12.00	I_{3E}	I_{2E}(+)	0.094	I_{2E}(-)	-1.114	-1.020
	(-) I_{2A}=(SumI_1/n) x	-0.22	0.00	0.00	0.00	0.00	-0.17	0.00	-0.08	0.00	0.00	-0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.25	-1.01	0.00	0.00	0.00	-1.58	-0.47	0.00	-0.13	0.00	-3.50	-3.18	-3.67	-1.69						
	Sum. I_1; I_1>0	1.40	0.00	0.00	0.00	0.00	0.00	0.00	14.20	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.10	4.50	0.00	0.00	0.00	5.80	3.04	0.00	1.00	4.00	0.00	0.00	0.00	0.00						
	(+) n Acciones	1.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	3.00	3.00	0.00	1.00	2.00	0.00	0.00	0.00	0.00	I_{3A}	I_{2A}(+)	0.090	I_{2A}(-)	-1.068	-0.977
	(+) I_{2A}=(SumI_1/n) x	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.24	0.13	0.00	0.04	0.17	0.00	0.00	0.00	0.00						

Not all the intersections need to have a value. $\boldsymbol{I}_2$ is elaborated for each line and each column. Consequently, there will be one $\boldsymbol{I}_2$ for each element $\boldsymbol{I}_{2\mathrm{E}}$ and each action ($\boldsymbol{I}_{2\mathrm{A}}$), with respect to their signs.

The $(\pm)\boldsymbol{I}_{2\mathrm{E}}$ works with each *element* capable of being affected (line) and, in this case, with a total of 16 intervening actions with value ($N = 16$). Eqs. (2) and (3) show the calculus of $(\pm)\boldsymbol{I}_{2\mathrm{E}}$.

$$(-)\boldsymbol{I}_{2\mathrm{E}} = \left[\sum(\boldsymbol{I}_1)_i \div n\right] \times \frac{n}{N} =; \boldsymbol{I}_{2\mathrm{E}} \in [-10, 0];$$
$$\forall(\boldsymbol{I}_1)_i \in (\boldsymbol{I}_1)\mathrm{y}(\boldsymbol{I}_1)_i\langle 0$$
$$n = \text{number of } (\boldsymbol{I}_1)_i\langle 0;$$
$$N = \text{Total of columns with value } (N = 16), \tag{2}$$

$$(+)\boldsymbol{I}_{2\mathrm{E}} = \left[\sum(\boldsymbol{I}_1)_i \div n\right] \times \frac{n}{N} =; \boldsymbol{I}_{2\mathrm{E}} \in [0, 10];$$
$$\forall(\boldsymbol{I}_1)_i \in (\boldsymbol{I}_1)\mathrm{y}(\boldsymbol{I}_1)_i\rangle 0$$
$$n = \text{number of } (\boldsymbol{I}_1)_i\rangle 0;$$
$$N = \text{Total of columns with value } (N = 16). \tag{3}$$

The $(\pm)\boldsymbol{I}_{2\mathrm{A}}$ is elaborated considering the *actions* (columns) that would affect the elements; in this case, a total of 24 elements affected with value ($N = 24$). Eqs. (4) and (5) show the $(\pm)\boldsymbol{I}_{2\mathrm{A}}$.

$$(-)\boldsymbol{I}_{2\mathrm{A}} = \left[\sum(\boldsymbol{I}_1)_i \div n\right] \times \frac{n}{N} =; \mathrm{I}_{2\mathrm{A}} \in [-10, 0];$$
$$\forall(\boldsymbol{I}_1)_i \in (\boldsymbol{I}_1)\mathrm{y}(\boldsymbol{I}_1)_i\langle 0$$
$$n = \text{number of } (\boldsymbol{I}_1)_i\langle 0;$$
$$N = \text{Total of lines with value } (N = 24), \tag{4}$$

$$(+)\boldsymbol{I}_{2\mathrm{A}} = \left[\sum(\boldsymbol{I}_1)_i \div n\right] \times \frac{n}{N} =; \boldsymbol{I}_{2\mathrm{A}} \in [0, 10];$$
$$\forall(\boldsymbol{I}_1)_i \in (\boldsymbol{I}_1)\mathrm{y}(\boldsymbol{I}_1)_i\rangle 0$$
$$n = \text{number of } (\boldsymbol{I}_1)_i\rangle 0;$$
$$N = \text{Total of lines with value } (N = 24). \tag{5}$$

The number of intersections can vary depending on the undertaking analysed by the EIS.

In order to make a global synthesis of the undertaking, an index is needed summarising all the detailed results and showing the impact extent of the suggested undertaking. Consequently, *Index 3* ($\pm\boldsymbol{I}_3$) was elaborated to synthesise the $\boldsymbol{I}_2$ results. The addition of $(+)\boldsymbol{I}_{2\mathrm{E}}$ and $(-)\boldsymbol{I}_{2\mathrm{E}}$ (elements) and that of $(+)\boldsymbol{I}_{2\mathrm{A}}$ and $(-)\boldsymbol{I}_{2\mathrm{A}}$ (actions) allows to assess the undertaking global impact. The $(\pm)\boldsymbol{I}_3$ equations are shown in Eqs. (6) and (7),

$$(\pm)\boldsymbol{I}_{3\mathrm{E}} = \left[\sum(+\boldsymbol{I}_{2\mathrm{E}}) - \sum(-\boldsymbol{I}_{2\mathrm{E}})\right]/N; \quad N = 24, \tag{6}$$

$$(\pm)\boldsymbol{I}_{3\mathrm{A}} = \left[\sum(+\boldsymbol{I}_{2\mathrm{A}}) - \sum(-\boldsymbol{I}_{2\mathrm{A}})\right]/N; \quad N = 16. \tag{7}$$

The result of $(\pm)\boldsymbol{I}_{3\mathrm{E}}$ and $(\pm)\boldsymbol{I}_{3\mathrm{A}}$ will globally determine if the undertaking produces positive, negative or balanced significant impacts. It is clear that the term balanced does not mean that there are not high value impacts; in this case, it is necessary to resort to the detailed information (**I_2** and **I_1**) to identify the relevant actions or elements as well as the higher impact intersections.

To stand out the maximums, a bar chart diagram has been prepared showing matrix 4 intersections for hypotheses 1 and 2 (see Figs. 1 and 2). This graph allows to establish the more affected areas through surfaces in which minimum, maximum and discontinuities can be identified.

If alternative stages are elaborated for a same undertaking, the indicators will allow to assess and compare its differences. The stages comparative analysis, will allow to justify and select the lower impact options.

In order to apply the EIS methodology with the proposed alternatives, an example with two working hypotheses is shown. The first hypothesis presents the height extension of an energy-intensive health institution with traditional technology, in a partially urbanised area and within a partially intervened piece of land. In the second hypothesis, energy conservation measures are incorporated, applied to the building envelope and quantified by thermal balances. Cleaning measures in the effluents by a treatment plant are also incorporated. In the example, the construction stage and its subsequent use are both considered. It is necessary to remember that the matrices can work with objective and subjective values, that is to say, some variable values are based on calculus procedures such as

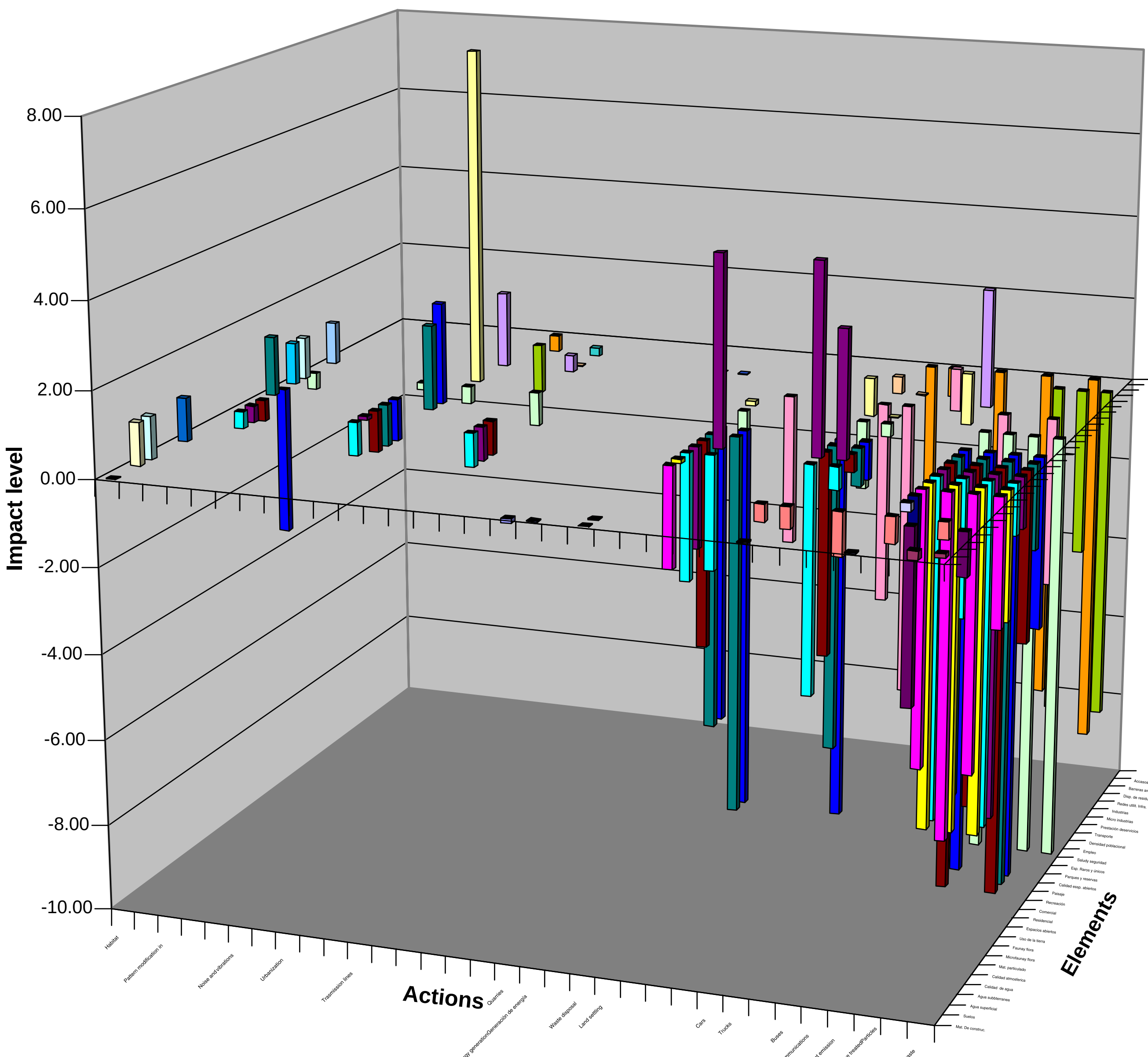

Fig. 1. EIS. **I_1** Results matrix. Hypothesis 1 (EXCEL 2000).

Hypothesis 2. Extension with alternative technology. Matrix 1.

Matrix 1 (Impact Extent)		Actions to be considered in the new or recyclable undertaking																																
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions			
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGeneració		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste
Inorganic	Construction elements	-1																-1	-1		-1						-3				-2			
	Soils																				-1												-1	-1
	Water quality																															-1		-1
	Atmospheric quality(Emis.)																									-1	-1		-1		-1		-1	
Organic	Microfauna																				-6										-1	-1		-1
	Fauna						-5																								-1			
	Flora																				-5										-2	-1		-2
	Open spaces																				-1										-5	-1	-5	-2
Urban activities	Undertaking building																				-3										-5	-1	-5	-2
	Residence	-4					-8					-4									-5	-3				-6	-9				-5	-1	-5	-2
	Commercial	4					-8					-4									-4					5	5				-5	-1	-5	-2
Recreation	Recreation	-5					-10					-4									-7					-6	-6				-7	-1	-7	-3
	Lamdscape	5					-10		4												-7	-9				-9	-9				-5	-1	-7	-2
	Open spaces quality	-5					-10		4												-7	-9				-9	-9				-7	-1	-7	-3
Services/ work	Health and security	-4					-8		-4			-4									-5					-2	-3				-7	-1	-7	-8
	Employment								9			4									1					3	2			4				
	Transport network																					-6				-6	-7		1		-4		-4	
Industrial sector	Service provision								3			4																		7				
	Micro industries											2														4	2							
	Industries																	1	1															
Infrastructure	Utilities netwoks infr.											2																		6				
	Garbage collector								-2																							-1	-7	-6
	Architectural barriers																																	
	Accesses and corridors								-2																	-6	-7		-2		-8		-9	

Hypothesis 2. Extension with alternative technology. Matrix 2.

Matrix 2 (Impact Extent)		Actions to be considered in the new or recyclable undertaking																																
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions			
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGeneració		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste
Inorganic	Construction elements	0.1																0.1	0.1		0.1						0.1				0.1			
	Soils																				0.2												0.2	0.1
	Water quality																															0.8		1.0
	Atmospheric quality(Emis.)																									0.4	0.5		1.0		0.6		0.4	
Organic	Microfauna																				0.1										0.1	1.0		1.0
	Fauna						0.7																								0.3			
	Flora																				0.1										0.2	1.0		1.0
	Open spaces																				0.1										1.0	1.0	1.0	1.0
Urban activities	Undertaking building																				0.8										0.8	1.0	0.8	1.0
	Residence	0.1					1.0					0.2									0.6	0.9				0.9	0.6				1.0	0.4	1.0	0.4
	Commercial	0.1					0.1					0.2									0.6	0.9				0.9	0.6				1.0	0.4	1.0	0.4
Recreation	Recreation	0.1					1.0					0.2									0.7					0.8	0.7				1.0	1.0	1.0	1.0
	Lamdscape	0.2					1.0		0.5												1.0	1.0				0.8	1.0				1.0	1.0	1.0	1.0
	Open spaces quality	0.7					1.0		0.6												1.0	1.0				1.0	1.0				1.0	1.0	1.0	1.0
Services/ work	Health and security	0.1					0.2		0.1			0.2									0.6					0.8	1.0				1.0	1.0	1.0	1.0
	Employment								1.0			0.1									0.1					0.3	0.1			0.3				
	Transport network																					0.6				0.8	1.0		1.0		1.0		1.0	
Industrial sector	Service provision								0.6			0.1																		0.4				
	Micro industries											0.1														0.1	0.1							
	Industries																	0.1	0.1															
Infrastructure	Utilities netwoks infr.											0.1																		0.2				
	Garbage collector								0.6																							1.0	0.5	1.0
	Architectural barriers																																	
	Accesses and corridors								0.2																	0.8	1.0		1.0		1.0	0.1	1.0	

Hypothesis 2. Extension with alternative technology. Matrix 3.

Matrix 3 (Impact Extent)		**Actions to be considered in the new or recyclable undertaking**																																
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions			
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGener		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste
Inorganic	Construction elements	0.1																1.0	0.2		0.1						0.1				0.1			
	Soils																				0.1												1.0	1.0
	Water quality																															1.0		1.0
	Atmospheric quality(Emis.)																									1.0	1.0		1.0		1.0		1.0	
Organic	Microfauna																				1.0										1.0	1.0	1.0	1.0
	Fauna						0.1																								1.0			
	Flora																				1.0										1.0	1.0	1.0	1.0
	Open spaces																				1.0										1.0	1.0	1.0	1.0
Urban activities	Undertaking building																				1.0										1.0	1.0	1.0	1.0
	Residence	1.0					0.1					1.0									1.0	1.0				1.0	0.1				1.0	1.0	1.0	1.0
	Commercial	1.0					0.1					1.0									1.0	1.0				1.0	1.0				1.0	1.0	1.0	1.0
Recreation	Recreation	1.0					0.1					1.0									1.0					1.0	0.1				1.0	1.0	1.0	1.0
	Lamdscape	1.0					0.1		1.0												1.0	1.0				1.0	0.1				1.0	1.0	1.0	1.0
	Open spaces quality	1.0					0.1		1.0												1.0	1.0				1.0	0.1				1.0	1.0	1.0	1.0
Services/ work	Health and security	1.0					0.1		1.0			1.0									1.0					1.0	0.1				1.0	1.0	1.0	1.0
	Employment								0.6												1.0					1.0	0.1			1.0				
	Transport network																					1.0				1.0	1.0		1.0		1.0		1.0	
Industrial sector	Service provision								1.0			1.0																		1.0				
	Micro industries											0.1														1.0	0.1							
	Industries																	0.1	0.1															
Infrastructure	Utilities netwoks infr.											1.0																		1.0				
	Garbage collector								1.0																							1.0	1.0	1.0
	Architectural barriers																																	
	Accesses and corridors								1.0																	1.0	0.1		1.0		1.0	1.0	1.0	1.0

Hypothesis 2. Extension with alternative technology. Matrix 4.

Matrix 1	(Impact Extent)	Actions to be considered in the new or recyclable undertaking																																	I_{2E}=(Sum. I_1/n) x n/N ; I_1<0			I_{2E}=(Sum. I_1/n) x n/N ; I_1>0		
		Pattern modification in							Land transformation and construction								Resources extrac.				Ground alterations					Traffic changes					Emissions									
Natural and Artificial Elements		Habitat					Noise and vibrations		Urbanization			Trasmission lines						Quarries	Energy generationGeneración de energía		Waste disposal	Land settling				Cars	Trucks		Buses	Communications	Contaminant emission	Effluents to be treated	Particles	Chemical waste	Suma I_1; I_1<0	(-)n campos	(-) I_{2E}	Suma I_1; I_1>0	(+)n campos	(+) I_{2E}
Inorganic	Construction elements	-0.01																-0.10	-0.02		-0.01						-0.03				-0.02				0	6	-0.01	0	0	0.00
	Soils																				-0.02												-0.20	-0.10	0	3	-0.02	0	0	0.00
	Water quality																															-0.80		-1.00	-2	2	-0.11	0	0	0.00
	Atmospheric quality(Emis.)																									-0.40	-0.50		-1.00		-0.60		-0.40		-3	5	-0.18	0	0	0.00
Organic	Microfauna																														-0.10				0	1	-0.01	0	0	0.00
	Fauna																														-0.60				-1	1	-0.04	0	0	0.00
	Flora																				-0.10										-1.00	-1.00		-2.00	-4	4	-0.26	0	0	0.00
	Open spaces																				-0.10										-5.00	-1.00	-5.00	-2.00	-13	5	-0.82	0	0	0.00
Urban activities	Undertaking building																				-2.40										-4.00	-1.00	-4.00	-2.00	-13	5	-0.84	0	0	0.00
	Residence	-0.40					-0.80					-0.80									-3.00	-2.70				-5.40	-0.54				-5.00	-0.40	-5.00	-0.80	-25	11	-1.55	0	0	0.00
	Commercial	0.40					-0.08					-0.80									-2.40					4.50	3.00				-5.00	-0.40	-5.00	-0.80	-14	7	-0.91	8	3	0.49
Recreation	Recreation	-0.50					-1.00					-0.80									-4.90					-4.80	-0.42				-7.00	-1.00	-7.00	-3.00	-30	10	-1.90	0	0	0.00
	Lamdscape	1.00					-1.00		2.00												-7.00	-9.00				-7.20	-0.90				-5.00	-1.00	-7.00	-2.00	-40	9	-2.51	3	2	0.19
	Open spaces quality	-3.50					-1.00		2.40												-7.00	-9.00				-9.00	-0.90				-7.00	-1.00	-7.00	-3.00	-48	10	-3.03	2	1	0.15
Services/ work	Health and security	-0.40					-0.16		-0.40												-3.00					-1.60	-0.30				-7.00	-1.00	-7.00	-8.00	-29	10	-1.80	0	0	0.00
	Employment								5.40												0.10					0.90	0.02			1.20					0	0	0.00	8	5	0.48
	Transport network																					-3.60				-4.80	-7.00		1.00		-4.00		-4.00		-23	5	-1.46	1	1	0.06
Industrial sector	Service provision								1.80			0.40																		2.80					0	0	0.00	5	3	0.31
	Micro industries											0.02														0.40	0.02								0	0	0.00	0	3	0.03
	Industries																	0.01	0.01																0	0	0.00	0	2	0.00
Infrastructure	Utilities netwoks infr.											0.20																		1.20					0	0	0.00	1	2	0.09
	Garbage collector								-1.20																							-1.00	-3.50	-6.00	-12	4	-0.73	0	0	0.00
																																			0	0	0.00	0	0	0.00
	Accesses and corridors								-0.40																	-4.80	-0.70		-2.00		-8.00		-9.00		-25	6	-1.56	0	0	0.00
	Sum. I_1 ; I_1<0	-5					-4		-2			-2						-0.10	-0.02		-30	-24				-38	-11		-3	0	-59	-10	-64	-31	I_{3E}	$I_{2E}(+)$	0.08	$I_{2E}(-)$	-0.77	-0.69
	(-) n Acciones	5			6				3			3						1	1		11	4			8		9		2	0	15	11	13	12						
	(-) I_{2A}=(SumI_1/n) x n/N ; I_1<0	-0.200					-0.168		-0.083			-0.100						-0.004	-0.001		-1.247	-1.013				-1.583	-0.470		-0.125	0.000	-2.472	-0.400	-2.671	-1.279						
	Sum. I_1 ; I_1>0	1			0				12			1			0				0		0	0			6		3		1	5	0	0	0	0	I_{3A}	$I_{2A}(+)$	0.07	$I_{2A}(-)$	-0.74	-0.66
	(+) n Acciones	2			0				4			3						1	1		1	0				3	3		1	3	0	0	0	0						
	(+) I_{2A}=(SumI_1/n) x n/N; I_1>0	0.06					0.00		0.48			0.03						0.00	0.00		0.00	0.00				0.24	0.13		0.04	0.22	0.00	0.00	0.00	0.00						

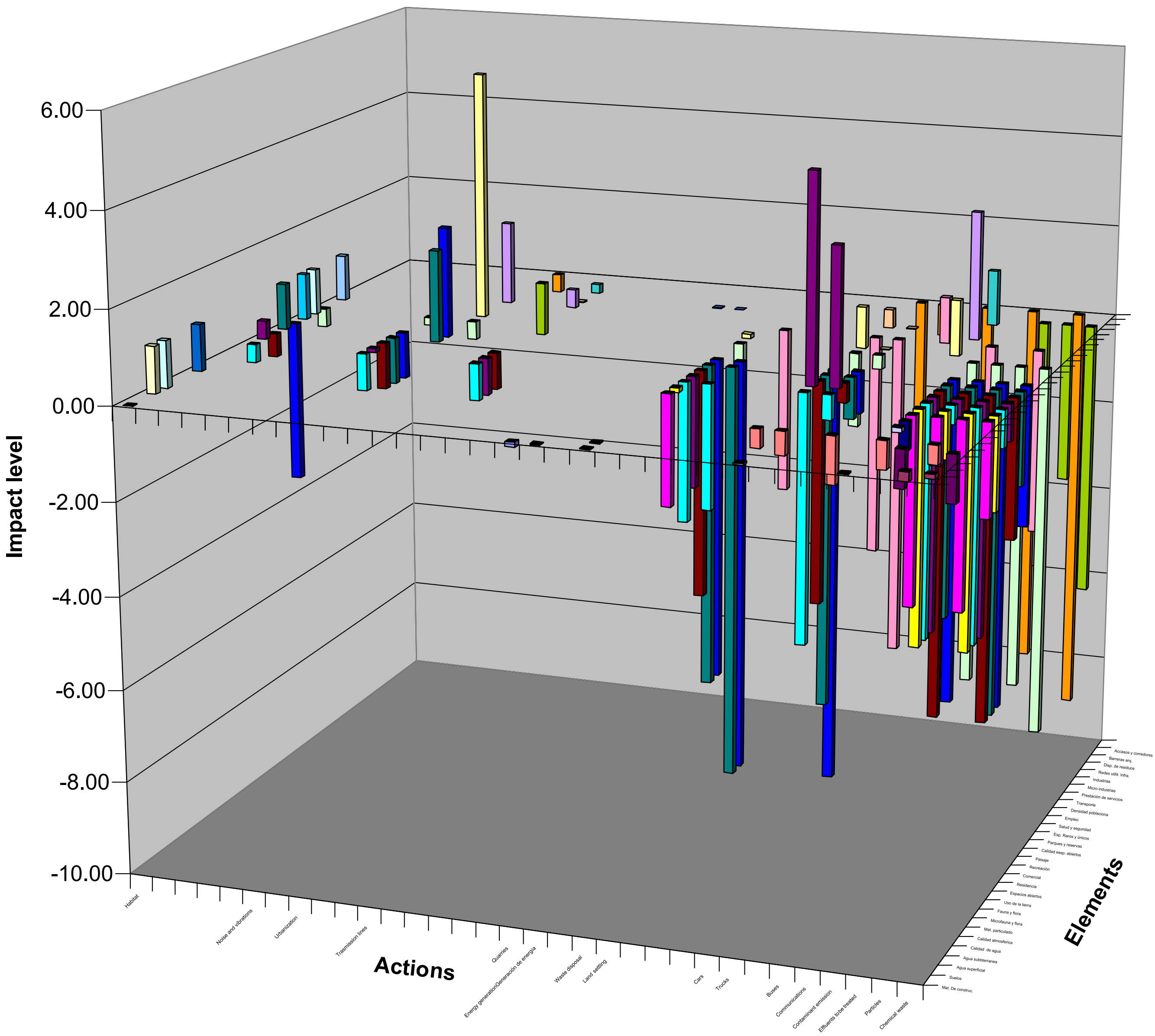

Fig. 2. EIS. $\boldsymbol{I}_1$ Results matrix. Hypothesis 2 (EXCEL 2000).

thermal balances, gas emission calculus, treatment capacity, etc.

4. Results

If $\boldsymbol{I}_1$ values are considered in the first hypothesis, the areas with intersections and rank density between ± 10 indicate the relevant variables for the study. The intervention complexity will determine the number of intersections to analyse. The actions, that register the greatest negative interventions are "ground alterations", "traffic changes" and "particle-emissions settling" areas. Positive actions are registered in "land transformation and construction" area, specially the "urbanization" aspect in the intersection with employment; and "traffic changes" in the intersection with the commercial sector. As for the second hypothesis results, the negative values related mainly to the "particle-emissions settling" sector are minimised and the intersection "urbanization-employment" is slightly improved. The decrease in the energetic emissions areas is proportionally related to the values obtained in the energetic balances made with the improvements performed on the building envelope. As for those areas of "sewage", the incorporation of a treatment plant reduces the waste according to the treatment plant capacity and its dimensions. On the other hand, the treatment plant generates permanent jobs, positively modifying the corresponding intersections.

With regard to the $\boldsymbol{I}_2(\pm 10)$ for the first hypothesis, the relevant actions are mainly related to "particle-emissions settling", and, in a lesser way, to "waste disposal" and "vehicles". The affected elements are "Open spaces quality", "health and security", "landscape", "recreation" and "residence". In the second hypothesis, actions are mainly minimised in the "effluents" areas and, in a lesser way, in "chemical waste", "particles" and "contaminant emission". The affected elements improve in relation to the mitigation actions.

With regard to $I_3(\pm 10)$, though it is an important social-welfare intervention, it shows, in general, low negative impact results in the first hypothesis. In the second hypothesis, the mitigation measures register significant reductions but maintain the mentioned sign.

According to the intervention hypothesis, the suggested exercise qualifies and quantifies the results with an acceptable approximation as it highlights the most critical and relevant situations. The EIA methodology, development integrated to the diagnosis one, makes it possible to understand and to approach the real situation. The proposed methodology provides necessary elements and information to the planned actions assessment in every urban intervention. It also allows to quickly define and fundament new mitigation stages. The different proposals and situations comparison allows their consequences assessment and the impacts minimisation.

References

[1] Gallopín GC. El futuro de nuestro, Sección I, Capítulo 2, Elementos de política ambiental, H., Cámara de Diputados Pcia. de Bs.As., La Plata, Argentina, 1993.

[2] Gallopín GC. Prospectiva ecológica para América Latina: Futuros alternativos, Sección XI, Capítulo 70, Elementos de política ambiental, H Cámara de Diputados Pcia. De Buenos Aires, 1993.

[3] Berlin Department of Urban Development, Environmental Protection and Technology, Berlin Digital Environmental Atlas, Germany, 1987.

[4] European Communities. The urban audit. Towards the benchmarking of quality of life in 58 European city. Luxenbourg, 2000.

[5] Ashton J. Ciudades sanas. Barcelona: Masson; 1993.

[6] OPS (Organización Panamericana de la Salud). Municipios Saludables: una estrategia de promoción de la salud en el contexto local, Washington DC, 1992.

[7] Morris PY, Therrivel R. Methods of environment impact assessment. UCL, Londres, 1995.

[8] Papparelli A, et al., Diagnóstico ambiental de ecosistemas humanos. FAU-UNSJ, San Juan, Argentina, 1999.

[9] Gobierno de la Ciudad Autónoma de Buenos Aires, Plan Urbano Ambiental. Elementos de diagnóstico. Buenos Aires, Argentina, 1998.

[10] PNUMA, FB, y IDEE. Manual de Cuentas Patrimoniales. México, 1996.

[11] Discoli C. Estudio de impacto ambiental. Desarrollo de matrices de análisis y construcción de indicadores de evaluación. Revista Avances en Energías Renovables y Medio Ambiente. ISSN 0329-5184. Vol. 2(2). Argentina, 1998. p. 06.21–24.

[12] Domínguez MC, Ferreyro CF. Evaluación previa para las intervenciones urbanas. Propuesta metodológica. III Seminario Internacional Patrimonio y ciudad contemporánea: políticas, prácticas y nuevos protagonistas. CECRE, Facultade de Arquitetura da Universidade Federal da Bahía. Salvador da Bahía, Brasil, 2002.

[13] Gomez Orea D. Evaluación del impacto ambiental. Un instrumentopreventivo para la gestión ambiental. EdicionesMundi-Prensa y Editorial Agrícola, Madris. 1999.