VIABILITY OF THE CAR PARKS ABOVE GROUND TO THE UNDERGROUND

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ABSTRACT

This writing is intended to highlight the differences and economic resources between a parking lot built in two different situations; underground and above ground.
To do so, is designed a model more integrated as possible in a specific urban reality with benefits and same construction characteristics, except those bound by its situation, so that they can be compared according to the theory of the global cost in construction area. So, has been implemented the model designed in two situations, underground and above ground, and studied and compared the costs of investment, exploitation, demolition and recycling, as well as a first assessment evaluation of the resources needed for the implementation of the same ones, with a 50-year life cycle.

Keywords: transport, urbanism, works underground, construction, urban planning

1.- Introduction

The use of vehicles has dragged always with it the problem of storing them when they are not in use. We know the importance that has had from the antiquity this question and the determinant influence in the construction of buildings, the stables, the alighting-places and stores of carriages form a part of the domestic, bourgeois architectures, palace and defensive of all the times. With the appearance of the car, specially in cities, it continues appearing the problem of his temporary warehouse or storage in the intervals of time in what it is not in use, being named parkings to the spaces or buildings destined to such goal. According to countries and moments different solutions have been adopted for the matter. In any place of the world, the problem of parking will exist or not depending on the design of the city that in general will have an occupation and intensive use in the centers and more distended and extensive in the peripheries. The problem therefore will appear principally in the centers of the cities and places where the building is very intensive and does not have these spaces reserved. In the centers or congested sectors it is solved by time-restricted parkings, which they are usually being regulated by hourly zone, extensive on above ground spaces enabled for it, them underground located in basements of buildings or of exclusive use to park and the placed ones in buildings constructed on low designed for it. This range of solutions has been diverse variants and associated costs of implantation and operation. It is obvious and generally admitted that a parking on low has minor costs that underground one of similar characteristics, as well as fewer pollutant emission nevertheless, we do not know that there have been realized up to the date studies that with some methodologically accepted procedure it determines or comes closer the value of these costs.

Fig. 1 “Image of the parking of Düsseldorf's airport, Germany”. Source: Internet

In this occasion, we are interested particular in the study of the buildings of parkings constructed above ground and placed underground. Studies that are considered to be indispensable both for the survival of the existing ones and for the future interventions. In this work in I make concrete, we are interested in investigating the

nature of these differences with a view to a major future sustainability always supporting the hypothesis of which the particular vehicle is going to have an important presence in the transport inside the city.
The analysis is going to be realized in three successive areas; first from the theory of necessary resources to execute the works, later there will apply to themselves models derived from the theory of the global cost, that is to say studies where it is analyzed I complete of the life cycle of the building, finally, to integrate the information obtained in the most recent models of ecological footprint.
There are made two hypothesis of construction of the same parking, one buried and other one in surface with the same conditions of environment, legal services, legislation, qualities and services so that later the obtained information is compared.

2.- Objectives

It is considered to know closely the existing differences between the parkings above ground opposite to them underground.
This work is the first dip in the topic of the sustainability of parkings, with ecological criteria of vital importance for the future, in the hypothesis of which the private vehicle continues having an important leadership in the transport. The analysis was realized in the light of the theory of the global cost, that is to say of the life cycle of the building, known as:

Global Cost = Investment Cost + Exploitation Cost + Demolition and Recycling Cost

$$GC = IC + EC + RC \quad (1)$$

From the experience of design and construction of numerous parkings in Andalusia (Spain) as well as in the analysis of the viability of the same ones there is approached the accomplishment of a comparative study of economic costs as the first step towards a major area in which there are quantified the energetic costs as well as the emission of pollutants.

3.- Methodology

To be able to make a comparative model of costs considers to establish a theoretical parking in a supposed location, developed the project above ground and underground. For it the following methodology has been established:

3.1.- Location of the scene of the investigation

A plot will be looked in a known city, and where seemingly it were viable and suitable the building of a new parking

3.2.- Analysis of urban development viability

It will be verified the urban development viability of the parking, though it is not basic for the object of the study, since many urban development regulations do not foresee parkings above ground.

3.3.- Fundament and design of the models of parking

There will develop two models as similar as possible, one above ground and another underground, according to the regulation in force. There will never be able to be absolutely alike due to the constructive different characteristics.

3.4.- Cost studies models

The cost study will be made for each one, including the total cost of the life of the building (Global cost C_G):

- Investment Cost **C_I**
- Exploitation Cost **C_E**
- Demolition and Recycling Cost **C_R**

Proceed to make a comparative analysis of the costs of both models.

3.5.- Viability studies of the models

A viability study of income and expenses that show the models studied may be able to.

3.6.- Comparative study of costs

A comparative study of the data obtained in the following areas will be done:

- Investment Cost **C_I**
- Exploitation Cost **C_E**
- Demolition and Recycling Cost. **C_R**
- Global cost **C_G**

3.7.- Estudio comparativo de recursos.

- Supplies. **M_t**
- Equipment **M_q**
- Manpower **M_o**

3.8.- Tools used

For the comparative study we have used the following tools:

- Price Database of the Junta de Andalucía 2013.
- Software of budget and measurements Presto 8.8.
- Memory of the Banco de Precios, Junta de Andalucía 2013. Indirect Cost counting itemized.

In the process of valoration and quantification have proceeded to develop a single database composed of sections common to both models. In the specific sections of each model are valued at zero those who do not correspond to the specific model. Thus has been made a base price of epigraphs and only allow a comparative analysis.

4.- Model of parking studied

4.1.- Definition and justification of the models of parking proposed for the study.

- **Location**

The location is chosen in Seville, where it has a large amount of data to perform various assessments. The location corresponding to a site where there is now a parking irregular surface and is usually saturated, indicating lack of parking space for cars, and the demand for it.

- **Number of levels**

Parking below ground is raised with four floors underground because it is the maximum allowed by the General Plan of Seville, demand is high and the geotechnical study suggest reinforced concrete retaining wall from level -3m approximately, so is decided to go to the fullest.
Therefore to carry out a logical comparison, it will be four levels at the parking above ground too.
In this sense, a priori in a model with the maximum number of the impact of roof spaces and covers foundations is lower, which makes both models are similar.

- **Number of places**

The experience in this area tells us that a rotation parking lot to make it profitable must have spaces between 200/600, since a higher number causes access problems.
For parking of cession (towards their residential surroundings) the maximum number of spaces must be about 300 spaces, as the population density of the area, a larger number of spaces are not needed for surrounding users.

- **Typology**

A very common, simple, linear type, which are available wealth of data on costs is chosen. Within the city there are several similar car parks which data are available, f. e. Paseo de Colón, Virgen de Lujan, Argentina, Avenida de Roma, Dr. Fedriani, etc.

4.2.- Design fundamentals of models parking

Firstly, in order to do the comparative study of both models of parking lots, we have to establish a set of general design features for both in order to have the closest thing as possible comparable models. Then the particular characteristics of each model are established.

4.2.1.- Common features of both models

1. **Location**: street address C/ Luis Rosales after the stop train Virgen del Rocio and near the neighborhood of Porvenir and Bami.
2. **Number of parking spaces**: 412 4-wheeled vehicles and 50/51 2-wheeled vehicles.
3. **Number of floors:** four floors.
4. Structural system chosen: by slab foundation, pillars and floor slabs, all in reinforced concrete.
5. **Building system chosen**: according to regulations brick masonry envelopes, brick partitions, carpentry, locksmith and surface coatings.
6. **Installations according to regulations**: in each case are adapted to building model chosen; elevators, etc.

4.2.2.- Specific features of parking underground

1. **Reinforced concrete retaining wall**: For perimeter containment lands.
2. **Urbanization**. It is urbanized entire plot of action.
3. **Installations**. Specific of ventilation, fire protection, water evacuation.

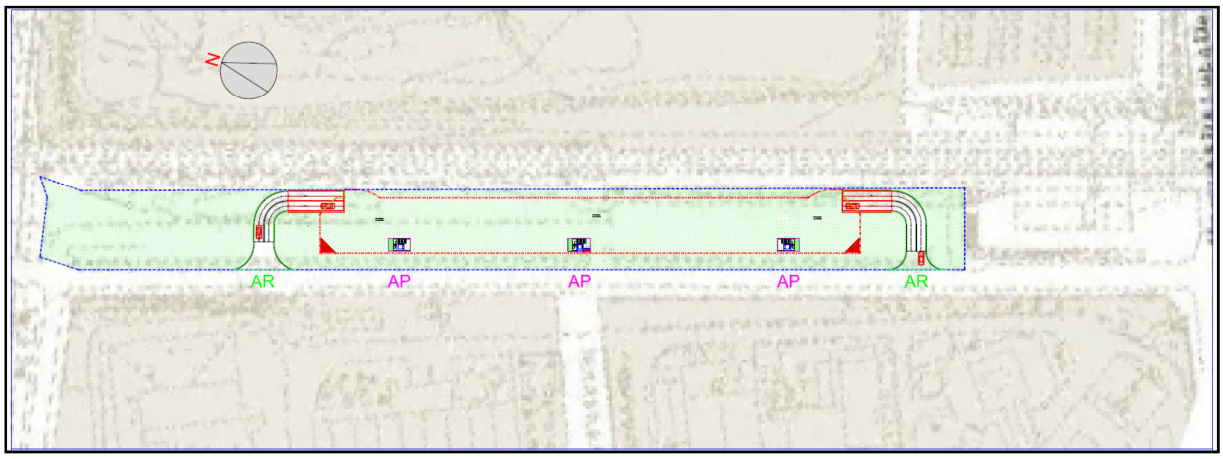

Fig.2 “Underground Parking. Implementation and the plot”. Source: Author.

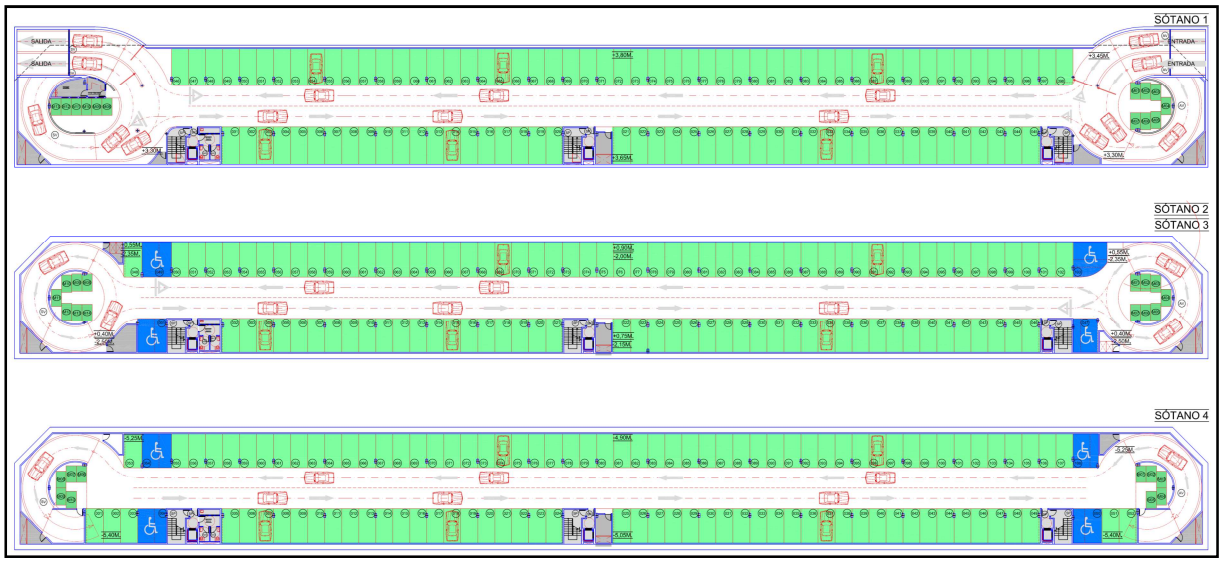

Fig. 3 “Underground parking. Distribution floors”. Source: Author.

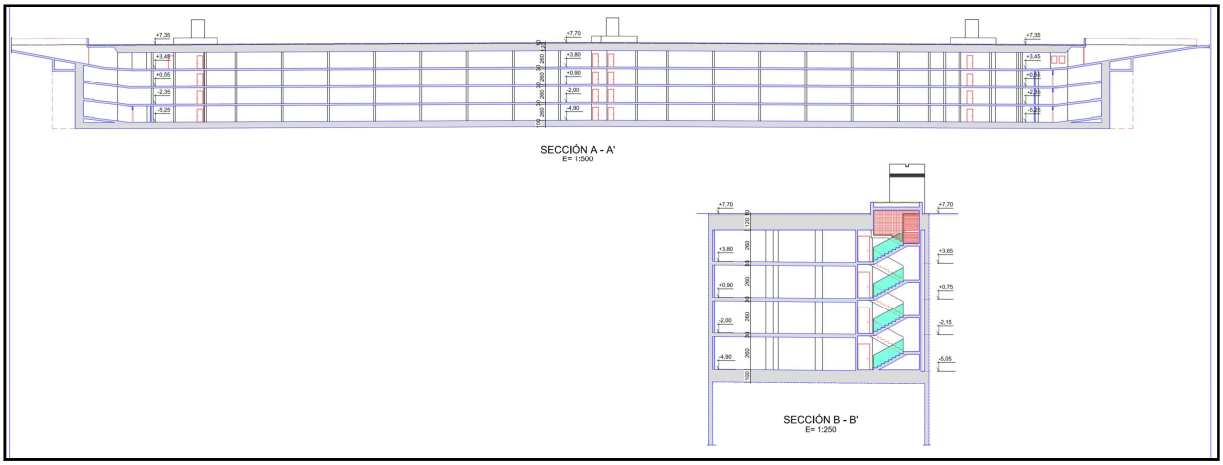

Fig. 4 “Underground Parking. Sections”. Source: Author.

SUPERFICIES DE APARCAMIENTO.	
Superficie (m²)	construida
Sótano 1	3.213,24
Sótano 2	3.109,76
Sótano 3	3.109,76
Sótano 4	3.109,76
TOTAL APARCAMIENTO.	**12.542,52**
Nº Total de plaza de vehículos de cuatro ruedas (coches)	412
Nº Total de plaza de vehículos de dos ruedas (motos)	51
Nº Total de plaza de aparcamiento	463
Repercusión por plaza (m²/plaza coches)	30,44

Table 1 “Underground Parking. Parking Surface”

SUPERFICIES DE URBANIZACIÓN.	
Superficie (m²)	construida
SUPERFICIES OCUPADA	
SUPERFICIES OCUPADA EN SÓTANOS	**3.213,24**
SUPERFICIE OCUPADA POR ACCESOS	**638,03**
Accesos rodados	546,25
Accesos peatonales	91,78
TOTAL OCUPADO	**3.851,27**
SUPERFICIE AREA DE ACTUACIÓN	**7.795,15**
SUPERFICIE LIBRE DE URBANIZACIÓN (NO OCUPADA POR ACCESOS)	**7.157,12**

Table 2 “Parking Underground. Surface of urbanization”.

4.2.3.- Specific features above ground parking

1. **Envelope**: construction characteristics indicating that it is an open parking.
2. **Urbanization**. Part of the plot of action, since the building occupies part of it.
3. **Cover**. Designed as non-trafficable roof, just for maintenance. Assume improve indoor parking costs this model and would not be comparative with the other model.

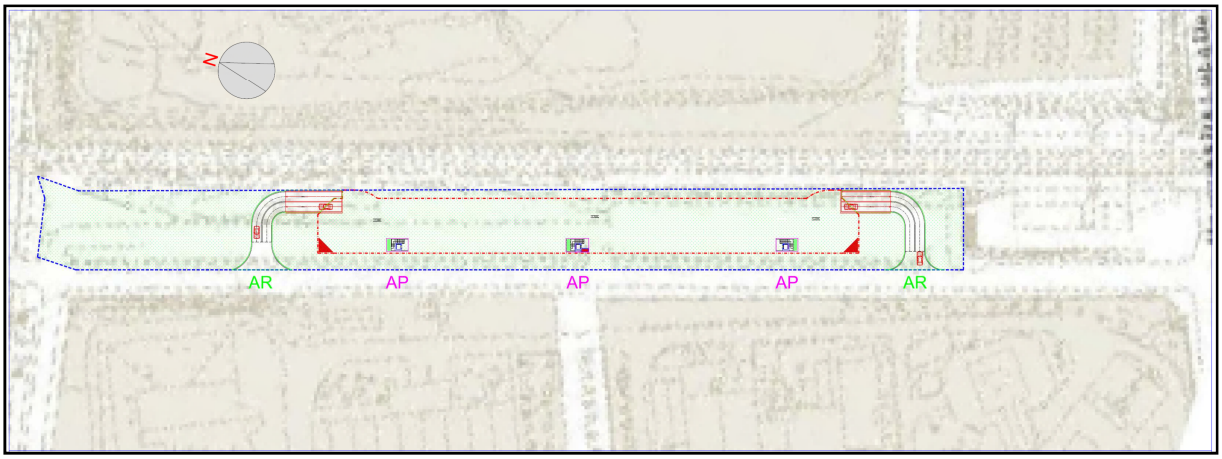

Fig. 5 “Parking above ground. Implementation and the plot”. Source: Author.

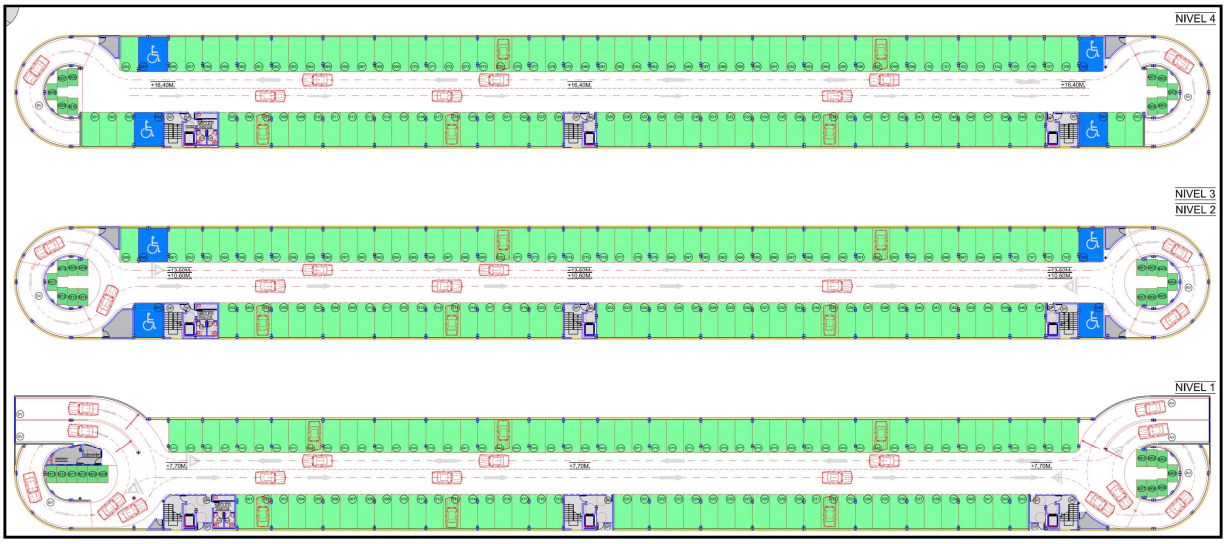

Fig. 6 “Parking above ground. Distribution floors”. Source: the author

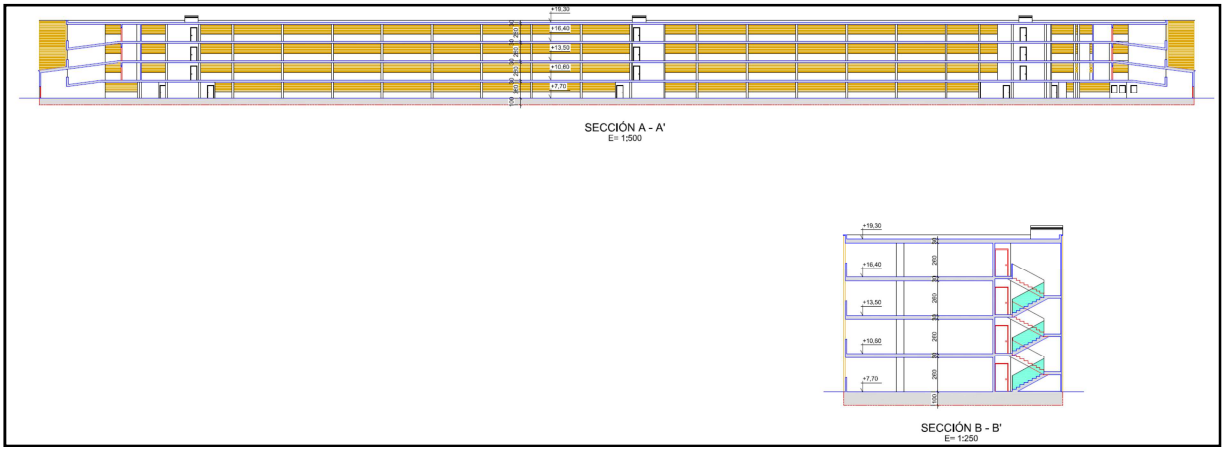

Fig. 7 “Parking above ground. Sections”. Source: Author.

SUPERFICIES DE APARCAMIENTO.	
Superficie (m²)	**construida**
Nivel 1	2.813,28
Nivel 2	2.813,28
Nivel 3	2.813,28
Nivel 4	2.813,28
TOTAL APARCAMIENTO.	**11.253,12**
Nº Total de plaza de vehículos de cuatro ruedas (coches)	413
Nº Total de plaza de vehículos de dos ruedas (motos)	51
Nº Total de plaza de aparcamiento	464
Repercusión por plaza (m²/plaza coches)	27,25

Table 3 “Parking above ground. Surface parking”.

SUPERFICIES DE URBANIZACIÓN.	
Superficie (m²)	construida
SUPERFICIES OCUPADA	
SUPERFICIES OCUPADA EDIFICACION SOBRE RASANTE	**2.813,28**
SUPERFICIE OCUPADA POR ACCESOS	**591,86**
Accesos rodados	591,86
Accesos peatonales	0,00
TOTAL OCUPADO	**3.405,14**
SUPERFICIE AREA DE ACTUACIÓN	**7.795,15**
SUPERFICIE LIBRE DE URBANIZACIÓN (NO OCUPADA)	**4.390,01**

Table 4 “Parking above ground. Areas of urbanization”.

5.- Cost global study. comparative analysis of costs

We focus in this section on valuations of the two models, demand forecasts and economic viability of the development nor the justification for each building systems, installations and exploitation chosen, are not the subject of this article, that are developed in detail in the study of Ms. Dª Inmaculada Guzmán Carrizosa[3].

5.1.- Investment costs

CALCULO COSTE INVERSION		APARCAMIENTO BAJO RASANTE	APARCAMIENTO SOBRE RASANTE	DIFERENCIA	%
COSTE DIRECTO		4.563.119,14 €	3.275.558,54 €	1.287.560,60 €	39%
COSTE INDIRECTO		538.904,37 €	410.755,04 €	128.149,33 €	31%
	PEM	5.102.023,51 €	3.686.313,58 €	1.415.709,93 €	38%
P.A. Reurbanización Zona Actuación		420.930,00 €	237.060,54 €	183.869,46 €	78%
Subtotal1		5.522.953,51 €	3.923.374,12 €	1.599.579,39 €	41%
COSTES GENERALES	13%	717.983,96 €	510.038,64 €	207.945,32 €	41%
BENEFICIO INDUSTRIAL	6%	331.377,21 €	235.402,45 €	95.974,76 €	41%
COSTE INVERSION		6.572.314,68 €	4.668.815,20 €	1.903.499,47 €	41%

Table 5 “Comparative analysis of annual investment cost”.

[3] Viabilidad de los aparcamientos sobre rasante frente a los bajo rasante. Cuantificación. Autora: Inmaculada Guzmán Carrizosa. Sevilla, diciembre 2013. Desarrollado como Proyecto Fin de Master del Master en Gestión Integral de la Edificación.

5.2.- Exploitation cost

COSTES DE EXPLOTACIÓN (ANUALES)	BAJO RASANTE				SOBRE RASANTE				DIFERENCIA	
		B.I.	IVA	TOTAL CON IVA		B.I.	IVA	TOTAL CON IVA	B.I.	%
0. Datos	Nº				Nº					
0.1. Nº plazas coches	412				413					
0.2. Nº plazas motos	51				51					
0.3. Nº plazas totales	463				464					
1. Personal. Empleados		20.600,40 €	- €	20.600,40 €		20.611,20 €	- €	20.611,20 €	- 10,80 €	-0,05%
2. Sumistros		15.000,00 €	3.150,00 €	18.150,00 €		9.000,00 €	1.890,00 €	10.890,00 €	6.000,00 €	40,00%
3. Seguros		3.000,00 €	630,00 €	3.630,00 €		3.000,00 €	630,00 €	3.630,00 €	- €	0,00%
4. Impuestos		52.000,00 €	10.920,00 €	62.920,00 €		52.000,00 €	10.920,00 €	62.920,00 €	- €	0,00%
5. Contratos de mantenimiento (obligatorios)		16.800,00 €	3.528,00 €	20.328,00 €		11.700,00 €	2.457,00 €	14.157,00 €	5.100,00 €	30,36%
6. Reparaciones (fuera de contratos de mant.)		28.155,67 €	5.912,69 €	34.068,36 €		31.723,26 €	6.661,89 €	38.385,15 €	- 3.567,59 €	-12,67%
7. Reposiciones		51.756,47 €	10.868,86 €	62.625,33 €		57.871,97 €	12.153,11 €	70.025,08 €	- 6.115,50 €	-11,82%
TOTAL		187.312,54 €	35.009,55 €	222.322,09 €		185.906,43 €	34.712,00 €	220.618,43 €	1.406,11 €	0,75%
REPECUSIÓN POR PLAZA		404,56 €				400,66 €			3,90 €	0,96%

Table 6 “Comparative analysis of exploitation costs”.

5.3.- Demolition cost

CALCULO COSTE DEMOLICION		APARCAMIENTO BAJO RASANTE	APARCAMIENTO SOBRE RASANTE	DIFERENCIA	%
COSTE DIRECTO		847.748,45 €	414.241,52 €	433.506,93 €	105 %
COSTE INDIRECTO		90.030,89 €	43.992,45 €	46.038,44 €	105 %
	PEM	937.779,34 €	458.233,97 €	479.545,37 €	105 %
COSTES GENERALES	13 %	121.911,31 €	59.570,42 €	62.340,90 €	105 %
BENEFICIO INDUSTRIAL	6%	56.266,76 €	27.494,04 €	28.772,72 €	105 %
COSTE DEMOLICION		1.115.957,41 €	545.298,42 €	570.658,99 €	105 %

Table 7 “Comparative analysis of demolition costs”.

5.4.- Summary of global cost

	APARCAMIENTO BAJO RASANTE	APARCAMIENTO SOBRE RASANTE	DIFERENCIA	%
COSTE INVERSION	6.572.314,68 €	4.668.815,20 €	1.903.499,47 €	41%
COSTE EXPLOTACION	187.312,54 €	185.906,43 €	1.406,11 €	1%
COSTE DEMOLICION	1.115.957,41 €	545.298,42 €	570.658,99 €	105 %
PERIODO EJECUCION	18	12	6	50%

Table 8 “Comparative analysis of annual global cost”.

6.- Results

After analyzing the previous documentation we highlight the following findings and conclusions:

6.1.- Global cost

COSTE GLOBAL PARA UNA VIDA UTIL 50 AÑOS								
	COSTE INVERSION C_I		COSTE EXPLOTACION C_E		COSTE DEMOLICION C_R		TOTAL C_G	
APARCAMIENTO BAJO RASANTE	6.572.314,68 €	39%	9.365.626,99 €	55%	1.115.957,41 €	7%	**17.053.899,07 €**	100%
APARCAMIENTO SOBRE RASANTE	4.668.815,20 €	32%	9.295.321,50 €	64%	545.298,42 €	4%	**14.509.435,13 €**	100%
DIFERENCIA	**1.903.499,48 €**	75%	**70.305,49 €**	3%	**570.658,99 €**	22%	**2.544.463,94 €**	100%
	41%		**1%**		**105%**		**18%**	

Table 9 “Conclusions. Global cost for a useful life time of 50 years”.

According to the results achieved, the difference in cost between implantation Global cost CG model located above ground and underground is € 2,544,463.95, which represents an increase of under over on the above ground of 18%. Although this result was expected, was surprised that the difference between the two implementations is not higher.

This difference is most investment cost compared to CI (41%), And analyzing the study of the costs realized of a cost estimate of the exposed models, that are developed in detail in the study of Ms. Inmaculada Guzmán Carrizosa[4], especially by civil works, particularly heading excavation, foundation slab and retaining wall, reached 300%, compared to the chapters Iinstallations difference is 15%, which could increase by changing the conception of building. Also to note the deadlines, this implies a lower amount of indirect costs and faster commissioning and return on investment.

As for the operating costs are much like having great influence personnel costs on energy costs. If parking on grazing has lower costs than 1%, ie € 1,406.11 / year. It is observed that the Demolition Cost model above ground is € 570,658.99 inferior to the implementation underground, which is a cheaper 105% a mortgage is left underground in the case of the model considered more important under ground, since it is not possible to demolish it in its entirety.

As summary above ground parking lot is more sustainable economically, for investment costs and demolition and recycling, not for maintenance, which latter are not sensed at the start of this work and methodically has tried to ponder. Noteworthy that in both car parks operating costs accounting for over 50% of the overall cost. We need to find solutions that minor this percentage as much as possible.

6.2.- Other results obtained in the study development

6.2.1.- Divert services

Diverting services in both model systems implementation in both situations involve the same costs. The previous study of these costs indicate the impact on the investment costs, which can in some cases, recommend that the investment is not made, being unsustainable over the cost investment.

6.2.2.- Land occupation

The implementation of the model above ground implies the occupation of public space, while the implementation model underground releases a space as possible. The qualification of this situation is a function of the impact that this space has in the space freed parking in the neighborhood. It would be a parameter relating to the quality of life.

[4] Viabilidad de los aparcamientos sobre rasante frente a los bajo rasante. Cuantificación. Autora: Inmaculada Guzmán Carrizosa. Sevilla, diciembre 2013. Desarrollado como Proyecto Fin de Master del Master en Gestión Integral de la Edificación.

It seems clear that parking Under ground is best placed in the city center areas where there is no land available and should be placed under Public Domain areas or services (roads, parks, office buildings, shopping, etc.).
The parking above ground, given its lower cost and greater sustainability are indicated in peripheral areas where there is land available or can be booked ground at the urban planning.

6.2.3.- Cost of parking spaces

Closely related to the above conclusion, saying that the scope for promotion or benefit of it is for the model under ground of € 27,531.59, while for the case above ground is € 2,216,862.80.
Amounts with an impact on a lower cost of transfer of spaces, it will be irrelevant to the case under ground, but for the above ground will cause the price of the places decrease by 25%. As shown below;
Getting revenues amounting € 6,529,500, reaching almost the amount of investment expenditure amounting to € 6,489,137.20.

6.2.4.- Urban legality

It is noteworthy that the current legislation urbanist in Spain contain no specific plots for parking above ground and may parcels used for any other compatible use used. Also the uses defined by the various Plans General clearly not collect the parking above ground as a dotacional use.
Facing a future sustainability would proceed a review of the planning regulations, especially laws that develop later a General Plans.

6.2.5.- Building typology

Regarding to the results achieved of this study, we observed that operating costs the building front, in the parking above ground, in 50 years, leveling the costs of both options, establishing the difference we have already mentioned 18%.
The approach of implementing above ground is like a 'building' with urban facade, conservative design choice that is what has been taken on this project for a city like Sevilla, to comply with current regulations in this country. If propose with another more closely linked to the economy and functioning of the rules, type for example the parking above ground located in Dusseldorf, Germany, or the Marina Tower in Chicago, USA, in which there is no facade, but simply protection systems the costs of investment and maintenance would be reduced significantly, according to the following modified results table in which case the percentage difference between the two locations would rise to 30%.

COSTE GLOBAL CONSIDERADO VIDA UTIL 50 AÑOS, CONSIDERANDO UN DISEÑO DE FACHADA NO CONSERVADOR				
	COSTE INVERSION	COSTE EXPLOTACION	COSTE DEMOLICION	TOTAL
APARCAMIENTO BAJO RASANTE	6.572.314,68 €	9.365.626,99 €	1.115.957,41 €	**17.053.899,07 €**
APARCAMIENTO SOBRE RASANTE	4.193.970,82 €	8.402.614,06 €	545.298,42 €	**13.141.883,31 €**
DIFERENCIA	1.903.499,47 €	963.012,92 €	570.658,99 €	3.912.015,76 €
%	41%	11%	105%	30%

Table 9 “Global cost. Useful life time of 50 years. Design of non-conservative façade”.

7.- Discussion

- The operating costs are empirical and accounting information received total character data. To develop a model should be established a similar price to the

bank in which tasks, chapters, resources, operation and maintenance plans are defined methodology. Future studies should be addressed similar systems operating costs, maintenance and consumption in greater depth as well as demolition and recycling. Finally, a study of energy cost, which would complete the study.

- Environmental. Neither is subject matter of this study . But it is important to highlight the route as relevant research that opens here since the 'sustainability in parking above ground against the ground under and their quantification' no data to date. With existing documentation resources investment costs can start working on the ecological footprint of the same.

- You could pose the same job for a metal structure easy to go up, which will probably be an increase in the cost of investment, but savings in the costs of demolition and recycling. Besides that equal economic cost could imply a smaller ecological footprint.

8.- Conclusions

- To sum up you can set that the parking above ground is more sustainable economically, both investment costs as demolition and recycling.

- Operating costs and maintenance are very similar in both models, considering that these costs account for over 50% of the general cost CG.

- It is necessary to find solutions being lower operating and maintenance costs.

- It seems clear that the parking underground is best placed in areas of the city center where there is no land available and should be placed under Public Domain areas or services (roads, parks, office buildings, shopping, etc.).

- The cost of CI Investments of parking above ground, can become cheaper by 25% compared to the parking underground, which added to their greater sustainability causes are indicated in peripheral areas where there is land available or can be booked ground at the urban planning.

- It is noteworthy that the current legislation urbanist in Spain does not collect specific above ground parking lots, parcels used may be used to support any other use. Also the uses defined by the various Plans General clearly not collect the parking above ground as a dotacional use. Facing a future sustainability would proceed a review of the planning regulations, especially laws that develop later General Plans.

Final conclusion: In summary it can be said that both the global economic cost and investment in resources is lower in the parking above ground to underground. Regarding the economic cost by 18% and compared to investment in resources by 40%.
It is needed to study and redesign the implantation above ground in order to increase these differences.

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