# METHODOLOGY TO ASSESS THE IMPACT OF THE INTRODUCTION OF NEW TECHNOLOGIES IN SMART CITIES

Pablo E Branchi, Carlos Fernández-Valdivielso and Ignacio R Matías-Maestro

Smart Cities Institute - ISC. Universidad Pública de Navarra (UPNA). Campus de Arrosadía, S/N.
31006 Pamplona. Tfno. +34 948 169288. pebranchi@hotmail.com, carlos.fernandez@unavarra.es, natxo@unavarra.es
Received: 13/oct/2014 - Accepted: 12/dec/2014 - DOI: http:/dx.doi.org/10.6036/7388

# METODOLOGÍA PARA EVALUAR EL IMPACTO DE LA INCORPORACIÓN DE NUEVAS TECNOLOGÍAS EN CIUDADES INTELIGENTES

**ABSTRACT:**
We are facing a revolution of digital and communication systems, where the role of technology will keep growing up exponentially. It is transforming society, and has high impact on infrastructure, transport systems, buildings and in public spaces. Urban areas are rebuilding the traditional technological scenario, with systems that create new needs, discovering new realities, and seeking new solutions. The aim of this paper is to establish a methodology to set an assessment tool for different technologies in terms of their usefulness and consequences, and to consider the impact of their applications. With it, policy makers and influencers can evaluate the advantages of each initiative, the virtues of the available technologies and systems towards their application in Smart Cities.

Keywords: Smart Cities, Urban infrastructures, New technologies, Assessment methodologies, Social implications

**RESUMEN:**
Estamos frente a una revolución producto de los sistemas digitales y de comunicación, donde el papel de la tecnología continuará creciendo exponencialmente. Está calando profundamente en la sociedad, y tiene un alto impacto en las infraestructuras, los sistemas de transporte, en los edificios y en el espacio público. En el ámbito urbano se reconfigura el escenario tradicional tecnológico, con sistemas que generan nuevas necesidades, descubriendo nuevas realidades que buscan nuevas soluciones. El objetivo de este trabajo es el de establecer una metodología para la elaboración de una herramienta de evaluación para las diferentes tecnologías en función de su utilidad y consecuencias, contemplando la incidencia de sus aplicaciones. Con ella se podrán evaluar, por parte de políticos y técnicos prescriptores, las ventajas y desventajas de cada iniciativa, las virtudes de las tecnologías y sistemas disponibles, y el modo óptimo de su aplicación en las Ciudades Inteligentes.

**Palabras clave**: Ciudades Inteligentes, Infraestructuras urbanas, Nuevas Tecnologías, Metodologías de evaluación, Implicaciones sociales.

## 1.- INTRODUCTION

For decades, experts have been studying the role that the city and its inhabitants play in the advent of new technologies. Some authors feared for a digital disaster, contrasting the tele-presence as a negation of space for time [1], how the concentration of movements, money and information, can turn the geographical space [2], or perceiving virtual city as dissolution of reality [3]. Others contributed to the vision of the city as a complex ecosystem that metabolizes energy, materials and information, transforming them into goods and services [4]. New technologies allow greater socialization behaviors in new spaces, and the XXI century will establish appropriate conditions to create a civilized urbanity based on information flows [5].

With new technologies, cities will be made of buildings and infrastructures that could be seen as the hardware, and networks that will form the software: a civic ‘intelligence’, building intelligent spaces. (‘intelligence building’ reads as ‘secret services building in English, so better use ‘’ and ,) It brings new standards for social organization [6] and the role of information and communication technologies are essential, with the duty to guarantee the ability for citizens to understand these new tools and avoid any socio-technological exclusion. It will be necessary to remove the ‘fear of the unknown’, try to learn the way to study it, and to provide analysis tools to understand how to best apply these new systems. Thanks to the implications of new technologies, the priorities are relationships and movements, where everything is interconnected, which require new logics, new analytical tools and new concepts [7]. In the digital-city, new technologies will help improve the management of communication networks, mobility and energy, but the



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com

implementation and monitoring of those systems remains the Achilles heel of urban planning [8]. The city loses its fears and embraces the dominant role of technologies, acquiring the title of Smart City (SC), the natural context for this work.

Simulating the behavior of different systems and testing scenarios (dropping ‘future’ as ‘future scenarios’ reads as scenarios that will be developed in the future, and not ‘scenarios about the future’) improve the sustainability of cities. Furthermore, the use of simulation tools provides a fair assessment for designing strategies to support designers from the early stages of decision making [9]. New methodologies need to be aligned with the main aspects of sustainability: environmental, social and economic [10], and processed with a systemic vision. Those aspects should be designed in order to identify emerging features and improve every area of opportunity, through technological, economic, social and political improvements [11]. In this work, we describe the process that led us to the development of a methodology for the technologies and systems analysis in urban environments, developing a useful tool to assess the effect of those systems in SC. We set the general criteria, as well as how to interrelate them, by defining a methodology based on the combination of both quantitative and qualitative variables that will help achieve a rating to evaluate the application of technologies and systems, and their immediate effects.

Cities and their planning cannot be detached from the technologies that shape them, and they still hold a future of great evolution. Therefore, an open, scalable and revisable instrument is presented, capable of analyzing any technology, system or urban infrastructure that could be part of new SC strategies. The basis of the methodology is detailed, as well as the analysis process based on the study of different initiatives and joint work with experts from the Spanish Smart Cities Network (RECI), analyzing their implanted systems. Finally, the results obtained after the assessment of more than 50 systems and technologies are presented, before concluding on the usefulness of the tool and highlighting future steps.

## 2.- DEVELOPMENT

### 2.1.- SCOPE OF WORK

Many authors have made a critical review of the literature trying to define what a SC is, from a sociological [12] [13] or economic perspective [14] [15]. Others even opposed to this term by considering it a fashion fad [16]. However, it seems clear that it has enough depth in public spheres and is widely accepted by numerous organizations, institutions and scientific world. This new term must question both the assumptions and contradictions involved in its concept [12]. It is yet difficult to precisely define SC, given the large spectre of different elements involved and the multiple approaches.

Numerous ranking systems have been developed both in Europe [17] and Spain [18], but the authors behind them recognize that the parameters used are not completely quantifiable, due to the vagueness of the SC term itself. That is why the methodology developed in this paper - besides offering a great tool to help better define SC strategies and the choice of systems and technologies to apply - can provide a methodology to compare SC from an objective point of view.

To evaluate this tool, Pamplona City Council was contacted and its municipal strategy initiatives under development were analyzed [19]. The Smart City Spanish Network (RECI) [20] was also approached in order to collect data on their SC initiatives. The 18 RECI cities with which we have worked have shown interest in the tools we propose with this methodology. In fact, comments from experts from these cities have helped us outline the main concepts to focus on and the first scheme indicators. Different systems of strategic definition have been studied [21][22][23] as well as several SC cases were analyzed [24][25] to define the main areas of focus.

While this focus remains large given the complexity of SC and all the ramifications involved, there is one strong consensus among experts: Mobility. The second major focus which has emerged is Energy efficiency. The third most important aspect of SC is less clearly defined, and we have encompassed it under the concept of Quality of life, which includes areas such habitability, waste management, pollution and environmental management, and services. This segmentation does not seek to catalog solutions. The idea is rather to recognize their mainstreaming - the same technology can affect more than one areas at a time - which seems appropriate in order to weigh different solutions in each area with the tool developed here, and to evaluate the overall impact on a SC strategy.

While assessing the concept of SC, we can’t afford to underestimate the potential negative impact of the spread of new technologies. Local policies should emerge to support an appropriate planning of urban cyberspace [26]. A City cannot be labeled as Smart simply because of its adoption of sophisticated ICT [12], and must urbanize the deployed technologies, making them accessible and useful to the people they affect directly [13].

## 2.2.- PROPOSED DEVELOPMENT OF AN ASSESSMENT TOOL

The tool proposed in this work should allow the emergence of easily identifiable data to evaluate the different technologies available to city managers, policy makers and urban planners. For this task, a number of technology analysis systems have already been studied. In the early 70s, the term Technology Assessment (TA) [27] is introduced, and in the 90s we saw the emergence of the idea that TA should take into consideration the impact of emerging technologies on societies and their environments [28]. Since then, TA has been seen as a scientific, interactive and communicative process, studying the social implications of new technologies in the urban fabric. [29].

Because of SC’s constant evolution, there are no universal tools that can be applied to all TA studies. It requires new approaches to adapt to new demands [30]. Several methods to define appropriate indicators to assess the environmental and sustainable performance of cities have been proposed [31] , as well as new hybrid approaches for the selection of emerging technologies by building index [32] (‘by building index’ syntax doesn’t work, but I can’t change because I’m not sure of the sentence, I’ll let you tweak). However, these methods are not specific to the field of SC, so it is pertinent to develop a methodology exclusively focused on technologies applicable to SC.

Due to the multiplicity of factors, the complexity lies in defining a model that will incorporate all the different layers of analysis and help determine whether a solution being examined is the most appropriate in terms of meeting the needs at the root at any given project. The model must be able to assess and quantify in a relational and permanent way both the initial problem to solve and the instruments to achieve the expected results. Criteria should be defined in order to be crossed-checked in a double-entry matrix with several elements that will constitute the Impact, through a series of variables such as functionality, expected results and consequences. There will be another series of variables composing the Background: personal, social, urban, environmental, economic and energy requirements [33]. The Impact and the Background will be crossed-checked while quantified variables will be defined. This will enable us to compile them and reach a final grade for each technology. The methodology must have a fair balance between quantitative and qualitative variables to make sure it is both effective and flexible, as well as relevant to any system or technology to be applied in the city. This will be the Technology Assessment Matrix (TAM).

## 2.3.- TECHNOLOGY ASSESSMENT MATRIX (TAM)

The final score for a particular technology will be the result of the combination of multiple mesured elements and their consecutive average (Fig.1). In each box, a value from previously defined indicators is placed, and an overall result will be obtained by combining each line and column respectively. By compiling the partial results, an average of the final grade (TT) will be obtained.

The consecutive scaling of different and interrelated concepts gives an objective and balanced result. From this scheme, the matrix is developed in a way that takes into account the concepts proposed for both the Background and the Impact. The following table (Table I) shows the analyzing process for the TAM.

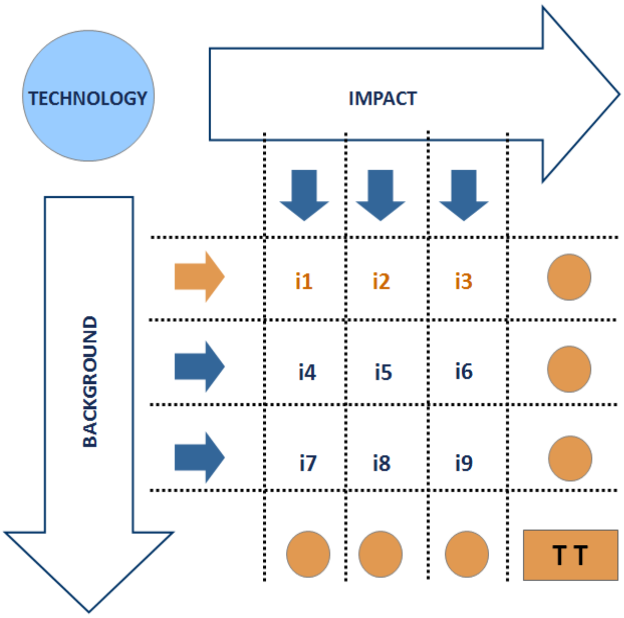


*Fig.1. TAM evaluation process.*

| Technology (name) | | IMPACT | | | Total |
|---|---|---|---|---|---|
| | | 1. Functionality | 2. Expected results | 3. Consequences | |
| BACKGROUND | a. Citizen | 1.a | 2.a | 3.a | **Ta** |
| | b. Social | 1.b | 2.b | 3.b | **Tb** |
| | c. Urban | 1.c | 2.c | 3.c | **Tc** |
| | d. Environment | 1.d | 2.d | 3.d | **Td** |
| | e. Economic requirements | 1.e | 2.e | 3.e | **Te** |
| | f. Energetic requirements | 1.f | 2.f | 3.f | **Tf** |
| **Total** | | **T1** | **T2** | **T3** | **TT** |

*Table I: Technology Assessment Matrix (TAM): Main Concepts and qualification*

By combining each Background concept with Impact issues, a numerical data will be obtained in each box: a value that goes from 1 (lowest impact) to 5 (highest impact) according to a number of indicators, which will allow us to make the distinction between the different impacts on each element of the background the technology is set to have. Each line and column generates subtotals of the global balance of each criterion in the sum of elements of the environment (T1, T2, T3), and the full impact of that technology (Ta, Tb, Tc, ...) that can be assessed. By averaging the subtotals for each row and column, the final result of a particular technology will be obtained as a whole. As an example, the impact of each Impact criterion in the different elements of the Background will be graded as shown in the following (Table II).

| **1. Functionality** | **Poor (1)** | **Average (2)** | **Good (3)** | **Very Good (4)** | **Excellent (5)** |
|---|---|---|---|---|---|
| a. Citizen | | | **O** | | |
| b. Social | | **O** | | | |
| c. Urban | | | | **O** | |
| d. Environment | | | | **O** | |
| e. Economic Req. | **O** | | | | |
| f. Energetic Req. | | | | | **O** |

*Table II: Assessment process for a particular technology*

The final result of the impact from the technology's Functionality on all the elements of the environment will be (Eq.1):

$$1.a = 3 \qquad 1.b = 2 \qquad 1.c = 4 \qquad 1.d = 4 \qquad 1.e = 1 \qquad 1.f = 5$$

$$T1 = (3 + 2 + 4 + 4 + 1 + 5) / 6 \qquad \mathbf{T1 = 3.17} \tag{1}$$

To determine which value is assigned to each box, indicators and variables must be defined to be used with each concept. For this, an initial suggestion of five potential indicators that could be used in different criteria is presented (Tables III, IV and V).

| **1.FUNCTIONALITY** | **Poor (1)** | **Average (2)** | **Good (3)** | **Very Good (4)** | **Excellent (5)** |
|---|---|---|---|---|---|
| **a. Citizen** | Impossible to be used by non-experts | Not easily usable. Requires prior knowledge or other complex systems | Easy to use, but requires simple systems and subscriptions | Semi-automatic system. Requires other simple systems | Automatic system. It requires no other systems |
| **b. Social** | Distorts the normal social functioning | Slightly affects relationships in urban life | Does not affect life in society by its functionality | Allows an improvement in social relations | Optimizes social relationships |
| **c. Urban** | New buildings and infrastructures should be built | New infrastructures should be built | Does not affect the physical urban environment | Uses existing infrastructures | Improves existing infrastructures |
| **d. Environment** | Hinders the current environmental management | Does not allow any environmental management | Facilitates environmental management | Provides improvements to environmental management | Automatizes environmental management systems |
| **e. Economic Requirement** | Has a cost higher than 20 pct. of the problem to solve | Has a cost lower than 20 pct. of the problem to solve | Does not involve any expense, does not generate income | Improves sales and services, making it a profitable investment | Generate direct income once installed |
| **f. Energetic Requirement** | Requires new energy sources | Requires new energy infrastructure | No need for new energy infrastructure | It does not use energy | Optimizes the energy consumption of other systems |

*Table III: Concepts and indicators to evaluate Functionality*

Both positive and negative elements are taken into account when analysing the overall impact. The fact that a system requires additional energy sources or technologies represents a negative impact because of the additional needs regardless of the positive impact the system may bring. A system could be inexpensive and readily usable, for example a computer application working in real time, but if every citizen need to have a smart phone (additional elements) to use the system, and the phones must be charged (requires an energy source), the negative impact overall could offset the positive effects the system may have. Also, we have to take into account the security risks associated with computer systems, such as power outages and hacking.



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com

| 2.RESULTS | Poor (1) | Average (2) | Good (3) | Very Good (4) | Excellent (5) |
|---|---|---|---|---|---|
| **a. Citizen** | Negatively affects people's lives | Produces no improvement for citizens | Produces slight improvements on people's lives | Produces considerable improvements on people's lives | Produces major improvements on people's lives |
| **b. Social** | Adversely affect community life | It does not affect life in society | Produce slight improvements in the community life | Improves social life in the community | Optimizes urban life and communication in society |
| **c. Urban** | Adversely affect existing infrastructures | It does not affect existing infrastructures | Brings infrastructure improvements | Optimizes existing infrastructure | Optimizes infrastructure and improves public spaces |
| **d. Environment** | Produces environmental damage occurs | Produces no environmental damage or improvement | Produces minor environmental improvements | Optimizes environmental conditions | Significantly improves the environmental conditions |
| **e. Economic Requirement** | Very expensive system (more than 15 years of amortization) | Expensive system (more than 10 years of amortization) | Not very expensive system (more than 5 years amortization) | Low investment (more than 2 years of amortization) | Immediate net income |
| **f. Energetic Requirement** | More energy consumption than prior to system installation | No energy consumption improvement | Energy improvement in less than 20 pct. | Energy improvement in more than 20 pct. | Energy improvement in more than 50 pct. |

*Table IV: Concepts and indicators for evaluate Expected results*

| 3.CONSEQUENCES | Poor (1) | Average (2) | Good (3) | Very Good (4) | Excellent (5) |
|---|---|---|---|---|---|
| **a. Citizen** | Affects any of the three areas | No improvement in any of the three areas | Improvements in just one area | Improvements in two areas | Improvements in the three areas: m, e, q |
| **b. Social** | Security risks to the IT system | Additional security systems required | No security risk | Optimizes security | Improves security and data protection |
| **c. Urban** | Negatively affects the public space | No change in urban environment | Improvements in public space | Improvements in public space and buildings | Urban regeneration of degraded areas |
| **d. Environment** | Contaminates the environment (acoustic and pollution) | Contaminates the environment (acoustic only) | Does not contaminate | Reduces contamination by less than 20 pct. | Reduces contamination by more than 20 pct. |
| **e. Economic Requirement** | Requires expensive maintenance and updates | Requires expensive periodic updates | Does not require expensive updates | Scalable, and updates bring improvements. | Optimizes system operation and/or produces savings in other systems |
| **f. Energetic Requirement** | Uses polluting energy sources | Depends on external sources of energy | Generates its own energy for self-consumption | No energy required | Can provide clean energy |

*Table V: Concepts and indicators for evaluate Consequences*

Once indicators are established, the next step is to define the link between the technology and the different elements of SC strategies. Correction values must be applied to the score obtained on the TAM depending on mobility, energy efficiency and quality of life. It is not intended to define specific indicators in each area, since each one will have its own strategy, but to define a tool capable of assessing the overall functioning of all variables that affect a SC. Therefore, in these three areas, each factor will be combined with the other criteria. For that, these areas will have a display of 5 indicators each, scoring from 0.2 to 1 in steps of 0.2. If a technology gets a specific TT scoring in the TAM, upon the application of these correction values, the impact can vary significantly in the strategy. A technology can be highly valued by the TT, but have only a positive impact on one area of the overall SC strategy. When the proposed technology or system generates a greater impact on the three main axes (m; e; q), the rate will be increased (Table VI).



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com

| COEFFICIENTS | Very low impact (0,2) | Low impact (0,4) | Average impact (0,6) | High impact (0,8) | Very high impact (1,0) |
|---|---|---|---|---|---|
| **m. Mobility** | Does not affect mobility | Control systems, without mobility improvement | Provides management and information improvements | Mobility improvements | Mobility and management improvements |
| **e. Energy Efficiency** | No impact on Energy efficiency | 10 pct. improvements in Energy efficiency | 30 pct. improvements in Energy efficiency | 50 pct. improvements in Energy efficiency | Greater than 70 pct improvement in Energy efficiency |
| **q. Quality of Life** | No impact on Quality of Life | Provides new information to citizens | Improved services management | Reduces pollution, improves air quality | Improves management and reduces polition |

*Table VI: m, e y q indicators*

The TT score, once the mobility coefficient is applied, will be called TTm; the Energy Efficiency will be designated as TTe, and the one for Quality of life, TTq. The new overall scoring adjusted to these three concepts will be named TTg (Table VII).

| | Mobility Coef. (m) | | Energy Eff. Coef. (e) | | | Quality of Life Coef. (q) |
|---|---|---|---|---|---|---|
| | **Technology (name)** | | **IMPACT** | | | **Total** |
| | | **1. Functionality** | **2. Expected results** | **3. Consequences** | | |
| **BACKGROUND** | **a. Citizen** | 1.a | 2.a | 3.a | | **Ta** |
| | **b. Social** | 1.b | 2.b | 3.b | | **Tb** |
| | **c. Urban** | 1.c | 2.c | 3.c | | **Tc** |
| | **d. Environment** | 1.d | 2.d | 3.d | | **Td** |
| | **e. Economic requirements** | 1.e | 2.e | 3.e | | **Te** |
| | **f. Energetic requirements** | 1.f | 2.f | 3.f | | **Tf** |
| | **Total** | **T1** | **T2** | **T3** | | **TT** |
| | **TTm** | | **TTe** | | | **TTq** |
| | | | | | | **TTg** |

*Table VII: Technology Assessment Matrix (TAM): Complete*

## 2.4.- THEORETICAL MODEL PERFORMANCE

Technologies may have an impact on one, two or three of the areas outlined above. For example, a system could have a TT score of 4.29, which is an high score (since the maximum would be 5). However, a coefficient of 0.2 linked to Mobility could be applied, while the impact in terms of Energy efficiency could result in a coefficient of 0.8, and for the Quality of life the coefficient could be 0.4. Then (Eq.2):



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com

TTg = ( TTm + TTe + TTq ) / 3
TTg = ( 4,29*0,2 + 4,29*0,8 + 4,29*0,4 ) / 3
TTg = ( 0,858 + 3,432 + 1,716 ) / 3 (2)
TTg = 6,006 / 3
**TTg = 2,002**

Different scenarios can be used as an example to explain how best criteria should apply to the allocation of the corresponding coefficients.

a- A traffic management system: produces improvements in mobility management (coefficient m = 0.6) helps to reduce pollution (q = 0.8), and produces minimal energy improvements (e = 0.2)
b- The implementation of electric vehicles policies: produce improvements in mobility management (m = 0.6), reduces pollution (q = 0.8) and produces an energy consumption improvement over 50 pct (e = 0, 8)
c- The promotion of cycling: improves mobility (m = 0.8), reduces pollution (q = 0.8) and produces full energy savings (e = 1)
d- The promotion of e-government: improves city management and reduces pollution by paperless (q = 1), indirectly provides improvements to mobility by reducing unnecessary travels (m = 0.8) and slightly reduces energy consumption (e = 0.4)

In some of the previous examples, no improvement occurs, but it is considered appropriate to maintain a minimum ratio of 0.2 because in any new system there are positive side effects (eg, avoiding unnecessary travel, which affects energy efficiency). When qualifying technologies by functionality, results and consequences, those negative effects are taken into account.

The process is complete by obtaining the overall score for an applicable technology in SC, and a quick viewing of partial qualifications for different areas is available on the TAM. The computerized matrix (Fig.2) shows data for each item as well as TT and TTg total scoring. A specific letter is assigned, indicating the value of such technology to be applied in SC environments. Through these letters, TT Label indicates the actual value of the technology, and the SC Label determines the 'weight' of the system in a SC strategies.

| TECNOLOGÍA O SISTEMA | Descripción | LABEL TT | B |
|---|---|---|---|
| NOMBRE | Descripción | | |

| Coeficiente Movilidad ( m ) | | Coeficiente Eficiencia Energética ( e ) | | Coeficiente Calidad de Vida ( q ) | | LABEL SC | C |
|---|---|---|---|---|---|---|---|
| No afecta a la movilidad | 0,2 | Busca mejoras del 70% en ef. ener. | 1 | Ofrece información al ciudadano | 0,4 | | |

| EVALUACIÓN | | IMPACTO 1. Funcionalidad | | | 2. Resultados esperados | | | 3. Consecuencias | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTORNO | a. Usuario / Ciudadano | Sistema automático. No requiere otros sistemas | 1.a | 5 | No produce mejoras para el ciudadano | 2.a | 2 | Mejoras en dos de los aspectos | 3.a | 4 | Ta | 3,67 |
| ENTORNO | b. Social | No afecta a la sociedad | 1.b | 3 | No afecta la vida en sociedad | 2.b | 2 | Optimiza la sensación de seguridad | 3.b | 4 | Tb | 3,00 |
| ENTORNO | c. Urbano | Mejora infraestructuras existentes | 1.c | 5 | Mejora espacio urbano e infraestructuras | 2.c | 5 | Mejoras al espacio público | 3.c | 3 | Tc | 4,33 |
| ENTORNO | d. Medioambiente | Facilita gestión ambiental | 1.d | 3 | Optimiza condiciones medioambientales | 2.d | 4 | Reduce la contaminación >20% | 3.d | 5 | Td | 4,00 |
| ENTORNO | e. Requisitos económicos | Costo superior al 20% del problema a solucionar | 1.e | 1 | Costoso (>10 años amort.) | 2.e | 2 | Sin actualizaciones costosas. | 3.e | 3 | Te | 2,00 |
| ENTORNO | f. Requisitos Energéticos | No requere nuevas infraestructuras | 1.f | 3 | Mejora consumo > del 50% | 2.f | 5 | Depende de fuentes externas de energía | 3.f | 2 | Tf | 3,33 |
| Total | | T1 | | 3,33 | T2 | | 3,33 | T3 | | 3,50 | TT | 3,39 |
| RESULTADOS SMART CITY | | TTm | | 0,68 | TTe | | 3,39 | TTq | | 1,36 | TTg | 1,81 |
| | | LABEL m | | E | LABEL e | | B | LABEL q | | D | | |

*Fig.2: TAM matrix computerized.*



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com

# 3.- RESULTS

## 3.1.- CASE STUDY

Thanks to the agreement signed with the City Council, we were able to jointly evaluate already implemented systems in the strategy of Smart City of Pamplona [19] and, in association with RECI experts, we studied other initiatives also implemented in their cities. It was also considered appropriate to evaluate systems in other cities outside the Spanish territory, assessing a number of projects which have become international benchmarks, such as the city of Amsterdam, in The Netherlands, and the new urban development of Songdo, in South Korea.

The premise of this methodology is to study all types of technologies and systems for SC. Therefore, the study focused on initiatives devoted to ICT projects such as the development of web applications for citizen information; combined systems which improve infrastructure management systems (auto-adjustable lighting, citizen cards); or less technological but equally efficient initiatives in areas of SC, such as the promotion of bicycle use.

## 3.2.- OBTAINED RESULTS

A comparative graph of the results is presented (Fig.3), with a ranking from 'high' to 'low' for TTg scoring, and a summary (Fig.4) with the 58 studied technologies and systems.

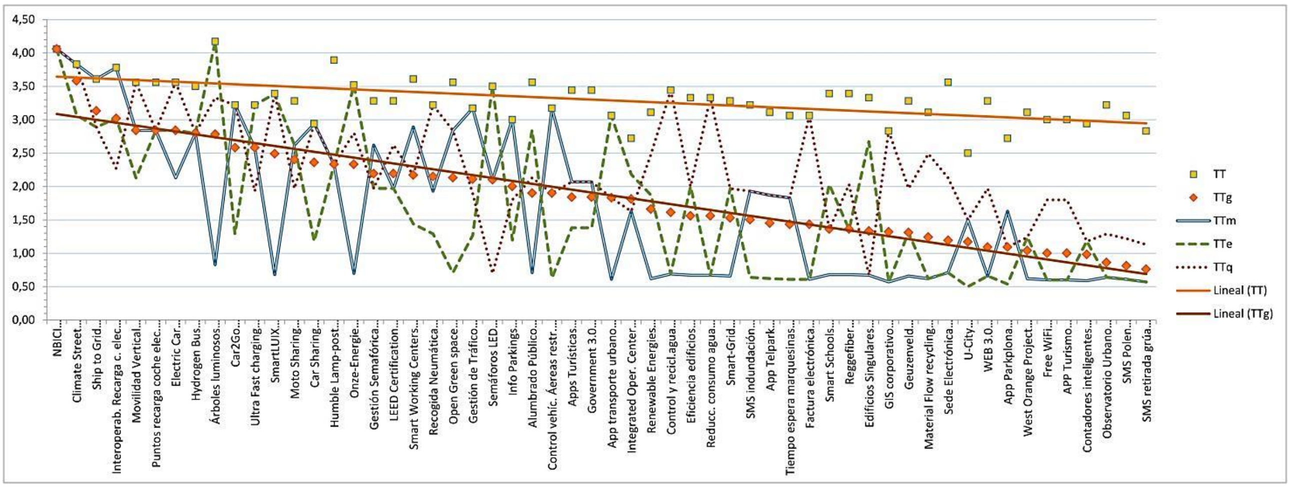


*Fig.3: Graphic comparing the technologies assessed with TAM.*

After this analysis, we were able to confirm that the methodology allows for objective and comparable scores, regardless of their nature and complexity, in the aggregate value for the technology (TT) and also in its weighing when applied in each SC area (TTm, TTe, TTQ), as well as in an overall score for an SC strategy (TTg). The results showed a pattern of TT scores ranging between 3.00 and 4.00 (88%), which are relatively high scores and perhaps too homogeneous. This results from the fact that all the systems analyzed were from SC strategies already being implemented. However, by applying the (m, e and q) correction coefficients the TTg score provides more variability, even dropping below 1.00 in some examples, which demonstrates that this methodology could be useful for decision-making.

| Ciudad | Nombre | Descripción | TT | Label TT | TTg | Label SC | TTm | Label TTm | TTe | Label Tte | TTq | Label TTq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PAMPLONA | Observatorio Urbano | Gestión de datos a disposición del ciudadano | 3,22 | B | 0,86 | E | 0,64 | E | 0,64 | E | 1,29 | D |
| | SMS retirada grúa | Servicio SMS por retirada de vehículos pro grúa | 2,83 | B | 0,76 | E | 0,57 | E | 0,57 | E | 1,13 | D |
| | SMS indundación | Avisos por SMS por riesgo inundación | 3,22 | B | 1,50 | D | 1,93 | C | 0,64 | E | 1,93 | C |
| | SMS Polen | Aviso por SMS del nivel de polen en la ciudad | 3,06 | B | 0,81 | E | 0,61 | E | 0,61 | E | 1,22 | D |
| | Free WiFi | Zonas de acceso libre a iunternet en espacios públicos | 3,00 | B | 1,00 | E | 0,60 | E | 0,60 | E | 1,80 | C |
| | APP Turismo | Aplicación web para información turística en teléfonos inteligentes | 3,00 | B | 1,00 | E | 0,60 | E | 0,60 | E | 1,80 | C |
| | Eficiencia edificios | Optimización de consumo energético en edificios públicos | 3,33 | B | 1,56 | D | 0,67 | E | 2,00 | C | 2,00 | C |
| | Alumbrado Público | Mejora sistemas gestión y regulación alumbrado público | 3,56 | A | 1,90 | C | 0,71 | E | 2,84 | B | 2,13 | C |
| | Semáforos LED | Cambio de luminarias en semáforos a tecnología LED | 3,50 | B | 2,10 | C | 2,10 | C | 3,50 | B | 0,70 | E |
| | Contadores inteligentes | Sustitución de contwadores para permitir telemetering | 2,94 | B | 0,98 | E | 0,59 | E | 1,18 | D | 1,18 | D |
| | Edificios Singulares | Aplicación de energías renovables en edificios | 3,33 | B | 1,33 | D | 0,67 | E | 2,67 | B | 0,67 | E |
| | Recogida Neumática | Sistema de recogida neumática de residuos en casco histórico | 3,22 | B | 2,15 | C | 1,93 | C | 1,29 | D | 3,22 | B |
| | Movilidad Vertical | Colocación de rampas y ascensores públicos | 3,56 | A | 2,84 | B | 2,84 | B | 2,13 | C | 3,56 | A |
| | Gestión Semafórica | Sistemas de gestión inteligente centralizada de la red semafórica | 3,28 | B | 2,19 | C | 2,62 | B | 1,97 | C | 1,97 | C |
| | Gestión de Tráfico | Centro de Control de tráfico integrado | 3,17 | B | 2,11 | C | 3,17 | B | 1,27 | D | 1,90 | C |
| | Control vehic. Áereas restr. | Sistemas de control de acceso para vehículos áreas restringidas | 3,17 | B | 1,90 | C | 3,17 | B | 0,63 | E | 1,90 | C |
| | Info Parkings | Sistemas de información mediante carteles en zonas públicas | 3,00 | B | 2,00 | C | 3,00 | B | 1,20 | D | 1,80 | C |
| | App Parkplona | Aplicación disponibildiad plazas de aparcamiento de rotación | 2,72 | B | 1,09 | D | 1,63 | D | 0,54 | E | 1,09 | D |
| | App Telpark | Sistema de pago vía web para aparcamiento limitado | 3,11 | B | 1,45 | D | 1,87 | D | 0,62 | E | 1,87 | C |
| | Puntos recarga coche elec. | Distribución de puntos de recarga para coche eléctrico | 3,56 | A | 2,84 | B | 2,84 | B | 2,84 | B | 2,84 | B |
| | Interoperab. Recarga c. elec | Sistema de interoperabilidad entre ciudades para recarga coche elec. | 3,78 | A | 3,02 | B | 3,78 | A | 3,02 | B | 2,27 | C |
| | Car Sharing | Coche eléctrico Compartido | 2,94 | B | 2,36 | C | 2,94 | B | 1,18 | D | 2,94 | B |
| | Moto Sharing | Moto eléctrica compartida | 3,28 | B | 2,40 | C | 2,62 | B | 2,62 | B | 1,97 | C |
| | NBICI | Sistema de alquiler público de bicicletas con tarjeta ciudadana | 4,06 | A | 4,06 | A | 4,06 | A | 4,06 | A | 4,06 | A |
| | Tiempo espera marquesinas | Paneles con información tiempo de espera en marquesinas bus | 3,06 | B | 1,43 | D | 1,83 | C | 0,61 | E | 1,83 | C |
| | App transporte urbano | Aplica<ción smartphone con información transporte público | 3,06 | B | 1,83 | C | 0,61 | E | 3,06 | B | 1,83 | C |
| | Sede Electrónica | Sistemas de gestión ciudadano a través de web municipal | 3,56 | A | 1,19 | D | 0,71 | E | 0,71 | E | 2,13 | C |
| | Factura electrónica | Gestión de pagos electrónicos mediante firma digital | 3,06 | B | 1,43 | D | 0,61 | E | 0,61 | E | 3,06 | B |
| | GIS corporativo | Gestión de información municipal geoposicionada | 2,83 | B | 1,32 | D | 0,57 | E | 0,57 | E | 2,83 | B |
| AMSTERDAM | West Orange Project | Visores de consumo energético en viviendas | 3,11 | B | 1,04 | D | 0,62 | E | 1,24 | D | 1,24 | D |
| | Geuzenveld | Smart metering en un barrio completo | 3,28 | B | 1,31 | D | 0,66 | E | 1,31 | D | 1,97 | C |
| | Ship to Grid | Puntos de recarga para barcos y cruceros eléctricos | 3,61 | A | 3,13 | B | 3,61 | A | 2,89 | B | 2,89 | B |
| | Ultra Fast charging | Puntos de recarga rápida para coches eléctricos | 3,22 | B | 2,58 | B | 2,58 | B | 3,22 | B | 1,93 | C |
| | Smart Schools | Sistemas de gestión energética en colegios públicos | 3,39 | B | 1,36 | D | 0,68 | E | 2,03 | C | 1,36 | D |
| | Climate Street | Proyecto piloto en una calle comercial del centro de la ciudad | 3,83 | A | 3,58 | A | 3,83 | A | 3,07 | B | 3,83 | A |
| | Reggefiber | Colocación de fibra óptica para gestión de datos | 3,39 | B | 1,36 | D | 0,68 | E | 1,36 | D | 2,03 | C |
| | Smart-Grid | Despliegue de una red de gestión energética en el municipio | 3,28 | B | 1,53 | D | 0,66 | E | 1,97 | C | 1,97 | C |
| | Onze-Energie | Cooperativas ciudadanas para instalación de aerogeneradores | 3,52 | A | 2,33 | C | 0,70 | E | 3,52 | A | 2,80 | B |
| | Smart Working Centers | Centros de Co-working | 3,61 | A | 2,17 | C | 2,89 | B | 1,44 | D | 2,17 | C |
| | Apps Turísticas | Aplicaciones para smart-phones con información para turistas | 3,44 | B | 1,84 | C | 2,07 | C | 1,38 | D | 2,07 | C |
| | Car2Go | Coche eléctrico Compartido | 3,22 | B | 2,58 | B | 3,22 | B | 1,29 | D | 3,22 | B |
| SONGDO | Open Green space | Sistema de áreas verdes, peatonales y ciclables | 3,56 | A | 2,13 | C | 2,84 | B | 0,71 | E | 2,84 | B |
| | Material Flow recycling | Política de reciclaje para todos los materiales de construcción | 3,11 | B | 1,24 | D | 0,62 | E | 0,62 | E | 2,49 | C |
| | LEED Certification | Todos los edificios certificados con protocolos LEED | 3,28 | B | 2,19 | C | 1,97 | C | 1,97 | C | 2,62 | B |
| | Renewable Energies | Incorporar energías renovable sen edificios | 3,11 | B | 1,66 | D | 0,62 | E | 1,87 | C | 2,49 | C |
| | Control y recicl.agua | Recuperacion agua de lluvia | 3,44 | B | 1,61 | D | 0,69 | E | 0,69 | E | 3,44 | E |
| | Reducc. consumo agua | Automatización para obtener un 30% de ahorro en consumo agua | 3,33 | B | 1,56 | D | 0,67 | E | 0,67 | E | 3,33 | B |
| | Electric Car | Centros de recarga del vehículo eléctrico con energ. Fotovoltaica | 3,56 | A | 2,84 | B | 2,13 | C | 2,84 | B | 3,56 | A |
| | Hydrogen Bus | Autobuses públicos propulsados pro hidrógeno | 3,50 | B | 2,80 | B | 2,80 | B | 2,80 | B | 2,80 | B |
| | Integrated Oper. Center | Control de tráfico, seguridad y servicios públicos centralizado | 2,72 | B | 1,81 | C | 1,63 | D | 2,18 | C | 1,63 | D |
| | WEB 3.0 | Centros conferencia integrados, e-health, e-education | 3,28 | B | 1,09 | D | 0,66 | E | 0,66 | E | 1,97 | C |
| | Government 3.0 | Big Data analytics, Telegestión | 3,44 | B | 1,84 | C | 2,07 | C | 1,38 | D | 2,07 | C |
| | U-City | Servicios web para usuarios para generar la Ciudad Ubicua | 2,50 | C | 1,17 | D | 1,50 | D | 0,50 | F | 1,50 | D |
| OTROS | SmartLUIX | Alumbrado público LED tele-gestionado y autoregulado | 3,39 | B | 2,49 | C | 0,68 | E | 3,39 | B | 3,39 | B |
| | Humble Lamp-post | Red de antenas y sensores en farolas para gestión datos urbanos | 3,89 | A | 2,33 | C | 2,33 | C | 2.33 | C | 2.33 | C |
| | Árboles luminosos | Incorporación de nanotecnologías para generar luz noche en árboles | 4,17 | A | 2,78 | B | 0,83 | E | 4,17 | A | 3,33 | B |

*Fig.4: Matrix summarizing all technologies assessed with TAM.*



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com

## 4.- CONCLUSIONS

In a Smart City (SC) Strategy, many initiatives can arise, but their real impact are virtually impossible to foresee until the strategies are fully implemented. Using a dynamic tool that provides assessments, and uses coefficients for corrections, can significantly improve planification during the long road that involves all urban strategy and can help avoid pitfalls stemming from fashions and interests [34]. The study of urban realities and the potential impact of systems or technologies on the city should not be simplified.

All SC should use such a tool to assess its realities, from both top-down and bottom-up angles, and take into consideration both objective and subjective aspects. Here we have presented a methodology which attempts to capture the largest number of relevant criteria and variables that should be considered. For the development of this methodology, analytical principles are used to obtaining an objective score based on the sum of indicators, both quantitative and qualitative, considering the various overlapping elements which interact in a city. It has been useful to assess that some systems work better than others in some areas, while some of them may have a greater overall impact on the strategy because they affect more than one aspect of SC.

This constitutes the first step in defining the basis of our methodology and surely multiple revisions will follow, especially regarding the nature of the indicators used. That is why we will continue to work with the most active Spanish stakeholders in the field, analyzing their strategies and technologies. Among the next steps, it is necessary to carry on testing the tool in various cities and to refine the indicators, using the experience in real cases. It is also essential to develop a manual with guidelines on how to better use this tool in order to minimize the subjectivity in test results. Also, we are working on a second matrix in which the combined impact of different technologies and systems are evaluated from the individual TAM data, and we expect to obtain a system to rate global SC strategies. The results from this second matrix will be published in due course.

## ACKNOWLEDGEMENTS

We really appreciate the collaboration of the Smart-Cities Institute at the Public University of Navarra, as well as all members of the RECI implication, without whose support would not have been possible to obtain so valuable information.

## BIBLIOGRAPHY

[1] Virilio P. *El cibermundo, la política de lo peor*. 1st edition. Cátedra, 1997. 112p. ISBN 84-376-1574-7

[2] León F. "Metapolis: la ciudad deconstruida", *Astrágalo*. July 1998, Nº 9, p. 17-41

[3] Fernández Martorell C. "De la ciudad de Dios a la ciudad virtual". *Astrágalo*. September 1999, Nº 12, p. 69-75

[4] Hernández Pezzi C. "Artefactos de los nuevos sistemas urbanos". *Astrágalo*. December 2000, Nº 16, p. 71-83

[5] Mitchel W. *E-TOPIA, Urban life, Jim-but not as we know it*. 1st edition. The MIT press, 2000. 184p. ISBN 0-262-13355-5

[6] Castells M (ed.). *La Sociedad Red: una visión global.* 1st edition. Alianza Editorial, 2006. 560p. I.S.B.N.: 978-84-206-4784-5 (1st english edition, *The network society*, 2004)

[7] García Vázquez C. *Ciudad Hojaldre, Visiones urbanas del siglo XXI*. 1st edition. Gustavo Gili, 2004. 230p. ISBN 978-84-252-1970-2

[8] Fusero P. *E-City, digital networks and cities of the future*. 1st edition. List, 2008. 160p. ISBN 978-88-95623-06-1

[9] Tumini I, Higueras-García E. "Alcances y limitaciones de las herramientas de simulación para el estudio del microclima urbano". *DYNA Energía y Sostenibilidad*. ENERO 2013. Vol. 2-1 p.1-17. DOI: http://dx.doi.org/10.6036/ES6921

[10] Caro-Carretero R, García-Jiménez F. "Proceso de toma de decisiones de sostenibilidad en un proyecto técnico municipal". *DYNA Energía y Sostenibilidad*. ENERO 2014. Vol. 3-1 p.[1-14]. DOI: http://dx.doi.org/10.6036/ES7188

[11] Morales-Varela A, Rojas-Ramírez J, Hernández-Gómez L et al. "Modelación de la dinámica de sistemas: un enfoque de redes de Petri". *DYNA Management*. January 2014. Vol. 2-1 p.[1-13]. DOI: http://dx.doi.org/10.6036/MN7089

[12] Hollands, Robert G.: "Will the real smart city please stand up?" *City*. 2008, 12 (3), p.303- 320

[13] Sassen S. *Talking back to your intelligent city*. McKinsey and Company, 1 de febrero de 2011. Available Online: http://voices.mckinseyonsociety.com/talking-back-to-your-intelligent-city/ [Accessed: 10 March 2014]

[14] Caragliu A, del Bo C, Nijkamp P. *Smart cities in Europe*. Serie Research Memoranda 0048; VU University Amsterdam. 2009. Available Online: fttp://zappa.ubvu.vu.nl/20090048.pdf [Accessed: 10 October 2013]

[15] Shapiro JM. "Smart cities: Quality of life, productivity, and the growth effects of human capital". *Review of Economics and Statistics*. 2006, 88, p. 324-335.

[16] Borja J. *Ciudades Inteligentes o cursilería interesada*. Blog Otras miradas. Diciembre 2013. Available Online: http://blogs.publico.es/otrasmiradas/1395/ciudades-inteligentes-o-cursileria-interesada/ [Accessed: 14 April 2014]

[17] Giffinger R, Fertner C, Kramar H, et al. *Smart Cities: Ranking of European Medium-Sized Cities*. University of Technology: Vienna, 2007. Available Online: http://www.smart-cities.eu/download/smart_cities_final_report.pdf [Accessed: 15 November 2013]

[18] Achaerandio R, Bigliani R, Curto J, et al. *Smart Cities Analysis in Spain 2012 - The Smart Journey*; IDC España, 2012. Available Online: http://www.portalidc.com/resources/white_papers/IDC_Smart_City_Analysis_Spain_EN.pdf [Accessed: 18 November 2013]

[19] Ayuntamiento de Pamplona. Definición de la estrategia Smart City Pamplona. Available Online: http://www.pamplona.es/verDocumento/verdocumento.aspx?idDoc=264537 [Accessed: 4 November 2013]

[20] *Red Española de Ciudades Inteligentes*. Available Online: http://www.redciudadesinteligentes.es/sobre-la-red/quienes-somos/ampliar.php/Id_contenido/301/v/0/ [Accessed: 5 November 2013]

[21] IESE Business School, *Cities in Motion - Index 2014*. Available Online: http://www.iese.edu/research/pdfs/ST-0333-E.pdf (Accessed: 6 August 2014)

[22] Cohen, Boyd: *Smart Cities*. Available Online: http://www.boydcohen.com/smartcities.html (Accessed: 8 august 2014)

[23] AENOR: *El Papel de las Normas en las Ciudades Inteligentes Informes de Normalización.* Available Online: http://www.esmartcity.es/images/ESMARTCITY/media/content/20140723-aenor-papel-normalizacion-ciudades-inteligentes.pdf (Accessed: 24 July 2014).

[24] Neirotti, P.; De Marco, A.; Cagliano, A.C.; Mangano, G.; Scorrano, F.: "Current trends in Smart City initiatives: Some stylized facts", *Cities* 38 (2014); pp. 25–36

[25] Ojo, Adegboyega; Curry, Edward; Janowski, Tomasz: *Designing next generation Smart City initiatives: harnessing findings and lessons from a study of ten Smart city programs*. Twenty Second European Conference on Information Systems, Tel Aviv, 2014. p.1-14

[26] Aurigi A, Graham S. "Virtual Cities, Social Polarisation and the Crisis in Urban Public Space", *Journal of Urban Technology*. 1997, Vol.4, Number 1. p. 19-52

[27] Coates JF. "Technology Assessment – A Tool Kit". *Chemtech.* 1976 (June), p. 372-383.

[28] Porter AL. "Technology Assessment". *Impact Assessment.* Summer 1995, Volume 13. p. 135-151

[29] Decker M, Ladikas M (eds.). *Bridges between science, society and policy technology assessment - methods and impacts*. 1st edition. 2004. Springer Verlag. 252p. ISBN 978-3-662-06171-8

[30] Tran TA, Daim T. "A taxonomic review of methods and tools applied in technology assessment". *Technological Forecasting & Social Change.* 2008, 75, p. 1396-1405

[31] Diakaki C, Grigoroudis E, Stabouli M. "A risk assessment approach in selecting environmental performance indicators". *Management of Environmental Quality: An International Journal*. 2006. Vol. 17 Iss: 2, p.126-139

[32] Lucheng H, Xin L, Wenguang L. "Research on emerging technology selection and assessment by technology foresight and fuzzy consistent matrix". *Foresight.* 2010. Vol. 12, Iss: 2, p. 77-89

[33] Branchi P, Fernández-Valdivielso C, Matías I, *City & Technology: An analysis matrix to serve citizens*, International Conference on New Concepts in Smart Cities (SmartMILE), Dec. 201. IEEE, pp. 1-5. DOI: 10.1109/SmartMILE.2013.6708179

[34] Brugmann J. *Welcome to de urban revolution.* 2010. 1st edition. Bloomsbury Press. 344p. ISBN 978-1-60819-092-8



Publicaciones DYNA SL -- c) Mazarredo nº69 -3º -- 48009-BILBAO (SPAIN)
Tel +34 944 237 566 – www.revistadyna.com - email: dyna@revistadyna.com