CREATION AND DESIGN OF A GUIDELINED MODEL FOR THE MANAGEMENT OF PUBLIC URBAN SPACES AND SERVICES

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ABSTRACT

The objective of this project is the creation of a guidelined management model to optimize public spaces and urban services.

The indicators composing the computerized Balanced Scorecard of the model provide information of the subsystems that make up the spaces and its utilities in four strategic blocks that allow their expansion.

The model is founded on the basis of systematically collecting data and then processing the data to create quality indexes from the analyzed sections, depending on the level of degradation of its subsystems, as well as the estimated repair costs. This information makes it possible to prioritize the type of intervention to be made by the manager.

The purpose of this model is to be used, in the future, to estimate the durability of the different elements that compose the roads and to manage them in a more sustainable way.

The model was tested on the urban sprawl of Mataró (Barcelona), which consists of a total of 141,5 km of roads and 331 crossroads, analyzed with its public furnishings and fixtures.

The purpose of this article is to present the parameterised management model created and tested in the Building Laboratory of the Polytechnic University of Catalonia to optimise the management of public urban spaces and services.

The idea of creating this management model arose from the need to keep urban spaces and services in optimal conditions of use to prevent the risk of users having accidents and to meet society's requirements in general for quality, safety, suitability of use and environmental control. In the past, all efforts have focused on generating new infrastructures, thus, to a certain extent, neglecting existing stock, which generally becomes defective and obsolete.

Moreover, there are studies that show the cost associated with lack of maintenance [1]. The cost of no maintenance has two components: costs associated with upgrading work and with deficient service, in other words, if no maintenance is performed, the levels of deterioration become such that they end up having a negative impact on users. The latter cost is difficult to evaluate due to the diverse nature of additional costs that could be involved (longer journeys, more consumption of time and energy, users' physical and psychological inconvenience, etc.).

Therefore, current trends need a new approach focused on upgrades, whether these are total or partial, and on furthering what is known as "Maintenance Culture".

In this regard, the Town Council of Mataró and the Building Laboratory expressed their joint interest in conducting research to obtain technical and economic data to

produce reliable maintenance planning and management of the municipality's road system. Both parties' commitment was recorded in a collaboration agreement. The latter's objective was to implement an audit on the state of repair of the municipality's public highways, establish quality indicators, produce a catalogue on the current condition of urban spaces and services detailing the elements they consist of, existing street furniture, their state of use and necessary maintenance.

In this article, "study of the public highway" is understood to mean the complete inventory of the dimensions, materials, adaptability, types of existing defects, their location and severity, and their analysis for every one of the following urban elements: road, pavement, kerbing (understood as all the kerbs, drainage channels, tree pits and garage entrances) and street furniture. This inventory is created on the basis of field work, which involves inspecting highway stretches and collecting information.
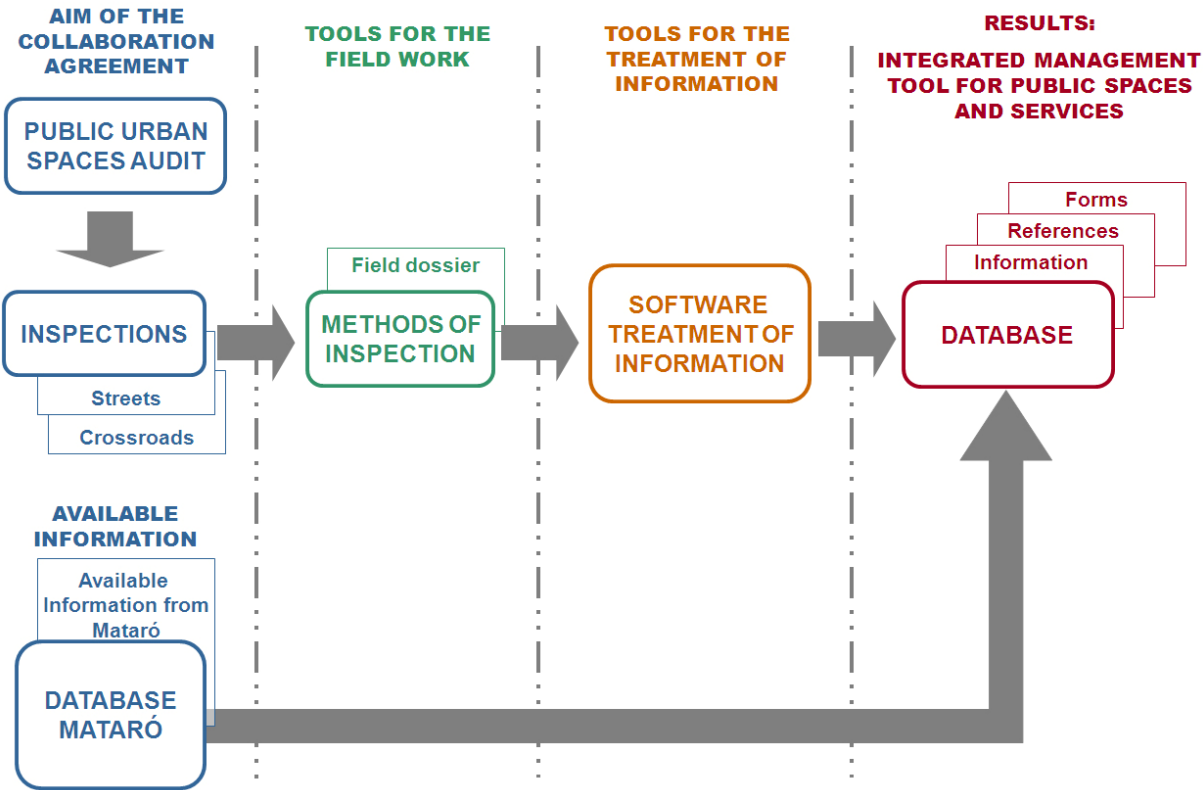

Figure. 1 "Start diagram to obtain the management model"

1.- Obtaining the Information

One of the major difficulties that are come across when implementing a parameterized management model is the uniformity of criteria when collecting information. That is why field documentation has been created that facilitates ordered collection of data and its assessment within some specific objective parameters agreed by all the inspectors.

In addition, the various variables for possible types of defects in the highways have been classified. The studies conducted by the City Council of Barcelona in this regard were taken as a reference in this phase of the study [2].

The field documents, consisting of data sheets, were generated with a view to them being implemented electronically by PDA (Personal Digital Assistant) equipment. The latter is easy to use in the field as it is small and data can be inserted directly in a digital format, thus making it quicker to enter them in a database. These data sheets have five sections for describing the current situation of the stretches inspected.

The first contains general information pursuant to municipal identifying parameters, which makes it possible to locate the stretch to be inspected geographically and provide actual data on its dimensions.

The second describes the section of the stretch insofar as road and lanes, pavements and kerbings are concerned, as well as the materials these elements consist of. The extent to which architectural barriers have been removed in these elements can also be studied.

The third section contains a diagram or sketch of the stretch inspected, which synthesises the information collected in a visual manner. The location of the street furniture is included in this sketch.

The fourth section is for the assessment of the state of repair of the elements forming the stretch inspected, as well as the quantification of the defects detected and an appraisal of the possible reason for them. This level of deterioration is assessed taking into account the parameters in Table 1:

Appraisal of Severity	Description of the Defect	Value
Good condition	No defect observed.	0
Slight	Defects not very pronounced and not very inconvenient, either for vehicles or for people with reduced mobility.	1
Considerable	A defect that does not represent any danger, but which users can notice.	2
Serious	An important defect that is dangerous for vehicular traffic and a serious threat to the state of repair of the rest of the highway.	3
Very serious	A defect that threatens road safety and represents a real danger to users. It means that the stretch is not in use and needs immediate corrective action.	4

Table. 1 "Assessment of the defects observed in the elements forming the public highway"

The fifth section is for assessing the rate of use, paying attention to parking spaces, loading and unloading areas, emergency exits and special lanes (bus, bicycle, etc.). It also analyses existing overhead lines and the street furniture on the inspected stretch. All the descriptive information referring to the location, dimensions and state of deterioration of these elements is noted and the defects are assessed pursuant to Table 1.

After the inspections have been completed, the data collected are processed to obtain the information needed to manage these spaces by determining the type of actions required to improve the state of repair of the public highway, and the schedule for them, which is prioritised on the basis of objectively parameterised indicators.

2.- Information Processing

The processing of the data obtained is possible due to the creation of a computer tool that automates the entire indicator calculation process, as well as the definition of the state of repair of the stretches in the street plan. The inspectors can use this tool to enter the information obtained (automatically, if the data was collected using an electronic medium, and manually otherwise) and process them using the system described in the following sections.

2.1.- Rate of Highway Deterioration

The first indicator the computer tool calculates is the Rate of Highway Deterioration (R_{hd}), in other words the overall rate of the stretch inspected considering the state of repair of each and every one of the elements it consists of. This indicator is obtained from the calculation of the weighted average of the partial deterioration rates of the road (R_r)), the pavement (R_p), of the kerbs (R_k) and of the surface elements and/or street furniture (R_{sf}) by using the following formula (eq. 1):

$$R_{hd} = \frac{0,6R_r + 0,2R_p + 0,1R_k + 0,1R_{sf}}{0,6 + 0,2 + 0,1 + 0,1} \ (1)$$

First the computer tool uses the following functions to obtain the partial deterioration rates:

- Partial deterioration rates of the road (R_r): (eq. 2)

$$R_r = \sum \frac{W * DL * \frac{S_A}{S_T}}{W_{[max]} x DL_{[max]}} x100 \ (2)$$

Where:

W = weight of defect "X" (for the programme produced for the Town Council of Mataró a scale of values was established between 1 and 3, which differentiates the varying importance of some defects compared with others).

DL = deterioration level generated by defect "X", assessed at the time of the inspection (using the values in Table 1).

SA = road surface affected by defect "X".

ST = total road surface.

W[max] = maximum value of the scale of values referring to the weight of the defects (in the programme for the Town Council of Mataró, this value is always 3).

DL[max] = maximum value of the scale of values referring to the deterioration level (according to Table 1, this value is always 4).

- Partial deterioration rates of the pavement (R_p): (eq. 3)

$$R_p = \sum \frac{W * DL * \frac{S_A}{S_T}}{W_{[max]} x DL_{[max]}} x 100 \ (3)$$

Where:

W = weight of defect "X" (for the programme produced for the Town Council of Mataró a scale of values was established between 1 and 3, which differentiates the varying importance of some defects compared with others).

DL = deterioration level generated by defect "X", assessed at the time of the inspection (using the values in Table 1).

SA = road surface affected by defect "X".

ST = total road surface.

W[max] = maximum value of the scale of values referring to the weight of the defects (in the programme for the Town Council of Mataró, this value is always 3).

DL[max] = maximum value of the scale of values referring to the deterioration level (according to Table 1, this value is always 4).

- Partial deterioration rates of the kerbs (R_k): (eq. 4)

$$R_k = \sum \frac{W * DL * \frac{S_A}{S_T}}{W_{[max]} x DL_{[max]}} x 100 \ (4)$$

Where:

W = weight of defect "X" (for the programme produced for the Town Council of Mataró a scale of values was established between 1 and 3, which differentiates the varying importance of some defects compared with others).

DL = deterioration level generated by defect "X", assessed at the time of the inspection (using the values in Table 1).

SA = road surface affected by defect "X".

ST = total road surface.

W[max] = maximum value of the scale of values referring to the weight of the defects (in the programme for the Town Council of Mataró, this value is always 3).

DL[max] = maximum value of the scale of values referring to the deterioration level (according to Table 1, this value is always 4).

- Partial deterioration rates of the surface elements and street furniture (R_{sf}): (eq. 5)

$$R_{sf} = \sum \frac{W*DL*\frac{U_A}{U_T}}{W_{[max]}xDL_{[max]}}x100 \ (5)$$

Where:

W = weight of the defect "X" (for the programme produced for the Town Council of Mataró, it was established that all the possible defects that can affect street furniture always have the same importance, so the W value is always 1).

DL = deterioration level generated by defect "X", assessed at the time of the inspection (using the values in Table 1).

UA = street furniture units (of the same type) affected by defect "X".

UT = total units of the same street furniture.

P[max] = valor máximo de la escala de valores referentes al peso de las lesiones (en la aplicación para el Ayuntamiento de Mataró, este valor siempre es 1).

DL[max] = maximum value of the scale of values referring to the deterioration level (according to Table 1, this value is always 4).

The system is capable of generating detailed and individual information for each of the partial indicators, as well as establishing an overall ratio to determine a deterioration parameter comparable to the perception of the user's level of satisfaction of the whole stretch inspected.

3.- Interpretation of the Results

The results of applying formula eq. 1 to obtain the Rate of Highway Deterioration are assessed taking into account the parameters shown below (Table 2).

When the formula R_{hd} (eq.1) is used, a value is obtained, which, according to the interval it is included in, will define the highway's state of repair.

R_{hd} (intervals)	State of Repair	Colour
[0, 1]	Very deteriorated	Dark green
(1, 10]	Deteriorated	Light green
(10, 20]	Deficient	Yellow
(20, 40]	Good	Orange
(40, ∞]	Optimal	Red

Table. 2 "State of repair pursuant to the Rate of Highway Deterioration"

Furthermore, as also shown in Table 2, every RHD is assigned a colour, so that the state of repair of every stretch inspected can be marked on the street plan using a GIS (Geographic Information System) programme (Fig. 2).This is a fast way of obtaining an overview of the urgent intervention needed in certain highways and of the city's state of repair.

Figure. 2 "Use of the Rate of Highway Deterioration in a sector of the urban road network"

A link can be established with the GIS programme between the graphic representation of the urban road network and the alphanumeric information generated from entering the inspection data into the computer tool.

4.- Intervention Schedule

Once the state of deterioration of the road is known, the next important point to be determined is when the corrective operations should be performed (the time margin available for scheduling the actions).

Some criteria have been established to prioritize the interventions needed objectively based on the following parameters:

- The rate of quality of the road obtained from the eq. 1
- Recent actions and expectations of deterioration pursuant to the following regulations of the *Ministerio de Fomento* [Ministry of Development]
    - *Orden del M.O.P.U., de 26/03/80 BOE (31-05-80) Instrucción 6.3-IC Sobre refuerzo de firmes.*
    - *O.C. 9/2002 sobre "Rehabilitación de firmes".*
    - *N.S. sobre renovación de la capa de rodadura en función de los valores del CRT determinados con el equipo SCRIM (1-2-91).*
    - *N.I. sobre el efecto de la renovación del pavimento en la accidentalidad (18-2-91).*
    - *N.S. sobre actuaciones y operaciones en firmes dentro de los contratos de conservación. Mayo-95.*
- The characteristics of the road (on the basis of the data collected in the inspections and studies performed by the corresponding Administration): uses, traffic, noise levels, etc.
- Citizens' explicit requests

Using the first of the criteria established, the interventions will be prioritized according to the data included in Table 3:

Public highway element, reference indicator	Prioritisation of the Interventions				
	Urgent	Short-term	Medium-term	Long-term	Indefinite
	≤ 6 months	≤ 1 year	≤ 3 years	≤ 6 years	> 6 years
Road, R_r	(40, ∞]	(20, 40]	(10, 20]	(1,10]	(0, 1]
Pavement and kerbs, $\frac{R_p+2R_k}{3}$					
Street furniture, R_{sf}					

Table. 3 "Prioritization of the interventions on the various public highway elements pursuant to reference indicators"

The recommendations of the *Colegio de Aparejadores y Arquitectos Técnicos de Barcelona* [Association of Building Surveyors and Architectural Technicians of

Barcelona] [3] were used to define the type of action to perform. According to them, there are four repair types:

- Basic repairs: these are interventions that do not involve an alteration in the normal operation of the infrastructures affected.
- Partial repairs: these are actions that usually affect the normal operation of the infrastructures, although only slightly.
- General repairs: these are operations that involve the replacement of the parts affected, resulting in infrastructures in a optimal state of repair. These interventions involve a shutdown or a significant decrease in normal operation.
- Total repairs: these are actions where the infrastructure has to be replaced, providing the same or better characteristics.

The decision on which type of repair is the most suitable is made on the basis of the calculation of the percentage of highway affected based on the following campaigns:

1. Highway campaign
2. Pavement and kerbs campaign
3. Street furniture campaign

4.1.- Highway Campaign

The extent of the repair in this campaign will depend on the percentage of highway affected by defects in the stretch analyzed. This percentage is defined by applying the following calculation (eq. 6):

$$\% \, road \, affected = \left(\frac{affectation}{LxW}\right) x100 \,\, (6)$$

Where:

L = total length of the highway stretch

W = total width of the road

The type of repair to be performed as far as extent is concerned is determined on the basis of the parameters shown in Table 4:

	Percentage Intervals	Type of Repair
Road Campaign	(0, 30]	Specific repair
	(30, 100]	General repair

Table. 4 "Extent of the repair on roads pursuant to the percentage affected"

4.2.- Pavement and Kerbs Campaign

The extent of the repair in this campaign will depend on the percentage of pavements and kerbs affected by defects in the stretch analyzed. This percentage is defined by applying the following calculation (eq. 7):

$$\% \, pavement \, and \, kerbs \, affected = \left(\frac{affectation}{LxW}\right) x100 \,\, (7)$$

Where:

L = total length of the highway stretch

W = total width of the pavements plus the existing kerbings

The type of repair to be performed as far as extent is concerned is determined on the basis of the parameters shown in Table 5:

	Percentage Intervals	Type of Repair
Pavement and Kerbs Campaign	(0, 75]	Specific repair
	(75, 100]	General repair

Table. 5 "Extent of the repair on pavements and kerbs pursuant to the percentage affected"

4.3.- Street Furniture Campaign

As far as street furniture is concerned, the repairs are always basic, so the intervention does not affect the infrastructure's normal operation.

The extent of the repair will also be conditioned by the percentage of units affected (Table 6):

	Percentage Intervals	Type of Repair
Street Furniture Campaign	(0, 50]	Specific repair
	(50, 100]	General repair

Table. 6 "Extent of the repair on street furniture pursuant to the percentage of units affected"

5.- Estimated Economic Assessment of the Interventions

In the computer tool, all the possible defects in the public highway have been linked to all the possible associated repair actions with an estimate of the cost pursuant to whether the intervention is specific or general.

As a result of this application, approximate economic assessments can be obtained so that economic forecasts can be established and the distribution of municipal budgets facilitated.

Based on the implementation of the management model in the locality of Mataró, it was discovered that every stretch of road needs to be studied in detail to be able to decide on the optimal type of repair at the lowest cost. Table 7 shows the example of applying estimated costs to the repairs associated with an inspected street.

Stretch / crossing code	Cost of the specific repair	Cost of the general repair	Optimal cost of the repair	Optimal repair
A015	2.559,07 €	13.674,94 €	2.559,07 €	Specific
Y415	4.661,65 €	11.397,05 €	4.661,65 €	Specific
A005	2.881,83 €	26.328,91 €	2.881,83 €	Specific
Y560	3.072,74 €	2.040,96 €	2.040,96 €	General
Total Cost	13.175,30 €	53.441,85 €	12.143,52 €	

Table. 7 "Example of applying estimated costs associated with repairs in a street in Mataró"

The results extracted from the application shown in Table 7 are that the optimal repair (which is the most economical) is the combination of a general intervention and three specific ones. However, it should also be considered that the decision to perform specific or general repairs can depend on the need to adapt the stretch or crossing to the urban conditions required.

6.- Conclusions

This article presents a parameterized management model to optimize space management and public urban services to make them more sustainable and safe.

By using the management model designed, the state of repair of urban infrastructures can be determined and the operations needed to keep them fully operational in the future can be planned. Furthermore, monitoring the model improves operation conditions and safety, it facilitates the detection of architectural barriers so they can be removed easily, it makes a more efficient distribution of the economic resources for their upkeep possible and it improves the public image of municipalities.

This system has been implemented for roads, pavements, kerbings and street furniture, so that they can be regulated and balanced, but it can be extended to other elements in public spaces.

The model was tested on the urban sprawl of Mataró (Barcelona), which consists of a total of 141,5 km of roads and 331 crossroads, analyzed with its public furnishings and fixtures.

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