A Methodological Approach for the Assessment of Parametric Costs of Sustainable Urban Roads: An Application to the City of Rome (Italy)

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Abstract. In the context of the maintenance of urban and extra-urban road infrastructures, the need to support Public Administrations in the selection of technological solutions able to, on one hand, pursue compliance with i) environmental issue, ii) urban planning and iii) protection of cultural and landscape heritage regulations, and, on the other hand, to be financially sustainable, is relevant. The aim of the present research concerns the definition of a methodological approach for the assessment of the parametric costs of innovative technological solutions, by taking into account their differentials compared to the traditional ones, i.e. the solutions generally applied in the considered contexts. With reference to twenty roads located into the city of Rome (Italy), assumed as case studies, the parametric costs for the traditional solutions and the innovative ones have been built, by evaluating all the working expenses that occur for their realization. Finally, the cost differentials between them have been highlighted.

Keywords: Urban roads infrastructures · parametric costs · working · evaluation

1 Introduction

It is widely agreed that the construction industry contributes significantly to pollution, resource depletion, waste generation, global warming, and climate change [1]. The last years has been characterized by a scarce public economic resources availability that has determined the increasing need to develop adequate evaluation tools for the optimization of their allocation (especially with reference to the current and relevant European funding) [2]. Within the mentioned framework, the main driver of the building sector has concerned the refurbishment and redevelopment investments [3, 4]. With reference to the topic of the present research, the construction and the maintenance of the road

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infrastructures constitutes an intensive process. The finished structure strongly impacts the aesthetics of the urban context and can affect the noise pollution and, in general terms, the existing ecosystem [5–9].

From a quality point of view, the pavements in urban spaces are one of the largest and significant elements in defining the perception of the urban landscape, both aesthetically and functionally. The surfaces of these areas must respond to multiple needs, by including the perceptive-landscape and historical-iconographic nature and guaranteeing high levels of safety, well-being, usability and liveability. Therefore, the urban infrastructures should have functional requirements according to their type of use that, necessarily, affects the choice of the materials and layings.

The resurfacing of an urban pavement requires, where it is possible, the preservation of the construction traditions of the site, by respecting its material and chromatic characteristics, and by considering climatic and lighting conditions and the needs for comfort, efficiency and sustainability [10].

Effective road design can make a significant contribution not only to mobility, but also to the environment through, for example, the planting of trees, the adoption of specific materials to improve the microclimate, to reduce air and noise pollution, and to increase the resilience of the urban system [11, 12]. In fact, the road pavements construction sector is constantly evolving both to optimise the performance and the durability levels and to pursue goals such as i) the reduction of air pollution, ii) the decrease of noise pollution, iii) the decline of heat island, iv) the increase of the water drainage, v) the improvement of the energy efficiency, vi) the growth of the perceptive quality.

In order to support the Public Administration in the selection of effective technological solutions for the urban road infrastructure, the aim of the present research is to define a methodological approach to compare the costs of traditional technologies and innovative ones. The pursued objective is developed with reference to the case study, i.e. by considering twenty roads in the city of Rome (Italy), and by determining a parametric cost for the construction and maintenance of road infrastructures. The obtained outputs could constitute a valid support for the local Public Administration, within the preliminary assessment phases of the projects, for an effective allocation of the available resources. In fact, the results of the present analysis consists of useful economic references both for the different types of interventions generally carried out and for those related to the innovative solutions.

The paper is organized in the following Sections. In Sect. 2, the methodological approach and its main phases are illustrated. In Sect. 3, the conclusions and possible further insights are drawn.

2 Methodological Approach

The methodological approach proposed in the present research is illustrated with reference to the chosen case study, referred to twenty roads located into the city of Rome (Italy). The assessment of the parametric costs and the determination of the percentage cost differentials between the traditional solutions referred to an ordinary maintenance intervention of the selected roads and the innovative ones, require the following five phases implementation:

1. Systematic analysis of the tendering procedures (active and performed), within the road infrastructures pertaining to the *Dipartimento Sviluppo Infrastrutture e Manutenzione Urbana* (CSIMU) [13], included in the city of Rome. This phase has firstly allowed to identify the categories of workings that mostly contribute to defining the construction costs of the interventions, as well as the main types of project on the road infrastructures.
2. Evaluation of the parametric construction costs per type of performance solution related to the traditional interventions, i.e. defined in the technical and economic documents of the Master Agreement for the "*Ordinary maintenance and emergency maintenance of the roads of the so-called Grande Viabilità, the roads of EUR, the Tramway Headquarters and the relevant works of art (bridges, tunnels, overpasses, subways, etc.) - divided into twelve lots for the three-year period 2021–2023*" (hereinafter the "Master Agreement") [14]. In this phase, the classification of the workings set in the Master Agreement ("superficial", "medium", "deep", "deep-bis") has been borrowed, by considering the macro-categories of workings constituting the roadway (e.g. pavements, and driveway paving). For each of them, an estimated metric calculation has been developed for the assessment of the parametric cost (€/m^2), by adopting the Price List of the Lazio Region updated to 2022 for the unit workings costs identification [15].
3. Determination of the parametric cross-sectional costs per longitudinal linear meter related to the twenty roads included in the case study and with reference to the classification of the traditional interventions reported by the Master Agreement. These values have been assessed by parameterizing the construction costs per linear meter of road, taking into account the actual cross-sectional dimension of the different components for each of the identified twenty roads.
4. Estimation of the parametric construction costs for the designed innovative solutions. This phase has allowed to obtain at both a cost per square meter, by remodeling the cost items of the workings related to the traditional interventions through the improved technological solutions, and at a new parametric cost per longitudinal linear meter for the twenty roads identified as case studies.
5. Calculation of the percentage cost differentials between the traditional solutions referred to a possible ordinary maintenance of the chosen roads and the planned innovative ones.

2.1 Phase 1: Systematic Analysis of the Tendering Procedures

The analysis has been carried out by consulting primarily two online portals made available by the Municipality of Rome, one referring to all workings and services tenders [16], and the other one specifically dedicated to road infrastructure maintenance [17].

In order to draw up a representative framework of the reference context, both the documents of tenders with the traditional procedure and those referring to the Master Agreement have been considered. Firstly, from the processing of the collected data, it has been possible to identify the most recurring workings categories, and, for these, the percentage of incidence on the total cost of the intervention has been calculated. This analysis allows to verify the empirical evidence, by highlighting that the categories of workings related to the driveway component of the road infrastructure (as binder and layering) are those that mostly contribute to the definition of the total intervention cost (Fig. 1).

Following this analysis, a further research has been carried out with reference to the presence (or absence) of possible new costs related to special or specific workings that could not be attributed to the items already included in the regional reference Price List. In this sense, a list of the "new prices" adopted in the consulted economic documents has been drawn up, as a further market reference for the interventions involving these specific workings.

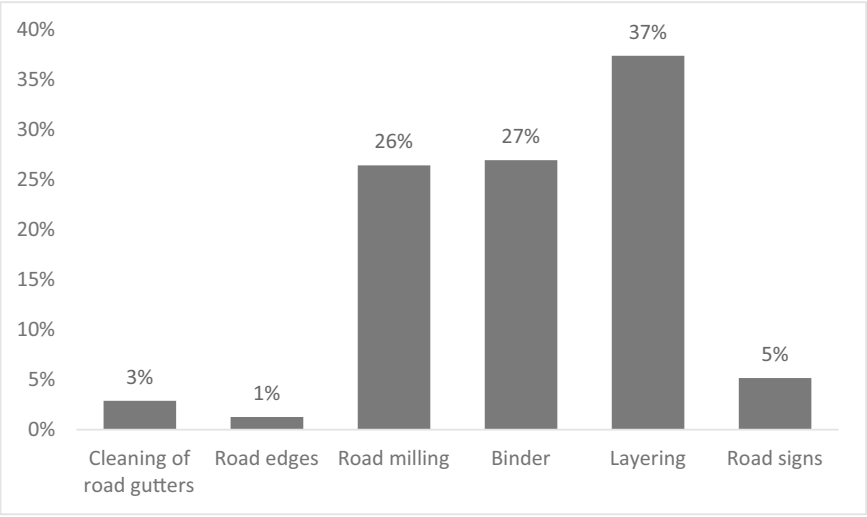

Fig. 1. Main categories of workings in road infrastructure contracts

2.2 Phase 2: Evaluation of the Parametric Construction Costs Per Type of Performance Solution Related to the Traditional Interventions

First of all, it should be highlighted that the analysis of the documentation related to the current Master Agreement has allowed the identification of the different types of performance solution for each type of intervention ("superficial", "medium", "deep" and "deep-bis") and for the macro-category of workings, used as a reference for the parametric costs assessment. In particular, the following macro-categories are identified in the Master Agreement:

– sidewalk;
– paved pavements;
– road paving.

For the workings on the pavements, the following categories are distinguished in relation to the used materials:

- type A - bituminous conglomerate pavement;
- type B - poured asphalt pavement;
- type C - basalt slab pavement;
- type D - concrete pavement;
- type E - paved pavement/porphyry.

As far as the paving is concerned, the main differentiation among the types of intervention regards the specific envisaged workings, which are progressively (from "superficial" to "deep-bis") more substantial and relevant.

In order to determine the parametric cost of each performance solution distinguished by type of intervention ("superficial", "medium", "deep" and "deep-bis") and with respect to the used materials, for the fundamental portions that characterize the road resurfacing interventions (pavements and carriageway), the stratigraphy of the performance solutions defined in the Master Agreement has been analyzed.

The construction unit costs to be associated with the different layers identified in each section relating to the "driveway pavement" and "pavement" components have been borrowed by the Lazio Region 2022 Price List and the unit of measurement has been specified. The aggregation of the different unit prices in the parametric cost of the intervention has been carried out by considering a portion of the road of 1 m^2 (1 m for the length x 1 m for the width).

In this way, to each performance solution a parametric cost has been associated: this differs according to the considered workings, the type of intervention ("superficial", "medium", "deep" and "deep-bis") and the used materials.

As an example, Table 1 reports the analytical calculation for one typological section related to the sidewalk of the Master Agreement. The assessed parametric cost is equal to 47.76 €/m^2.

This type of calculation has been performed for all the traditional materials included in the Master Agreement. The synthesis of this analysis is reported in Tables 2, 3 and 4.

Table 1. Calculation for the sidewalk in bituminous conglomerate - "superficial" type

Working description	Quantity	Unit of measurement	Unit cost [€]	Total cost [€]	Code of the Lazio Region 2022 Price List
Demolition of existent pavement	0.80	m^2	5.61	4.49	A 03 01 015 j
Alignment road edges or substitution (when needed)	0.80	m	25.96	25.96	B 1 06 6 b
Foundation curb	0.01	m^3	185.99	1.86	A 06 01 001 01 a
New paving in bituminous conglomerate	0.80	m^2	19.32	15.46	B 01 05 005

Table 2. Summary of the assessed parametric costs related to sidewalk work [€/m^2]

Type	Bituminous conglomerate	Asphalt	Basalt	Concrete pavements	Paved pavements
Superficial	47.76	49.46	201.32	70.78	159.69
Medium	69.26	70.95	221.60	89.94	186.11
Deep	116.43	118.12	257.92	137.11	
Deep-bis	118.86	120.56	260.36	139.55	

Table 3. Summary of assessed parametric costs related to paving work [€/m^2]

Type	Bituminous conglomerate
A1 – Squared	147.99
A2 – Round	195.61

Table 4. Summary of assessed parametric costs related to road works [€/m^2]

Type	Bituminous conglomerate
B1	12.19
B2	16.25
B3	20.31
B4	34.31
B5	33.26
B6	71.34

2.3 Phase 3 and Phase 4: Determination of the Parametric Cross-Sectional Costs for the Traditional Solutions and for the Designed Innovative Ones

For each of the twenty roads identified as case studies in the city of Rome, an assessment of the parametric costs per longitudinal linear meter of section has been carried out. The selected roads have been defined as representative of the heterogeneity of the city's road system, that includes "main" and "local" types streets. In Fig. 2 the types and the specific roads considered are reported.

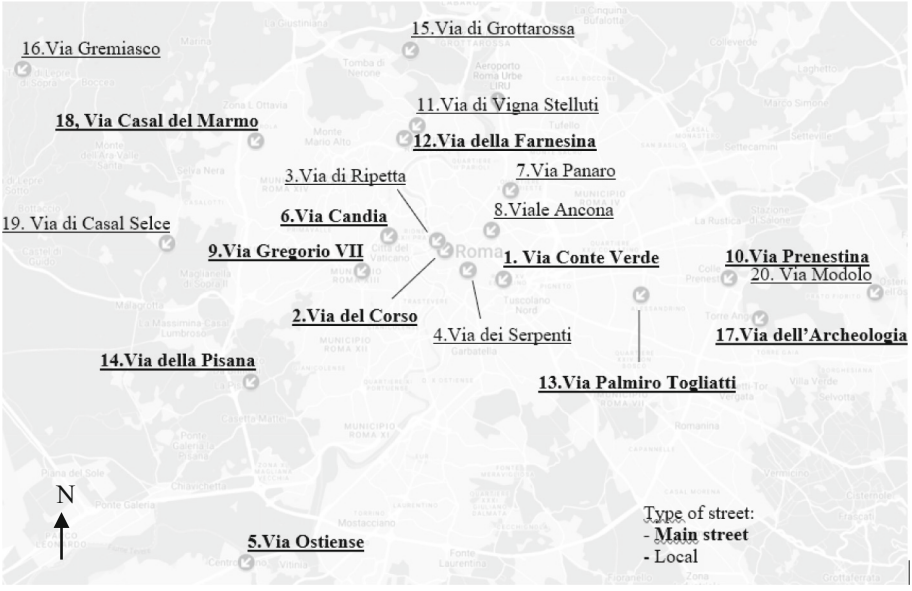

Fig. 2. Identification of the selected twenty roads located in the city of Rome

Table 5. Evaluation of the parametric construction costs for the traditional solutions

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
1	Pedestrian	Bituminous Conglomerate	3.10	12.19	37.79	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Bituminous Conglomerate	10.00	12.19	121.90	
	Driveway	Bituminous Conglomerate	11.50	12.19	140.19	
						487.53
2	Pedestrian	Basalt slabs	9.60	114.67	1 100.83	
		Granite road edges	2.00	93.83	187.66	
	Driveway	Bituminous Conglomerate	5.30	12.19	64.61	
						1 353.10
3	Pedestrian	Basalt slabs	2.60	114.67	298.14	
		Granite road edges	2.00	93.83	187.66	
	Driveway	Pavement paving	7.48	111.18	831.63	
						1 317.43
4	Pedestrian	Bituminous Conglomerate	4.81	12.19	58.63	
		Granite road edges	1.00	93.83	93.83	
	Car Park	Bituminous Conglomerate	6.70	12.19	81.67	
	Driveway	Bituminous Conglomerate	5.64	12.19	68.75	
						302.89
5	Pedestrian	Bituminous Conglomerate	2.60	12.19	31.69	
		Granite road edges	2.00	93.83	187.66	
	Driveway	Bituminous Conglomerate	23.35	12.19	284.64	

(*continued*)

Table 5. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
	Car Park	Bituminous Conglomerate	8.50	12.19	103.62	
						607.61
6	Pedestrian	Bituminous Conglomerate	5.00	12.19	60.95	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Bituminous Conglomerate	5.00	12.19	60.95	
	Driveway	Bituminous Conglomerate	9.00	12.19	109.71	
						419.27
7	Pedestrian	Bituminous Conglomerate	6.32	12.19	77.04	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Bituminous Conglomerate	6.85	12.19	83.50	
	Driveway	Bituminous Conglomerate	5.90	12.19	71.92	
						420.12
8	Pedestrian	Bituminous Conglomerate	5.00	12.19	60.95	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Bituminous Conglomerate	6.55	12.19	79.84	
	Driveway	Bituminous Conglomerate	3.50	12.19	42.67	
						371.12
9	Pedestrian	Bituminous Conglomerate	8.60	12.19	104.83	
		Granite road edges	2.00	93.83	187.66	

(*continued*)

Table 5. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
	Cycle path	Bituminous Conglomerate	3.00	12.19	36.57	
	Car Park	Bituminous Conglomerate	10.00	12.19	121.90	
	Driveway	Bituminous Conglomerate	9.00	12.19	109.71	
	Driveway pref	Bituminous Conglomerate	6.00	12.19	73.14	
						633.81
10	Pedestrian	Bituminous Conglomerate	8.40	12.19	102.40	
		Granite road edges	4.00	93.83	375.32	
	Cycle path	Bituminous Conglomerate	3.00	12.19	36.57	
	Car Park	Bituminous Conglomerate	5.00	12.19	60.95	
	Driveway	Bituminous Conglomerate	20.49	12.19	249.77	
	Quay	Paving in concrete	1.30	64.79	84.23	
						909.24
11	Pedestrian	Bituminous Conglomerate	5.09	12.19	62.05	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Bituminous Conglomerate	5.00	12.19	60.95	
	Driveway	Bituminous Conglomerate	8.67	12.19	105.69	
						416.34
12	Pedestrian	Bituminous Conglomerate	2.95	12.19	35.96	

(*continued*)

Table 5. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Bituminous Conglomerate	12.40	12.19	151.16	
						274.86
13	Pedestrian	Bituminous Conglomerate	10.74	12.19	130.92	
		Travertino road edges	3.00	43.87	131.61	
	Cycle path	Bituminous Conglomerate	2.00	12.19	24.38	
	Car Park	Bituminous Conglomerate	5.68	12.19	69.24	
	Driveway	Bituminous Conglomerate	19.23	12.19	234.41	
	Driveway	Bituminous Conglomerate	7.57	15.85	119.96	
						710.53
14	Pedestrian	Bituminous Conglomerate	2.60	12.19	31.69	
		Travertino road edges	2.00	43.87	87.74	
	Car Park	Bituminous Conglomerate	7.80	12.19	95.08	
	Driveway	Bituminous Conglomerate	7.20	12.19	87.77	
						302.28
15	Pedestrian	Bituminous Conglomerate	3.20	12.19	39.01	
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Bituminous Conglomerate	6.80	12.19	82.89	

(*continued*)

Table 5. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
						209.64
16	Pedestrian	Bituminous Conglomerate	2.58	12.19	31.45	
	Driveway	Bituminous Conglomerate	7.11	12.19	86.67	
						118.12
17	Pedestrian	Bituminous Conglomerate	4.34	12.19	52.90	
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Bituminous Conglomerate	13.23	12.19	161.27	
						301.92
18	Pedestrian	Bituminous Conglomerate	1.35	12.19	16.46	
		Travertino road edges	1.00	43.87	43.87	
	Driveway	Bituminous Conglomerate	8.03	12.19	97.89	
						158.21
19	Pedestrian	Bituminous Conglomerate	2.00	12.19	24.38	
		Travertino road edges	1.00	43.87	43.87	
	Driveway	Bituminous Conglomerate	7.00	12.19	85.33	
						153.58
20	Pedestrian	Bituminous Conglomerate	2.60	12.19	31.69	
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Bituminous Conglomerate	16.36	12.19	199.43	
						318.86

For each road, the existing road section, the main components of the infrastructure (pedestrian, car park, driveway), the characteristics and types of performance solutions adopted for its construction and their main dimensions have been studied. Starting from this analysis, the appropriate costs included in the Lazio Region 2022 Price List have been identified. Then, the costs for one meter of road section have been assessed, taking into account the ordinary maintenance interventions, and the cost of the workings envisaged by the proposed design guidelines has been evaluated. The parametric cost has been obtained in € per meter in the longitudinal direction, since the width of the road and the subdivision of its parts are known both from the survey and from the project. Tables 5 and 6 show, respectively, the parametric costs assessed for the twenty roads, by considering the traditional solutions and the innovative ones.

Table 6. Evaluation of the parametric construction costs for the designed innovative solutions

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
1	Pedestrian	Basalt slabs	3.30	114.67	378.41	
		Granite road edges	1.00	93.83	93.83	
	Car Park	Drainage paving	10.00	138.98	1 389.75	
	Driveway	Draining bituminous conglomerate	11.50	17.07	196.26	
						2 058.25
2	Pedestrian	Basalt slabs	10.00	114.67	1 146.70	
		Granite road edges	2.00	93.83	187.66	
	Driveway	Drainage paving	5.30	138.98	736.57	
						2 070.93
3	Pedestrian	Basalt slabs	3.00	114.67	344.01	
		Granite road edges	1.00	93.83	93.83	
	Driveway	Drainage paving	7.48	138.98	1 039.53	
						1 477.37

(*continued*)

Table 6. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
4	Pedestrian	Drainage paving	5.01	138.98	696.26	
		Granite road edges	1.00	93.83	93.83	
	Car Park	Drainage paving	6.70	138.98	931.13	
	Driveway	Drainage paving	5.64	138.98	783.82	
						2 505.05
5	Pedestrian	Draining bituminous conglomerate	2.60	17.07	44.37	
		Granite road edges	2.00	93.83	187.66	
	Driveway	Draining bituminous conglomerate	23.35	17.07	398.49	
	Car Park	Draining bituminous conglomerate	8.50	17.07	145.06	
						775.58
6	Pedestrian	Draining bituminous conglomerate	3.40	17.07	58.02	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Drainage paving	5.00	138.98	694.88	
	Driveway	Draining bituminous conglomerate	9.00	17.07	153.59	
						1 094.15
7	Pedestrian	Draining bituminous conglomerate	6.32	17.07	107.86	

(*continued*)

Table 6. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
		Granite road edges	2.00	93.83	187.66	
	Car Park	Eco-active screeds	6.85	50.71	347.34	
	Driveway	Draining bituminous conglomerate	5.90	17.07	100.69	
						743.54
8	Pedestrian	Draining bituminous conglomerate	5.00	17.07	85.33	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Draining bituminous conglomerate	6.55	17.07	111.78	
	Driveway	Draining bituminous conglomerate	3.50	17.07	59.73	
						444.50
9	Pedestrian	Basalt slabs	8.60	114.67	986.16	
		Granite road edges	2.00	93.83	187.66	
	Cycle path	Draining colored bituminous conglomerate	3.00	41.04	123.12	
	Car Park	Drainage paving	10.00	138.98	1 389.75	
	Driveway	Draining bituminous conglomerate	9.00	17.07	153.59	

(*continued*)

Table 6. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
	Driveway pref	Draining bituminous conglomerate	6.00	17.07	102.40	
						2 942.69
10	Pedestrian	Draining bituminous conglomerate	8.40	17.07	143.35	
		Granite road edges	4.00	93.83	375.32	
	Cycle path	Draining bituminous conglomerate	3.00	17.07	51.20	
	Car Park	Draining bituminous conglomerate	5.00	17.07	85.33	
	Driveway	Draining bituminous conglomerate	12.30	17.07	209.91	
	Dock	Draining bituminous conglomerate	1.30	138.98	180.67	
						1 045.78
11	Pedestrian	Basalt slabs	5.09	114.67	583.67	
		Granite road edges	2.00	93.83	187.66	
	Car Park	Draining bituminous conglomerate	5.00	17.07	85.33	
	Driveway	Drainage paving	8.67	138.98	1 204.91	
						2 061.57
12	Pedestrian	Draining bituminous conglomerate	2.95	17.07	50.34	

(*continued*)

Table 6. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Draining bituminous conglomerate	12.40	17.07	211.62	
						349.70
13	Pedestrian	Draining bituminous conglomerate	10.74	17.07	183.29	
		Travertino road edges	3.00	43.87	131.61	
	Cycle path	Draining colored bituminous conglomerate	2.00	41.04	82.08	
	Car Park	Draining bituminous conglomerate	5.68	17.07	96.93	
	Driveway	Draining bituminous conglomerate	19.23	17.07	328.18	
	Driveway interrail	Draining bituminous conglomerate	7.57	22.19	167.95	
						990.04
14	Pedestrian	Draining bituminous conglomerate	2.60	17.07	44.37	
		Travertino road edges	2.00	43.87	87.74	
	Car Park	Draining bituminous conglomerate	7.80	17.07	133.11	
	Driveway	Draining bituminous conglomerate	7.20	17.07	122.88	
						388.10

(*continued*)

Table 6. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
15	Pedestrian	Draining bituminous conglomerate	3.20	17.07	54.61	
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Draining bituminous conglomerate	6.80	17.07	116.05	
						258.40
16	Pedestrian	Draining bituminous conglomerate	2.18	17.07	37.20	
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Draining bituminous conglomerate	7.11	17.07	121.34	
						246.28
17	Pedestrian	Draining bituminous conglomerate	9.67	17.07	165.03	
		Travertino road edges	4.00	43.87	175.48	
	Driveway	Draining bituminous conglomerate	10.23	17.07	174.59	
	Cycle path	Colored bituminous conglomerate	2.60	41.04	106.71	
	Car Park	Draining bituminous conglomerate	11.25	17.07	191.99	

(*continued*)

Table 6. (*continued*)

n	Type of function	Material	Length [m]	Unit cost [€/m^2]	Total cost [€/m]	Parametric cost [€/m]
						813.79
18	Pedestrian	Draining bituminous conglomerate	1.35	17.07	23.04	
		Travertino road edges	1.00	43.87	43.87	
	Driveway	Draining bituminous conglomerate	8.03	17.07	137.04	
						203.95
19	Pedestrian	Draining bituminous conglomerate	2.00	17.07	34.13	
		Travertino road edges	1.00	43.87	43.87	
	Driveway	Draining bituminous conglomerate	7.00	17.07	119.46	
						197.46
20	Pedestrian	Draining bituminous conglomerate	2.60	17.07	44.37	
		Travertino road edges	2.00	43.87	87.74	
	Driveway	Draining bituminous conglomerate	16.36	17.07	279.20	
						411.31

Phase 5: Calculation of the percentage cost differentials between the traditional solutions and the innovative ones.

Once calculated the costs both for the traditional and the innovative solutions, the percentage cost differentials between the two types of solutions have been calculated (Table 7) The results have allowed to provide the Municipal Administration with a relevant and useful indication on the main categories of workings that affect the total cost of the maintenance of urban road infrastructures interventions and the relative contribution. It is evident that the main differences occur when a significant change in the materials choice are planned, or new elements are considered for the realization and include in the overall project (e.g. a cycle path).

It should be noted that for both the parametric costs evaluation - traditional and innovative one - the road infrastructure subgrades have been assumed unchanged: therefore, the construction cost of the interventions has been estimated referring only to the surface component of the system.

Table 7. Comparison between the assessed parametric costs of traditional and innovative solutions for the considered twenty roads

No	Traditional solution	Innovative solution	Delta
	Parametric cost [€/m]	Parametric cost [€/m]	
1	487.53	2 058.25	322%
2	1 353.10	2 070.93	53%
3	1 317.43	1 477.37	12%
4	302.89	2 505.05	727%
5	607.61	775.58	28%
6	419.27	1 094.15	161%
7	420.12	743.54	77%
8	371.12	444.50	20%
9	633.81	2 942.69	364%
10	909.24	1 045.78	15%
11	416.34	2 061.57	395%
12	274.86	349.70	27%
13	710.53	990.04	39%
14	302.28	388.10	28%
15	209.64	258.40	23%
16	118.12	246.28	109%
17	301.92	813.79	170%
18	158.21	203.95	29%
19	153.58	197.46	29%
20	318.86	411.31	29%

3 Conclusions

In the present research a methodological approach for the assessment of parametric costs of innovative technological solutions related to urban road infrastructures intervention has been proposed. In particular, the developed operational tool represents a valid reference for the Public Administrations: it allows to calculate the parametric construction

cost differentials between the traditional solutions (those generally applied in the considered contexts) and the innovative ones. In this sense, the approach can be applied at two different levels, from the urban scale to the construction details and technical architectural design specifications. The proposed five phases implementation intends to pursue a harmonic management of maintenance interventions of the urban road pavements, in order to interrupt the current process of fragmentation that frequently characterises the cities' road systems.

The application of the approach to the case study related to twenty roads located in the city of Rome has pointed out, on the one hand, the heterogeneity and richness of the different urban tissues, and, on the other hand, the opportunity to differentiate the intervention strategies consistently with the considered context [18].

The design experimentation activity has been subsequently checked for suggestions and recommendations in order to update the parametric reference costs for maintenance workings (mainly extraordinary) and for performance specifications. In this direction, a dynamic and continuously updatable system of street mapping, starting from the elaboration and updating of digital mapping in open form, could be carried out. Therefore, future insights of the research may concern the development of a digital mapping of the roads within the competence of the CSIMU in GIS environment [19–22], in order to test the management of maintenance interventions of the entire road network and public spaces of the city of Rome and to export the developed approach to other national and international contexts.

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