# Urban Infrastructure Requalification Index: the central viaduct in Brasília

## Índice de Requalificação da Infraestrutura Urbana: o viaduto central em Brasília

Stefano Galimi [I]
Márcio Augusto Roma Buzar [II]
João da Costa Pantoja [III]

**Abstract**

Memories and pride of the past related to cultural places, often provided by the urban infrastructure itself, are resources for urban development and regional identity, which can be recreated, interpreted and re-functionalized to suit current and future generations. This work uses an urban retrofit intervention model in the central area of Brasília, represented by the Galeria dos Estados viaduct, the capital's main arterial road. The methodology adopted for the classification of urban infrastructure according to the Urban Infrastructure Requalification Index (IRU) considers a multi-criteria model based on three parameters: structural, environmental and spatial. The data point to the feasibility of implementing these parameters in the assessment of existing infrastructure, connectors of contemporary cities.

**Keywords**: urban infrastructure requalification index, urban retrofit, road infrastructure, bridges, conservation of modern heritage.

**Resumo**

*Memórias e o orgulho do passado relacionados a locais culturais, muitas vezes proporcionados pela própria infraestrutura urbana, são recursos para o desenvolvimento urbano e de identidade regional, que podem ser recriados, interpretados e re-funcionalizados para atender às gerações atuais e futuras. Para tanto, este trabalho utiliza um modelo de intervenção de retrofit urbano na área central de Brasília, representado pelo viaduto da Galeria dos Estados, principal artéria viária da capital. A metodologia adotada para a classificação da infraestrutura urbana segundo o Índice de Requalificação da Infraestrutura Urbana (IRU) considera um modelo multicritério baseado em três parâmetros: estrutural, ambiental e espacial. Os dados obtidos apontam para a viabilidade de implementação desses parâmetros na avaliação das infraestruturas existentes, conectores das cidades contemporâneas.*

**Palavras-chave:** *índice de requalificação da infraestrutura urbana; retrofit urbano; infraestrutura viária; obras de arte especiais; conservação do patrimônio moderno.*

# Introduction

The transformation of the environment built over the centuries and its symbiotic behavior towards human beings are themes intrinsically related to the architecture that involves societal, economic and cultural changes.

Observing recent years' scenario of urban interventions in road infrastructures, it becomes evident that the need to requalify a Special Work of Art, whether a bridge or a viaduct, has been largely induced by maintenance scarcity factors which, in turn, generate a situation of precariousness of boundary urban spaces. This urgency factor has been accompanied by the ever more important need for reconstruction or refunctionalization of the existing heritage that suffered or went through some situation of deterioration, more or less severe.

Given this context, the urban retrofit, used as a tool for revitalizing cities, is capable of bringing considerable improvements to society, which benefits from urban areas not only for commuting, but also for leisure and entertainment. This type of intervention underpins the prerogatives for the reuse of historic structures as culture renewal centers, social capital incubators and experimental areas for new urban developments.

This work stresses and develops arguments concerning the need to set guidelines for action in listed sites' built heritage, with an integrated approach that comprises social, cultural, environmental and economic phenomena. Therefore, it is necessary to refine the analysis techniques for the intervention in listed buildings with regard to their impact on present-day society.

Modernist buildings are aging, particularly those that use their structure itself to fulfill the ultimate purpose for which they were intended. Bridges and viaducts, also known as Special Works of Art, represent key elements not only for the connection of both neighborhoods in a city and people, but also for the access to healthcare, culture, transportation, among other services. The structural and physical precariousness of an urban infrastructure determines a severe risk for contemporary cities, both in terms of social insecurity, leading to the degradation of urban areas, as well as enormous economic damage to society.

In the spatial and morphological configuration of their main roads, the ancient Romans distinguished two perpendicular axes: the cardo, going from North to South, and the decumanus, going from East to West (Mumford, 1961, apud Freire, 2017).

Likewise, the establishment of the entire infrastructure of Plano Piloto [Pilot Plan] in the city of Brasília is arranged in two mains axes that intersect at a right angle. The Eixo Monumental [Monumental Axis] descends towards Paranoá Lake, while the Eixo Rodoviário [Residential Axis] crosses the whole city, from North to South. The city of Brasília expanded and developed its urbanistic layout starting from this sketched plane (Galimi et al., 2020, p. 142).

Due to late circumstances experienced in the federal capital of Brazil and in the international scenario, questions about retrofit, maintenance and preservation of architectural heritage must begin with a theoretical contextualization, in order to envision practical decision-making. The proposed model, which has the partial structural collapse of the Viaduct over Galeria dos Estados [Gallery of States] as its premise, represents a solid starting point for the maintenance operations of the infrastructural heritage of the Brazilian capital, being the major thoroughfare in Plano Piloto. Alongside considerations about the value of authenticity and integrity of the work conceived by architect Lúcio Costa, an analysis was carried out on the structural performance of the viaduct before and after the retrofit, its morphological changes, intervention process and decision-making after the downfall. In spite of the fact that the protection of cultural heritage is widely recognized by society as a priority, the availability of financial resources is often insufficient or limited. Therefore, it is paramount to use the available resources as efficiently as possible, assessing ways to reduce the financial burden of urban retrofit enterprises to public treasury and increase the durability of modern infrastructural heritage.

## Urban retrofit

Urban retrofit is a practice of intervention on a city scale, able to requalify and repurpose a given area and its urban equipment, in order to improve the standard of living of people who benefit from public spaces. Hence, not only does this concept imply a restoration, but also a replacement of elements that perhaps have become obsolete over time (Negreiros, 2018). In the case of urban infrastructure, analyzed as a booster for the virtue of the cities' road connections, it is necessary to seek effective parameters in order to understand how to target the conservation of Modern Heritage and its subsequent endurance.

The urban requalification of cities, a fundamental premise for the economic and social growth of a country, must begin with the understanding of the existing urban infrastructure in order to support the necessary interventions to be implemented. According to Newton (2013, apud Negreiros, 2017, p. 7), among the most critical themes in the urban field, the aging of the cities' infrastructure subsystems represents a complex issue, especially when it comes to listed cities.

Observing recent years' scenario of urban interventions in road infrastructures, it becomes evident that the need to requalify a Special Work of Art, whether a bridge or an elevated road, has been largely induced by maintenance scarcity factors which, in turn, have generated a situation of precariousness of boundary urban spaces. This emergency has been accompanied by the ever more significant need to reconstruct or refunctionalize the existing heritage that suffered or went through a situation of deterioration, more or less severe.

In Brazil, there is a deficit in strategies aimed at the conservation of public buildings, which leaves many Special Works of Art in precarious structural and functional situations, puts users at risk as well as incurs losses to the national economic sector (Vitório, 2005). According to D'Ayala et al. (1997 apud Ferreira et al., 2013), the valuation of economic and financial losses plays a key role in the implementation of urban planning and retrofit strategies, allowing costs to be reduced while aiming at user safety.

In the case of the city of Brasília, the interventions on material infrastructural heritage, the potential to preserve the proportion of urban scales, as recommended by architect Lúcio Costa, and also to provide a safer use of urban space, are considered the indispensable parameters for the premise of an urban retrofit project. Moreover, in view of the increased concern to protect the listed urban areas, there is a growing demand for the retrofit solution due to cost reduction regarding new constructions. Retrofitting existing buildings is complex and difficult, involving numerous factors at political, decision-making, economic, scientific, technical and other levels (Varum, 2003).

The urban infrastructure of bridges and viaducts, which represents the most complex infrastructural subsystem of all due to issues linked to the possibility of moving within the city not only in a dynamic but also in a safe way, needs to be monitored in order to detect a potential demand for urban retrofit intervention, focusing on the rehabilitation of structures. It is thus essential to provide resources for constant monitoring and modernization of SWA's as they are crucial elements in the road infrastructure network.

Rethinking existing buildings and architectural works on the basis of safety, energy, communications and sustainable infrastructure represents the first step towards a paradigm shift in the evolution of modern cities in Europe and in the world. In order for an intervention to be defined and conceptualized as urban retrofit, it must comprise, within the existing urban space, among others, an integrated, sustainable and structurally safe road transport system, a polycentric city with an efficient public transport system, a dense city capable of supporting the expected increase in population, as well as being flexible and able to face the changes that will inevitably occur over the years (Verones, rinaldi and Rebecchi, 2014).

## The Urban Infrastructure Requalification Index (URI) – methodology

The present work proposes in its methodology the implementation of an Urban Infrastructure Requalification Index – URI – considering a multicriteria model to assess the modern infrastructural heritage that encompasses Special Works of Art. To this end, the study presents the application of an integrated analysis of the urban environment branching out into three sets, or macrodimensions, namely Structural, Installations and Implementation. Eight urban indicators were adopted, having the same unit value. The three dimensions, weighted unevenly to compose the URI, were used to guide the assessment of urban retrofit interventions and, consequently, to classify the urban infrastructure of bridges and viaducts based on those parameters. These scales encompass a set of relevant elements that allow to establish an interaction between the architectural or urban elements and the society as well as the listed heritage of contemporary cities. In addition to improving the understanding of infrastructure performance in urban space, the methodology used aims to determine a simple and easily understandable parameter to properly qualify retrofit interventions. As a practice still largely unexploited in Brazil thanks to the lack of specific legislation on the subject (Negreiros, 2018), urban requalification has the potential to contribute to the preservation of our cities.

Firstly, the methodological approach of research on the various architectural objects related to urban infrastructure, such as bridges and viaducts, must follow a procedure that begins by gathering data on the concerned object's architectural and structural concept. When dealing with this type of work, the dimensional magnitude of the object in question must be made understandable, as well as its insertion in the urban scale of the city, its functional role as a road connection, the safety it provides to commuters whether they travel by means of private or public transport, and so on. As stated by Kohlsdorf and Kohsdorf (2017, p. 56), the evaluation of the urban built environment is based on values that refer to social expectations and morphological dimensions of places, such as bioclimatic, co-presential, economic-financial, expressive-symbolic, functional, topoceptive, etc. For the sake of achieving the general purpose of this study, the proposed methodology aims to evaluate the Special Works of Art of bridges and viaducts with a view to safeguarding Built Heritage.

The methodology adopted for obtaining the Urban Infrastructure Requalification Index – URI – implies the use of a multicriteria model based on the weighted average of three macrodimensions used for urban infrastructure, as follows:

1) Structural (55% weight): a set of 7 structural sub-elements typical of infrastructure, mesostructure and superstructure systems that make up a Special Work of Art (Table 1).

2) Installations/Facilities (15% weight): a set of 5 sub-elements regarding basic, sustainable and technological systems applicable to the infrastructure of bridges and viaducts (Table 2).

3) Implementation (30% weight): a set of 6 sub-elements pertaining to accessibility, landscaping and outdoor elements (Table 3).

Apropos of urban infrastructure Special Works of Art, the structural dimension was normalized to have the greatest weight, calibrated at 55% of the total, and consists of a series of sub-elements which are detailed below.

Figure 1 – URI composition for SWA's chart

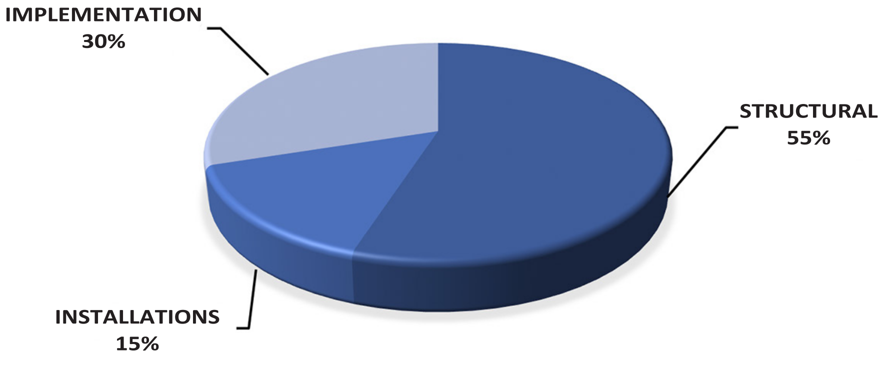



Table 1 – Elements that make up the structural dimension of a SWA

| Structural – Special Work of Art |
|---|
| **1 – Fundation blocks**<br>Structural foundation elements in reinforced concrete, which transfer the heavy load from the superstructures to the soil. |
| **2 – Retaining walls**<br>Structural elements of soil containment (in reinforced concrete). |
| **3 – Deck slabs**<br>Flat elements to support road traffic, supported by horizontal beam elements, such as longerons, stringers and transversines. |
| **4 – Pillars**<br>Vertical structural element, whose function consists of absorbing the stresses originating from the superstructure and consequently unloading them to the soil+foundations infrastructure. |
| **5 – Support system**<br>Connection and static linkage between the deck system and the vertical support system (pillar). |
| **6 – Main girder**<br>Main horizontal elements represented by longeron stringer beams (larger span). |
| **7 – Secondary girders**<br>Secondary horizontal elements represented by transversines (smaller span). |

Source: author.

All structural sub-elements adopted in the table above make up the whole of the load-bearing system of a SWA wherein, for the scope of the case studies presented in this article, all those structural components typical of cable-stayed bridges, such as stays and masts were not considered.

$$STRUCTURE = \frac{\Sigma\,(BLOCKS+CURTAINS/WALLS+SLABS+PILLARS/COLUMNS+SUPPORTS+STRATES/STRINGERS+TRANSVERSINES)}{7}$$

The sets of Installations and Implementation, presented and specified in the following tables, were adjusted in such a way that they represent, respectively, 15% and 30% of the total weight of the Urban Infrastructure Requalification Index. The Installations dimension is represented by a set of five items, of which the main ones belong to the technological sphere related to the infrastructure of bridges and viaducts. Hence, a weight of 15% was assigned to the calculation of the final calculation of the Urban Infrastructure Requalification Index, leaving it as a less significant parameter compared to the Implementation (30%) and the Structural (55%) parameters. The mathematical formula to obtain it results in the following expression:

$$INSTALLATIONS = \frac{\Sigma\,(HVAC + DRAINAGE + LIGHTING + POWER + MONITORING)}{5}$$

Table 2 – Elements that make up the Installations system of a SWA

| **Installations – Special Work of Art (SWA)** |
|---|
| **8 – Internal HVAC system**<br>The purpose of the heating, ventilation and air conditioning system is to control the temperature, humidity, movement, renewal, and air quality of a given environment. |
| **9 – Drainage system**<br>A set of structures that are installed in a given location with the purpose of retaining and transposing rainwater. |
| **10 – Lighting system**<br>The lighting system has its projects and material specifications aimed at energy efficiency, cost reduction and compliance with the minimum photometric requirements stipulated in standards (NBR 5101:1992). |
| **11 – Sustainable energy generation system**<br>The photovoltaic solar energy system that captures light and generates direct current (DC) as a result of photovoltaic effect, which is in turn converted to alternating current (AC). Thereby, electricity is distributed or stored on-site. |
| **12 – Structural monitoring system**<br>Early warning system for the detection of damage to the structure, predicting critical situations and structural failures, reducing intervention times and repair costs. |

Source: author.

Finally, the third dimension, represented by the set of five sub-elements of Implementation, constitutes 30% of the URI and should be considered as:

$$IMPLEMENTATION = \frac{\Sigma\,(ACESSIBILITY + SIDEWALKS + LANDSCAPING + VEGETATION + FURNITURE)}{6}$$

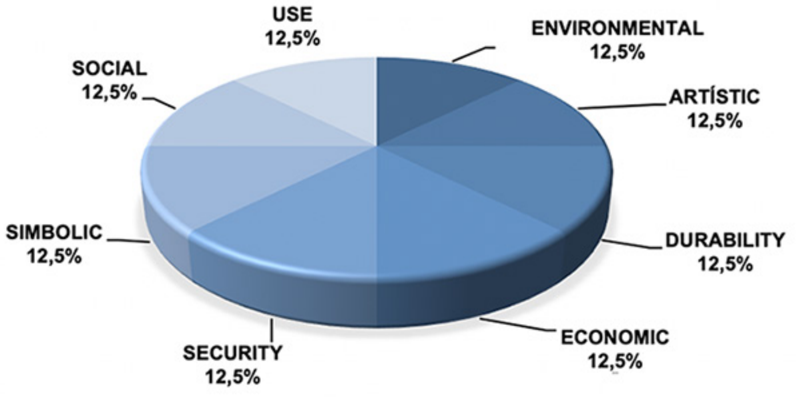
Table 3 – Sub-elements of the SWA Implementation system

| Implementation - Special Work of Art (SWA) |
|---|
| **13 – Acessibility**<br>Possibility to access a place, service, product or information in a safe and autonomous way, without any kind of architectural barrier, benefiting all people, with or without disabilities and in all stages of life. |
| **14 – Sidewalks**<br>The sidewalk is the public space reserved for pedestrians' daily commuting in the city. |
| **15 – Bikeway**<br>A lane intended exclusively for bicycle circulation. |
| **16 – Landscaping**<br>Technique for designing, planning and preserving urban spaces, in order to create micro landscapes, according to aesthetic and sustainable criteria of each place. |
| **17 – Vegetation**<br>Urban greening, characterized by the vegetation that composes the scenery or landscape of cities, has a fundamental role in improving the quality of life of the population, providing municipalities with ecological, aesthetic, economic and social benefits. |
| **18 – Street furniture**<br>Collective term for urban objects and equipment installed on streets and roads for various purposes. |

Source: author.

Based on the bibliography used to elaborate the list of indicators potentially capable of qualitatively defining the urban infrastructure represented by SWA's, eight evaluation parameters were identified for each sub-element contained in the three macrodimensions (Structural, Installations and Implementation) as a means to obtain the URI. The indicators which were chosen to assess the urban infrastructure of bridges and viaducts were environmental, artistic, durability, economic, structural safety, symbolic, social and, finally, usage.

Figure 2 – Chart depicting the composition of the Indicators used to evaluate the SWA's




Source: author.

Following the inclusion of all eight indicators chosen to obtain the Urban Infrastructure Requalification Index – URI, a simplified assessment with YES or NO options must be assigned to each sub-element of the dimensions (structural, installations and implementation), by means of documentary survey and on-site visual analysis, as well as the rich photographic collection available in those cases in which it was not possible to observe the element on the spot. When filling out the evaluation form, a score must be assigned to each specific indicator in each sub-element, resulting in the Parameterized Total cell, referenced on a scale ranging from 0 to 8, where each YES represents an increment by the unit value of 1. As a result, the minimum score is represented by the value of 0/8, and the maximum score by the value of 8/8. This scale range was parameterized from 0 to 1, so that the process of obtaining values would be clear, simple and straightforward for any scope. Thus, to obtain this proportionality, simply use the following equation:

$$X : 8 = PT : 1$$

For which

X = Unknown that represents the number generated by the amount of "YES".

PT = Unknown that represents the value of the Parameterized Total.

Once a point has been assigned for each of the "YES" values and the entire form has been filled out according to the adopted methodological criteria, we must use the expression below to obtain the Urban Infrastructure Requalification Index – URI, like so:

$$\boldsymbol{IRU} = ((STRUCTURE \times 0{,}55) + (INSTALLATIONS \times 0{,}15) + (IMPLEMENTATION \times 0{,}30))$$

Finally, once the index is obtained from these three dimensions (Structural, Installations and Implementation), we are able to proceed with the rating of urban retrofit interventions on six levels or grades wherein an URI ≥ 0.9 corresponds to the highest grade – Overall Requalification Status – and an URI of 0 corresponds to the lowest grade – Obsolescence Status.

For each of the six categories established, a different color was assigned, referring to the chromatic scale, which aimed to graphically and intuitively signal the Urban Infrastructure Requalification Index.

The model, exemplified by the Viaduct over Galeria dos Estados in Brasília - DF, was chosen for several factors, emphasizing those that highlight its structuring importance in the urban fabric of the listed capital and the nature of the structural collapse it suffered, albeit partial and victimless. Moreover, being located within the listed perimeter of a city recognized as a World Heritage Site by Unesco and having been designed and having been conceived by the design of architect Lucio Costa and the ingenuity of mathematician Bruno Contarini, this infrastructure has all the necessary characteristics to support the methodology previously proposed. Furthermore, the urban retrofit intervention in the viaduct's area showed the quality of the architectural, urbanistic and structural project, providing a pleasant space for its users.

Table 4 - URI rating grades

| IRU | Classification | Conditions | Color |
|---|---|---|---|
| 0,9 – 1 | **Maximum degree**<br>Global requalification status | All parameters of the proposed indicators totally achieved | |
| 0,7 – 0,8 | **Medium/maximum degree**<br>Parcial requalification status | All parameters of the proposed indicators partially achieved | |
| 0,5 – 0,6 | **Medium degree**<br>Structural integrity and implementation status | All structural and implementation parameters of the proposed indicators totally achieved | |
| 0,3 – 0,4 | **Medium degree**<br>Structural integrity status | All structural parameters of the proposed indicators totally achieved | |
| 0,1 – 0,2 | **Minimum/medium degree**<br>Structural criticality status | All structural parameters of the proposed indicators partially achieved | |
| 0 | **Minimum degree**<br>Obsolescence status | None | |

Source: author.

## The architectural complex and the structural system

The object of research is part of the road infrastructure of Brasília's central area, allowing direct access not only to *Plano Piloto*'s Central Bus Station, but also to *Setor Bancário* [Banking Sector], *Setor Comercial* [Commercial Sector], *Setor Hospitalar* [Hospital Sector] and *Setor de Autarquias* [Autarchy Sector] for all users who travel across *Asa Sul* [South Wing] and *Asa Norte* [North Wing]. Located in the southern part of the *Eixo Rodoviário de Brasília* (DF-002), the Viaduct is centrally located in the commercial heart of *Plano Piloto*.

Figure 3 – Location of urban infrastructure, *Plano Piloto, Eixo Rodoviário*, Brasília-DF – 6/12/2021

Source: adapted from Google Earth.

The Viaduct over *Galeria dos Estados* was conceived under the road paradigm (Costa, 1991), and thus intended for a significant portion of the South-North commuting, and vice-versa. It is therefore considered one of the main road arteries of Brasília, both in terms of importance with respect to urban structure (Holanda, 2018) and in terms of traffic volume (Barros, 2006).

The urban infrastructure, composed of six traffic lanes and a central presidential lane, totaling 28 meters wide and approximately

Figure 4 – View of the Central Viaduct of Brasília – 6/28/2021

Sourve: author.

200 meters long, was designed and built between December 1959 and February 1960 by architect Lúcio Costa and Bruno Contarini, Oscar Niemeyer's engineer, who was responsible for calculations.

## The viaduct over *Galeria dos Estados*' retrofit and the URI

In compliance with the Brazilian accessibility – NBR 9050:2015 – and design of concrete structures – NBR6118:2014 – standards, the viaduct's urban and structural retrofit project was carried out by the *Departamento de Estradas de Rodagem do Distrito Federal* (DER/DF) [Department of Roads of the Federal District] and by *Companhia Urbanizadora da Nova Capital* (Novacap) [New Capital's Urbanizing Company]. The architect responsible for urban requalification, accessibility and landscaping around the viaduct, Francisco Afonso de Castro Júnior, showed that it is possible to provide a pleasant space, suited for aggregation and that adds value to one of the central areas of Brasília.

According to the project memorial, for the sake of rescuing the original character of Lúcio Costa's project, the architectural design of the new *Praça dos Estados* [States Square] was developed with the purpose of restoring the remnant space, obsolete after the structural collapse of the infrastructure up until then. On that premise, the architects sought to qualify some aspects that would guarantee universal accessibility for all, through paths with both ramps and stairs, the durability of the materials used and the safety of the area during the day and at night. In addition, the *Praça dos Estados* shows a more direct interaction with the gallery's commerce of goods and services through a wide open area.

> *The occupation will be accomplished by the people themselves, on a daily basis by workers, on weekends by families, by the elderly, by young people, by children, by society. The idea is that over time, the population will decide whether or not they want new functions and/or equipment in the square. It is neither up to designers nor architects nor engineers to claim to completely solve the demands and variables of the project. Also, in face of the celerity of present life, a certain openness to the case is necessary. The greatest aim is to become a meeting point between the wings of the city, since in the symmetrical section on Asa Norte, it is the Eixo Rodoviário that passes under the viaducts. A meeting point is not possible there. Hopefully, there will be an area bursting with activities. Children playing under the overpass, local rock bands playing under the trees, families gathered under the shade, food trucks, artists trying to sell their work*". (Castro, 2018)

Executed by DER/DF and Novacap, the retrofit project applied to the Viaduct over Galeria dos Estados aims at improving user safety and guaranteeing a longer durability, without altering the harmonious proportions of the "hang glider" shaped pillars that were designed and planned by architect Lucio Costa. In order to propose solutions for the reconstruction/functionalization of the viaduct, a decision was made to partially demolish the structure and to recover the existing infrastructure.

Figure 5 – Praça dos Estados' landscaping plan, above, and view of the viaduct, post urban retrofit, below – 6/28/2021


Source: adapted from Francisco Afonso de Castro Júnior and Jansen Zanini (2018).

The engineer responsible for calculating both the original project and the reinforcement of the Viaduct over *Galeria dos Estados* was Bruno Contarini, known for having accompanied many works by Rio de Janeiro architect Oscar Niemeyer. Some of Brasília's main modernist buildings were calculated by the engineer, most notably the *Instituto Central de Ciências da Universidade de Brasília* (ICC/UnB) [Central Institute of Sciences of the University of Brasília], the *Teatro Nacional Cláudio Santoro* [Cláudio Santoro National Theater], Brasília's Central Bus Station platform, the *Superior Tribunal de Justiça* (STJ) [Superior Court of Justice], the *Tribunal Superior Eleitoral* (TSE) [Electoral Superior Court] and the *Tribunal Regional Federal* (TRF) [Federal Regional Court]. Therefore, the importance of having a structural retrofit project signed by one of the main authors of the city envisioned by architect Lucio Costa expresses an artistic emphasis that must be attributed to the value of the *Galeria dos Estados*' viaduct's infrastructural set.

The urban retrofit intervention, enriched by the presence of engineer Bruno Contarini, shows in its foundation a special attention to the preservation of Brasília's modern heritage, a fundamental value of the city's conception sprouting from its main actors and urban scales.

Bruno Contarini contributed to the work conceived by architect Costa, in which the construction technique and the structural system stand out in the architectural form.

Figure 6 – Engineer Contarini at the site where
the Galeria dos Estados' Viaduct collapsed – 2/7/2021


Source: Larissa Batista.

As Inojosa (2019) points out, in this historical period of Brasília's modernist architecture, there is an outstanding concern with the exploration of the structure as a plastic element and the pursuit of knowledge application in construction. The original drawings of the structural detailing of the viaduct's reinforcement are attributed to Bruno Contarini's engineering firm and show all the project's technological guidelines adopted for the *Galeria dos Estados*' structural retrofit.

Based upon the information collected throughout the chapter, an evaluation sheet was prepared for each moment of the lifespan of the existing structures, namely:

*Pre-retrofit* Phase.

*Post-retrofit* Phase.

Following the inclusion of all indicators chosen to obtain the Urban Infrastructure Requalification Index – URI, a simplified assessment consisting of YES or NO options was assigned to each sub-element of the dimensions (structural, installations and implementation), by means of documentary survey and on-site visual analysis, as well as the rich photographic collection available in those cases in which it was not possible to observe the element on the spot. In light of this, we will show this application through the first practical example. In the following URI evaluation sheet (Figure 7), applied to the Viaduct over Galeria dos Estados before the retrofit operations (Pre-retrofit time situation), it appears that no indicator is marked "YES" in the "structural system" dimension and "foundation block" sub-element, totaling 0 in the "Parameterized Total" score. The same situation applies to the structural sub-elements of the retaining wall, deck slabs, support system and main and secondary beams. Only in the pillars sub-element it appears that the sole indicators that were marked with "YES" were the artistic and the symbolic. These parameters show that, even in a state of partial collapse, the architectural beauty of the supporting elements, together with the symbolism they represent for the community of Brasília, is valued within the proposed model for calculating the URI. The value in the "parameterized total" cell, in this case equaling 0.25 of 1, will be added to all other results obtained by the same evaluation in the "structural system" dimension, and this numerical parameter will be divided by the number of sub-elements, which in this case is 7 (namely foundation blocks, retaining walls, deck slabs, pillars, support system, main beam, secondary beam).

$$GLOBAL\ STRUCTURE = \frac{\Sigma\ (BLOCKS+CURTAINS/WALLS+SLABS+PILLARS/COLUMNS+SUPPORTS+STRINGERS/STRATES+TRANSVERSINES)}{7}$$

In this evaluative condition, the "global structure" of the Viaduct over *Galeria dos Estados* (Pre-retrofit) resulted in 0.04, which represents a typical value for an obsolete structure. In general, the situation does not change for the dimensions of installations, with the exception of the drainage system item, which totaled a result of 0.38 by scoring the environmental, safety and usage indicators. Even with part of the structure compromised at the time of the partial collapse, the drainage system continued to function regularly, ensuring the flow of rainwater, and thus not requiring retrofit operations.

Figure 7 – URI Evaluation sheet – Viaduct over *Galeria dos Estados* – pré-retrofit

| Viaduct "Galeria dos Estados"<br>Year: 1961<br>Designer: Lúcio Costa / Bruno Contarini<br>Place: Brasília – Federal District – Brazil<br>Status: Pré Retrofit | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | **Environmental** | **Artistic** | **Durability** | **Economic** | **Securit** | **Simbolic** | **Social** | **Use** | **Total parameterized** |
| **Structural system** | | | | | | | | | |
| Foundation blocks | No | No | No | No | No | No | No | No | 0,00 |
| Retaining walls | No | No | No | No | No | No | No | No | 0,00 |
| Deck slabs | No | No | No | No | No | No | No | No | 0,00 |
| Pillars | No | Yes | No | No | No | Yes | No | No | 0,25 |
| Support system | No | No | No | No | No | No | No | No | 0,00 |
| Main girden | No | No | No | No | No | No | No | No | 0,00 |
| Secondary girdens | No | No | No | No | No | No | No | No | 0,00 |
| **Global structure** | | | | | | | | | **0,04** |
| **Installations** | | | | | | | | | |
| Internal HVAC system | No | No | No | No | No | No | No | No | 0,00 |
| Drainage system | Yes | No | No | No | Yes | No | No | Yes | 0,38 |
| Lighting system | No | No | No | No | No | No | No | No | 0,00 |
| Sustainable energy generation system | No | No | No | No | No | No | No | No | 0,00 |
| Structural monitoring system | No | No | No | No | No | No | No | No | 0,00 |
| **Global installations** | | | | | | | | | **0,08** |
| **Implementation** | | | | | | | | | |
| Acessibility | No | No | No | No | No | No | No | No | 0,00 |
| Sidewalks | No | No | No | No | No | No | No | No | 0,00 |
| Bikeway | No | No | No | No | No | No | No | No | 0,00 |
| Landscaping | No | No | No | No | No | No | No | No | 0,00 |
| Vegetation | No | No | No | No | No | No | No | No | 0,00 |
| Street furniture | No | No | No | No | No | No | No | No | 0,00 |
| **Global implementation** | | | | | | | | | **0,00** |
| **I.R.U.** | | | | | | | | | **0,03** |

Source: author.

Figure 8 – URI Evaluation sheet – Viaduct over *Galeria dos Estados* – pós-retrofit

| Viaduct "Galeria dos Estados"<br>Year: 2019<br>Designer: Bruno Contarini<br>Place: Brasília – Federal District – Brasil<br>Status: Pós Retrofit | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | **Environmental** | **Artistic** | **Durability** | **Economic** | **Security** | **Simbolic** | **Social** | **Use** | **Total parameterized** |
| **Structural system** | | | | | | | | | |
| Foundation blocks | No | No | Yes | Yes | Yes | No | Yes | Yes | 0,63 |
| Retaining walls | No | No | Yes | Yes | Yes | No | Yes | Yes | 0,63 |
| Deck slabs | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| Pillars | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | 1,00 |
| Suport system | No | No | Yes | Yes | Yes | No | Yes | Yes | 0,63 |
| Main girder | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| Secondary girders | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| **Global structure** | | | | | | | | | **0,73** |
| **Installations** | | | | | | | | | |
| Internal HVAC system | No | No | No | No | No | No | No | No | 0,00 |
| Drainage system | Yes | No | Yes | Yes | Yes | No | No | Yes | 0,63 |
| Lighting system | Yes | No | Yes | Yes | Yes | No | No | Yes | 0,63 |
| Sustainable energy generation system | No | No | No | No | No | No | No | No | 0,00 |
| Structural monitoring system | No | No | No | No | No | No | No | No | 0,00 |
| **Global installation** | | | | | | | | | **0,25** |
| **Implementation** | | | | | | | | | |
| Acessibility | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| Sidewalks | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| Bikeway | No | No | No | No | No | No | No | No | 0,00 |
| Landscaping | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| Vegetation | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | 0,88 |
| Street furniture | Yes | No | Yes | Yes | Yes | No | Yes | Yes | 0,75 |
| **Global implementation** | | | | | | | | | **0,65** |
| **I.R.U.** | | | | | | | | | **0,63** |

Source: author.

It can be inferred from the proposed evaluation sheet that the Urban Infrastructure Requalification Index is extremely unsatisfactory for the viaduct in the Pre-retrofit situation, as it attained a score of 0.03, which reflects its condition of loss of service performance and user safety. The situation of the viaduct's Urban Infrastructure Requalification Index (Post-retrofit) is surprising due to the expressive/significant increase in the sub-indices represented by the structural dimension, installations and implementation. The URI, after the urban retrofit intervention, reached the value of 0.63, exponentially increasing its requalification degree. It is possible to observe that, within the scope of the structural system, all indicators related to durability (lifespan), economic, safety, social and usage were marked for all sub-elements that compose the global structural dimension of the SWA.

The artistic and symbolic indicators are still marked solely by the pillars, which really represent the architectural essence of the tangible and the intangible. Increasing structural safety and durability over time, while still respecting the original "hang glider" shape, the pillars totaled a score of 1, which represents the highest grade within the structural dimension.

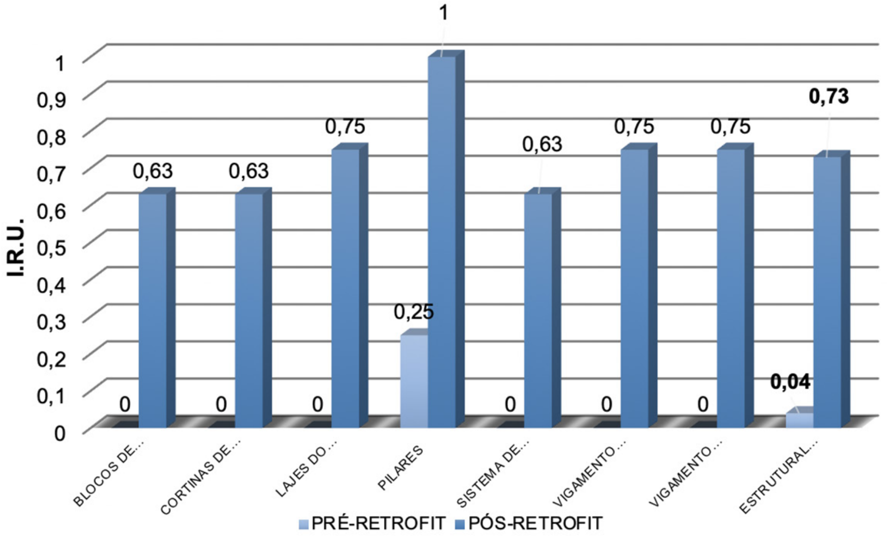
The presence of the environmental indicator was detected for the structural sub-elements of the deck slabs, pillars, main and secondary beams, while the structural retrofit of these elements repurposed the existing structure, reinforcing the elements that were in good conditions and generating considerable savings for society from all the aforementioned points.

The result achieved by the structural dimension was valued at 0.73, while that obtained by installations (0.25) was not substantial, compromising the URI score. The sub-elements represented by both drainage and lighting systems have environmental (permeable concrete pavement and LED lighting), durability, economic, safety and usage values. The implementation dimension (0.65) is quite encouraging, given the requalification of the *Galeria dos Estados* square, which currently provides wide and safe spaces for all types of accessibility. Whilst computing the symbolic indicator for the implementation elements, the choice was made not to characterize it as a place too recent to be assimilated as a symbol by the population of Brasília, especially given the historical period we are living.

Considering all comparative diagrams in the structural, installations and implementation dimensions as much as in the final indexes, the difference between the pre-retrofit and post-retrofit moments of the infrastructure of the Viaduct over *Galeria dos Estados* is quite significant. This multi-criteria model for evaluating urban retrofit interventions in Special Works of Art suited the case study of the Viaduct over *Galeria dos Estados*, showing the main limitations in the installations dimension, as they were not designed for a relatively short segment of infrastructure.

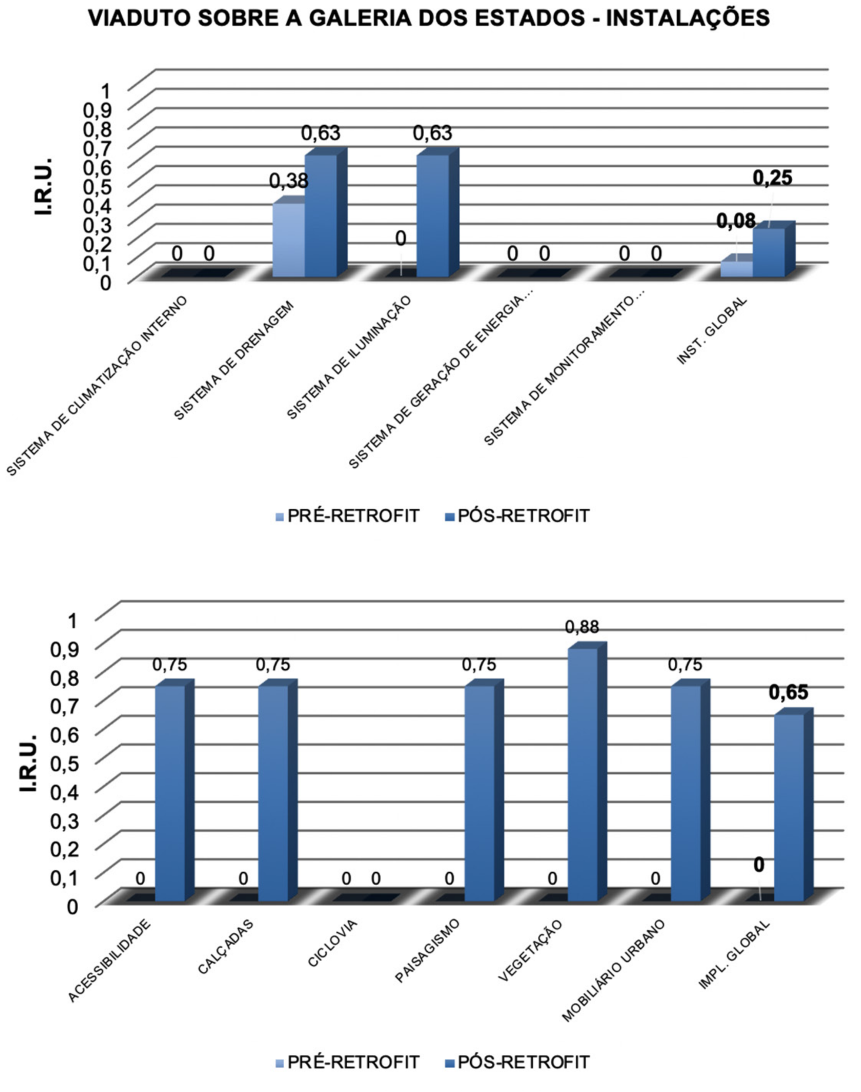
The URI index achieved by the SWA post-retrofit is 0.63, resulting in a medium grade, flagged by the light green color, while at the pre-retrofit phase the URI attained corresponds to the lowest grade (red color), due to its structural obsolescence situation.

Figure 9 – Comparative diagrams of the structural dimension of the Viaduct over *Galeria dos Estados* – pre-retrofit vs. post-retrofit



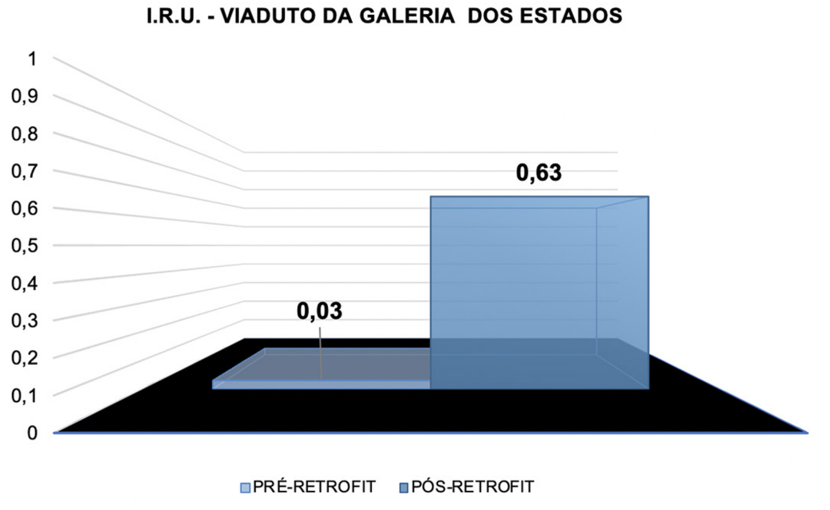

Source: author.

Figure 10 – Comparative diagrams of the installations and implementation dimensions – Viaduct over *Galeria dos Estados* – pre-retrofit vs. post-retrofit




Source: author.

Figure 11 – Comparative diagram URI – Viaduct over Galeria dos Estados – pre-retrofit *vs.* post-retrofit




| URI | Classification | Conditions | Color |
|---|---|---|---|
| 0,9 – 1 | **Maximum degree**<br>Global requalification status | All parameters of the proposed indicators totally achieved | |
| 0,7 – 0,8 | **Medium/maximum degree**<br>Parcial requalification status | All parameters of the proposed indicators partially achieved | |
| 0,5 – 0,6 | **Medium degree**<br>Structural integrity and implementation status | All structural and implementation parameters of the proposed indicators totally achieved | |
| 0,3 – 0,4 | **Medium degree**<br>Structural integrity status | All structural parameters of the proposed indicators totally achieved | |
| 0,1 – 0,2 | **Minimum/medium degree**<br>Structural criticality status | All structural parameters of the proposed indicators partially achieved | |
| 0 | **Minimum degree**<br>Obsolescence status | None | |

Source: author.

## Conclusions

Urban retrofit is considered an intervention in the built environment that serves to requalify and give a new function to certain historic or listed areas that need an efficient response to the problem concerning the city. However, the heritage charters published throughout the 20th and 21st centuries as well as preservation instruments such as heritage listings or handbook prescriptions for intervention in historic cities published by the *Instituto do Patrimônio Histórico e Artístico Nacional* (IPHAN) [National Institute of Historic and Artistic Heritage] do not seem enough to manage the conservation or maintenance guidelines for a particular work of art and its immediate surroundings. Urban retrofit, on the other hand, embodies multiple aspects that range from structural issues to landscaping and user experience in the area.

The case of the Viaduct over *Galeria dos Estados* proves that the preservation of the Gregarious Scale and of the "hang glider" geometric shape of the main structural element – the pillar – imagined by architect Lucio Costa, together with both the quick response to society and the increase in durability and infrastructure safety in compliance with current standards, contributed to a less onerous response to society, from a budget standpoint, fostered by the retrofit interventions in Brasília.

Contemporary architecture often has the ability to fit into a historical context without aggravating linguistic dissonances, unlike in recent decades, when a certain degree of dispute over the past was a necessary evidence of modernity.

**[I] https://orcid.org/0000-0002-3694-9133**
Universidade de Brasília, Faculdade de Arquitetura e Urbanismo, Departamento de Tecnologia, Programa de Pós-Graduação em Arquitetura e Urbanismo. Brasília, DF/Brasil.
stefanogalimi.arch@gmail.com

**[II] https://orcid.org/0000-0002-1164-2784**
Universidade de Brasília, Faculdade de Arquitetura e Urbanismo, Departamento de Tecnologia, Programa de Pós-Graduação em Arquitetura e Urbanismo. Brasília, DF/Brasil.
marcio.buzar@gmail.com

**[III] https://orcid.org/0000-0002-0763-0107**
Universidade de Brasília, Faculdade de Arquitetura e Urbanismo, Departamento de Tecnologia, Programa de Pós-Graduação em Arquitetura e Urbanismo. Brasília, DF/Brasil.
joaocpantoja@gmail.com

**Translation:** this article was translated from Portuguese to English by Leonardo Farias Saraiva, leonardofariassaraiva@gmail.com

# References

ABCHICHE, L. (2017). *A relação do marketing territorial e plano diretor urbano; a questão do legado urbano do projeto Porto Maravilha no Rio de Janeiro.* Dissertação de mestrado. Brasília, Universidade de Brasília.

BARROS, A. P. (2006). *Estudo exploratório da Sintaxe Espacial como ferramenta de alocação de tráfego*. Dissertação de mestrado. Brasília, Universidade de Brasília.

CASTRO, A. (2018). *Notas sobre as inovações da portaria n. 166/2016-Iphan para a Preservação do Conjunto Urbanístico de Brasília*. Brasília, Iphan.

CAVALCANTE, G. H. F. (2019). *Pontes em concreto armado: análise e dimensionamento*. São Paulo, Blücher.

COSTA, L. (2014). "Relatório do Plano Piloto de Brasília, 1991". In: COSTA, L. *Brasília, Cidade que inventei.* Brasília, Instituto do Patrimônio Histórico e Artístico Nacional.

FERREIRA, O. L. (2011). *Patrimônio cultural e acessibilidade: as intervenções do Programa Monumenta, de 2000 a 2005.* Tese de doutorado. Brasília, Universidade de Brasília.

FERREIRA, T. M.; VICENTE, R.; MENDES, J. A. R. da S.; VARUM, H.; COSTA, A. (2013). Seismic vulnerability assessment of historical urban centres: case study of the old city centre in Seixal, Portugal. *Bulletin Earthquake Engineering*. v. 11, n. 5, pp. 1753-1773.

FREIRE, R. A. (2017). *Infraestrutura urbana*. Londrina, Editora e Distribuidora educacional.

GALIMI, S.; PANTOJA, J.; BUZAR, M.; SANTOS MACHADO, P. R. (2020). Retrofit em obras tombadas de infraestrutura urbana: o caso do Viaduto sobre a Galeria dos Estados. *Paranoá: cadernos de arquitetura e urbanismo.* Brasília, v. 26, n. 1, pp. 140-156.

HOLANDA, F. (2018). *O espaço de exceção*. Brasília, FRBH.

INOJOSA, L. da S. P. (2019). *O protagonismo da estrutura na concepção da arquitetura moderna brasileira*. Tese de doutorado. Brasília, Universidade de Brasília.

KOHLSDORF, G.; KOHLSDORF, M. E. (2017). *Ensaio sobre o desempenho morfológico dos lugares*. Brasília, FRBH.

MUMFORD, L. (1961). *The city in history: its origins, its transformations, and its prospects*. Boston, Houghton Mifflin Harcourt.

NEGREIROS, I. (2018). *Retrofit Urbano: uma abordagem para apoio de tomada de decisão.* Tese de doutorado. São Paulo, Escola Politécnica de São Paulo.

NEWTON, P. W. (2013). Regenerating cities: technological and design innovation for australian suburbs. *Building Research & Information.* Londres, v. 41, n. 5, pp. 575-588.

ROLNIK, R. (1988). *O que é cidade?* São Paulo, Brasiliense.

ROMERO, M. A. (2007). Frentes do urbano para a construção de indicadores de sustentabilidade intraurbana. *Paranoá: cadernos de arquitetura e urbanismo*. Brasília, v. 6, n. 4, pp. 47-72.

RUSKIN, J. (1921). *The seven lamps of architecture*. Londres, J.M Dent & Sons.

VARUM, H. S. A. (2003). *Avaliação, reparação e reforço sísmico de edifícios existentes.* Tese de doutorado. Aveiro, Universidade de Aveiro.

VERONES, S.; RINALDI, A.; REBECCHI, S. (2014). *Retrofit e rigenerazione urbana – Il progetto EPOurban.* Monfalcone, Edicom.

VITÓRIO, J. A. P. (2005). A importância da manutenção para a sustentabilidade do espaço construído – Manutenção e gestão de obras de arte especiais. In: VII ENCONTRO NACIONAL DAS EMPRESAS DE ARQUITETURA E ENGENHARIA CONSULTIVA DO BRASIL. *Anais*. Recife.

Received: November 30, 2021
Approved: February 18, 2022