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# Athens Journal of Architecture

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Characters of Ancient Architectural Orders and their Mannerist Interpretation in Dietterlin’s Book from 1598

By Vladimir Mako*

The aim of this paper is to explore a particular metaphorical pictorial language used by German mannerist painter Wendel Dietterlin in his book on architecture at the end of the sixteenth century. It was formed through personal imaginary interpretation of the Vitruvian notion regarding personal characters of the five ancient architectural Orders. In that context it has all aspects of the mannerist approach in inventing metaphorical meanings by combining ancient, mediaeval, and contemporary narratives. However, in that process Dietterlin unavoidably refers to cultural and social aspects of his time, particularly when reflecting on the issue of the invention of the ‘new [German] architecture’. By this, Dietterlin enters the group of the majority of German sixteenth and seventeenth century authors on architecture emphasizing one particular prerogative in their writings: to merge the ancient roots with the longing for a coherent German cultural identity. However, it seems that in the process of narration, used to ‘invent’ new forms of architectural expression, Dietterlin refers also on particularities related to the historical development of mankind in a personal manner.

Introduction

The sixteenth and seventeenth century German culture marks an intensive appearance of treatises dealing with the art of architecture. Mostly they are introducing characteristics of five classical Orders, based on the Vitruvian and Italian Renaissance tradition, and supplemented with new ideas regarding contemporary (German) architecture. However, the ideas of what contemporary architecture based on the ancient tradition can be, developed in a particular sense of creation of new forms. In that sense, German examples seems to follow the general attitude developed in Italy and other neighboring countries, that architectural design applies more to the idea of intuitional invention than rational thinking. In that context the Italian term ‘Invenzione’ transformed into expression where personal experiences took the essential role in conceptualizing architectural ideas.1

The very essence of such creative impulse opposite to the Renaissance design concept, has been accurately defined by Rykwert in his opinion that "the architecture of the sixteenth century could not simply make its appeal to nature and reason, or base its procedure on the operations of reason prompted by philosophy; in the sixteenth century rules which had to have the sanction of grace,

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*Professor, Faculty of Architecture, University of Belgrade, Serbia.
had to be derived from, guaranteed by divine revelation.”2 In that sense we should speak rather of a creative development under the influence of personal artistic sensibility than of a model based on analytical approach to ancient tradition. In that context we should mention two German authors which work indicates the change of interest from a structural approach to art of building developed in Italian Renaissance, towards decoration as a dominant aspect in cultural evaluation of architecture. The book published by Blum in 1560 presents exclusively proportions and ornaments applied on details of the entablature of five Orders, and Stoer in his engravings from 1567 used the decorative forms of scrollwork as fundamental element of architectural creation.3 In that sense and mainly through their sensibility for pictorial values they magnified the importance of decoration as the essence of architectural expression, which as an idea was already generally developed in German art and culture of the time. Probably that was the reason way the majority of historians defined the sixteenth century in the north Europe, particularly in Germany, as an epoch of decorative art.4 It seems that in such context visually presented ideas could also develop a particular narrative expression and easy understandable metaphors rooted in common contemporary culture.

One of such works is undoubtedly the treatise on architectural Orders published by Wendel Dietterlin in 1598.5 The main characteristics of this work are already noted and presented by a few scholars, showing that Dietterlin’s approach to the composition of his book was predominantly guided by mannerist understanding of personal creativity. Establishing his ideas almost exclusively on engravings, he interpreted the five Orders moving into particular personal narrative form of expression. In that sense, Dietterlin “considered the Orders as catalysts rather than prescriptive rules,”6 and shifting his interpretation far from Vitruvian and Renaissance tradition by merging Christian themes and classical mythological personalities and stories.7 Nevertheless, it seems that such approach to different traditions could be recognized as usual in German sixteenth century culture.8 That notion is from particular importance for our discussion while it

opens the possibility that Dietterlin’s personally developed metaphors are reflecting on accepted cultural narratives of his time. In Dietterlin’s book there are notions regarding a more structural role of decoration in actualizing observer’s sense in differentiating levels of social and cultural importance of architecture. Reflecting on that issue, Forssman’s notion that “decoration made house a city hall” identifies the potential that decorative expression in architecture could be used in establishing social and cultural meanings. Consequently, it seems that through the approach to the field of art of building, Dietterlin pervades a sense of a complex relationship among different artistic expressions, using their narrative potential in offering new visions and meanings of contemporary culture.

In that context, we should emphasize the possibility that such complexity of cultural narrative emerged from his consideration of five Orders rather as essentially meaningful characters, than as pure architectural masses. This notion would be based on Dietterlin’s active development of Vitruvian and Renaissance metaphors regarding the identification of five Orders with human characters. In that context, we should emphasize once more that the main artistic media through which Dietterlin formed his metaphorical ideas was sculpture, with carefully chosen figures according to their mythological meaning. That is the reason why in our discussion we will pay attention particularly on engravings shaped through metaphorical narrative based on sculptural compositions incorporated into architectural presentation of Orders.

At the beginning of our discussion regarding metaphors that Dietterlin developed as his vision of each Order’s character, we should briefly pay attention on a few important aspects essential for the general structure of the book. In two introduction texts, the longest ones in the whole book, Dietterlin mainly emphasizes that the focus of his presentations reflects on symmetry and proportions of all named and depicted architectural elements. By that Dietterlin the painter builds his essential notion on architecture by emphasizing the importance of proportion, symmetry, and consequently geometry as creative tools in all arts, developed in European and particularly German sixteenth century culture. In that context at the beginning of each book on a particular Order, he introduces proportional regulations of columns and entablature with all necessary differences that belong to their particular characters. There is a probability that Dietterlin’s depictions of proportional regulations have been under the Serlio’s influence. However, one can think on even more essential engagement of Italian master’s ideas reflecting on existence of perfectly proportioned architectural

elements as universal values. In the first book on Tuscan Order, at the beginning of the section presenting portals, Dieterlin in the engraving 23 gives a schematic proportional and compositional depiction of a perfected ideal example mainly used on all portals in the book. It proves his understanding that perfected proportional and compositional scheme forms universal essence of any architectural design despite of the factual materialization of details. Moreover, it seems that the compositional role of portals as the "backdrop of an ongoing scene" is from a particular importance.\textsuperscript{14}

However, it would be an overstatement that Dieterlin followed precisely all ideas offered by Italian Renaissance architects. His variable approach to the issue of ancient Orders and their essential characteristics as cultural metaphors is evident at the very beginning of the book on the Tuscan Order.

\textbf{Tuscan Order}

Architectural historians, dealing with the origin and characteristics of the Tuscan Order, usually refer on Serlio’s notions regarding the issue.\textsuperscript{15} In that context, his comment that the Tuscan Order is the first in line among other four because it is the most rustic one, have been taken as a key point relevant for general understanding of its essence. In a particular way this issue is important also for our discussion. Namely, in his short introduction on Tuscan Order, Dieterlin cites Plinius by stating that it is the oldest one in the first place, and just after that he is mentioning the Order’s strength and roughness.\textsuperscript{16} More than that, Dieterlin gives a remark that the name of the Tuscan Order comes from the giant Tuscano, who was the father of Germans.\textsuperscript{17}

This obscure comment, linking the oldest of five Orders and the primordial father of German people derives from an unknown source. However, it mainly indicates existence of a longing for national identification through art and architecture in the sixteenth century German culture and later. One can think that this longing was probably the impulse for Dieterlin’s merging of ancient mythological and Christian religious aspects, as bearers of early European artistic tradition and contemporary German cultural forms. However, we should not neglect Dieterlin’s mannerist artistic sensibility in shaping figures and their pictorial and compositional appearance, as an important part in expression of particular complexity and richness of metaphorical narration. This refers mostly on the column like figures placed on the first illustrative pages regarding each Order.

\textsuperscript{14} Skelton, “Shaping the Book and the Building: Text and Image in Dieterlin’s \textit{Architectura},” 2007, 27.
\textsuperscript{16} Dieterlin, \textit{Architectura von Ausstheilung/Symetria und Proportion der Funff Seulen/und aller darauss volgender Kunst Arbeit von Fenstern Caminen/Thurgerichten/Por tales/Bronen und Epitaphien}, 1589, 5.
They probably depict Dietterlin’s primal notion regarding their architectural metaphorical characters.

Regarding the Tuscan Order, there is in engraving 6 a depiction of a male figure compounded out of a number of objects, vine and grapes. Human torso has been supplemented with a barrel as a trunk, wooden pail as a capital, spoon as forehead emblem, and decorated with a jug cut in half and placed between vine and grapes covering the lower part of the figure (Figure 1). Already at the first glance it shows that this interpretation, essentially associated with Tuscan Order, is far from reflecting on military and protective function - an idea developed in Italian Renaissance of the sixteenth century.18 Its rudimentary appearance directs our attention more on human impulse for satisfying elementary worldly needs for eating and drinking, than on higher cultural and ethical aspects. However, standing far from a classical form of Bacchus, this figure looks more as a German contemporary depiction of an innkeeper.

Nevertheless, in the serial of compositions of Tuscan portals, we encounter two examples which are reflecting on the initial idea metaphorically presented in the analyzed figure. In the engraving 29, Dietterlin presented a rustic portal with a sculptural composition over the entrance. The composition consists on the figure of young Bacchus surrounded with jugs and two male goats. In this example Dietterlin is aiming our attention directly to the ancient god of wine, marking the character of the Tuscan Order as the bearer of human elementary impulses. He repeats this notion in the next engraving (Figure 2). A man dressed as innkeeper is presented passing into the building, carrying dishes. The arch over the entrance is decorated with emblematic ornaments composed out of spoons and knives. Two figures of Pan in the lower zone are flanking the entrance. In the higher zone of the composition, on the right side a men playing the pan’s flute is represented, and in the middle a figure identified as Cyclops Polyfem takes place.19

Figure 1. Dietterlin, Architectura, Engraving 6, 1598

Figure 2. Dietterlin, Architectura, Engraving 30, 1598
Presence of the mythological giant indicates development of Dietterlin’s narrative in a particular way. It seems that through the idea of combining metaphors of elementary human needs with mythological characters from the beginning of the world’s history he speaks of primordial content of human existence placing it within contemporary cultural context. That is probably the reason why in engraving 24, Dietterlin composed a portal which aims to illustrate the dawn of humankind, assembling figures of Adam, Eve, and their two sons, accompanied with a number of different animals, real and mythological (a unicorn on the left side of the portal).

The architectural form of the portal was materialized by using rough blocks of stone. However, it is not a representation of a ruin, but an idea of how one imagines rudimental use of stone in building (Figure 3). To this conclusion drives us the sense of primordial character of the scene, and particularly the disposition of portal’s parts. They refer on geometrical perfectness outlined in the idealistic proportional scheme presented in engraving 23 (Figure 4). It underlines the idea that even architectural example belonging to primordial epoch and build in a raw material, should contain a divine spark – proportion and geometry as the essence of world’s harmony. People’s basic impulses and living habits are equalized with the mythological time. Through the presence of divine laws of harmony they become parts of one entirety, which also reflects through the first and oldest ancient Order, the Tuscan.
It seems that this idea continually develops through the examples of fountains and pools related to the Tuscan Order. Besides the engraving 35, repeating the characteristics of compositions with the Bacchus figure accompanied with motives as Pan, goat, and vine (Figure 5), Dietterlin presents a few other narratives more complex in their cultural meanings.

The engraving 32 depicts culmination of a dragon slayer story, obviously as an unavoidable reference to the primordial character of the Order (Figure 6). There are two possibilities related to the source of the motive. The first one, that it is the representation of the fight of the Greek hero Cadmus, the mythological founder of Thebes.\textsuperscript{20} However, there are a few important elements indicating the possibility that depiction could be related to the Nordic – German story of Siegfried the dragon slayer. Dragon has the bat-like wings without the snake like body, which is opposite to all ancient Greco–Roman sources related to the story. More than that, the hero brandish with a sword for the final blow, which is an important detail in the story of Siegfried’s fight. He kills the dragon with his sword named ‘Balmung’ (Nordic ‘Gram’), containing almost magical powers and strength. Nevertheless, belonging to the first or second tradition, the narrative is important as a representation of an essential fight between good and evil. However, it is not a military motive but a reflection on the struggle between cultivation and chaos, which belongs to the primordial times and the earliest history of shaping human society, culture, and beliefs, and by that inexorably linked to the Tuscan Order. To the dramatic atmosphere of the dragon slayer composition correlates the engraving 36, where a hunting scene is presented. In the middle of the pool around a Tuscan column a crowd of figures of hunting dogs is placed, and a hunter stubbing a bear with a spear in a strong movement.

Figure 5. Dietterlin, Architectura, Engraving 35, 1598

Figure 6. Dietterlin, Architectura, Engraving 32, 1598

Opposite to these violent scenes, the engraving 34 is composed in a completely different temper. A serene feeling of basic and important everyday routine on which the beauty of simple life is established, emerge from the composition 34. A young man pumping water from a fountain composed as a highly sophisticated piece of architecture, and a girl carrying water from the well,
are presented as the centre of the narrative. Fountain is placed on the tri-partite geometrically shaped water collectors. This perfectly formed and by time unspoiled architectural object is placed within a ruin, probably as a part of Dietterlin’s metaphorical narrative. We can guess about the real meaning of the presentation, but it seems that it carries a few fundamental thoughts probably related to the inviolable notion of *fons vita*, and the family life as the essence of human existence. While everything around it decays, the real well of life remains unspoiled.

**Doric Order**

Contrary to his personal metaphorical interpretation of the Tuscan Order, Dietterlin at the first place, follows in a precise way the Vitruvian and Renaissance tradition regarding the Doric Order’s meaning established mainly as the male warrior character. This is evident from his engravings 46 and 73, presenting a male warrior figure equipped and surrounded with various pieces of arms (Figure 7 and 8). However, this dominant metaphor has been supplemented with other corresponding meanings presented through narratives belonging to ancient mythological, Biblical, and contemporary tradition. They broad our understanding of strength, war, the notion of fight and struggle in general, as the human personal and social activity.

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Following the engraving 73 representing a portal with the male warrior character, a fully armed soldier on the top of the entablature, the composition 74 depicts the principle of its female counterpart, one of the ancient warrior goddess Diana. Being also the hunting goddess, Diana carrying a spear, is surrounded with a number of dogs. Portal is decorated with heads of a deer, bear, and boar. On the right side of the portal a bear is presented carrying a broken spear. This engraving seems to be in a direct correspondence with the next one in the line (engraving 75), representing a portal of a tavern, decorated with a hunting catch, boar heads and sausage. Two male characters are presented. In a lower zone a column like figure of an innkeeper, and up the entablature a young male with a horn of plenty. It seems that the presented motive reflects on Dietterlin’s personal artistic approach to interpretation of characteristics of architectural orders through free associations – here probably as the benefit of hunting through the idea of plenty.

One of the purest ancient mythological motives we can find in engraving 77, where in the upper zone a figure of Jupiter is presented seated on an eagle, and carrying aegis and scepter in his hands. Personifications of Sol seated on a bull on the left, and Luna seated on a lion on the right side are accompanying the god, confirming that Jupiter’s appearance is a cosmic event. Eagle as symbol of heavenly sphere, bull as symbol of natural forces, and lion as symbol of earthly power, are completing the idea of Jupiter as the supreme authority in spiritual and material universe, and the leading warrior against chaos. He represents a sublime male power in its essence, and according to Dietterlin, it seems that by this characteristic such representation belongs to the Doric Order (Figure 9).
To his collection of portals shaped through various interpretations of characteristics of the Doric Order, Dietterlin attached two examples containing historical connotations. In engraving 76, he presented an exceptionally decorated portal with the bust of Caesar over the entrance, probably referring to the dictator
as the personification of supreme warrior in ancient history. The second engraving (no.66) illustrates the generally accepted opinion, developed by the Vitruvian and Renaissance tradition, according to which the Doric Order originates from primordial wooden structure. However, Dietterlin subordinated the characteristics of the portal’s form to his vision of general proportional and compositional values, presented at the beginning of the book in the engraving 23. Except the pair of columns flanking the entrance, and presented almost as untilled trunks, the other structural parts of the portal are executed and assembled with high precision (Figure 10). Actually, Dietterlin designed a sixteenth century mannerist portal made of wood. A counterpart of this structure is presented in engraving 52, as a wooden window with almost the same characteristics, and together with the first example testifies for Dietterlin’s ambition to interpret all important aspects concerning the Order.

His reflection on various religious and cultural notions connected to generally assumed characteristics of the Doric Order, Dietterlin continues to develop in design of fountains and pools. Composition presented in the engraving 78, is identified as the scene from the book of Genesis, where angel presents itself to Hagar and Ismail on their trip to Egypt. Not entering into the theological particularities of the story, we should emphasize that in the Christian tradition it was usually interpreted as a metaphor of struggling for redemption and against oppression. In that context, the righteous fight for the purification of a soul seems to be for Dietterlin a sufficient point for associating it with the strength of the Doric Order (Figure 11). Probably from the similar reasons the depiction in engraving 79, took the place within the collection of various Doric characteristics. Composition presents a splendid design of a well with a figural composition on its top: the figure of Christ blessing two jars carried by servants. It seems to be a Christian counterpart of the previous story from the Old Testimony, presenting the moment of the first Christ’s miracle performed at Cana in Galilee: transformation of water into wine. From that moment new faith began to fight for the redemption of peoples’ souls, and the recognition as truthful religion.

One more important Christian theme has been presented in the engraving 82, where the cross like fountain carries a complex figural composition. In the centre of the fountain a dominant figure of St. Christopher is positioned carrying the divine child, taking a step over a water creature (Figure 12). Over their heads a globe with the cross on the top is placed, identifying the child Christ as the redeemer of the universe. However, this basic iconographic motive Dietterlin supplemented with four grotesques like water demon creatures wearing various objects allegorically identified with sins of egoism and immoderate earthly pleasures, by which they try to tempt the holly couple. We should emphasize that such compositional additions to St. Christopher’s iconography are not unusual in the European sixteenth century art, particularly in artistic circle under the influence of Hieronymus Bosh. We can refer, for instance, to the painting of Jan Mandijn, from the middle of the sixteenth century, now in the State Hermitage in St.

Petersburg, where similar fantastic context of the subject is presented. It seems that Dietterlin as mannerist painter accepted such a phantasmagoric approach, emphasizing the essence of the theme, crossing over the water of sin, and struggle for spiritual virtue through the Christian fate.

Figure 11. Dietterlin, Architectura, Engraving 78, 1598

Figure 12. Dietterlin, Architectura, Engraving 82, 1598
Ionic Order

After presenting a number of various subjects exposing the nature of power and force of arms, but also themes of spiritual struggle, as dominant characteristics related to the Doric masculine sensibility, Dietterlin develops a different kind of sensitivity affiliated to what Vitruvian and Renaissance tradition generally named as feminine character of the Ionic Order.

In his engravings, it seems that Dietterlin points out two conceptual approaches in defining metaphors linked to this Order. The first one is particularly attributed to the nature of variable feminine characters as possible representatives of the Ionic Order, while the second group contains examples through which we can experience the general sensibility regarding the Order itself as a generator of cultural ideas. In this context, attained complexity of metaphorical narrative intensified by Dietterlin’s method of side by side presentation of ancient, Christian and contemporary motifs.

To analyze this approach we should pay particular attention on two compositions, one presenting characters from ancient Greek mythology, and the other based on the story from Christian tradition. In engraving 105, a monumental female figure is presented standing on a pedestal carrying inscription *Libertas*. It seems that the female personification of Freedom, as a notion added to the Ionic Order, refers in a way to the logic of succession of five Orders in Vitruvian and Renaissance architectural tradition. After examples illustrating various aspects of masculine sensibility for fight and struggle exposed within the Doric Order, the next one in line, the Ionic, spreads out a sense of relief, emphasizing the nature of feminine character through notions of freedom and peace. Such an orderly succession also seems to reflect on the change of seasons in nature, or the subsequent trace of events and their causality in human history.

Nevertheless, in the same engraving Dietterlin added to the composition a pair of embraced figures, a female and male, placing them in the left upper corner. By the bow in the female’s hand and the boar’s head with an arrow in its forehead, placed between the characters, they are identified as Atalanta and Meleager. According to the ancient mythology, Atalanta appears to be a victorious heroic character, free of passions as lust and envy. In a way, as an independent female character she achieved personal freedom, and by her capabilities was truly equal to all men and at the end to her husband Meleager. Probably that is the reason why the figure of Libertas points with her right hand towards Atalanta.

Emphasizing the female spiritual qualities, Dietterlin presents in engraving 117, the story of Christ and Samaritan woman. The well-known event occurred on Christ’s way back to Galilee, where Photine (the luminous one), how the Samaritan women was named after her baptism, understood and recognized Christ as the Savior of the world, the bread and water of eternal life, becoming by that almost an apostolic figure in the Christian tradition. Using spiritually elevated female characters, Dietterlin seems to refer to the strength of eternal values of

virtue, understanding and compassion as particular notions attached to the essential experience of the Ionic Order.

It seems that such Dietterlin’s idea may be acknowledged through other engravings illustrating more general constitution of the Order’s character. In the engraving 102 we can find a profound relationship between the character of the Ionic Order and the idea of peaceful times. Armor and arms are arranged as a decorative motive, accompanied by a figure of a putty holding palm and olive branches, as symbols of triumph and peace. More than that, there are engravings with motives of horns of plenty with figures of Bacchus like male characters. Dietterlin added scenes containing depiction of divine creative labor, as in engraving 109, where Hephaestus was presented accompanied by Venus and Amor (Figure 13). Moreover, in other compositions in equal manner are presented ancient divinities in elegant and tranquil atmosphere. Even in engravings depicting architecturally framed examples of warriors’ monuments, they expose triumph rather than aggression.

In this context, engraving 123 is of a particular interest. A fountain is presented, designed as a perfect complex geometrical shape, with personifications of four German rivers, among which just one is named as Renus – Rhine. It is the one of the rare compositions in the book without any mythological or religious connotations, but emphasizing the natural wealth of Germany in a geographic notion. The rivers are presented as a source of plenty, and as a life giving power of the land (Figure 14).

However, despite the fact that all figures, female and male, presented in the book on the Ionic Order have been designed according to the tradition of classical elegance and sophisticated proportional system, one of them – first in the line, the statue column in the engraving 95, has been designed in the manner used for the column like male figure of the Tuscan Order. Composed out of different decorative and symbolical elements, this female figure leaves an impression as representing elementary earthly aspects combined with associations on a housewife role. Floral decorative elements instead of hair, symbolical image of a turtle on her skirt, household keys hanging from her belt, and unidentified wrinkle placed on the stomach, are making an impression of unsophisticated grotesque (Figure 15).
Opposite to the female character from the introductory Ionic engraving, for the first presentation of the Corinthian Order, Dietterlin shaped a highly sophisticated image of a young girl according to the best classical artistic tradition.
(Figure 16). Besides, decorative elements added to the figure, the basket with acanthus plant placed over her head, are closely linked to the Vitruvian story of Callimachus’ discovery of the Corinthian capital, presented in the Dietterlin’s introductory text. Moreover, it seems that there is evidently a transformation of these elements into ornamental system applied to columns.  

It seems that Dietterlin through his choice of themes illustrating the Corinthian Order, developed various expressions related to the sense of sophisticated spiritual elevation as a general notion. In that context, the absence of motives as the horn of plenty and figures of Bacchus as metaphors of material wealth is particularly indicative. Also, instead of images of taverns, innkeepers, and hunt catch, to the perceiver is, for instance in the engraving 144, presented composition depicting a Christian moral critique of two mortal sins – envy and gluttony.

Personifications of envy, Invidia, and of gluttony, Gula, are chained to bases on which the figures presenting their retribution or righteous infliction are placed. At the left Invidia is lying, depicted as demonic old women devouring her own heart, accompanied by a wild animal, probably a bear. She is looking on an elegant female figure with a lamb at her feet, and cracking a heart, illustrating the act of retribution for the sin of envy. Placed on the right, personification of Gula eating, has been watched by a female character carrying a fork with just one radish and a glass with a small amount of liquid, probably water. The moralistic tone calling for the virtue of restraint is evident. Moreover, for his pictorial presentations of two sins, Dietterlin probably inclined to the customary sixteenth century iconographic model, broadly known and published at that time.26

Nevertheless, Dietterlin presented also more known and better understood biblical themes regarding the domination of spiritual strength and faith over earthly life and material world. In that context a simple composition of David carrying Goliath’s head is depicted in the engraving 143, reminding the observer on the notion of being strong in God. The key moment in Christianity when Christ ascended to heaven, is shown in the engraving 146, as a picture incorporated within an architectural frame with a sculpture of personification of Church on the top.

However, in his further presentations of notions regarding spiritual elevation, Dietterlin also used themes arranged around ancient mythological characters and stories. One of them presented in the engraving 148, with Hercules as central figure, links the mythological story of his deeds and the virtue proclaimed by the Christian faith. In his glorious appearance Hercules stands between two other figures symbolically prizing him, as it seems, with offers. At the left a young man orientaly dressed, in seducing arrogant pose offering the cup of vanity, and on the right side personification of Church in a humble and inviting pose of open arms carrying a cup with a cross inside. Turning his head towards the Church, Hercules acts in favour of eternal virtue of obedience and patience, as a sign of completeness of his spiritual strength (Figure 17).

Contrary to this composition addressing a simple spiritual message, the next two examples, are dealing with more complex ancient Greek mythological narratives. In the engraving 149, a known story is presented, that of Zeus and Io. The couple seated on an eagle is centrally placed in the upper section of the composition accompanied by putty. One of them is holding a lyre as the symbol of

harmony, and the other one a rabbit as the symbol of fertility. In the lower zone, at the left the figure of Argus is depicted. He was primordial giant with hundred eyes, servant of Hera and the guard of Io. He was killed by Hermes which figure is placed at the right side of the composition, aiming towards the giant. These two characters are obviously presented to complete the narrative, which by its nature is not a lascivious one, as it can appear at the first glance, but based on the mythological notion of divine fertility and spreading of the new generation of more spiritually elevated beings.

Composition depicted in the engraving 150 seems to be engaged with the notion of the supremacy of the divine musical harmony, obviously based on the story of the competition between Apollo and Marsias. However, in comparison to the original mythological narrative, Dietterlin entered a few differences into his pictorial interpretation.

Figures of two rivals are placed in the lower part of the scene, Apollo on the right side with his lyre and the laurel wreath placed on his head, and Marcias with the Pan Flute on the left. As the judge in the competition, instead of muses, a female character is presented, which by the added attributes (the book, putty with a torch, and the crescent moon on her forehead) can be identified as the personification of Cognition. It is important to emphasize that this figure corresponds with the iconographic model, circulating in Europe at the end of the sixteenth and the beginning of the seventeenth century. As the larger iconographic difference to the usually accepted pictorial model of cognition is the appearance of an empty plate placed in her right hand. It seems that Dietterlin added this detail as a part of the communication between Cognition and Marsias, at the end of her verdict. Giving the advantage to Apollo as the god of harmony, she was presenting to Marsias his award, an empty plate as a cynical gesture of despising lowness and emptiness of his spirit.

Analyzed compositions, rich in narration, Dietterlin presented as integral parts of illustrated windows and fireplaces. In the collection of portals, he accepted a more moderated approach using figures mainly as personifications of highly esteemed cultural notions and relevant institutions of the society. Nevertheless, Dietterlin’s affection with themes of spiritual purity and morally elevated ideas is not weakening. It takes just a variable form of expression, where figures are incorporated within particularly sophisticated architectural presentations which artistic characteristics are following the main metaphor in the composition.

Figure 17. Dietterlin, Architectura, Engraving 148, 1598

Figure 18. Dietterlin, Architectura, Engraving 152, 1598
The first of those examples Dietterlin presented in the engraving 152. Architecture of the gate, which opens a view down a garden path, is richly decorated with grotesque like female busts composed with additional floral elements. Moreover, floral motives are also added to the surface of the building’s elements, and it seems that they are used as constitutive metaphorical meaning of the whole composition. On the right side of the gate two figures are placed. A sitting young male is presented as exchanging a lily flower with a standing female figure. The exact meaning of this act is uncertain, but keeping in mind that the lily flower symbolizes the virtue of purity, it seems to be related to a presentation of maidenhood without any approval for passing the gate can’t be gained (Figure 18).

Two more symbols are incorporated into the presentation, and it seems that they are essentially correlated with the general metaphorical meaning of the scene. In the oculus positioned immediately over the gate arch, figure of phoenix is placed, as a symbol of spiritual rebirth within the eternal circle of life, and from the top of the whole composition dominates a figure of an eagle presenting the supreme divine heavenly power. Sentimental feeling developed through analyzed elements suggests the metaphorical depiction of the garden of eternal life, maybe related to the introductory story of the Corinthian maiden.

The metaphorical meanings of the next two examples are more certain and understandable.

A portal designed in a strict manner with plane columns and even surfaces, is presented in the engraving 157. By these characteristics architecture supports the notion of gravity that the institution of Justice should have. The figure of personified Justice is placed on the top of the architectural composition, carrying in her hands a sword and a weight. To her dominant and almost holy appearance two female figures are complementing. At the right side of the personification of Justice, Dietterlin placed a figure of young women holding the tablets of Ten Commandments and a torch, while at the left side the other one is attributed with a victorious wreath and a palm branch as insignia of triumph (Figure 19).

The engraving 160 contains the second example we will pay attention to. It is a presentation of architecturally balanced composition, almost classical in its expression. To its sophisticated design contributes the absence of exaggerated decoration visible in the majority of Dietterlin’s engravings. One can sense the harmoniously restrained notion of the architectural form, which embraced just a few figures. The most important of them, placed in the upper part of the gate, are five maidens, a company of musicians performing for the goddess Athena. The scene brings up her attributes as goddess of cultivation and ascent of reason, as prerequisites for a harmonious human society. In that context, the figure of Pegasus, the ancient symbol of spiritual elevation, placed on the top of the architectural composition, completes the notion of this profound metaphor.

The last example we will discuss within the line of engravings characterizing the Corinthian Order, is also compositionally the most complex one. It presents a fountain assembled from four parts, each of them personifying one of the elements of the material world we are living in. The engraving 162 presents the element of
fire; the element of air in the engraving 163; of water in 164, and earth in 165. They are all arranged together around the pool in the engraving 166, by placing the personification of water in the middle, with the fire above it. On the left side from the central part, the personification of earth is placed, and on the right of air. All together, they form a complex metaphor presenting the entire material nature of the universe (Figure 20). It seems that this way Dietterlin emphasized the entirety of material principles of natural laws, as fundament of permanency between divine and human manifestations of elevated spiritual values. By this, he characterized the Corinthian Order as a supreme expression of sophisticated dualistic completeness of the material and spiritual world.

Figure 19. Dietterlin, Architectura, Engraving 157, 1598

Figure 20. Dietterlin, Architectura, Engraving 166, 1598

Composite Order

In comparison to the first four books, the fifth, illustrating the characteristics of the Composite Order, contains the smallest number of engravings. Moreover, to his selection of themes Dietterlin did not include any mythological narrative belonging to the ancient Greek and Roman tradition. It seems that his idea, presented in the small introduction text, that the Composite Order is “more pure and subtle than Corinthian”, developed through his pictorial interpretations in a particular way. Dealing with ideas of triumphant spiritual and moral powers as universal human and social values in his fourth book, in the next one Dietterlin continuously developed an image related to the supremacy of the Christian universe and its essential teachings. However, it seems that according to this task he developed approach related to various particularities of that universe and their representations.

In the context of Dietterlin’s statement regarding purity and subtlety of the Composite Order, the characteristics of the column like female image represented in the introductory engraving 176 looks almost confusing. It is composed in the same manner and by similar means as the introduction figures of the Tuscan and Ionic Orders. These three representations seem to create a coherent ideological motive, and if we may say, almost a German principle of a new artistic invention (Figure 21).

Nevertheless, in the engraving 187-188, Dietterlin presented the idea of gradation of the five Orders, as a pure architectural sensation related to their visual characteristics and perceptual qualities. The first plan of the engraving is occupied with shaded representation of three Greek Orders, Doric, Ionic, and Corinthian, placed one upon the other. It is an accurate depiction of their ancient features, without any Renaissance or Mannerist supplements. However, by presenting the five Renaissance Orders through a shiny grandiose architectural structure just behind this shaded image, Dietterlin was contrasting the architectural characters of these two groups of orders. At the same time he emphasized their generative connection. In that context, the second architectural structure consisting on five Renaissance Orders, appears to be a complex one, particularly by the manner how Dietterlin interconnected their characters.

The oldest one, strongest and most rustic Tuscan Order took the ground floor. More elegant but still strong in appearance, the Doric Order occupies the position of the first floor. By using Ionic elements the second floor is structured and supplemented with a classical caryatid on the corner. With elements of the Corinthian Order the third floor is shaped, extending to a terrace with an obelisk on the corner finishing an elegant balustrade. Unusually presented, the idea of Composite Order is suggested through the appearance of one single column placed on the corner of the roof terrace.

However, our perception of this usual successive structural arrangement of five Orders has been manipulated by Dietterlin in a particular way. From the

ground floor to the top, every following floor differentiates not only by proportions inherent to each Order. Their heights are subordinated to the successive reduction, forming a perspective sensation in a way that it attained visual lightness of the upper floors. This effect offers an impression where the elegant architectural structure of the fourth and fifth floor visually merges with the sky. Accordingly, Corinthian and Composite Orders are not only visually most pure and subtle, but they also through use of metaphorical language offer the possibility in expressing the most elevated and sophisticated spiritual ideas.

Moreover, in this context one can assume that the Composite Order offers more possibilities than other four to be the carrier of new architectural inventions. One of these mannerist inventions, as already stated by other researchers, relates to the Dietterlin’s idea that the Composite Order by its potential can be intertwined with Gothic elements.\textsuperscript{30} However, in this context one should be more precise when defining the possible Gothic elements used in Dietterlin’s arrangements.

As shown in the engravings 197 and 203, we can perceive use of a system based on arrangement of different architectural elements in multiple layers. Actually, it proves the approach of overlapping as the essence of mannerist invention, and according to this, the value of intuitional perception shading the rational architectural structuralism.\textsuperscript{31} These kind of achieved perceptional values are supporting appearance of different intuitionally invented architectural characters as new cultural artistic expressions (Figure 22).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{image.png}
\caption{Dietterlin, Architectura, Engraving 176, 1598}
\end{figure}


In the examples in focus, the primal architectural composition is based on the mannerist sense of monumentality. Over it, as the second layer, appears a woven lace like decorative system, which is not integrated structurally with the primal wall, but just visually supplemented to it. However, the architectural characteristics of this second layer seem to follow the spirit of the Gothic architecture, but at the end they are not formed according to a pure Gothic expression. Rather it is a hybrid form of decoration incorporating elements of the sixteenth century art of Grotesque which in a linear way imitates Gothic shapes.

Nevertheless, Dietterlin used elements of, at that time, popular art of Grotesque in his book abundantly, and in that context such hybrid decorative forms have not been far from his artistic sensibility. It should be noted that one of the architects, Vredeman de Vries, whose influence on Dietterlin has been already recognized through his metaphorical approach to architectural design, also published a book on the art of Grotesque. Actually, it seems that his ideas also extended on the Dietterlin’s use of grotesque as a form of creative expression. However, in analyzed examples these forms, as it seems, are profoundly and systematically arranged in a search for invention of a new German architecture,
but as an element incorporated in a complex expression of the sixteenth century culture.34

The second important theme related to the presentation of universal values as expressive characteristics of the Composite Order, develops through narratives capital for the Christian faith and the Church. The engravings 203, 205, and 206 are presenting compositions of coronation of the Mother of God, adoration of magi, presentation of the instruments of martyrdom to Christ, the victory of St. Michel over the devil, and the Mother of God with the Christ child in glory. These compositions released from any extreme passion correlate with the idea of sophisticated spiritual elevation, as the essential character of the Composite Order (Figure 23).

However, there is one exception in this context. The engravings 199 and 200 offer a glorious design of a fountain which sculptural composition presents the martyrdom of St. Sebastian. He was universally popular saint at that time in Europe, as the protector from plague, and because his two martyrdoms have been a model of persistence in faith. Actually, this was the most excellent theme of the sixteenth century, and by that unavoidable in Dietterlin’s collection of Christian narratives.

The engraving 201 depicts a fountain on four corners carrying figural interpretations of world’s continents: America, Africa, Asia, and Europe. This theme correlates in a broader sense with other two fountain designs already mentioned in our discussion, i.e. the personifications of four German rivers in the engraving 123, and of four material elements in illustration 166. Actually, these three examples are forming a separate topic in Dietterlin’s book, revealing his permanent interest in presenting allegorical constituents of particular geographic areas, local and global, or material elements on which the nature consists. Such an artistic activity seems to be result of an intellectual impulse, and especially in the third example, for expressing new global human knowledge related to contemporary discoveries of the geographic and cultural wonders of the world. It offers a new sensation of completeness of the human existence, worldly and spiritually.

However, the last two engravings we will discuss are related to the notion of time: as nature’s permanent cycle of seasons, but also as impermanency of the human earthly existence.

Placed within an architectural composition classical in its character, the personification of summer seated on a lion, represents the central motive of the engraving 198.35 Under her feet a seasonal clock is depicted with the personifications of spring and autumn. On the top of the composition a huge clock is carried by the personification of time. His figure is attributed with scythe and winged sand clock, metaphorically showing the power of time over the mortal beings.


This somber indication of human temporality is fully expressed in the engraving 209, as the last Dietterlin’s metaphorical message to his readers. Universality of death as human’s unavoidable end, has been presented by a crypt ‘decorated’ with figures of an old man and women, a skeleton, candles, arms and armors hanging on the wall. Over this arrangement presides a pair of huge wings, sand clock and two trumpets, probably as announcing instruments of the Judgment Day. Two saints seated in the front of the crypt, Moses on the right and Hieronymus on the left side, are reminding the observer on the final stage of the earthly life (Figure 24).

Figure 23. Dietterlin, Architectura, Engraving 205, 1598

Figure 24. Dietterlin, Architectura, Engraving 209, 1598
Conclusions

Our discussion on Dietterlin’s interpretation of characters of five architectural Orders originated from the Vitruvian and Renaissance tradition, emphasize not only the individual Mannerist approach, but also a complex engagement with the sixteenth century German cultural and social aspects relevant for the issue in focus. Moreover, architectural Orders have been interpreted as integrative factor of ancient and contemporary culture of the time, resulting in a process of experimenting with new architectural inventions. Actually, Dietterlin developed a creative pictorial language as a kind of complex historical and cultural narrative, including general reflections on permanent human spiritual elevation. Without entering his narratives in detail, followed by the process of comparison of each character given to the five Orders, the general idea of Dietterlin’s book would remain in the field of obscure interpretation. That is probably the reason why some architectural historians expressed a level of reservation regarding the permanency in Dietterlin’s intention to define the “spirit of the Orders.”

Particular value of Dietterlin’s approach to cultural merging of ancient and contemporary elements refers to his attitude that Classical architecture can be thought as universal cultural achievement, a base on which one can imprint almost any artistic invention. This position is established on an understanding that the Classical proportional system appears to be a universal artistic value, and that the contemporary sensibility should form its own variation of character applied to each architectural Order. This gave to Dietterlin a possibility to synthesize various cultural aspects and narratives, ancient and those developed in his own time, using the creative power of integrating architecture, sculpture, and pictorial expression. By this, he proves decoration to be a metaphorical cultural system of his time.

Nevertheless, the book is composed by using an intriguing mixture of various mythological traditions, which often gives to the acting personalities and their characters ambivalent narrative roles and meanings. However, we should emphasized that Dietterlin’s imaginative representations also display well established knowledge regarding, for instance, ideas of primordial character of materialization and structuring through which some Orders appeared in the first place. We should emphasize that by all indicated qualities, Dietterlin’s book remains a unique work not only in the sixteenth century Germany. The seventeenth century in Germany can be named as period when Mannerism flourished in the full cultural capacity. There is indication that Dietterlin’s book played an important role in the process of forming its cultural language. However, the possible influence of this work on the future development on architectural and artistic ideas should be further analyzed.

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The Architectural Illusion of Edoardo Tresoldi: The Reconstruction of the Basilica of Siponto

By Francesco Del Sole*

The Ministry of Tourism commissioned Edoardo Tresoldi in 2016 to restore the Basilica of Siponto (Puglia, Italy), of which only ruins remain. The project is obtained through metal wefts that intertwine in the air presumably reconstructing the original environments: it is an example of creative restoration. This essay aims to examine the genesis of this artwork that has rekindled the debate on the usefulness of this type of restoration, introduced for the first time by Cesare Brandi (1906-1988) and Renato Bonelli (1911-2004) who gave rise to a critical discussion on the role that restoration must play in reconstructing the original spaces of a lost monument. Creative restoration tends to include in the concept of “restoration” all those actions of reconstruction necessary to restore “truth” to the lost monument in order to guarantee its enjoyment, making the “evocative fantasy” take over. Faced with an architecture that has now lost its face, the added value of Tresoldi’s creative restoration will be highlighted, which is not only the reconstruction of the Basilica but the possibility, through the wire mesh that generates transparency, to understand the monument not only as a historical document but as an artwork that needs to be experienced aesthetically, safeguarding the genius loci, making the site a place to be rediscovered in its link with the territory.

Introduction

In September 2013, the Regional Direction for the Cultural and Landscape Heritage of Apulia published a public notice in “Gazzetta Ufficiale” for the realization of the “works of recovery and enhancement of the Archaeological Park of Siponto (restoration and enhancement of the early Christian basilica; restoration and enhancement of the two levels of the Romanesque church etc.).” The task would be entrusted to the young artist Edoardo Tresoldi who, assisted by historians, archaeologists and architects, would create the project entitled “Where Art Reconstructs Time”, an installation obtained through metal wefts that intertwine in the air, reconstructing the presumably original rooms of the now disappeared early Christian basilica, complete with columns, capitals and trusses, defined in terms of plan and dimensions on the basis of strictly philological criteria. As such, the new basilica of Tresoldi has a weight of 14 tonnes, due to the 4500 metres of double galvanised welded mesh. The work of the artist’s young

*Assistant Professor, Department of Cultural Heritage, University of Salento, Italy.

1. “Gazzetta Ufficiale della Repubblica Italiana - 5° Serie Speciale - Contratti Pubblici n. 110 del 18-9-2013 - MIBAC - Direzione regionale per i beni culturali e paesaggistici della Puglia - Bando di gara CIG: 53013826D1”. The project was carried out with structural funds from the Interregional Operational Programme. Cultural, natural and tourism attractions - P.O. In. 2007-2013. It is possible to consult the full text of the public notice at the site: https://www.gazzettaufficiale.it/.
team, with an average age of 25 years, lasted approximately five months and was inaugurated with great enthusiasm in the initial days of March 2016. Importantly, we are not dealing with a simple work of contemporary art; the Apulian institution, when describing the technical details of the public contract, uses very precise terms: it had to be a restoration and enhancement of the site. The choice to give life to this contemporary experiment can certainly be considered brave, but a vital position as well within the debate on the nature of architectural restoration, in this case, applied to a strategic archaeological site.

The Early Christian Basilica of Siponto: Historical Hints

Located on the slopes of the Gargano peninsula, Siponto was born as a Roman colony around 194 BC. Abandoned between the 4th and 5th centuries A.D. following repeated looting, was reborn under the aegis of Christianity when freed from invaders. Presumably around 465 A.D., the Gran Duomo Sipontino was built, which later took the name of Basilica di Santa Maria Maggiore. Accordingly, a renovation work of the following century enriched the basilica with valuable mosaic floors, of which some traces remain. The church thus acquires the splendour that makes it an obligatory stop for pilgrims from continental Europe, passing through Rome, to Siponto before continuing on to the Gargano sanctuaries and embarking from the ports of Apulia to Jerusalem. The plan of the early Christian Basilica consists of three naves separated by columns with a raised


3. An important text to consult in order to take stock of the policies adopted in the field of restoration is V. Cazzato, Istituzioni e politiche culturali in Italia negli anni Trenta (Rome: Istituto Poligrafico dello Stato, 2001).

central apse. The early Christian basilica probably remained in function until the 11th century and was the object of rehashing by Archbishop Leone (1023–1050). Moreover, the archbishop himself promoted—adjacent to the early Christian building—the construction of a new square basilica with two apses, a jewel of Apulian Romanesque architecture. Unlike the Romanesque counterpart, only the foundations of the early Christian basilica—which over time has become a pile of ruins—have been preserved. The old town was then finally evacuated in 1223, when King Manfred of Swabia founded the New Siponto, now Manfredonia. Only centuries later, the discovery of a pillar and an altar in 1872 dedicated to the goddess Diana rekindled interest in the aforementioned and gave rise to a series of reliefs that allowed us to outline the overall layout of the site. From the observation of the stratifications, the portion of the wall made of *opus reticulatum* emerged distinctly, which must, in fact, have included a very large environment then hidden by the building of the cathedral’s naves. Furthermore, the elevation of the apse in tiles and bricks would have been instead retraced to the original architecture of the Basilica, since it was built with the same technique. Consequently, there is no doubt that the poor state of conservation of the finds is largely due to the obstinacy with which natural disasters and sieges struck the territory (see Figure 1).

**Figure 1.** The Siponto’s Archaeological Park before the Intervention of Edoardo Tresoldi  
*Source:* Wikimedia Commons.
The Creative Restoration of Edoardo Tresoldi (Utilitas)

The reconstruction of Tresoldi recalls the last phase of the ancient factory. At first, a careful study of the ancient parts was carried out, allowing the realization of a preliminary survey for the restoration; then the consolidation of the wall structures was carried out. The installation was implemented on sacrificial surfaces placed above the ancient structures that protected the crests of the walls and allowed Tresoldi’s work to not interfere with the monument while ensuring its reversibility. Previously, the monument had lost its face and the ideal reconstruction of the sacred space was the prerogative of a few scholars. As such, the architectural approach aimed to identify with a common visitor who finds himself in an archaeological area where the mere presence of masonry structures makes it difficult to understand the third dimension. As a result—intended as an active enhancement of the monument—the restoration was necessary. Beyond the various theories on architectural restoration, a basic concept is common to every vision: man, with his intervention, must tend to preserve the architectural significance of a monument. The usefulness of Tresoldi’s work is to be found precisely in the attempt to propose an innovative action of protection which, in the wake of Alois Riegl’s teachings (1858-1905), must not miss the opportunity to propose renewed alliances between conservation and innovation, ensuring that the results of historical research are useful for the enjoyment of the work by a wide public. Currently, we are rather distant from that decadent devotion of Camillo Boito (1836-1914), who, in the wake of John Ruskin (1819-1900), highlighted the right of ancient monuments to sleep undisturbed in their last sleep, hoping for a sort of religious preservation of the relics in their state of abandonment (his


6. Famous is his phrase: “What value does the entire cultural heritage have if experience does not unite us to it?”, in Scarrocchia, *Alois Riegl – Il culto moderno dei monumenti* (Bologna: Nuova Alfa, 1990), 22. All references to Riegl’s theories on architectural restoration are taken from this edition of Scarrocchia, which edited the Italian translation.
The definition of “stupendous filth” is famous. Gustavo Giovannoni (1873-1947) would reaffirm the importance of a restoration even “scientifically imperfect, which represents a lost record of the history of architecture, rather than the complete renunciation of the monument.” If the anastylosis was willingly accepted since the Athens Charter of 1931—because it is a simple reconstruction with the original materials of the monument itself—the problem arose when it was considered necessary to add missing parts for an effective restoration. The following provisions over the years (from the Instructions for the Restoration of Monuments of 1938, to the Venice Charter of 1964, up to the Restoration Charter of 1972) are in marked contrast to the false antique, openly condemning it and reaffirming the principle that “restoration must stop where the hypothesis begins” (art. 9.) However, the Venice Charter itself, the fundamental pivot of modern restoration theories, states in the same article: “in terms of conceptual reconstruction, any work of completion, recognized as indispensable for aesthetic and technical reasons, must be distinguished from architectural design and must bear the mark of our times. The restoration will always be preceded and accompanied by a historical and archaeological study of the monument”. With regard to the insertion of new elements, considered necessary starting from a critical judgement of value, these will have to guarantee the harmony between old and new as well as showing “not to be ancient works, but to be works of today. The above is in accordance with the principle of “modern discrimination of additions” elaborated by Boito long before.


**8.** Gustavo Giovannoni (1873-1947) is “pupil” and Boito’s heir with regard to the concept of restoration. Engineer, he dedicated himself to the study and restoration of architecture: in the 20s and 30s he promoted the first Faculty of Architecture in Rome, where he established the Chair of Architectural Restoration, which he held until his death. See G. Giovannoni, *Il restauro dei monumenti* (Roma, 1945); S. Casiello, *La cultura del restauro. Teorie e fondatori* (Venezia: Marsilio, 1996), 267-290; L. Vlad Borrelli, *Conservazione e restauro delle antichità* (Roma: Viella, 2010), 191-193.

**9.** Venice Charter (1964), art. 9; The International Charter of Restoration (known as the Venice Charter) was promulgated at the conclusion of the Second International Congress of Architects and Technicians of Historic Monuments held in Venice from 25 to 31 May 1964.

**10.** “Excluding in fact the act of imitation (equal matter), not being able to grant an exclusively material differentiation (which could turn the intervention into an act of competition), operating with the intention of establishing instead with the original chromatic fabric of reference an identity of effect, just using the colors that will converge there will result that it will be appropriately ‘in relation’ with the original, ‘equal and at the same time differentiated’ and ‘neutral’ to the expressive potential of the work on which therefore will not interfere in any way altering”, in U. Baldini, *Teoria del restauro e unità di metodologia* (Firenze: Nardini, 1981).
monument as a modality that the restorer must implement in order to propose a restoration of the image without touching the remaining ruins, as if it were a visual correction, conducted “almost exclusively with museum techniques.” This reflection was followed by other theories of scholars, such as Cesare Brandi (1906-1988), who spoke of “legitimate secretion of the image,” and Renato Bonelli (1911-2004), who proposed a critical restoration that must make use of the evocative imagination “to recompose the missing parts or reproduce the hidden ones and finally find the complete unity of the work.” From this debate, therefore, the definition of “creative restoration” was born, a type of restoration useful to restore “truth” to the lost monument in order to guarantee its enjoyment, understood not only as a historical document but as a work of art that needs to be experienced aesthetically. Experts and scholars in the field of architectural restoration, such as Giovanni Carbonara, took Edoardo Tresoldi as a model, who, with his creative restoration, brings art and architecture back to being democratic, ensuring that a “prudential restoration” also goes hand in hand with the comprehensibility, for a wide public of early Christian architecture. In accordance with the above, Carbonara recalls how, especially in recent times, no artist has distinguished himself for similar operations in the restoration of a monument. In the past, some “revolutionary” architects have proposed similar forms of restoration, such as Franco Minissi (1919-1966) and Franco Ceschi, making transparency the key element to enhance the landscape where “the artistic wonders” of the site are located (see Figure 2).

14. Giovanni Carbonara, in the report held in Venaria as part of the International Conference “Sustainable Restoration Value. Constellation of Comparisons on Restoration” promoted on 25 February 2016, takes up the notion of creative restoration, one of the pivots of Roberto Pane and Renato Bonelli’s theories: “Restoration is a way of making criticism and making history, not expressed verbally but translated into action. We work on the material work and not on its conception, we do not act on copies as in literature, poetry and music, but always and only on unique and unrepeatable originals, and for this we need better and better professionalism and more and more refined techniques that reduce the invasiveness of the intervention, that guarantee reversibility and compatibility. The integration of artwork and restoration leads to that creative restoration that can reintegrate great gaps”. Text available on the site: http://www.ppan.it/stories/valore-restauro-sostenibile-carbonara-porta-a-venaria-il-modello-siponto-con-l-opera-d-arte-di-tresoldi/ (10/06/2020).
15. The need to integrate, in the discipline of restoration, the attention to “matter” and “image” is recalled in the theories of Longhi, Brandi and Bonelli cited below.
16. “In the ‘50s and ‘60s Franco Minissi in Villa del Casale in Piazza Armerina has created a metal roof as a landscape element, denotative of the ancient space and ancient volumes. In Veio, in the ‘90s, Franco Ceschi virtually reconstructed the Temple of Apollo, an Etruscan work that was reduced to a few centimetres from the ground, reproducing its height with steel rods”, in P. Pierotti and A. Nonni, Dove l’arte ricostruisce il tempo. Il parco archeologico di Santa Maria di Siponto. Un modello di valorizzazione a Manfredonia (Roma: PPAN - Comunicazione e networking per il costruito, 2016), 21. Carbonara had already mentioned in 1996 the “revolutionary restoration” of Minissi in Sicily, recalling Brandi’s support for the project: “In this regard, a reflection on the
The Material and Transparency: Protection of the Genius Loci (Firmintas)

With the work Incipit, presented in 2015 as part of the contemporary art exhibition “Meeting del Mare”, Tresoldi introduced the public to the archetype of the absolute vision that would soon be accomplished with the installation of Siponto. On that occasion, the artwork was a declaration of intent and represented a true manifesto of the mechanism of deployment of the “Materia Assente” applicable to the architectural project. Moreover, Incipit represented the original aspect of a form entrusted to the imagination of the spectator in relation to the landscape (see Figure 3). Tresoldi brings back to Siponto this transparent, almost illusory architecture, present in terms of volume and absent in terms of material. The importance of the use of a new material—the wire mesh that generates transparency, a characteristic element of the intervention—is to be found in the renewed concept of protection that derives from the most recent reflections on restoration.

proposals, still very topical, put forward more than thirty years ago by Brandi for the excavations of Piazza Armerina in Sicily proves to be very timely. [...] The scholar, having examined various solutions, including traditional ones, expressed his appreciation for the one which, with the help of a ‘light and transparent material’ proved to be ‘entirely modern and entirely modest’; an idea which was then concretised by Franco Minissi’s genius. [...] The site [...] is to be saved in its rural charm and protected as the ‘artistic wonders’, the villa and the famous mosaics it contains”, in G. Carbonara, Trattato di restauro architettonico (Torino: Utet, 1996), 1, 48. Brandi’s writing referred to in Carbonara’s text is Brandi, “Archeologia siciliana” Bollettino dell’Istituto Centrale del Restauro (1956), 27-28. On the problem of restoration and types to be applied in archaeological areas see M. C. Laurenti, Le coperture delle aree archeologiche. Museo aperto (Roma: Gangemi, 2006).
The Krakow Charter of 2000 is the last stage of the discussion on the subject at an international level (later transposed in 2004 by the Italian Code of Cultural Heritage and Landscape in Italy); not only a very important step appears institutionalized—which provides for the application of the principles of restoration no longer to the individual architectural monument but to the entire built heritage—but also a concept of protection that includes all the unbuilt landscape areas, since it is the entire territory that preserves important elements of human history and culture. In drawing up the public call for proposals, the Regional Direction for Apulia proposed a dialogue between archaeology and contemporary art that is part of an overall vision of landscape understood in its complexity, between architectural evidence of the past and the present, following that intentional value as a memory that allows today’s man a conceptual restoration of architecture, visually representing the idea of the time elapsed since its construction (see Figures 4-5). The contemporary value of this architecture is expressed by respecting the original use value of the basilica, safeguarding the sacrosanctity of the place, albeit in new forms, and re-introducing the site into the tourist circuit of the Gargano with the aim of intercepting even the religious pilgrimage. At the same time, it is important to ensure the necessary value of novelty that stimulates curiosity and attention to the monument even by those who are not experts, and—through the artistic value of the installation—can imagine the original form of the sacred place.17 It is, as Anna Mattirolo says, “a happy

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17. “The courageous choice of the public commission has made this experimentation possible, investing in innovation and creative industry to carry out the restoration and redevelopment of the existing ancient structures, with the aim of re-introducing them into the tourist circuit of the
mental disorientation between two historical times.” Accordingly, the monument does not become past but is always kept alive, and it is possible, as the Granada Convention (1985) states, “to enhance the preservation of the architectural heritage in public opinion both as an element of cultural identity and as a source of inspiration and creativity for present and future generations.” The material used by Tresoldi becomes a means to protect not only the archaeological ruins but also the landscape in which they are immersed, giving it a scenic value as if it were a theatrical backdrop designed to experience the basilica, thereby safeguarding the genius loci, making the site a place to be rediscovered in its link with the territory. The installation shuns any further sign that is not of nature. The apsidal basin, for example, is no longer a space to contain the altar and the Eucharistic tabernacle, but creates a new bond with the Pinus Halepensis behind it, a secular and distinctive species of the territory of Foggia. Thus, far from its history but never from the place that welcomes it today, the grey nudity of the structure reveals a different sacredness, no longer religious but rather having always resided in the landscape. Tresoldi’s artwork exploits the neutrality of space and the use of architectural archetypes as well as transforms the contradiction generated in the encounter between the artificiality of the square mesh and the naturalness of the landscape. “Incorporated, not restored, it is pure ruin, it becomes a source of information, as it contains the imprints of time, in the same way as a beautiful wrinkled face.” Now, in its entirety “is, ultimately, present” (see Figures 6-8). Resultantly, a few years later, the Regional Direction’s bet is won: the archaeological park of Siponto is one of the most visited places in the region with arrivals from all over the world.

Gargano, intercepting also the religious pilgrimage”. The quote comes from the press kit distributed by the Regional Management on the occasion of the inauguration of the work. Text available on the site: http://puglia.beniculturali.it/index.php?it/406/santa-maria-di-siponto-dove-larte-ricostruisce-il-tempo (10/06/2020). Giovanni Carbonara is also of the same opinion: “Tresoldi's proposal [...] is open to comprehensibility even for those who do not have a specific culture, it recovers the high and reproduces the third dimension”, Pierotti and Nonni, Dove l’arte ricostruisce il tempo. Il parco archeologico di Santa Maria di Siponto. Un modello di valorizzazione a Manfredonia, 2016, 21.

19. “Convention for the Protection of the Architectural Heritage of Europe” (Granada Convention), 1985, art.15;
20. “A place is a space which has a distinct character. Since ancient times the genius loci, or ‘spirit of place’, has been recognized as the concrete reality man has to face and come to terms with in his daily life. Architecture means to visualize the genius loci, and the task of the architects to create meaningful places, whereby he helps man to dwell”, in C. Norberg-Schulz, Genius Loci (Milano: Electa, 1979), 5.
Figure 4. Edoardo Tresoldi, Siponto, Early Christian Basilica, Detail of the Creative Restoration by Edoardo Tresoldi in relation to the Ruins of the Basilica. Source: Roberto Conte, 2016.

Figure 5. Edoardo Tresoldi, Siponto, Early Christian Basilica, Detail of the Column and Capital in Metal Wefts. Source: Roberto Conte, 2016.
Metaphysical Ruin (Venustas)

Edoardo Tresoldi, indicated by *Forbes* magazine as one of the most influential “under 30” in the world, is very shy in his way of intervening space. His architecture is a filter, fitting into the context without pretending to become the main attraction itself. The primary objective is to capture the essence of the place by celebrating the dialogue between the different elements and man, building spaces that allow to be reached. The rhythms of transparency generate amplified points of view while the light and atmospheric factors determine its readability in ever-changing situations. His works have been defined as aesthetic or even poetic architectures; they aim to arouse amazement, succeeding in drawing in the air and allow the user to see the sky beyond a “dome”. These are precisely the criteria for the public contract drawn up by the Regional Direction, hoping for a restoration project aimed at “emotional and sensorial involvement.”


23. “Gazzetta Ufficiale della Repubblica Italiana - 5° Serie Speciale - Contratti Pubblici n. 110 del 18-9-2013 - MIBAC - Direzione regionale per i beni culturali e paesaggistici della Puglia - Bando di gara CIG: 53013826D1”. The project was carried out with structural funds from the Interregional Operational Programme. Cultural, natural and tourism attractions - P.O.In. 2007-2013. It is possible to consult the full text of the public notice at the site: https://www.gazzettaufficiale.it/
life, which aims to build a bridge with the past through such a game of volumes. In the artist’s conception, the work becomes fully inserted in the cycle of the monument, becoming a real metaphysical ruin. Following his reasoning, from the encounter between man’s project (form) and matter, the architectural act is born; then the abandonment takes over, a phenomenon that starts the dynamic process of alteration and decomposition of the place, the state of ruin: matter disintegrates and enriches itself with its temporal experience due to the inexorable action of nature. This gradual metamorphosis slowly leads the monument to disappearance. The metaphysical ruin comes into play as a further stage of the life cycle; it tells about the encumbrances and languages of the original architecture, rekindling the memory and proposing a real concatenation of remains, but at the same time, it accompanies the visitor towards an authentic emotional experience of the space contaminating itself with the surrounding landscape. The language of transparency proposes a new monument, a “path to act,” to be experienced from different angles, deeply distinct from the mere contemplation of ruin. In the young artist’s vision, his aesthetic architectures are the means to tell contrasts and temporal symbiosis, absorbing the landscape itself, contributing to bring back the sacredness of the site to life.

Conclusions

The basilica of Siponto is now an “open work”. On purpose, Tresoldi’s team has limited itself to the reconstruction of the first three bays of the main nave (see Figures 9-10). This indeterminacy allows each visitor to fill in the missing parts, stimulating evaluations and questions. In order to understand the new basilica of Siponto, it is necessary to intuit the aesthetic value of a new architecture that aims to make the objectivity of a historical document accessible to a vast public, articulated in a wise interweaving of subjectivity and objectivity “so as to obtain a work that is both modern and ancient at the same time, somehow new but also totally and authentically original, working on the double register of the poetic and the diacritic.” The greatest reflection that the experiment conducted at Siponto proposes is the hypothetical (and provocative) ideal continuation of the concept introduced by Article 9 of the Venice Charter: “Restoration must stop where the hypothesis begins: where restoration does not arrive, the imagination can.”

Figure 9. Edoardo Tresoldi, Siponto, View of the Nave Left Unfinished  
*Source:* Roberto Conte, 2016.

Figure 10. Edoardo Tresoldi, Siponto, View of the Artwork in relation to the Adjacent Romanesque Church  
*Source:* Roberto Conte, 2016.
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Adalaj Stepwell: A Magical Resonance of Architectural Ingenuity

By Unni Sriparvathy * & T.N. Salahsha ±

The term Stepwell defined as "Well with Stairs" is a window to the ethnicity of forgotten civilizations. Stepwells are structures up to 3 to 5 storeys down from ground level, many of which are artistically designed with exquisite workmanship. These stepwells collect water during seasonal monsoons and in the deeper part of the ground with shadows around, such water bodies undergo slow evaporation process. In India, stepwells have been around since the age of Harappa and Mohenjo-Daro, about 4,500 years ago. During this period, bath wells with steps were created, with rooms surrounding the well-pit for resting. Such stepwells were once integral to the semi-arid regions of India, as they provided water for basic amenities for subsistence. These wells were also venues for colourful festivals and sacred rituals, paving the way for a rich cultural legacy. One such unique stepwell is located in Adalaj village in Gujarat, India, initiated by Raja Veer Singh in 1499 and completed by King Mohammed Begada for Rani Rudabai, wife of the Raja. The cultural and architectural representations in the stepwell at various levels are a tribute to the history, built initially by Hindus and subsequently ornamented and blended with Islamic architecture during the Muslim rule. But present-day perception, nurtured by technological advancements, has shifted. The paper focuses on the effects of the changing urbanscape on the architectural and visual connectivity with the cultural heritage of Adalaj so that adequate conservation measures can be proposed to preserve this icon of Indian architecture. Understanding the cultural relevance of such structures is crucial for their continued appreciation and protection.

Introduction

From the dawn of creation, water has played an integral part in the evolution of mankind. The earliest of civilizations in the world originated on the banks of rivers such as the Nile, the Euphrates, the Tigris, the Yangtze and the Indus. Water is the lifeline that essentially decides the opulence of a community. Water is an indispensable element for survival; from the very first phase of the evolution of human culture, it played a vital role in the abundance of crops, prosperity in agriculture, and the birth and flowering of civilizations. Throughout history, numerous civilizations have peaked substantially and faded into oblivion just as suddenly. In most cases, the underlying cause for both their rise and fall was found to be the same - Water. This precious natural resource has been the impetus of progress in the past and will continue to be a determining factor for development in the present as well as in the future to come. According to the author Jared Diamond, the importance of environmental conditions has often been understated

*Assistant Professor, Holy Crescent College of Architecture, India.
±Assistant Professor, Holy Crescent College of Architecture, India.
in the narration of human history.¹ His book "Guns, Germs and Steel," highlights the pivotal role that the environment played in the progress of societies. Most environmental diversities in different parts of the world stem from the presence or absence of water bodies in the surrounding area.

The study of ancient civilizations provides insight into how the present societies have evolved. The key aspect of development is the availability of water and how it was used to manage and sustain life. Today, water is an abundant resource and hence gets taken for granted. It is quite difficult to imagine how early civilizations operated and relied on water. Life cannot exist without water, due to which, mankind has always been evolving and adapting to new means of obtaining this life-sustaining element. In the past, several civilizations, identifying the importance of water as a means for survival, viewed it as revered. Water held a sacred position in the Indus Valley, Egyptian and Mesopotamian Civilizations, taking the essential role in rites and rituals.

Water has played a fundamental role in the development of early societies through its alliance with the agriculture sector. As the need for food supply increased due to the escalation in population, more water was needed for crops and cultivation. People began using a myriad of irrigation techniques to divert water from rivers and streams directly to their farmland. Designing such systems was a major step in development, one which ultimately helped bring societies together. Irrigation technology allowed societies to redevelop uninhabitable land into fertile, habitable land. Societies focused on weather patterns to understand the harvest seasons and to ensure maximum yield. Water aided agricultural activities, which enhanced the system of trade and economy between civilizations. Families and societies worked together to build irrigation canals, which developed class organizations leading to harmony and peace treaties. But water has also played a pivotal role in the harness of power by the leaders of society. Rulers would often threaten to cut off or re-direct water as they felt necessary, to maintain control over peasants.

Over time, the inevitability of water for the subsistence of life has been greatly overlooked and the availability of potable water has been taken for granted. But the superfluous and materialistic lifestyle, coupled with rising population and rapid development of technology has led to an urgent need for an alternative approach. Dwindling supplies, impending effects of climate change and a rising population have once again brought water to the forefront of future development strategies. The climatologists, environmentalists and strategic planners of today are once again stressing the importance of water for the continuance of life in the future. Regardless of whether the core strategy to highlight the significance of water, is religious or scientific, the time has come for people to unite and make conscious efforts to manage water efficiently and preserve this precious resource for future generations.

Aim and Scope

The paper aims to study the significance of stepwells in drought-prone regions of Northern India, particularly in Adalaj, Gujarat. The architecture of the stepwell, construction materials, designs and culturally significant motifs need to be understood to appreciate their aesthetics and functionality. The study can bring to light architectural practices of pre-Independence India and the evolutionary changes undergone by the stepwell through colonization and multiple battles. Understanding the architectural principles used in the construction of such water buildings can aid in the conception of technological models to obtain potable water in arid regions. The paper can also shed light on forgotten architectural monuments that have undergone years of damage, which is crucial for suitable conservation measures.

Limitations

The study is limited to understanding the architectural principles and cultural significances of Adalaj Stepwell, Gujarat.

Methodology

The paper is a descriptive study carried out in three phases:

- The first phase involves understanding the importance of water in Indian culture.
- Stepwells from different regions of India were studied based on religious beliefs, climate, cultural significance and geographical positions.
- The stepwell at Adalaj village in Gujarat was analyzed in detail, tracing its history, evolution, architecture, community benefits, cultural significance and its present status.

Sanctity of Water in India

Just like in many other parts of the World, civilizations in India also flourished around water sources, and rivers remain as the bedrock of development of the various dynasties in India. Rivers and other water bodies have an auspicious influence on the people. The seven important rivers - Ganga (the Ganges), Yamuna, Godavari, Saraswathi (underground river), Narmada, Sindhu (Indus) and Kaveri (Cauvery) spanning from the northern Himalayan ranges to the southern part of India, had connected the people with different lifestyles, languages, costumes, etc.

The ancient civilizations of Harappa and Mohenjo-Daro have brought to light sacred truths behind religious practices emphasizing the role water played in the rich cultural heritage of India. In Sanskrit, one meaning of the word "Jeevan" (life) is "water." In other words, water is equivalent to life itself. Water is referred to as "Jeevanam Sarva Jeevanam" meaning that the entire world depends on water for
survival. Water is a vital part of many rituals, funeral rites, festivals and other auspicious events in many religious traditions around the world. This is most evident in India as water is always associated with births, marriages, and funerals. Most religious communities in India also believe that submerging oneself in the holy waters of the Ganges River will cleanse them of their sins. Another common notion is that in a parched land, the gift of Water was so precious that the simple act of providing water to quench the thirst of men and animals was deemed meritorious and worthy in the eyes of God, one that gained great merit for the donor. The philosophy behind this is that the only difference between life and death is Water. Accordingly, men and women of monetary means were active in proving funds and patronized the construction of wells and other water buildings for the use of the common people. It was believed that through such charitable acts, they could achieve immortality or "moksha."

Purification Powers of Water

From the Archeological excavations conducted in 1922 on the banks of the Indus River, it was discovered that the earliest form of bathhouses or "Public Baths" were seen in the Indus Valley Civilization. This became the genesis for the construction of individual baths in each housing units as established in the findings. This led to the conclusion that water houses or bathing areas were an essential part of the daily routine, and ritualistic practices required them to use such bathhouses regularly. As water is known to purify a person’s soul, large water bodies were present in temple complexes for ritualistic purposes. The religious significance of water in the Indian traditions continues to the present day, evident from the use of the sacred water in religious buildings.

Healing Powers of Water

In Vedic traditions, water is said to be endowed with exceptional magical and transformative powers; the dwelling places for water nymphs and spirits. Water is said to contain medicinal properties, on account of the mineral content in it. Referring to the healing qualities of water, the Rig Veda states:


3. Moksha (also known as mukti) is the concept of ultimate freedom and liberation in Indian philosophy and religion. Derived from the Sanskrit word, mukt, which means "liberation," "release" and "emancipation," it is the release from the life-death cycle and from the limitations of worldly existence. To reach the state of moksha is to attain absolute freedom, peace and oneness with the Divine.

4. The "Rig Veda" is an ancient Indian text collection that compiles 1,028 Vedic Sanskrit hymns and 10,600 verses dedicated to Rigvedic deities. It is organized into 10 books, called mandalas. Together with "Yajur Veda," "Sama Veda" and "Atharva Veda," "Rig Veda" is one of the four canonical sacred texts of Hinduism, known collectively as the Vedas. "Rig Veda" is the oldest of the Vedas, and one of the oldest extant texts in any Indo-European language.

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Healing are the watery billows.
Water cools the fever’s glow.
Healing against every plague.
Health to thee brings water’s flow.

It is quite evident that the healing and curative powers of water in certain wells caused them to be venerated and held to the most auspicious standards in society. It was a common belief that bathing in many of these holy waters will cure people of various diseases. They presented offerings to the gods and other divine spirits that reside near the water bodies as well.

Water and Fertility

From time immemorial, water has always been associated with fertility and childbirth; not merely for animals, but for humans as well. Many great poets have also compared water to feminine grace. This led to the construction of many shrines, adjacent to water bodies dedicated for the use of women and worshipping for safe childbirth, to cure barrenness, etc. became a common practice; one which is still being practised to this day.

Another commonly held myth was that Apsaras or celestial nymphs along with the Gandharvas or the divine musicians who preside over fertility are said to reside over water bodies. They take the form of aquatic birds and bless the women who honor them with their offerings. Therefore, beautiful carvings and inscriptions of various aquatic birds are depicted prolifically along the walls of many great stepwells in India. Figure 1 illustrates a niched carving of Goddess Saraswati riding a chariot pulled by peacocks depicting feminine beauty and aquatic fauna.

Figure 1. The Motif of Swans with Goddess Saraswati, at Stepwells in Bundi, Rajasthan

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Water and Climate

Large bodies of water generally affect the climate of an area to a great extent. The water heats up and cools down more slowly compared to land. Therefore, in the summer, the coastal regions will stay cooler and in winter warmer. A more moderate climate with a smaller temperature range is created. If there are no bodies of water to moderate the climate the same conditions follow as with vast, flat plains. Therefore, water plays an important role in controlling the microclimate of a particular region. Water bodies regulate temperatures in the surrounding area by the process of evaporative cooling. The process of turning water to vapour requires energy, which is called latent heat of evaporation. When non-saturated air (i.e., air that does not contain liquid water but only water vapor) comes in direct contact with water, evaporation occurs. During this process, the moisture content in the air is increased. The vapour leaves the surface, taking the extra heat with it. The result is a decreased amount of heat and thus, decreased temperature in the surrounding area. This is how evaporative cooling works. India, especially in the arid regions, even a small body of water can make a huge impact in cooling the surrounding areas. As these cooler regions along the water's edge become a communal space, where cultural and racial boundaries are transcended, the primal need to escape from the heat to enjoy respite becomes the main objective. Such areas become a hub for a knowledge-sharing platform, as well as a religious and culturally influential area.

Thus, the influence of water on a region is not only cultural but also climatologically adept.

Voices from the Deep - Stepwells of India

In 1864, the famous French world traveller Louis Rousselet stated that "[a] vast sheet of water, covered with lotuses in flower, amid which thousands of aquatic birds are sporting" at the shores of which bathers washed, surrounded by jungle greenery. It was not a beautiful lakeside scene or a Ghatian river bank he was describing, but one of the most ancient relics that have mesmerized Indians as well as foreigners alike - The Stepwells.

Stepwells in India are exquisite structures which consist of broad steps leading from the ground level to deep within the earth to the underground water reservoir; some going 8 to 10 storeys below the surface. These exceptional structures are not found anywhere else in the world. Stepwells are deep trenches or rock-cut wells or pools of water reached by a set of stairs or steps and are known by a variety of regional names like "bawdi," "baoli," "vav," "vavdi," "vai," "kalyani," or "pushkarni." The Sanskrit Silpa-Shastras and ancient inscriptions refer to them as "Vapi" or "Vapika."

7. Silpa-shastra means the Science of Shilpaarts and crafts. It is an ancient umbrella term for numerous Hindu texts that describe arts, crafts, and their design rules, principles and standards.
Stepwells are examples of traditional Water buildings, which came up for the purpose of storage of water and irrigation tanks that were developed in India, primarily to manage the seasonal fluctuations in the availability of water. Some of the other notable structures that are encompassed in the category of Water buildings are ponds, tanks, and temple tanks. Temple tanks (or tanks) are large reservoirs of water with a few steps leading to the water level (Figure 2). But due to the proportions, water is mostly used for bathing and in the case of temple tanks, used for ritualistic purposes. There were neither shaded areas around it nor any spaces for respite. These were purely utilitarian in nature and served specific purposes.

![Image of a stepwell](image)

**Figure 2. Temple Tank at Vittal Temple Pushkarani at Hampi**  
*Source: www.nativeplanet.com.*

The basic difference between stepwells and tanks is that stepwells make it easier for people to reach the groundwater and to maintain and manage the well (Figure 3).

Western India has a hot and arid to semi-arid climate with capricious and often scanty annual rainfall. Therefore, the only option for obtaining water during the dry season was to harvest the rains during the Monsoon season in wells, so that they can be easily accessed by all. This practice was the inception behind the development of Stepwells. For centuries they remained an integral part of the western Indian communities as a hub for drinking, washing, bathing, socializing, as well as for celebrating colourful festivals and performing sacred rituals. They also became cool sanctuaries for caravans, pilgrims, traders and travellers during the heat of the day. But these magnificent structures were much more than utilitarian reservoirs. During the harsh heat of the day, when water is sparse and rains are scanty, these wells provided life-giving water to people as well as animals and birds, and also enabled the surrounding areas to become fertile.

One of the most intriguing aspects of the Indian Stepwells is that, during excavations, it came to light that 25% of these stepwells were commissioned or built by women - queens, princesses, noble women, wives of merchants, ordinary

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women, courtesans, and even servant girls. This was done to attain immortality and to gain religious merit through the gift of water. Many other stepwells have been built taking inspiration from certain prominent women of the region. Thus, a common element of femininity shrouds these stepwells.

Stepwells served dual functions - providing water and respite as well as acting as the site for many rituals. The linked three worlds: the subterranean, the earthly and the celestial.9

Figure 3. Chand Baoli, Rajasthan
Source: www.travelplanet.in.

Stepwell Architecture

Most stepwells consist of two parts:

1. A vertical shaft—protected from the direct sunlight by a full or partial roof, which acts as the point of collection of the rainwater that is drawn into the inner well pit. The wells were excavated several stories below the ground to reach the water table; the level at which the soil or rock is always saturated with water content (for example, Figure 4).
2. The surrounding inclined subterranean passageway, the stairway or steps and the adjacent chambers or resting areas, which provided access to the well below (for example, Figure 5).

Though most stepwells have common features, they differ from one another in many ways. The four main types of Stepwells are:

- Nanda: Stepwells with just one entrance.
- Bhadra: Stepwells with two entrances.
- Jaya: Stepwells with three entrances.
- Vijaya: Stepwells with four entrances.

From these types, stepwells coming under the Viajaya type are usually the biggest and the most elaborate ones usually termed as "Dirdhika," meaning the

9. Ibid.
length of 3,000 bows. Stepwells which are known as "Living Stepwells" are so named because they are perennial sources of water; never devoid of water throughout the year. Stepwells are usually built using sandstones, Kota stones and other types of stones and rocks, mortar, bricks, rubble, stucco and in some cases, even marble.

The lattice-like walls with its intricately carved pillars, decorated towers in the surrounding areas and culturally blended style of iconography have made them exceptionally rich monuments of Indian architecture. Incorporating flights of stairs leading from the ground level down to the water, most stepwells functioned as Hindu temples as well; featuring colonnaded pavilions with elaborate stone carvings. Islamic versions had more sedate adornment and often incorporated arched side-niches. Both architectural types had cylindrical wells. Commissioned by royal, wealthy, or powerful patrons, they are complex engineering feats and are stunning examples of both Indian and Islamic architecture.

Each successive level of most stepwells, was punctuated by covered pavilions, which are accessed by ledges as the water level rose and are considered as vital sun shading devices, at the same time buttressing the walls against intense pressure. Many stepwells gradually narrowed from the surface to the lowest tier, where the temperature remained constantly cool. By building underground rather than above, a reverse architecture was created.

![Figure 4. The Vertical Shaft of Adalaj Stepwell, Gujarat](Source: Photographed by Author.)
History and Evolution

The first rock-cut stepwells in India appeared between 2\textsuperscript{nd} and 4\textsuperscript{th} centuries A.D., born out of necessity in an erratic monsoon climatic zone that is bone-dry for most of the year but drenched by torrential rains for many weeks. It was essential to guarantee a year-round water supply of water, particularly in the arid regions of India where the water table could be inconveniently buried 10 stories below. Over time, design and planning of stepwells evolved into astoundingly complex structures. The next stage of evolution witnessed the construction of wells at Dhank, near Rajkot, Gujarat (550–625 A.D.) and of the stepped ponds at Bhinmal, in the Jalore district of Rajasthan (850–950 A.D.)\textsuperscript{10} Continuing the legacy, around thousands of other stepwells, varying in proportion began to be constructed in various parts of western India. Stepwell construction saw its peak from the 11\textsuperscript{th} to 16\textsuperscript{th} century. But studies show that the construction of such structures might have originated much earlier than that. Following the reported discovery of as many as 700 wells in just one section of the city of Mohenjo-Daro, the scholars are led to believe that these "cylindrical brick-lined wells" might have been invented by the people of the Indus Valley civilization and may be the predecessors of the stepwell.\textsuperscript{11} Scholars have estimated that by the 19\textsuperscript{th} century, several thousand stepwells of varying degrees of grandeur had been built throughout India—in the cities, towns, villages, and eventually in private gardens where they came to be known as "retreat wells" as it was used by traders, who take

\textsuperscript{11} Ibid.
refuge from the harsh climate. It was considered extremely meritorious to commission a stepwell, either as a charitable act or as a memorial to a loved one. Some notable examples of Stepwell Architecture are shown in Figures 6-9.

Figure 6. Chand Baoli, Rajasthan
Source: Scroll.in.

Figure 7. Mukundpura Baoli, Haryana
Source: Scroll.in.
Contributions of Women to Stepwell Architecture

The pages of history give clear evidence of the significant part women have played in the construction of several significant stepwells. They are known to have inspired creation as well as commission of most of the stepwells. Women of means, albeit mostly royal women, have been donors and commissioned many great stepwells to be constructed. Some stepwells have also been commissioned by ordinary women. Common women, wives of merchants, courtesans and servants have also been donors to several great stepwells. The primary goal behind the intent is to construct a place away from domestic life, where women could be free and enjoy the company of other women and in the process gather water for their homes. This was especially significant in the past, where traditionally, the women were confined to the back service quarters of their homes, while the men would be free to enjoy their time in the spacious and open areas of the house. Women took the opportunity to socialize with themselves, learned new crafts, participated in rituals and special festivals and through all this, got exposure to a vivid life away from their domesticated stature. Throughout history, men have made a mark for themselves through the construction of grand and imposing temples, palaces, mausoleums, etc. Perhaps women also yearned to immortalize themselves, one
way or the other and chose to aid in building utilitarian water houses that could benefit every other woman in the area as well as providing the sacred gift of water to all. In an era where women held little to no value in society other than to raise a family, this step towards commissioning works of architecture for the greater good was truly an inspiring step towards a progressive society - one in which women stood side by side with men and demanded a place for themselves in the pages of history. They created architectural marvels that inspired many generations to imagine, write poems and literature, and draw about. The stepwells allowed women to step out from the familial realm into the public domain. These structures also became the hub for community spaces which could transcend religious differences and sectarian conflicts. This form of religious and cultural tolerance and a spirit of assimilation were rarely witnessed elsewhere in India. Even when most Hindu temples suffered desecration when invaders attacked, most of the stepwells were left untouched. Realizing the practicality behind these structures they were allowed to remain intact. Hence, the walls of these magnificent structures can tell the tales of the women who built them and the life they had celebrated at that time.

Stepwells of Gujarat

Stepwells are mostly seen in the hot and dry climatic zones of Northern and North-Western India like Gujarat, Rajasthan, Haryana, etc. But among them, the stepwells of Gujarat are few of the most enchanting, and well-preserved water buildings in history. As they follow their own traditional and cultural systems in the construction, they remain unique wonders even today. These underground structures peculiar to the Gujarat region was the outcome of the hot, arid climate and the severe paucity of water available for use. This outcome was further enhanced due to the sporadic nature of monsoon rains.

These stepwells celebrate water and take this style of regional architecture to its zenith. Stepwells can be found in towns like Patan, Jhinjuwada, Viramgam, Vadhvan, Sarsa, Dhadhalpur, Chobri, Anandpur, Gondal, Virpur, and Jetpur and all the way up to the coast in Somnath in Gujarat. There are hundreds of these "water shrines" in this region, but the stepwells of Adalaj (near Ahmedabad) and the Rani-kivav of Patan (the old Solanki capital in the north of Gujarat) are the ultimate examples of this style of architecture. They are also a testament to the grandeur and exquisiteness of the Solanki Architecture style.

Figure 10 illustrates a few of the notable stepwells found in Gujarat. These stepwells are located in the arid, desert-bordering villages which used to supply the local communities with drinking water during harsh summer months.

In the whole of India, especially in the western coast, Gujarat was known for its commercial activities. The social, cultural and economic activities held an important position due to the steady rise in its graph as an important commercial centre. It served as a convergence point whereby, traders from many parts of the country as well as from other Asian countries could conduct their business as well as pass-through to other regions of the country. In the network of the external trade of Gujarat, the commercial relations with the West Asian, South-East Asian and the African coast were most prominent. The coastal region of Gujarat, which had a
flourishing maritime trade, extended from Dwaraka in the North to Chaul in the South. When Gujarat became a part of the Mughal Empire, the ports became the "sea-gates" of Northern India.

![Map Showing Prominent Stepwells of Gujarat](image)

**Figure 10. Map Showing Prominent Stepwells of Gujarat**  
*Source: Author.*

All these factors led to the additional imposition on the scantily available water resources. Harsh climatic conditions also made it challenging for weary travelers to transport their goods and animals. This instigated the need for a system of effective water harvesting techniques that could preserve the resources, as well as provide respite to the travelers. Already the formulation of a primitive system of wells was prevalent from the Indus Valley civilization onwards. But more sophisticated means of trapping rainwater and creating reservoirs for the dryer seasons started surfacing. This led to the inclusion of resting areas or rooms for the traders and travelers with provisions for their animals to rest, below the surface of the ground. It was also understood that, as one moves down from the surface level, the temperature gradually decreases. The presence of a water body further enhances cooling of air through the slow evaporation process. Thus, a comfortable and safe haven was envisaged by the people. Many rudimentary versions of stepwells were constructed serving basic purposes. But the form got its full artistic voice during the 10th and 15th centuries when the artisans and craftsmen of the Solanki and post-Solanki era infused unique and exquisite regional art forms to these "subterranean shrines". The stepwells act as doorways to their era; offering a glimpse into architecture, religious practices, the daily life of the rich and the poor and the cultural sphere of the people.
Adalaj Stepwell, Gandhinagar, Gujarat

The stepwell at Adalaj which was built along the main caravan route of Ahmedabad and Patan (the then capital of Gujarat) districts, about 13 km away north of Ahmedabad, was commissioned in 1499 A.D. by Queen Rudabai who was the widow of the Rajput Rana Veer Singh Vaghela. Muslim Sultans who were ruling Gujarat, infused Islamic architectural style to the traditional Rajputani architecture. Adalaj Stepwell is a magnificent example of this fusion of Hindu craftsmanship and the floral, geometric patterns of Islamic architecture.

This five-storeyed subterranean structure is octagonal in form, with the main well in the centre (Figures 11-12). It is 250 feet in length surrounded by columns on all four sides. The five storeys of the stepwell had cross beams all along their lengths. This stepwell, of the three-faced type or "Jaya vav" (as it has three entrances) as described in the classical manuals of Hindu architecture, is a mesmerizing procession of arabesque designs, intricately decorated columns, ornamental balconies with exquisite carvings, carved walls and niches with shrines of Hindu gods and goddesses, elephants, flowers, birds and chhatris seen throughout its five floors. There is an inscription comprising of 27 lines in Sanskrit and Devanagiri script which states the origins of this stepwell. The inscription compares the waters of this stepwell to the holy waters of the Ganges River and Mount Kailash. The inscription is full of praises for Queen Rudabai and compares her to Sita, the heroine of the epic Ramayana.

Figure 11. Adalaj Stepwell
Source: Photographed by Author.

12. Chhatris are elevated, dome-shaped pavilions used as an element in Indian architecture. The word Chhatri means "canopy" or "umbrella."

13. Devanāgarī, (Sanskrit: deva, "god," and nāgarī (lipi), "script of the city") also called Nāgarī, script is developed from the North Indian monumental script known as Gupta and ultimately from the Brāhmī alphabet, from which all modern Indian writing systems are derived. In use from the 7th century and occurring in its mature form from the 11th century onward, Devanāgarī is characterized by long, horizontal strokes at the tops of the letters, usually joined in modern usage to form a continuous horizontal line through the script when written.
A Passage to the Past

The history of the stepwell was established with the help a Sanskrit inscription found on a marble slab positioned in a recess on the first floor, from the eastern entry to the well. Its construction was started by Rana Veer Singh of the Vaghela dynasty. But he was killed in a war, where after the Muslim king Mahmud Begada continued the construction in the Indo-Islamic architectural style, in 1499 A.D. The cultural and architectural depictions in the deep wells at various levels pay a tribute to the history of the stepwell, built initially by Hindus and subsequently ornamented and blended with Islamic architecture during the Muslim rule.

The construction of Adalaj Vav started in the late 16\textsuperscript{th} century by King Rana Veer Singh. He was from the Vaghela dynasty; they were the rulers of Dandai Desh, which became the present-day Gandhinagar, Gujarat. At a time when rains were scanty and drought was prevalent, Gujarat was under the control of Mahmud Begada (Sultan of Gujarat). Rana Veer Singh realized that people in Adalaj were suffering from severe water crisis and they had to walk miles to get water for their daily needs. Hence, he decided to create a Vav to solve this crisis. But before completing this structure, he died in battle against Mahmud Begada. After his death, his wife, Rani Rudabai continued the construction. She proposed many rooms to be added, to be used as resting areas for the weary travelers along with many areas for worshippers and pavilions for rituals or festivals to be conducted. She drew money from her treasury for this purpose and was praised by the people for her generosity. The Sultan Mahmud Begada, who fell in love with the Rani proposed marriage. The grief-stricken widow agreed on the condition that the Sultan completes the construction of the stepwell. Mahmud Begada accepted this condition and made significant efforts to construct an outstanding and unparalleled Vav, which is a fusion of Hindu, Jain, and Islamic traditions and architectural styles. The artisans who were responsible for producing this marvel were killed by the Sultan after the structure was completed, to prevent the possibility of the style

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of architecture being replicated. Hence Adalaj Stepwell will always remain unique.

By 1599 A.D., the construction of Adalaj Vav was completed. While showing her the completed stepwell, Rani Rudabai committed suicide by drowning herself in the well. The heartbroken Sultan could not marry the Rani and preserved the stepwell to honour her. Even today, Adalaj Vav is described as Rudabai Vav, named after the queen who sacrificed her life instead of marrying a Sultan. The tragic story associated with Adalaj Vav became a favourite theme of Gujarati folklore and poems. The people of Adalaj will forever cherish the memory of the Rani who was immortalized through sculptures and inscriptions describing her beauty, generosity, courage, and loyalty.

Though the tales behind the stepwell are tragic, the legacy which was started by the Rana lives on as a symbol of loyalty and solidarity between Hindu and Muslim dynasties. The legend has been kept alive for centuries and is now being depicted in movies and literature. The magnificence of the stepwell can be experienced in every carving and pillar (Figure 13). There are many stone inscriptions singing praises to Rana and the Sultan as well as the Queen.

Adalaj Stepwell was built in sandstone in Solanki architectural style. Solanki architecture mostly flourished in Gujarat. It closely resembles the Rajasthani style of architecture, with intricate stone carvings and trellis work. The fundamental features of Solanki architecture style are closed halls, hypostyle pavilions (Figure 14), a porch that is connected both internally and externally, and intricate and themed carvings on the walls and pillars. The stepwell consists of two well pits - one for everyday purposes and another one solely for the purpose of rainwater collection (Figure 15). The latter one will usually overflow into the main well pit during the monsoon season. This ensured a year-round supply of water for the people.

![Figure 13. A Sketch of the Beautiful Carving on the Lintels](source: Sketched by Ar. Jefrin Jabbar)

**Architectural Features**

The most striking feature of Adalaj Stepwell, and for other stepwells as well, is that there is a stark contrast between the ambient temperature at the ground level and inside the stepwell. As a person descends, the temperature keeps reducing. This is attributed to two possibilities:

16. Akshat Gupta, B.Arch, M.tech MBEP/Freelance photographer, CEPT University.
1. The air gets cooler due to the stone and the ground below acting as thermal buffers.
2. Evaporative cooling due to the presence of the water body.

Architectural Details

The five-storeyed structure is an octagonal polygon in plan (Figure 16). The Adalaj Stepwell is 75.3 meters in length and is oriented along the North-South direction. Each floor is spacious enough for the congregation of people. It was dug deep to access groundwater at the lower level, accounting for seasonal fluctuations in water level due to rainfall during seasonal monsoons. The air and light vents in the roof at various floors and the landing level are in the form of large openings with some being ornate with trellis decorations. The entrance is from the South with three staircases along the South, West and East directions leading to a spacious landing. Four small rooms with oriel windows\footnote{Oriel window: a large upper-storey bay with a window, supported by brackets or on corbels.} decorated with minutely carved brackets are provided at the landing level, at the four corners (Figure 17). At the bottom of the well is a square stepped floor in the shape of a funnel extending to the lowest plane for the ease of water collection.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure16.png}
\caption{Plan and Cross Section}
\label{fig:plan_cross_section}
\end{figure}

\textit{Source: Author.}
From the first storey level, three staircases lead to the bottom water level of the well, which is considered a unique feature. The structural system is the traditional trabeated style with horizontal beams and lintels. A square stepped platform is chiselled into a circular well. Above the square floor are, columns, beams, wall and arched openings spiral around; a feature that continues to the top. The top of the well is a hollow open-to-sky shaft (Figure 18). The four corners of the square are strengthened with stone beams, set at 45 degrees angle.
Adalaj Stepwell is a brilliant example of the fusion of Hindu craftsmanship and the floral, geometric pattern of Islamic architecture. Every floor uses cross beams throughout the length. Every major milestone in the construction of this stepwell is recorded on the walls through Hindu architectural elements but subsequently followed by Islamic designs (Figure 19). Step wells were used as meeting and resting places during summer since their cool interiors offered unbelievable respite from the scorching sun outside.

The three entrances meet in the first storey below-ground in a huge square platform. This platform has an octagonal opening and rests on 16 pillars, 8 on the corners, and 2 in front of each main side for built-in shrines, with doors, windows and balconies, marking the 4 corners of the platform (Figure 20). Walls of the stepwell are a veritable showcase of sculptures and ornamentation in a blended style crossing religious boundaries.

A notable feature of the structure is the sculpture of *Navgraha* at the farthest corner of the well which is believed to protect the historic site from evil spirits. The octagonal stepwell is supported by a large number of pillars (Figure 21). Every floor, as well as the landing spaces, had enough space for people to hold gatherings (Figure 20).

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19. *Navgraha* means "nine celestial bodies" in Sanskrit and are nine astronomical bodies as well as deities in Hinduism. These are the Sun, the Moon, Mars, Mercury, Jupiter, Venus, Saturn, Solar Eclipse, Lunar Eclipse.
The motifs of flowers and graphics of Islamic architecture blend very well with the symbols of Hindu and Jain gods carved at various levels of the well. The dominant carvings on the upper floors are of elephants (3 inches/76 mm) in size, each of different design. The niches at Adalaj Stepwell are either filled with lotus

20. Bhadrak column are intricately carved square columns with recesses and projections facing four sides.
medallions (Figure 23) or with a depiction of the great goddess. The great goddess is represented by her vehicle (vahana in Sanskrit) — the lion who carries a trishula (trident). This trishula could be interpreted as symbolizing the goddess.

![Ornately Embellished Niches](photographed_by_author)

Figure 23. *Ornately Embellished Niches*
*Source: Photographed by Author.*

The Adalaj Stepwell is both, a celebration and a tribute to water as well as a record of the societal life of the people who used to come there. One can only marvel at the organizational capacity needed to erect such a structure. Some niches have leafy branches that resemble the decorative aspects of some of the mosques in Ahmedabad, known for their glorious weaving of the Hindu and Muslim styles. An inscription in a niche declares that this stepwell of Queen Rudabai will stand as long as there will be sun and moon in the sky. Here, the string-courses run on pure beauty; the embellishing of all parts of the structure is just a pretext to create further beauty in stone. Each wall is a procession of divine sculptures; each panel creates the impression that this architecture was not created by human hands but rather some divine power from heaven had gently lowered it onto the surface of the earth.

The sculptures and figurative carving on the walls and pillars illustrate the nine planets, beautiful representations of the mother goddess, tigers, elephants, peacocks and other birds and animals, celestial dancers, other gods and goddesses, musicians, poets, people in amorous poses, objects of daily life and scenes of the domestic lives of ordinary women.
Role of Stepwell in Evolution of the Cultural Heritage of Adalaj

The Adalaj Stepwell was instrumental in shaping the traditions and creating a continued legacy in Gandhinagar, Gujarat. This stepwell not only served the mundane purpose of supplying water for regular activities but was also a cultural hub, where many dance and music festivals took place. The wide, spacious landing areas served as platforms where travelling artists could showcase their talents in a cool and stunningly picturesque backdrop. This made the Stepwell quite notable throughout history. The intricately carved walls and pillars of the stepwells make it a live museum exhibit, where the art and architecture at the peak of the Solanki dynasty coupled with the ornate Islamic style were showcased. The multitude of carvings and sculptures depicting the daily lives of the common people are perhaps the only reminders of the rich culture and traditions that existed in the past. They also served the purpose of being mini-temples, as statues of various gods and goddess were carved into them and many of the rituals were done by women, exemplifying the status and power of women in society.

This subterranean marvel, being 5 storeys below the ground level with a permanent water body at the lowest level will always have a 5 to 6 degrees temperature drop compared to the outside ambient temperature. This is due to the slow evaporation rates of the water which is shaded on all sides by massive walls; which in turns tempted the people to remain longer here and thus became an ideal rest stop for weary travelers.

The historical sacrifice and construction origins of Adalaj prompted it to become a place where religious and cultural differences were surpassed. All sections of society would congregate here and participate in the events that were conducted. This was truly a remarkable phenomenon during an era of religious disparities and wars.

Rich biodiversity also flourished in the vicinity of the stepwell, as many birds and animals were attracted to the cool waters of the well and food from the various rituals and festivals that were left behind. Even today, many rare migratory birds found a haven in the vicinity of this great stepwell.

Present Scenario

The magnificent Stepwells representing the finest examples of water architecture that inspired hymns and folklore for centuries ceased to be built after the establishment of the British rule in India in the nineteenth century. The British regarded water in these stepwells as dirty and unhygienic and prohibited the use of these wells. They introduced pumps, taps and tube wells. Many stepwells were declared off-limits which led to many of them crumbling to the ground, victims of neglect and disuse. Some of these wells were demolished and the stones that made up the walls were carted off for other construction activities. The few that survived the rampages of time stood out as silent reminders of the past; echoing the sounds of laughter, music and the many stories that the walls of these structures became privy to. But a subterranean universe where people and animals coexisted cloaked
in music, dance, divinity, and exquisite architecture will never cease to astound visitors today.

![Shrine at the Entrance of Adalaj](image)

**Figure 17. Shrine at the Entrance of Adalaj**  
*Source: Photographed by Ar. Achuth H*

The social scenario has shifted and India has witnessed many of these Stepwells being reclaimed mostly by women. They have been transformed into small shrines where they can worship local goddesses and female deities. Women are once again claiming a unique space for themselves, where the performance of rituals and worship centred around fertility, health and family prosperity is continuing. Construction of small shrines containing the sculptures of local goddesses adjacent to the stepwell will ensure sustained use of the space (Figure 24). Adalaj Stepwell has a similar shrine located adjacent to the outer wall which is being maintained by the local Brahmin women of the community. Women from the neighbouring communities come here to perform the rituals and pray for the blessings of the goddess. The convergence of many women to this stepwell will keep the legacy of the ancient wonder alive and relive its traditional purpose.

The present state of Adalaj Stepwell is mainly focused on the maintenance and preventative restoration of the sculptural elements within the structure. Protective balustrades guard sculptural elements against direct visitor interaction, and watchful caretakers ensure their upkeep. The more sensitive areas as defined by the architectural conservation organizations like the primary water collection pit or the octagonal vāv and certain shrine areas are currently off-limits to the general public. These measures prevent further damage to the structure. With the help of circular grill-covering above the well pits at the surface level, contamination of the water from waste dumping or bird droppings can be prevented.

Though the state of many great stepwells has deteriorated considerably over the years, a renewed interest in such water structures has slowly emerged at the turn of the century. In the last few decades, these stepwells have been revived and revitalized, not just for worshipping and obtaining water, but also as a backdrop for many concerts and performances. Many of these stepwells have been

22. Achuth Harikumar, Architect/PG student, Urban Housing, CEPT University.
proclaimed as World Heritage Site by UNESCO and have been granted protection under the Archaeological Survey of India (ASI) like Adalaj, Rani ki Vav, etc. The ASI along with the Gujarat Archaeological Department (GAD) is striving to protect and preserve existing stepwells. They have also been instrumental in restoring these structures and cleaning the stored water in these wells. At places, communities and organisations have taken it upon themselves to restore the crumbling structures. Provisions under these government bodies have granted monetary as well as technical support to local organizations to conserve and restore local stepwells. Under these government schemes, Jal Sampatti Vibhag (Gujarat Water Supply and Sewerage Board) has conserved the Khodiyar Mata ni vav in Devdi village, Ahmedabad to such a degree that locals use it as a resting place today. But in the process of restoration, they have covered the entire structure in cement plaster and whitewash. The stepwell now acts as a shrine, and porcelain tiles bearing the image of goddesses have been added in the niches.

Realizing the cultural significance of stepwells, the Government of India along with the Reserve Bank of India has used the image of Rani ki Vav as the face of the new 100 rupee note (Figure 25). This is another great step to uplift the status of stepwells to a cultural and architectural milestone in the construction history of India.

![Figure 25. Rs.100 Note Showcasing Rani ki Vav Stepwell](source: Google)

Today, research organizations like the Urban Management Centre (UMC) in Ahmedabad provide technical assistance to city governments to identify and conserve stepwells, especially around the Ahmedabad-Gandhinagar region in Gujarat. They are doing extensive research on conservation measures which not only preserve these structures but also encourage sensitive adaptive reuse for them. Similarly, through Awareness Drives and Clean Stepwells campaigns in Patan, Ambaji, Mehsana, Palanpur and other areas in Gujarat, the NGO called Historical and Cultural Research Centre were able to generate cleaning initiatives to salvage some of the lesser-known stepwells.

The major causes which lead to the degradation of any stepwell are pollution and dumping waste materials by visitors, as well as antisocial activities and vandalism. Curbing these can greatly impact the general management of these structures. Plastic bottles, wrappers, and other urban waste can stagnate and contaminate the water. Addressing these issues can pave the way to further technical conservation measures. After due consideration and analysis of the
local culture, climate, environment, social and economic context, revival strategies have been recommended that rejuvenate and retrofit these structure into public recreational areas. Parks, walking plazas, markets or bazaars are some of the space design strategies recommended to restore stepwells.

The truly unique and elaborate detailing on the walls and pillars of Adalaj Stepwell has made it one of the most visited World Heritage Sites in Gujarat. As a tribute to the rich historical and cultural history of Adalaj Stepwell, each year a Water Festival is held in the month of November to celebrate World Heritage Day. During the festival, musicians from around the country make the brilliantly lit walls and pillars of the stepwell reverberate with the sounds and storytelling, bringing life to the sculptures with their rhythmic tunes. It is an important cultural event attended by scores of people from around the world to celebrate this architectural marvel. Listening to the music and the rhythmic instruments allow the new generation of youth to rediscover the magnificence of this ancient wonder and in the process, will be exposed to the rich history of their ancestors. Queen Rudabai would have rejoiced that her prophecy, found in a stone inscription was coming true — “as long as the sun and moon shine, may there be joy and steadfastness.”

Conclusions

With the advent of industrialization, mass production has risen. Consumerism, materialistic exploits and over-exhaustion of natural resources has led to large scale pollution as well as depletion of these so-called renewable resources; not to mention an upheaval in global climate. Acute water shortage is the ultimate consequence. Most countries in the world are suffering from extreme scarcity of drinking water which has resulted in a rise in the death toll. This has greatly affected the agriculture sector which in turn has ten-fold repercussions on a global scale. Most modern technologies are striving to achieve solutions for this crisis. In light of this situation, a look to the past has greater significance; as the realization that past civilizations could survive in harsher odds through time tested means, has surfaced.

India has the second largest population growth rate in the world but is facing an acute water crisis with over 600 million people suffering from little to no water availability. This situation is only expected to worsen, threatening the country’s food security as over 80 percent of water is used in agriculture. This has led to an awakened consciousness towards the quest for finding more sources of water. Even the groundwater table has started to deplete rapidly and coupled with pollution and industrial waste being dumped rampantly, the scarcity of clean water is being felt in all levels of society. At this juncture, we find ourselves looking at the collection of rainwater as one of the most significant ways to replenish the water table. According to Purnima Bhatt, author of Her Space, Her Story, with the advent of modern irrigation and water systems, it is not very likely that the stepwells would be used in the future for the purpose they were built for.

However, they are knowledge banks for age-old water conservation strategies which can be incorporated into community-based water harvesting techniques, especially in drought-prone regions.

The relevance of ancient stepwells utilizing the basic points of Rainwater Harvesting is starting to gain notability. Regions, where rainwater harvesting and watershed development techniques were utilized, showed great potential in overcoming their water crisis. This has solidified the belief that clean and sufficient water is a fundamental right of all human beings which needs an immediate response.

The failure of adequate government support to address the water crisis in many Northern and Western Indian states who suffer from prolonged scarcity has led to shifting the focus to more alternative solutions in addition to existing approaches. There has been a revival of many community-based water harvesting initiatives undertaken as affordable solutions to water scarcity in many villages. For example, a community rainwater harvesting system was established in Junagadh district of Gujarat where around 2,500 underground rainwater storage tanks have been built which provided abundant drinking water at close proximity. Through semi-circular check dam with iron bars and stones in river sand bed, the run-off from monsoon rains gets stored in levels and ultimately collected in the underground tanks. Through these tanks, water for irrigation is pumped to the fields which practice crop rotation to retain the fertility of the soil. Such initiatives were spearheaded by government bodies like the Ahmedabad Municipal Corporation and the Narmada Control Authority. Thus, awareness of the greatest threat of the 21st century is awakened when studying about these ancient marvels as well as offering affordable solutions for it.

It is time to reflect on the words of the beloved Gujarati poet, Dayaram Dalpatram (1896) who, more than a century ago, predicted the crucial role of stepwells in the quest for water, in the years to come through numerous references in his writings and stated:

*Resettle the abandoned villages.*

*Seek out the stepwells, wells, rivers, streams and revive the old traditions.*

*Make this your sacred Dharma.* (Bhatt, 2014)

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Bibliography


The Impact of Vertical Densification on Public Lighting in Informal Settlements: Using Virtual Environments as an Evaluation Tool for Policy Making

By David Michael Kretzer* & Michael Walczak±

There are a variety of reasons to support the premise that public lighting is beneficial to urban communities. At the same time, a key challenge for the provision of public lighting in informal settlements is their constant physical transformation. The aim of this paper is to evaluate the application of virtual environments (VEs) in lighting planning and policy making. Despite the fact that VEs offer the opportunity to explore an environment by freely navigating through it, including environments that change over time, this feature is rarely taken into account in decision-making processes. A VE-based analysis tool for informal settlement lighting is presented using a case-study street in the informal settlement of Caracolí in Bogotá as its basis. The main data set for the VE scenarios was comprised of results from a household survey, spatial measurements, and participant observations as well as luminous intensity distribution curves. The household survey was used to collect time-related data on the incremental construction of Caracolí’s informal dwellings, which was then projected into past, present, and future night-time scenarios. The lighting quality of these different scenarios was systematically evaluated via lighting calculation software, revealing a variety of shortcomings caused by the current lighting approach. Based on these findings, an alternative lighting approach was developed and re-examined using lighting calculations. Finally, custom game-engine technology and GPU computing were deployed, which allowed for real-time visualisation of the different lighting scenarios and their lighting quality. This setup therefore enables fast iterative feedback loops for current and future lighting policy scenarios and the resulting lighting design. In the first instance, a VE can illustrate well how current lighting policy results in a significant delay of lighting provision in the early stage of a settlement as well as highlight the mismatch between lighting technology and the built environment during the vertical densification phases. Second, the VE is able to showcase alternative lighting technologies and policy approaches as well as the resulting lighting effects, enabling a visual comparison of different policy scenarios over several decades. In conclusion it will be argued that the dynamic VE technology appears to be a promising decision-making tool for illustrating potential planning and design shortcomings to policy stakeholders in a manner understandable to the layman.

Introduction

Informal settlements grow incrementally depending on the legal status of the dwelling lots and the financial resources of the residents. Consequently, dwelling material, dwelling width, dwelling length, and dwelling height are in a state of permanent transformation. In Bogotá, public lighting is provided by local authorities once informal settlements have reached formal legalisation. In contrast to the surrounding informal dwellings, the luminaires installed by the authorities constitute inflexible objects that remain constant over time. In addition, public

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*PhD Student and Research Assistant, ETH Zurich, Switzerland.
±PhD Student, University of Applied Arts Vienna, Austria & Research Assistant, ETH Zurich, Switzerland.
D. M. Kretzer and M. Walczak contributed equally to this work as first authors.
luminaires of a similar height can be found in streets of significantly different widths (see Figure 1).

Figure 1. Luminaires of Similar Height Lighting a Nine-Metre-Wide (left-hand side), Less than Six-Metre-Wide (middle) and Less than Three-Metre-Wide (right-hand side) Street

Lighting design tends to be a rather static process that is conducted before the installation of luminaires takes place. In a ‘formally’ built environment, it can be expected that the street and building design have been approved by a planning commission and that little physical change will take place in the future. Consequently, the lighting design is likely to be adequate for several decades. However, in an incrementally growing informal environment, the quality of the lighting design (done before the luminaire installation) is unlikely to be maintained over a long period of time. Hence, a virtual lighting-design planning process that considers future building-density scenarios is ideal. Virtual reality (VR) based on virtual environments (VE) represents a technological opportunity for time-related design planning of this type. Existing VE and VR frameworks permit real-time visualisations to be performed using GPU technology. This makes it possible to visually explore the planning outcomes by freely navigating within a virtual space. Custom coding enables the implementation of further large-scale datasets such as time, topography, architectural structures, and footfall (i.e. motion patterns of pedestrians). Virtual reality has its roots in conceptional and theoretical texts dating back to the 1930s, especially by filmmakers. More recently, VR has been gaining attention not only in the gaming industry, but also in scientific research including medication treatments, human decision-making, and analyses of human perception.

Lighting design is based on luminous intensity distribution files that contain the photometric characteristics of luminaires. Such files are provided by luminaire manufacturers and are compatible with both common lighting-calculation and VE software. Lighting-calculation software does in fact incorporate some aspects of VEs, such as a 3D-lit model that can be explored by navigation or a camera path. However, this does not unlock the full potential of game-engine technology, which can integrate dynamically changing objects and materials. A game engine offers
for example the opportunity to custom-code and materialise incrementally densifying architectural structures or to custom-code moving people and cars.

The first objective of this paper is to evaluate in quantitative terms the lighting quality created by a constant lighting installation within a vertically densifying environment. This will then be compared with a non-constant alternative lighting approach.

The second objective of this paper is to understand the benefits a virtual environment offers for informal settlement lighting planning and policy making.

**Literature Review**

Public lighting for pedestrians is an important requirement for outdoor nighttime life in both formal and informal environments. It allows for adequate obstacle detection,\(^1\) reduces fear of crime,\(^2\) supports more use of outdoor facilities as well as economic growth,\(^3\) and improves people’s orientation\(^4\) at night, to name a few examples. In terms of informal settlements, lighting can, for instance, support residents in safely finding their way to communal toilets at night, help them to avoid snakes and stray dogs, and enable them to run their businesses later into the night\(^5\).

Nowadays, around a billion people live in informal living conditions, and 95% of urban expansion over coming decades will take place in the developing world\(^6\). Municipalities in many developing countries lack the ability to effectively deliver infrastructure and services to their citizens.\(^7\) UN-Habitat\(^8\) cites the lack of basic services such as street lighting as a common characteristic of informal settlements. However, even in cases where informal settlements have already been formally supplied with public lighting, a lack of lighting can recur because of immigration and expansion of the settlement boundaries.\(^9\)

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settlements, the residents compensate for such lack by installing self-built ‘informal’ luminaires in the public space.\textsuperscript{10}

Informal settlements are characterised by constant physical transformation.\textsuperscript{11} Their building structures can emerge within a few days;\textsuperscript{12} hence, public space is subject to constant modification. The heights of informal dwellings can vary significantly – from one or two storeys up to as many as seven to ten storeys in height\textsuperscript{13} as a result of densification. Taubenböck, Kraff and Wurm\textsuperscript{14} discovered dwellings of up to four storeys in Makoko (Lagos) and Paraisópolis (São Paulo) as well as dwellings of up to seven storeys in Petare (Caracas) and Tondo (Manila), for instance. Such architectural structures grow incrementally over time, “mostly constructed through room-by-room accretion in a process driven by the imperatives of poverty and the slow accretion of resources.”\textsuperscript{15} House extensions can often be found in spaces usually belonging to the public realm having acquired private character through use.\textsuperscript{16} Such spaces can be regarded as semi-public.\textsuperscript{17} In contrast to the formal city, where the street network comes first and the architecture plugs into it, in informal settlements the buildings come first and access networks co-emerge with them.\textsuperscript{18} Once public luminaires are installed in such environments, it can be expected that both the architecture as well as the public space will subsequently undergo physical transformation. Consequently, the lighting effect created at the beginning of a lighting installation changes over time. Furthermore, both the lighting effect created by the luminaires and also the luminaires as physical objects themselves may be affected by such incremental building growth: Brillembourg and Klumpner\textsuperscript{19} reveal how a pole-mounted

\begin{thebibliography}{99}
\bibitem{17} Hernández-García, \textit{Public Space in Informal Settlements: The Barrios of Bogotá}, 2013.
\end{thebibliography}
luminaire has been absorbed completely over the years by an incrementally growing building in Caracas. Kretzer\(^{20}\) has evaluated the attempt to light informal settlements with high-mast luminaires, showing that such lighting results in low illuminance uniformity. His study comprised solely single-storey dwellings to create a ‘best case’ scenario. Furthermore, Kretzer\(^{21}\) analysed self-built ‘informal luminaires’ in Colombia, demonstrating that although they sometimes exhibit aspects of ‘smart lighting’ technology, at the same time they do not comply with product safety, efficiency, and light pollution standards.

Virtual environments (VEs) and their associated communication technique of virtual reality (VR) are being applied and deployed across a variety of fields.\(^{22}\) VR is an immersive visualisation that can follow human head and body motion through a head-mounted display. The strength of immersive environment exploration can be seen, for example, in “(...) using Virtual Reality as a therapeutic tool (...), [to] rely on VR simulations to perform a kind of exposure therapy wherein patients are asked to confront a traumatic experience or event in order to overcome it.”\(^{23}\) VR “(...) allows us to experience radically different environments and perspectives, and to challenge the dominant and habitual perceptual states we’ve come to know and understand.”\(^{24}\) Immersive experiences as a medium for communicating complex urban phenomena and spaces have not yet been explored extensively.\(^{25}\)

VR offers huge potential for application in the Global South, since many developing countries exhibit a fragmented provision of data as well as a lack of tools and methods for understanding the available data.\(^{26}\) Raw data, however, does not convey any information – in order to generate information and facilitate communication, it has to be organised and must make sense to any observer.\(^{27}\) The appropriate method of communication through the identification of more comprehensive ways of visualising, understanding, and engaging seems to support evidence-based decision and policy making. Human perception is primarily


\(^{24}\) Ibid.


vision-based, and modern society makes significant use of visual interfaces.\textsuperscript{28} Furthermore, Beck\textsuperscript{29} argues that humans understand things much better in 3D. Care has to be taken in choosing the way we communicate and visualise information since it is evident that these factors can drastically affect the viewer’s decision/point of view and potential research results.\textsuperscript{30} However, methods such as VR enable humans to understand cross-referenced parameters and their impacts on the built environment more easily.\textsuperscript{31} Visual media has the power to communicate complex facts in a comprehensible way and help more reasoned decisions to be made, enabling potential future scenarios to be imagined. In other words, long-term messages improve their chances of survival if they are reduced to the essentials: a sketch can be more meaningful than a drawing.\textsuperscript{32} In terms of lighting, Chen, Cui and Hao\textsuperscript{33} have shown that VR is more effective and reliable in presenting a lighting environment compared to videos and photos, as it is able to present several lighting attributes consistent with the physical environment. Furthermore, a daylight study by Chamilothori, Wienold and Andersen\textsuperscript{34} similarly concludes that no significant differences were observed between users’ evaluation of the real and virtual environments.

Using pixel comparison, Walczak\textsuperscript{35} showed consistency in VR with regards to luminaires, the built environment, and resulting shadows as well as the perceived perspective compared to a photograph taken in the same location.

**Methodology**

Six main steps were performed in order to evaluate the lighting conditions within vertically densifying informal environments and to assess the benefits of virtual environments for both lighting planning and policy making:

- **Step 1:** Data collection in an informal settlement street.
- **Step 2:** Creation of a 3D model.
- **Step 3:** Digital reconstruction of the current lighting.
- **Step 4:** Lighting calculations of five different degrees of vertical densification (zero storeys, one storey, two storeys, three storeys,

\begin{thebibliography}{9}
\bibitem{28} W. J. Mitchell, *Bildtheorie* (Frankfurt am Main: Suhrkamp, 2018).
\bibitem{31} Ibid.
\end{thebibliography}
Step 5: Lighting calculations in both the ‘best case’ and ‘worst case’ densification scenario of step 4, using an alternative two-phase lighting approach.

Step 6: Creation of a time-dynamic 4D virtual environment in order to illustrate the current lighting versus the alternative lighting approach, from the earliest reported construction data in the case-study street (i.e. 1985) to 2052.

For step 1, a multi-method case study was conducted in a 183-metre-long pedestrian street (see Figure 2) in Bogotá’s Caracolí settlement during January and February 2019. This included night-time street observations, spatial measurements, a household survey, a lighting audit, and illuminance measurements using a Konica Minolta CL-200 A. 88 metres of the street were lit by four high-pressure sodium street lights (referred to as ‘formal’ lighting), with the remaining 95 metres lit by nine self-built luminaires installed by the residents (referred to as ‘informal’ lighting). The street begins at an altitude of 2,720 metres and ends at an altitude of 2,770 metres, resulting in a very steep incline of over 35% (see Figure ). The majority of the dwellings are regarded as illegal, having been built on land classified as high risk due to the threat of landslides.

Since informal settlements are characterised by permanent physical transformation, spatial measurements were conducted using a drone, a 360° camera, a measuring wheel, a laser distance meter, and a measuring tape in order to document the neighbourhood. Both ‘formal’ and ‘informal’ self-built luminaires were analysed in terms of their geometrical and lighting characteristics. The luminaires’ height, the lamp types and wattages as well as the horizontal illuminance directly beneath each luminaire were recorded. Furthermore, the horizontal illuminance along the entire informally lit part of the street was measured. One informal luminaire was shipped to Europe in order to measure and digitise its photometry in a goniophotometer (see Figures 4 and 5).

The purpose of observing the street was to analyse residents’ night-time activities by mapping the number, type, and location of activities as well as to record people’s age and gender. Such information can be expected to have an impact on how people evaluate fear of crime under certain lighting conditions. Observations were conducted during both a weekday and a weekend day. During the hours of participant observation, the researcher was able to overlook both the formally and informally lit part of the street simultaneously, standing at the threshold of both parts of the street. Walking was the main activity. Furthermore, other outdoor activities such as talking, playing, smoking, smartphone use, and cooking were observed.

The household survey was used to collect the construction data from 36 out of 52 dwellings. The main questions were in what year each of the dwelling storeys had been built and what materials had been used. The data was compared with Google Earth satellite images and corrected if necessary. For the 26 dwellings for
which no survey was available, the construction dates of the first storey were estimated using satellite imagery or the data of neighbouring dwellings. The average duration until additional storeys (second and third storey respectively) had been constructed was used for the 26 dwellings without survey data, as well as for the storeys that will be constructed after 2019.

For step 2, transforming the data gathered by drone and 360° filming as well as distance measurements into a 3D model was a complex iterative process. The drone footage was the basis for establishing information about the plan view,
combined with information provided by Google Earth satellite imagery and digital elevation maps from the NASA shuttle mission. The 360° footage provided the vertical information for the model with regards to the number of building storeys as well as the location of windows, doors and stairs, the roof geometry, overhangs, terraces, materialisation, topography, and vegetation.

The static elements visualised within the VE/VR visualisation framework comprise the topography, buildings, vegetation as well as specific objects such as luminaire, fences, and tyres. Each of these elements is further explained in the following section.

As regards the static topography visualisation, the Geotiff raw data for Bogotá is accessed through the NASA shuttle mission. Within Q-GIS Version 3.4.8-Madeira, the QGis2Threejs Plugin is used to convert Geotiff Data into gltf format. Aspose.3D Conversion is used for the translation from gltf to stl format, allowing the topography to be opened in Rhinoceros 3D and the format to be translated to Unreal Engine readable format (fbx). Additional elements such as trees, bushes, and significant objects are added and materialised manually through the Rhinoceros 3D and Unreal Engine workflow.

![Image](image.png)

**Figure 3.** Section of the Case-Study Street Documented in 2019 Showing the Topography, Buildings with their Respective Color-Coded Construction Years, and the Location of Formal Lighting. This Planning Document was Produced via Automated Means Using the Unreal Engine and Rhinoceros 3D Framework. Source: Walczak, 2019.

Regarding the static building visualisation, the Unreal Engine is extended with custom C++ code. GDAL Library is used for loading all geolocated building footprints and their respective numeric building storeys provided by ‘Mapas Bogotá’. If no spatial building measurements could be taken the following method is applied: according to aggregated field observations, the building footprints are extruded by the multiplication of a 2.4-metre building height for the ground floor and 2.6 metres for all the subsequent floors, which have additional height for the ceiling compared to the ground floor which has its ground plate below ground

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level. Another observed specificity is that the first floor (i.e. the second storey) on average overhangs the streetscape by approximately 0.6 metres. Each consecutive floor, starting from the second floor, was found to overhang the streetscape by an average of around 0.2 metres. Custom code relocates the buildings by their altitude to their respective position in accordance with the topography by finding their intersection point. The buildings are materialised and UV-mapped automatically with a selection of common materials in the settlement including bricks, corrugated steel, glass, and wood. Windows, doors, railings, specific roof geometries, and terraces are added and materialised manually through the Rhinoceros 3D workflow and Unreal Engine framework.

A computer-based simulation research strategy was conducted for step 3. The lighting of the entire street (see Figure 2) was reconstructed in a lighting software program (see Figure 6) using the 3D model constructed in step 2 and photometric files. The software used for the calculation was Dialux 4.13. Each object within the model had matt surfaces with a reflectance of 0.5, and the ground’s matt surface had a reflectance of 0.3. Moreover, the informal luminaires had surface reflectances according to their object colours. A reflectance of 0.5 was chosen for the model objects (which are mainly architectural structures) as a value that represents a variety of building materials: dark red bricks have a reflectance of 0.1 to 0.15, light grey concrete has a reflectance of 0.4 to 0.6, and wood has a reflectance in the range of 0.1 to 0.5,\(^{37}\) to name some examples. A reflectance of 0.3 was chosen for the ground since the street was unpaved and sandstone has a reflectance of 0.2 to 0.4.\(^{38}\)

The calculations consisted of two main parts. The lighting of the four formal luminaires (F1-F4) in the lower part of street (see Figure 2) was reconstructed by documenting the luminaire codes written on the housing of each luminaire. Based on these codes, the luminaire specifications were provided by Bogotá’s public lighting authority. In this way, the luminaire manufacturer’s photometric file could be identified and used for lighting calculations. The height of the luminaire heads was 9 meters; the spacing was 22.5 metres between luminaire F1 and F2, 29 meters between F2 and F3 and 29.5 metres between F3 and F4.

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38. Ibid.
Figure 4. The Photometry of an Informal Luminaire is Measured in Zumtobel Lighting’s Goniophotometer.

Figure 5. Digitisation Process of Informal Luminaires Including Physical and Photometric Information
The lighting of the nine informal luminaires in the upper part of the street (see Figure 2) was reconstructed to ensure the correct lighting levels within the virtual environment software. The photometric file derived from a goniophotometer measurement was used for luminaire I1. Photometric files of comparable light sources were used for the other luminaires and integrated into 3D replicas of the
informal luminaires. The lighting levels were adapted in Dialux 4.13 to the on-site illuminance measurement results.

A horizontal illuminance of 15.4 lx was measured on site at a reference point under formal luminaire F4 (see Figure 2); the computer simulation resulted in a horizontal illuminance of 17.0 lx at the same point within the model.

For step 4, the impact of vertical densification on the lighting quality was calculated. This involved an analysis of the street segment currently featuring formal luminaires provided by the authorities (see Figure 2). These luminaires used 70 W high-pressure sodium lamps, and the luminous intensity distribution curve of the manufacturer was used for the calculation with a maintenance factor of 0.86 according to Bogotá’s lighting standard MUAP\textsuperscript{39}. Lighting calculations of five different degrees of vertical densification (zero storeys, one storey, two storeys, three storeys, and four storeys) were conducted for three different scenarios of horizontal densification respectively (a seven-metre-wide street,\textsuperscript{40} a five-metre-wide street, and a three-metre-wide street) under current lighting conditions (Figure 8).\textsuperscript{41} Three different aspects were analysed: horizontal illuminance on the street (in order to evaluate whether the requirements in Bogotá’s lighting standard MUAP would be met), horizontal illuminance on the dwellings’ roof (in order to analyse the degree of light pollution), and vertical illuminance on the dwellings’ façade (in order to evaluate how much light would potentially enter the interior through windows and disturb the residents, also called light trespass). This detailed analysis was done between formal luminaire F2 and F3 to ensure that there was an adjacent luminaire on either side that might impact the calculation results. For the horizontal illuminance measurements along the street, a one-metre ‘curved square grid’\textsuperscript{42} of calculation points at ground level was defined and laid out according to the centre axis of the street (see Figure 7). The calculation point spacing of one by one metre was arranged based on the plan view, resulting in a slightly greater spacing due to the inclination of the street. For the horizontal illuminance on the roofs, one calculation point was placed on each roof, one metre distant from the façade edge, perpendicular to the façade midpoint (seen from plan view). For the vertical illuminance on a façade, one calculation point was placed on the midpoint of each façade part (seen from plan view); the calculation point was located 1.2 metres below the ceiling height of the first storey and 1.3 metres below the ceiling height of the second, third, and fourth storeys respectively (since the first storeys tend to be 2.4 metres and the other storeys 2.6 metres high).

\textsuperscript{39} Alcaldía Mayor de Bogotá D.C. Manual Único de Alumbrado Público (Bogotá: Alcaldía Mayor de Bogotá D.C, 2001).

\textsuperscript{40} This is the current width at the beginning of the case-study street.

\textsuperscript{41} The luminaire outreach arms were shortened to 0.6 metre and 0.2 metre for the five-metre- and three-metre-wide street respectively in order to take into account the luminous intensity distribution with regards to the street width.

\textsuperscript{42} A square grid is recommended by the CIE for pedestrian areas of irregular shape; Commission Internationale de l’Eclairage, Road Lighting Calculations. 3rd Edition (Vienna: Commission Internationale de l’Eclairage, 2006).
For step 5, the four high-pressure sodium luminaires (evaluated during step 4) were replaced by two alternative lighting solutions (namely a 3.5-metre-high pole-mounted luminaire (phase 1) as well as a span-wire arrangement mounted 4.1 metres above ground (phase 2) as demonstrated in Figure 9). 43 These two lighting solutions constitute a two-phase approach in line with the legal status of the settlement: in the initial phase of settlement construction, temporary solar-run lighting is installed by the residents; once the settlement has been legalised and an electrical grid provided, the temporary lighting is replaced by a permanent solution. The aim was to use more luminaires that are more closely spaced in order to increase the local adaptability of the two lighting installations to the informal

building extensions (and hence to provide high illuminance uniformity); a further goal was to lower the height of the luminaires to reduce light trespass in the upper interior spaces and to limit light pollution caused by light reflections from the roofs of the dwellings during the early stage of densification (while the roofs are lower than the luminaires). Reducing the height of the luminaires from the current 9 meters also has the benefit of facilitating maintenance. The specific pole shape of the 3.5-metre-high luminaire shifts the pole (at a height of 2.3 metres) 0.6 metre into the street to prevent it from colliding with any overhanging upper storeys and to maintain a wide street space that is unobstructed by luminaire poles (see Figure 10).

These 3.5-metre pole-mounted luminaires were spaced at between 4 to 9.5 metres in the seven-metre-wide street and between 6.5 to 9.5 meters in three-metre-wide street, following a mix of a single-sided and staggered pole arrangement along the street. The span-wire solution was mounted 4.1 metres high on the second storey with a spacing of 15.5 metres in the seven-metre-wide street and 13.5 metres in the three-metre-wide street. A span-wire solution allows a light source to be mounted right above the centre of a street, which further decreases the chance of light being obstructed by informal building extensions protruding from the street edges; furthermore, no poles are required, which prevents obstruction of the informal street space or collision with overhangs. The height and spacing of both luminaire types were determined by several iterative calculations in order not only to meet the average illuminance and illuminance uniformity requirements, but also to avoid a very narrow spacing. The same calculation points as in step 4 were used for the evaluation of these two alternative lighting solutions.

Two cases were evaluated: the ‘best case’ and ‘worst case’ lighting (see ‘Results’ section) created by the current four high-pressure sodium luminaires compared to the lighting created by the two alternative lighting solutions. The seven-metre-wide street with four storeys was regarded as the ‘best case’, whereas the three-metre-wide street with two storeys was regarded as the ‘worst case’. These two cases resulted in eight scenarios as basis for the simulation in VE/VR, namely the current lighting, the two luminaire types of the alternative approach as well as daylighting – in two street-width situations respectively.

For step 6, a dynamic real-time visualisation framework was developed. The simulations and visualisations were run on multiple (six) CPU cores (9th Generation Intel(R) Core i7(R) CPU 9750H clocked at 2.6 GHz) with 32GB of RAM. The GPU-accelerated visualisation model runs on a single NVIDIA RTX 2070 with Max-Q Design and 8GB of RAM. The Unreal Engine version 28 is used as the elemental visualisation framework.

The dynamic elements visualised within the visualisation framework comprise the buildings, pedestrians/footfall, luminaire geometries, and photometric characteristics. Each of these elements is further explained in the following section.

In terms of the dynamic building visualisation, the time component in the form of the historical growth (as documented in the household survey) and

44. Moreover, the pole-mounted luminaire had to be within a height that can be installed by informal settlement dwellers; field observations had revealed that 3.5 metres would still be within an acceptable handling height.
anticipated densification process (extrapolation of historical data into future) of the settlement were translated into the visualisation framework by tagging each building with its respective years of storey construction and characteristics such as material or luminaire types. The respective buildings with all their characteristics are visualised for the specific year in which the user is navigating or is located.

Regarding the dynamic footfall visualisation, custom code allows for automated adaptation of pedestrian paths to the topography through an extrusion of multiple spline knots up to the moment of intersection with the topography surface. These intersected spline points are then again connected together and form the walking path of the footfall visualisation.

In input terms, it was necessary to import a geo-located spline as the path of each individual ‘agent’ (which in this case constitutes data in the form of a detailed night-time participant observation sequence of five minutes), to set the pedestrian walking speed, and to set a start time. The ‘agent’ appears at the start time and disappears as soon as the sequence is finished. The visualisation timeframe, in this case 30 seconds, can randomly start within the five-minute scenario sequence. The animated 3D characters including character geometry in the form of meshes and virtual skeleton of bones are from Adobe Mixamo.

The built-in Unreal Engine framework is applied to visualise the physical and photometric lighting characteristics within the dynamic environment, which allows for the use of three-dimensional photometric data in the form of IES files (see for example Figure 5) for each luminaire. Nvidia RTX graphics card and Nvidia CUDA technology enable real-time ray tracing to be used and more adequate lighting and reflection results to be achieved. Custom code is applied for the incremental upgrading of luminaires and the response of the luminaire in the form of motion sensors.

The interactive visualisation can be experienced through either front-of-screen or virtual reality in the form of Oculus Rift/Rift S goggles. The visualisation can be experienced either on a fixed/predefined path or open world. Where a predefined path is the input, it is necessary to provide a geolocated spline on which the user can be guided and also enter the movement/walking speed, as with the footfall visualisation framework. For an open world setting, the user can navigate either with a standard gaming setting (‘WASD’ or arrow keys) or with the Oculus joysticks (Oculus Touch). To experience the growth of the settlement, the user can navigate through years by pressing a dedicated keyboard or Oculus controller button. The respective year to which the user is exposed is displayed on the virtual ‘cockpit’, graphical user interface (GUI).

Results

The results of the lighting calculations of step 4 are presented below (Table 1). Various conclusions can be drawn regarding the different lighting characteristics calculated:

1) Average illuminance (lx) on street surface:
The more storeys, the higher the average illuminance. It can be assumed that this is caused by more square meters of dwelling façade that reflect light from the luminaires on to the street. Bogotá’s lighting standard requires for footpaths an average illuminance of at least 7 lx\textsuperscript{45}; this lighting level is achieved in all 15 scenarios.

2) Minimum illuminance (lx) and illuminance uniformity $U_0$ on street surface:
The wider the street, the higher the minimum illuminance and hence the illuminance uniformity.\textsuperscript{46} In this case, the lowest illuminance was calculated behind an informal building extension (see Figure 11) that shades the direct light emitted by one of the four luminaires. It seems that the wider the street, the more light could be emitted to surfaces nearby (that then reflect this light on to the calculation point measuring the lowest illuminance), since informal building structures (such as levelling foundations, porches, separation walls, and overhangs) protruded less into the street’s centre. According to Bogotá’s lighting standard\textsuperscript{47}, the uniformity $U_0$ should be at least 0.33 – however, in none of the 15 scenarios is this uniformity achieved.

3) Maximum illuminance on a roof (lx):
In all three street-width scenarios, most of the light is emitted on to the roofs when there is only one or two storeys. Significantly less light reaches the roof of three- and four-storey buildings; in this case, the dwellings have heights comparable to the street luminaires themselves – and the light therefore tends to be emitted against the façades. This makes sense: if a luminaire is located higher than the roof (and if the luminous intensity distribution of the luminaire is not focusing the light very precisely on to the street surface), a lot of light can be expected to be emitted on to the roofs. However, such light is partly reflected by the roofs into the sky, creating so-called light pollution. Light pollution has a negative impact on the night-time fauna: for example, migrating birds may be disorientated.\textsuperscript{48}

4) Maximum illuminance on a façade (lx):
In all three street-width scenarios, most of the light is emitted on to a façade of the four-storey scenario, with a maximum illuminance of 95.0 lx in the three-metre-wide street (on a calculation point of the third storey). However, light that is emitted on to a façade may enter a dwelling through windows and affect the residents’ circadian rhythms.\textsuperscript{49} The maximum

\textsuperscript{46} Illuminance uniformity $U_0$ is here defined as the minimum illuminance $E_{\text{min}}$ divided by the average illuminance $E_{\text{av}}$.
\textsuperscript{49} Ibid.
illuminance on a window should not exceed 1 lx, but in these scenarios, it is up to 95 times higher.

Table 1. Lighting Calculation Results

<table>
<thead>
<tr>
<th>Street width</th>
<th>7 m</th>
<th>5 m</th>
<th>3 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of storeys</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Average illuminance on street surface ( E_{av} ) (lx)</td>
<td>11.0</td>
<td>10.8</td>
<td>10.4</td>
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<td>Min. illuminance on street surface ( E_{min} ) (lx)</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Illuminance uniformity on street surface ( U_0 )</td>
<td>0.06</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Max. illuminance on a roof (lx)</td>
<td>0.1</td>
<td>3.9</td>
<td>14.0</td>
</tr>
<tr>
<td>Max. illuminance on a façade (lx)</td>
<td>33.0</td>
<td>32.0</td>
<td>32.0</td>
</tr>
</tbody>
</table>


Defining a ‘worst case’ and a ‘best case’ scenario for the alternative lighting approach (step 5) cannot be done in an absolutely clear way here, since there are a variety of characteristics that are not all consistently good or bad in each of the different densification scenarios. Hence, the characteristics need to be weighted: average illuminance \( E_{av} \) and illuminance uniformity \( U_0 \) are given first priority because they are the only ones defined in the local lighting standard MUAP. The degrees of light pollution (illuminance on a roof) and light trespass (illuminance on the façades) are given lower priority; however, since light trespass caused by high illuminance values on a façade could be mitigated by curtains on windows, it is regarded as a more minor issue in this context (third priority) compared to the light pollution (second priority) resulting from light reflected by the roofs. As a result, the seven-metre street width with four storeys scenario was selected as the ‘best case’ scenario, since it over-fulfils the average illuminance requirements, it has the highest illuminance uniformity value, the lowest maximum illuminance values on a roof, and the second lowest maximum illuminance value on the façades within the three- and four-storey scenarios. The three-metre street width with two storeys scenario was selected as the ‘worst case’ scenario since it has the lowest value of illuminance uniformity and the highest degree of illuminance on a roof, even though the maximum illuminance value on the façade was on the low side compared to most of the other scenarios.

The alternative two-phase lighting approach (see Figure 9) evaluated in step 5 improved all lighting characteristics created by the current lighting condition with the exception of just one criterion:

Regarding the ‘best case scenario’ (*seven-metre street width with four storeys*), applying the 3.5-metre-high pole-mounted luminaires created an illuminance uniformity $U_0$ of 0.34 ($E_{av}=12.3 \text{ lx}$), a maximum illuminance on a roof of 0 lx, and a maximum illuminance on a façade of 9.2 lx.

Applying the span-wire-mounted luminaires resulted in an illuminance uniformity $U_0$ of 0.36 ($E_{av}=10.1 \text{ lx}$), a maximum illuminance on a roof of 0 lx, and a maximum illuminance on a façade of 9.8 lx.

Regarding the ‘worst case scenario’ (*three-metre street width with two storeys*), applying the 3.5-metre-high pole-mounted luminaires created an illuminance uniformity $U_0$ of 0.40 ($E_{av}=11.6 \text{ lx}$), a maximum illuminance on a roof of 1.1 lx, and a maximum illuminance on a façade of 23 lx.

Applying the span-wire-mounted luminaires resulted in an illuminance uniformity $U_0$ of 0.36 ($E_{av}=8.3 \text{ lx}$), a maximum illuminance on a roof of 0.1 lx, and a maximum illuminance on a façade of 32 lx. The 32 lx on the façade created by the span-wire installation in the ‘worst case scenario’ was 3 lx higher than under the current nine-metre-high pole-mounted lights, and hence it constitutes the only criterion that was not improved by the alternative lighting approach. However, it is likely that the locations of the windows are already determined when the span-wires are attached to the façades. If a luminaire was initially planned to be mounted in front of a window, it could instead be mounted either below or next to...
such window: the uniformity of 0.36 exceeds the uniformity requirement of 0.33, and hence a little flexibility regarding the luminaire position would be possible. Mounting a luminaire below or next to a window reduces its negative effect on the interior space caused by high vertical illuminance. In contrast, such flexibility cannot be realised by a luminaire that is pole-mounted, nine metres high, and possibly installed before the storeys have been built.

Figure 10. Forseeing Vertical Densification: the Pole of the 3.5-Meter-High Luminaire (Used during Phase 1) does not Collide with Potentially Overhanging Upper Storeys (see figure on the right-hand side) and Results in a Wide Street Space that is Unobstructed by Luminaire Poles.

Figure 11. The Minimum Illuminance Value $E_{\text{min}}$ Illustrated by a Lighting Calculation Rendering (left-hand side), a Lighting Calculation Pseudo Colour Image (middle), and a Photograph Taken by a 360° Camera (right-hand side), the Low Value of $E_{\text{min}}$ (indicated by the red dot) is Caused by an Informal Building Extension (indicated by the white frame).

Apart from the lighting quality, the future vertical densification projection revealed shortcomings regarding the luminaire product design: it was found that all four formal luminaire poles collided with at least the fourth storey.
Regarding the VE/VR framework, this study shows the feasibility of (1) a method presented for the spatial and temporal documentation of rapidly changing informal environments in VE, (2) the medium for visualising such data in VR, and (3) the ability to generate lighting-specific features in multiple future scenarios in VE/VR.

(1) Custom code enables state-of-the-art game-engine technology to be enhanced with the capability to use temporal large-scale quantitative as well as empirical data sets in an automated manner. This is primarily a matter of visualising the historical as well as the projected future incremental development of architectural structures and their changes in materialisation terms (see Figure ). The output in the form of common planning documents such as sections and plans can be further used in planning processes. The visualisation of motion patterns of pedestrians in the form of animated human skeletons is a further key concern (see Figure 13).

(2) A custom graphical user interface (GUI) helps navigate the virtual environment by displaying in text form the current year that is being visualised or the tasks/functionalities that the user can access. Based on state-of-the-art game-engine technology, a range of media can be deployed to create visualisation output: in this case, VR. Since the output is a visual one, the viewer can use this medium for a visual inspection of the content displayed, for example any types of pole and overhang collisions or lighting non-uniformities. If the framework is documented, this presented workflow can be used for future studies, scaled, and transferred to other contexts.

(3) Custom code allows the expansion of state-of-the-art game-engine technology to accommodate dynamic incremental changes in luminaire types and their geometries. Custom code allows for a dynamic response to user behaviour in the form of additional lighting attributes such as motion sensors. Since all of these parameters and attributes can be changed dynamically in the form of a custom graphical user interface (GUI), the tool is particularly useful for iterative design processes and scenario planning.
The ‘2012’ Image, for Example, Clearly Illustrates the Delay of Formal Luminaire Provision in the Upper Part of the Settlement that had been already Covered with Informal Dwellings in 2010.

Figure 13. Scenario-Based Decision-Making Visualisation for a Multitude of Different Options, in this Case the Current Lighting Approach in the Case-Study Street as a ‘Seven-Metre-Wide Street with Four Storeys Scenario’, versus the Two-Phase Alternative Lighting Approach. All of the Scenarios Include Temporal Data such as Densification and Footfall. Visual Inspection Illustrates not only the Lighting Effect, but also Enables Detection of how the Light Column Collides with the Fourth Storey (see figure on ‘Current lighting policy’).

Discussion and Conclusions

To date, only sparse research has been conducted on the lighting quality of formal luminaires installed in informal environments. As regards vertically densifying informal settlements, it seems that nobody has previously tried to assess the resulting lighting conditions in a systematic way. By doing so, this paper has shown that the application of one type of nine-metre-high pole-mounted luminaires with a spacing of around 30 meters has several limitations: it results in low illuminance uniformity values, it creates high illuminance values on the roofs and hence light pollution, and it causes high illuminance values on façades and thus potential light trespass into the dwelling interiors.

Furthermore, this paper has shown that the illuminance uniformity limitations can be overcome and both light pollution and light trespass significantly reduced by a two-phase lighting approach: a 3.5-metre pole-mounted solution with a pole shape that anticipates the future building shape with a varying spacing of between 4 and 9.5 metres in the seven-metre- and between 6.5 and 9.5 metres in the three-metre-wide streets, followed by a span-wire solution mounted 4.1 metres high on the second storey with a constant spacing of 15.5 metres in the seven-metre-wide street and 13.5 metres in the three-metre-wide street. The pole-mounted luminaires were positioned with an unequal spacing between the luminaires due to the complex architectural characteristics of this informal street: the luminaires had to be adapted to the given environment – and this possibility is the advantage of such a lighting approach. The 3.5-metre-high pole-mounted luminaire allows for a flexible adaption due to its short spacing and its pole shape that prevents collision with the overhangs of the upper storeys as are common in Bogotá. Since span-wire lighting can be mounted right above the centre of a street, it also does not collide with overhangs and provides good uniformity values (which in this study are further ensured by relatively short spacing). Furthermore, it offers the possibility to be mounted further away from windows in order to prevent light trespass if necessary. Moreover, the span-wires can be mounted diagonally between buildings if no opposite façade mounting option is available. Once the second storeys are built, almost no illuminance is created on the roofs, since the luminaires hang lower and hence light pollution is reduced significantly.

The 3.5-metre pole-mounted solution (given the photometric characteristics used in the present study) would be able to address the current lighting quality shortcoming of the self-built ‘informal’ luminaires. If they were further equipped with a solar PV panel and a battery as well as both a photo and motion sensor, they could be installed instantly, overcoming the delay caused by the legalisation process.

Even though the shortcomings of the current formal and informal lighting approach as well as the improvements through the alternative approach can be proved using computer calculations, the question is how to translate those findings for the benefit of policy-making stakeholders who could potentially advocate this alternative approach. Average illuminance $E_{av}$, minimum illuminance $E_{min}$, and illuminance uniformity $U_0$ are abstract values and correspond to certain technological definitions that are unlikely to be understood by people outside the
lighting profession. However, virtual reality offers the possibility to translate those abstract values into a visual experience. While VR does not of course have the same visual quality as a real environment, it can create results that are close to it.\(^1\)

Compared to a lighting evaluation based on numeric calculation results (Table 1), static renderings, or pseudo colour images (Figure 11), a VE offers several additional possibilities for informal settlement lighting planning:

1) An observer can freely explore a three-dimensional environment from an eye-level perspective instead of relying on predefined viewpoints or camera paths. Semi-public building extensions can often be found in informal settlements. It seems fair that the lighting conditions in those semi-public/semi-private areas do not need to fulfil the street lighting standards. However, they are still part of the visual scene and may still have a negative impact on the perception of night-time space. Such building extensions may, for example, serve as a hiding place for a criminal. By being able to move freely through an environment, the observer can evaluate from different perspectives how a lighting solution impacts on such semi-public/semi-private public space.

2) The viewing radius in VE/VR is unrestricted, allowing the observer to turn around or to look up and down. Moreover, head-mounted displays (HMD) adapt the viewing direction to the natural movement of the head. This allows for a better evaluation of aspects related to the built environment such as the feeling of enclosure in a very narrow street.

3) A VE can include moving objects such as people which offers the possibility of exploring the degree of reassurance/fear of crime (resulting from the lighting design) in a more realistic way.

4) Moreover, for the evaluation of a lighting design’s effect on the fear of crime at night, it is also important to analyse the degree of fear during the day – in order to determine people’s baseline level of fear in a certain area.\(^2\) Brillembourg and Klumpner\(^3\) show that the daylight penetration into a dense informal urban fabric can be very low (i.e. 7% in their case study). Hence, the analysis of fear of crime in such environments appears to be very complex. In a VE, a daylight scenario can be integrated as a direct comparison to the night-time lighting, which helps to study such effects visually. Thus, it may even be possible to simulate dynamic elements of a daytime condition such as wind, moving clouds and trees, fog, or rain in VE/VR\(^4\) (see Figure 14).

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5) Physical transformation of the built environment including materialisation (e.g. horizontal and vertical densification over time) can be dynamically illustrated (see Figure).

6) Dynamic lighting technology such as sensor-driven adaptive lighting can be simulated.

7) By integrating sound, audio perception of an environment can be added to the given visual perception. This is likely to have an impact for example on expressing the degree of community confidence and hence informal social control.

8) Similarly to commonly used monitor hoods, VR enables screen surroundings to be masked with an HMD. This allows the viewer just to see the virtual image rather than the additional context of the viewing device. In this way, the observer is more strongly disconnected from the real world and not visually distracted.

9) VR/VE is well embedded as an interface between multiple existing and conventional digital tools and large-scale data sources. This makes it easier to automatically incorporate and combine complex characteristics of informal environments, such as a steep terrain, traffic simulation, and cadastral data into the virtual model.


Apart from the lighting planning, the VE/VR tool presented above has significant potential for lighting policy making in informal settlements. First of all, access to informal settlements is often limited for outsiders – both during the day and at night. This digital twin of a case-study street allows free visual exploration of the highly complex built environment that also contains temporal and motion data (including information on the age, gender, and activities of people) translated into a visual experience. The specific nature of incremental building growth and its direct interplay with the lighting is embedded into this VE/VR tool as well, based on survey data.

Furthermore, VE is not limited in terms of scale: it could range from a one-room dwelling to a whole city – and many of the required data for the creation of the VE can automatically be processed from sources such as satellite images as well as cadastral and census data. Huge parts of cities in the Global South may be
informally built: 50% of Bogotá, for example, is of informal origin. For policy makers, a VE/VR offers the opportunity to assess large-scale lighting scenarios, not only with regards to lighting quality but also regarding aspects such as legalisation processes, luminaire maintenance, lighting financing, and electricity consumption. In addition to the application of lighting planning, the VE/VR offers the opportunity for policy makers to translate cadastral data and satellite imagery into a visual archive of city development. The data in the tool presented could automatically reconstruct a large scale informal settlement based on cadastral data and satellite imagery, with an uncertainty of only around one meter per façade which might be caused by overhangs. However, since informal settlements are not bound to building standards, which makes it impossible to accurately predict future building characteristics, this one meter of inaccuracy can still serve as a planning basis. Furthermore, the lighting design could even be executed in a way to compensate for such unpredictable building features that may evolve in the future of a settlement.

For the reasons stated above, a VE appears to be a promising tool for the evaluation of lighting technologies in informal environments in addition to common lighting calculations. It can ‘communicate’ the lighting characteristics to different stakeholders in a manner understandable to the layman – for example to the non-technical staff of a city’s public lighting department, to the urban planning department, to NGOs, to international donors, and to the residents of informal settlements. Moreover, the lighting characteristics can be presented in a temporal way, which would be a helpful evaluation tool for policy makers because lighting policy consequences can be projected over several decades.

However, so far these are just theoretical considerations. Further empirical research would be required to test whether (and if so, to what degree) VEs can improve the communication of lighting characteristics compared to numerical calculation results, static renderings, or pseudo colour images. Another important question would be what level of detail would be required to adequately create an illuminated VE in terms of, for instance, the textures, the amount of greenery, the presence of sound, or the presence and behaviour of people.

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