CONTEMPORARY PUBLIC SPACE, A TOPOLOGICAL ANALYSIS METHOD

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Abstract

Along with the progressive building technology and massive urban transformation in contemporary times, the functional and formal requirements for urban spaces are changing as well. As a young branch of modern mathematics, topology has gradually penetrated into the architectural field. It breeds alternative thinking methods with a brand-new spatial dimension that makes it one of the heated trends in present urban projects. The article begins with the status quo of European cities particularly urban public spaces in the present day and then the elaboration of topology in urban spaces. Subsequently, the topological design method in urban spaces will be analyzed through actual cases, in block scale, architectural scale and urban scale respectively. Eventually, it comes to the summarization of topology as a physical and philosophic urban spaces design tool.

Keywords: topology; topological space; public spaces; city; scale

1. In the Era: Public Space as a Transitional Zone

Historical European cities have peculiar urban fabrics that unify buildings and blocks in a whole and compact environment. At the opposite, in contemporary cities, this character gets completely lost. Urban spaces are located among buildings of various scales and styles. One of the problematic issues of historical cities today is the visual and physical split between old and new urban fabrics. This article, based on a comparative analysis of case studies and on exercises of architectural and urban design, states that urban public spaces can play a pivotal role as transitional spaces between urban fragmentations belonging to different historical ages. Nowadays, pushed from the changes of contemporary architecture, urban spaces mutate their nature, such as squares grown in vertical direction and complex spaces articulated in multiple layers, often more integrated with the facades and interior space of the surrounding buildings. For instance, the recently built Piazza Gae Aulenti, in Milan, appears being wrapped into the building. Cantilever structure is now widely applied to modern architectures, which leave the ground floor open public spaces while upper floors building. Moreover, each floor plan of a contemporary architecture could shares different shapes and even positions. In this case, urban morphology is no longer comprehensive to analysis of urban design and public space, because it is not able to demonstrate vertical information. Then, the article is addressed to a series of selected public squares in Milan, analyzing construction timelines and regarding how their impact is, in reference with connecting the low-density areas with high-density ones, developing new relations among the surrounding buildings, exploiting new topological characters and potential qualities. Topology is not a realistic description of the existing place, but a possible opportunity.

2. Topology in Urban Public Space

Topology is concerned with the properties of space that are preserved under continuous deformations, such as stretching, crumpling and bending, but not tearing or gluing. [1] Therefore, in topology measures such as distance and angle are not important, but shapes, relative positions, and arrangements are. Topologically, two shapes are considered the same if one can be deformed to the other. For instance, a doughnut is the same as a coffee cup. Topology developed as a field of study out of geometry and set theory, through analysis of concepts such as space, dimension, and transformation. [2] In the 17th century, Gottfried Leibniz proposed geometria situs (Greek-Latin for "geometry of place") and analysis situs (Greek-Latin for "picking apart of place"). The notion of 'place' is evidently the root for topology. Since it was originally used to study the positional relationship between graphs, topology is also called 'geometry of Position'. It accidently matches up with de. Certeau's place theory. He defines the "place" as an "instantaneous configuration of positions".

Topological studies have shown that the shapes in reality are mostly orientable, including 2-dimensional planes, but there are also non-orientable ones. The Möbius strip discovered by the German mathematicians August Ferdinand Möbius and Johann Benedict has the mathematical property of being unorientable. It is a surface with only one side and only one boundary. [3] The discovery of Möbius strip makes the space more complex, and brings infinite imagination to urban public space design. As the French mathematician Poincaré described, topology as "the science that allows us to know the nature of geometric bodies that exist in space beyond the three-dimensional world"[4].

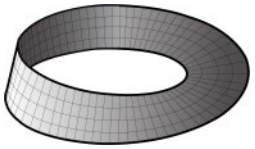

FIGURE 1.
Möbius Strip

Topology as a relatively new branch of mathematics has been used in many discipline fields. The birth of Leonhard Euler's Seven Bridges of Königsberg Problem brought up a heat among geographers around 60s and 70s of last century. By turning to topology in their research, they seek a mathematical language that could capture the shifting network of relationship. For architectural and urban design field, topology is referenced relatively late. Nevertheless, in contemporary architectural and urban design projects, design that takes deformation as a form and spatial tendency is becoming the mainstream of contemporary landmarks. Topology is becoming a theoretical support in the field of architectural and urban design by studying the characteristics of objects that remain unchanged under deformation. Continuously streamlined and curved spatial pattern is considered as a new styling of architecture and urban public space, such as Möbius strip air walkway, Klein Bottle Houses, Chinese National Aquatics Center "Water Cube" and so on.

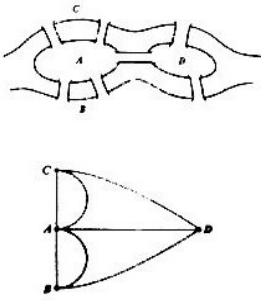

FIGURE 2.
Seven Bridges of Königsberg Problem

Topology breaks through the formal language of architecture under the constraints of Euclidean geometry and orthogonal Cartesian coordinate systems and inspires new patterns of spatial composition. It can be dedicated to the physical form and inner philosophy of architecture and urban spaces, creating a ground for fertile imaginations and possibilities.

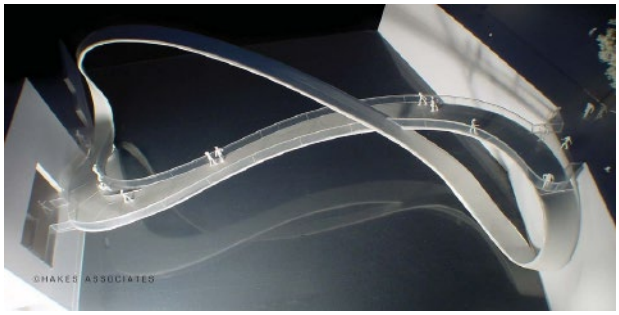

FIGURE 3.
Möbius Strip Air Walkway

FIGURE 4.
Klein Bottle House

3. Topology Applications in Multi-scale

Although there are still few iconic applications of topology in architectural field so far, analyzing urban spaces and transformations from a topological perspective is crucial to understand the nature, formation and pattern of space, since topology research is a qualitative research in nature rather than a quantitative one. It can identify possibilities or impossibility; assert existence or non-existence.

1) Block Scale, Micro-terrain

Topology captures objects at different times and collects them in the same space-time, forming a continuous 4-dimensional dynamic space model. Adding a time axis to the original Cartesian coordinate axes, the classic Euclidean space gets collapsed, compressed and stretched under the effect of time. We can imagine, for example, that after getting off from Milan central station, it takes 35 minutes by walking to get to the Cathedral of Milan, but only 7 minutes by subway. Then we can assume that the impression of the space on the high-speed subway is compressed. Following this logic, if we slow down the speed of passing through a place, the space will be stretched, at least in people's perception. This way limited land can be utilized more efficiently, especially in high-density cities. Tardiness of crossing enlarges how people perceive the space among buildings of different historical periods with various styles and scales, and therefore weakens the sense of huge fragmentation between the old and new neighborhoods, and brings people physical and mental relaxation.

Taking the city of Milan as an example. As a city with excellent architectural monuments and the fastest urban construction in Italy in the same time, Milan owns architectures of various historical periods, from ancient Roman walls to medieval Gothic and Renaissance buildings, international style during industrial revolution, and digital architecture at present, is all-encompassing. This diversity is both an opportunity and a challenge for the city. According to a social survey, most urban residents prefer to work in skyscrapers while live in low-rise buildings. These streamlined high-rises in Milan fulfill people's psychological needs for modernization and high-tech as they bring a strong visual impact and novelty. But at the same time, the huge differences in style and scale between the old and new built create a sense of fragmentation, especially for these Milanese who live there every day. The rigid and insufficient-transitional boundaries leave the city seems a battlefield divided by various camps. The void between buildings ought to provide people adequate room to breath and adapt themselves to the environment. There are several such cases in Milan.

The City Life area that currently under construction is one of the newest blocks in Milan. It covers 225 thousand square meters area and will become one of the largest pedestrian areas in Europe. As showed in the rendering on the left, the area is centered on three high-rise buildings designed by the Arata Isozaki, Daniel Libe skind and Zaha Hadid respectively, so that the subway station is named "Three Towers". Among the three towers, the one of Libeskind and the one of Hahaidid have been constructed and open to the public while Arata Isozaki's tower is still under construction. Being designed by outstanding post-modernism architects, three towers appear nothing in common with the surrounding buildings that constructed during 18th and 19th centuries, neither the architecture monomer, nor the architecture composition. For the monomer, the height of one single tower is more than ten times higher than any building in the neighborhood, and the facades of the towers tend to be flowing wavy forms instead of monotonous vertical and horizontal ones of the peripheral buildings; For the composition, three towers are clustered in the center of the block, surrounded by green vegetation that extends to the edge of the site. The surrounding plots are in accordance with the traditional Italian street layout, on the contrary, buildings are distributed along the border and enclose a courtyard in the middle. In short, the new block is growing from inside to outside while the traditional ones are growing from the outside to the inside.

FIGURE 5.
Rendering of City Life Area

The public spaces are essentially different in City Life area and its surrounding blocks. Most of the public spaces in the traditional Milan block layout appear as atriums that shared only by residents of this block and not with outsiders. Therefore they can only be regarded as semi-open public spaces whose overall characteristics can be analyzed via the basic principle of figure-ground in urban morphology, and conclusion will be illustrated through a simple, clear and two-dimensional way. However, the public space in City Life area is more complex relatively. It can be divided mainly into two parts, the square among three towers that will be discussed in the following part of architectural scale, and the green area between towers and surrounding streets. The green area is a public park named "a park between mountains and valley". It is located on the periphery of the main buildings and has direct contact with the surrounding environment. As the name implies, the vast green vegetation is planned with slopes, which fluctuates and simulates the spatial effects of mountains and valleys, filling the gap of form between the towers and the buildings around. Along the sloping terrain, there are naturally streamlined trails and bicycle lanes to guide people from outside in an open manner. This artificial micro-terrain not only enriches the spatial form, but more importantly amplifies the surface area of the plot, allowing people to wander longer in this place, and thereby the sense of split cause by buildings of different historical period is weakened.

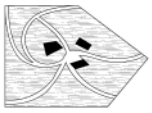

FIGURE 6.
Diagram of Architectural Composition

Not far from City Life area, the Park of Industrial Alfa Romeo is also somewhere that

worth a walk, in fact it is the green area of a residential area with the same name in Milan. The modeling of the park seems is very particular in such a city like Milan, which still manufactures the atmosphere of "between mountains and valleys", but being expressed in a more absurd and philosophical depiction. The micro-terrain here is manifested by the combination of a hill and a lake, which contains the philosophical implication of positive and negative volume. The park is a continuous of another hill named Montagnetta di San Siro. Both of them are built with rubble and excavated earth, linked by a footbridge, just like two reliefs embedded in the city of Milan, balance and coordinate other convex and concave in the city.

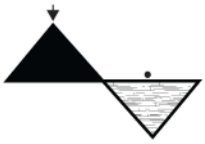

FIGURE 7.
Diagram of Hill and Lake

2) Architecture Scale, Connectedness

We assume that different buildings are states where the same object moves to different moments. For instance, the Roman wall is the state where the object moves to 3 seconds, the parametric building is the state where it moves to 15 seconds, and the buildings in between these two periods can be analogized according to the same hypothesis. Then we can try to capture the deformation laws of the movement of the object, and calculate the characteristics of the blank public space between various states through the conservation of energy. The relationship between traditional architecture and public space is usually clearly divided, since there is always a 90-degree right angle between their surfaces. However, due to the low elevation of the building itself, people in public space do not feel much a sense of distance to the building. After all, the urban space scales at the time when science and technology were not sufficiently developed are humanistic. Yet nowadays, with the promotion of technology, the elevation of the object movement is gradually increasing, as the dream of mankind has always been getting rid of gravity through science and technology. Corresponding to this, the blank space in between ought to be pulled up as the object is stretched upwards, becoming a continuous surface hovering along the surface of the object. In the absence of gravity effects, it is the prototype of Möbius strip in topology.

The square that mentioned above in City Life area is encircled with three skyscrapers. With curved stairs leading from the first floor to the second floor, the whole square is a continuous, band-like surface that spirals along the building skin. As the square ground going higher, people no longer look up to the skyscrapers around from horizon like a frog at the bottom of a well. They have the opportunity to personally reach the surface of the high-rises and go inside of them. Distant becomes at your fingertips. It is the same principle of opening up the ground floor of high-rise buildings for commerce, eliminating people's psychological distance. The surface of public space and building facades are now connected and form a whole, which breaks through the clear divisions of the traditional planning.

MiCo Milano Congresses in the northwest corner of City Life area borders few industrial period buildings and some residential buildings from the 50s to the 80s. Giving full consideration to deal with the relationship with the environs, a liquid flow-shaped roof is designed, which spans two adjacent blocks and covers all buildings in the blocks. On the one hand, the piece of top echoes the parametric style of City Life area and contributes to a nice visual transition between buildings and blocks of different construction periods. On the anther hand, it ensures the unobstructed connectivity between adjacent blocks. Pedestrians under one single roof can walk through freely, regardless of seasonal weather changes. The void between buildings is

no longer just a passing tunnel, but a place where public lives take place.

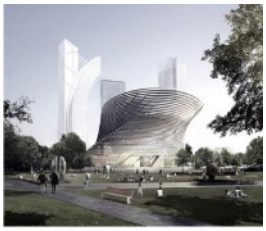

FIGURE 8.
Rendering of Museum of Contemporary Art
FIGURE 9.
Conceptual Diagram

Another upcoming architecture in City Life area, the Museum of Contemporary Art by Daniel Libeskind, has also strong topological features. The building itself is a dynamic process. It has a five-story vertical structure， as it moves upwards, each layer continuously rotates to create a fluid geometry that transforms into a circular terrace at the top. " A highly suggestive geometrical evolution on a vertical axis that recalls not only Leonardo da Vinci's golden section but also spherical astronomy and the process of evolution of art itself, which derives its beauty from the dynamics of transformation, the overlapping of images and the movement of different geometrical figures." [5] Applied advanced materials and building technology, the building pursues the highest level of environmental compatibility and zero-impact the rest of urban life. Moreover, the topological dynamics respond as flexibly as possible to today's unpredictable needs in the contemporary art space.

There is a relatively complete preservation of architecture and public space in Milan during all periods of time. Therefore, many other plots in the city deserve to be studied and compared. The next step of the research is in-depth study of the following selected public squares with a topological approach in order to obtain a longitudinal comparison.

Research Objects:

PUBLIC SQUARE NAME	YEAR	AREA	PEROID
Colonne di San Lorenzo	4 A.D (1935)	1.750 m2	Ancient Roman, medieval
Piazza del Duomo di Milano	14 A.D.	17.000 m2	Gothic, neoclassical
Arco della Pace	1838	16.000 m2	Neoclassical
Piazza XXIV Maggio	1802 (2014)	19.000 m2	Neoclassical
Gallaratese II Housing	1972	5.500 m2	Modern
Piazza Duca d'Aosta	1994	26.000 m2	Contemporary
Hangar Bicocca Milano	2004	1.500 m2	Modern renovation
Piazza Gae Aulenti	2012	7.850 m2	Contemporary

3) Urban Scale, Dynamic Balance

The ideal topological urban model is to allow the various elements and energy in the city to be crossed and parallel but remain order in the same time. The popular urban planning nowadays are the regular grids of Manhattan or Barcelona, which is in contrast to the seemingly undisciplined urban fabric of Mumbai. On the streets, cars, people and cattle walk through each other without causing any traffic accidents. With the second biggest population in India, Mumbai has continued to develop apace in recent years. The city has superior natural conditions, owning a deep natural water harbor, several world cultural heritages and the national park. However, this city is carrying a huge flow of people and goods, which is a challenge to city planning and design. How to maintain the order of the city and ensure people's quality of life in such a dense environment is a question. Although Mumbai still needs to improve the efficiency of land use and housing, but the vitality of the city cannot be ignored. This kind of vitality is the source of life that is extremely lacking in many cities under strict planning.

Topology as a tool and method can capture and analyze the hidden energy and flow

trajectory in cities, then establish a 4-dimentional abstract space model where activities, flows, logistics and other energies in each periods of time are all recorded. When the 4-dimensional virtual model meets the physical environment, the output will be more thoughtful and intelligent, because it understands more the specific needs of various energy and balances them better than a rigid "lattice" city.

4. Reflections triggered by new spatial forms

There are evident indications that the inclination of topology penetrating into urban spaces design. Topology as a neo design tool plays a consequential role in urban design, and topological space as an innovatory spatial form has a great potential for exploration. Thanks to the rapid development of science and technology, the scientific investigation of outer space is accelerating, and the veil of the enigmatic space beyond the earth is being uncovered layer by layer, such as dark matter and quantum etc., which are gradually discovered and perceived by scientists. The traditional notion of spatial dimension will become the past while the multi-dimensional spatial image will be confirmed by science and widely applied. The transformation and expression of topology today cannot yet be arbitrarily implemented since the construction on the earth is restricted by gravity. But one day, if the science and technology are sufficiently advanced, humans could build cities, buildings and parks in an environment without gravity effects, maybe on the earth or another planet. By that time, people will be able to walk along the unorientable surface and through the multi-dimensional space, like in a wonderland. Although the research on topology is only at the initial stage, it has become a trend to use topology methods to analyze and solve spatial design issues. The moment of topology in urban spaces design is coming.

FIGURE 10.
An illustration about gravity

As Prof. Christophe Girot, Chair of Landscape of Architecture of ETH said,

> *[Topology] is to integrate heterogeneous fields of action that can be both physical and philosophical and scientific and poetic – integrating past, present, and future potentials into a single meaningful whole. It will bring different design disciplines together to work on a better understanding of [public space] as a surface and a space in all its inherent beauty and wonder.* [6]

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6. Funding

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7. Annotation

1. "The definition of topology"

2. Bruner, Robert (2000). What is Topology? A short and idiosyncratic answer
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9. Images/Illustrations

FIGURE 1. Möbius Strip. Auther
FIGURE 2. Seven Bridges of Königsberg Problem. Baike.baidu.com
FIGURE 3. Möbius Strip Air Walkway. Blog.renren.com
FIGURE 4. Klein Bottle House. Blog.renren.com
FIGURE 5. Rendering of City Life Area. City-life.it
FIGURE 6. Diagram of Architectural Composition. Auther
FIGURE 7. Diagram of Hill and Lake. Auther
FIGURE 8. Rendering of Museum of Contemporary Art. Hayes Davidson
FIGURE 9. Conceptual Diagram Image. Studio daniel libeskind
FIGURE 10. An illustration about gravity. Julien Pacaud