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How did Public Buildings and Monuments Contribute to the Evolution of Agora to Forum during the Early Roman Period in Athens?

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Abstract: This article uses Athens in the early Roman Empire, the province of Achaia, and the political culture behind it as a research environment. Then focuses on two public spaces in Athens: Classic Agora and Roman Forum, which are used as cases to research the relationships between these public spaces. Based on the dynamic evolution of public buildings, monuments, and new public spaces in Athens during that period, this article explores the reasons for this adaptation and transformation of the Forum to Agora in the Roman period. Research suggests that the construction and existence of public buildings and monuments in Athens during the Roman period may have played a major role in promoting this transition from Agora to Forum.

Keywords: Public Space; Greek Agora; Roman Forum

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1. Introduction

When studying the historical public spaces, people always easily compare the ancient Greek agora with the ancient Roman forums, which is the classic of public spaces in these two great civilizations. Agora and Forum are not the same in the retrospective origin, but there are some reliable links between them. The origin of Forum, first appeared in The Law of Twelve Tables, describing the sepulchral vestibule. In the early days of the Roman Republic, it meant the flat, formerly swampy space between the Palatine and Capitoline hills, where public meetings could not be held in the Capitoline area [1]. After developed over centuries, it evolved to describe the public square, which was the area where the religious, political, and social activities of the Roman Empire took place. The term Agora, first appeared in Homer's works, which means where people gather or the surrounding environment where they gather. After gradual development, it became synonymous with an area in ancient Greek cities [2]. Free-born citizens in the city can gather here to listen to municipal radio, conducting and discussing military and political activities [3]. In the 5th century BC, the term was explicitly used to describe Greece urban core areas, where citizens' religious beliefs, political assemblies, judicial trials, social contacts, commercial contacts, and other activities took place. There is an inevitable connection between Agora and Forum due to the integration of Roman culture to a certain extent. Encyclopedia Britannica described it as an orderly spatial adaptation of Greek agora and the Acropolis in the Forum description [4]. This article attempts to speculate on the relationship and evolution of these two public spaces. The author uses Athens, the province of Achaia and its political culture in the early Roman Empire as the necessary study background, focusing on the wax and wane of the Ancient Agora of Athens. Through research and analysis, exploring the reasons for the adaptation and transformation of the agora to the forum. The author believes that the construction and existence of public

buildings and monuments in Athens during the Roman period may have contributed to the transition from Agora to Forum.

2. Early Roman Empire and The Classic Agora at Athens

2.1. Roman Empire, Hellenistic Civilization, the Province of Achaia

Rather than describing that the Roman Empire Romanizing Athens during that period, one can also think that the Romans absorbed the high civilization from the Hellenistic culture. As people familiar, the ancient Greek peaked in every field of human civilization in the classical era. Whether art, architecture or natural science, all these subjects were thriving, and establishing a democratic system gave birth to great philosophical ideas in the agora. Alexander the Great (356-323 BC) inherited his father's last wish and invaded Persia in an all-around way to avenge Persia's invasion of Greece in 480 BC. In the process, he was directed by Plato's great student Aristotle, spreading the Hellenistic civilizations to every place he had contacted [5]. Therefore, the ancient Romans felt the cultural influence early from Greek. They realized that they could benefit from a more prosperous and more mature civilization, hence made them stronger after long-term gains, which directly led to the annexation of Macedonia (168 BC), the Greek mainland (146 BC), the Kingdom of Pergamum (133 BC), and the entire Hellenized East finally. In addition to the Greek language, they absorbed the structure and technology from Hellenistic culture and further developed it with fantastic adaptability. From 119 or 118 BC, those who were not satisfied with studying Greek culture in Rome, local areas began to enter the Ephebic College for study at Athens [6].

In 146 BC, the Roman general Lucius Mummius captured and destroyed the Achaean league with Collins as its capital. This league is like a federal state consisting of twelve cities, and each participating city remains independent in internal affairs. Around 31 BC, it was separated from the province of Macedonia during the reign of Emperor Augustus, and on this basis, it became independent as Achaea Province, also known as Achaia Province. Geographically, it consists of the Peloponnese, central and eastern Greece, and parts of Thessaly, equivalent to southern Greece today roughly. Morley believes that the Augustus era's provincial system allowed the culture to be subtly integrated [7]; the imperial system paid more attention to establishing a standard order, common law and supreme monarch while respecting cultural diversity. The province of Achaea, where Athens is located, is senatorial in political management, so it does not station a large military. Some cities in Achaea, such as Athens and Sparta, are still allowed to maintain autonomy on their territory, with no destructive lifestyle changes. At the same time, due to Athens's highly prosperous education system, it became the cultural center for the Roman elite to receive education, and it was one of the most important cities in the cultural education of the Empire. As Horace said: "Greece captured the savage victor (Graecia Capta Ferum Victorem Cepit) [8]." Morley also believes that the Rome provincial system is conducive to the spread of civilization, and at the same time, it can strengthen the colony's sense of identity with the Empire through this system [9]. Until the late classical age, Achaia was a relatively prosperous and peaceful area of the ancient Roman Empire.

2.2 The Classic Agora of Athens during ancient Greece

In this context, if people want to understand some reasons or relationships that pushed the forum to transform from the agora, they need first to understand the Agora's architectural performance in ancient Greece. A city's Agora is mainly located in the urban center or near the port in a geographic location. The sense of boundary consists of public buildings, temples, or sometimes colonnades containing shops or stoa. At the same time, statues, altars, fountains, trees also will be embellished and decorated in the space. It is generally square or rectangular from the shape, but its shape is often defined according to the specific function of this area or by the boundary of surrounding functional constructions [10]. Although the essential physical elements that constitute an Agora will change with the times and the scale of the city, and the

political meaning and religious beliefs it contains will also vary, as a public space, its content richness can include "any activity one can imagine: in a sense, the ancient version of the World Wide Web [11]."

As shown in **Figure 1.**, the expression of the Athenian Agora during the Socrates and Plato periods, about the 5th-4th century BC, this Agora was still surrounded by Hellenistic civilization and has not yet been inserted into Roman context. The Classic Agora, located northwest of the Acropolis. At the center of the Agora is the ancient Greek altar ("bômos" in Greek), which enshrines the most representative twelve gods in Greek mythology. The northwest of the altar is four stoas, namely Poikile Stoa, Royal Stoa, and Stoa of Zeus. Poikile Stoa means "Painted Porch" in Greek, which depicts the Athenians' victory in war. Royal Stoa is the Royal Archon (Archon Basileus) seat and includes a copy of the city's laws and the stone sworn by new officials. The Stoa of Zeus is used to commemorate Zeus in recognition of his defeat of the Persians in Plataia. Below it is the Temple of Fatherly Apollo (Apollon Pairóos). The building just at the west of Agora is Hephaistion or Theseion, a temple used for Hephaestus and Athena Ergane, decorated with the daily life events of Hercules and Theseus. The two constructions below are the Bouleuterion, the meeting room of The Five Hundred ("Pentacosiomedimnes"), the left one is new, and the right one is the old Bouleuterion. On their eastern open space is the Monument of the Eponymous Heros, a monument to the same name's heroes from the ten tribes of Athenian democracy. The rotunda is Tholos, which is the residence of the rightful "prytany" in the Athenian democratic system during office. The Strategeion located in the southwest corner is used as a meeting room for the Athenian ten generals. The Agora Stone near it is also the boundary stone of this Agora, marking the entrance. Next to the entrance is "Heliæa," dedicated to Aegina's hero Aiakos, used to display the verdict and later developed into a granary.

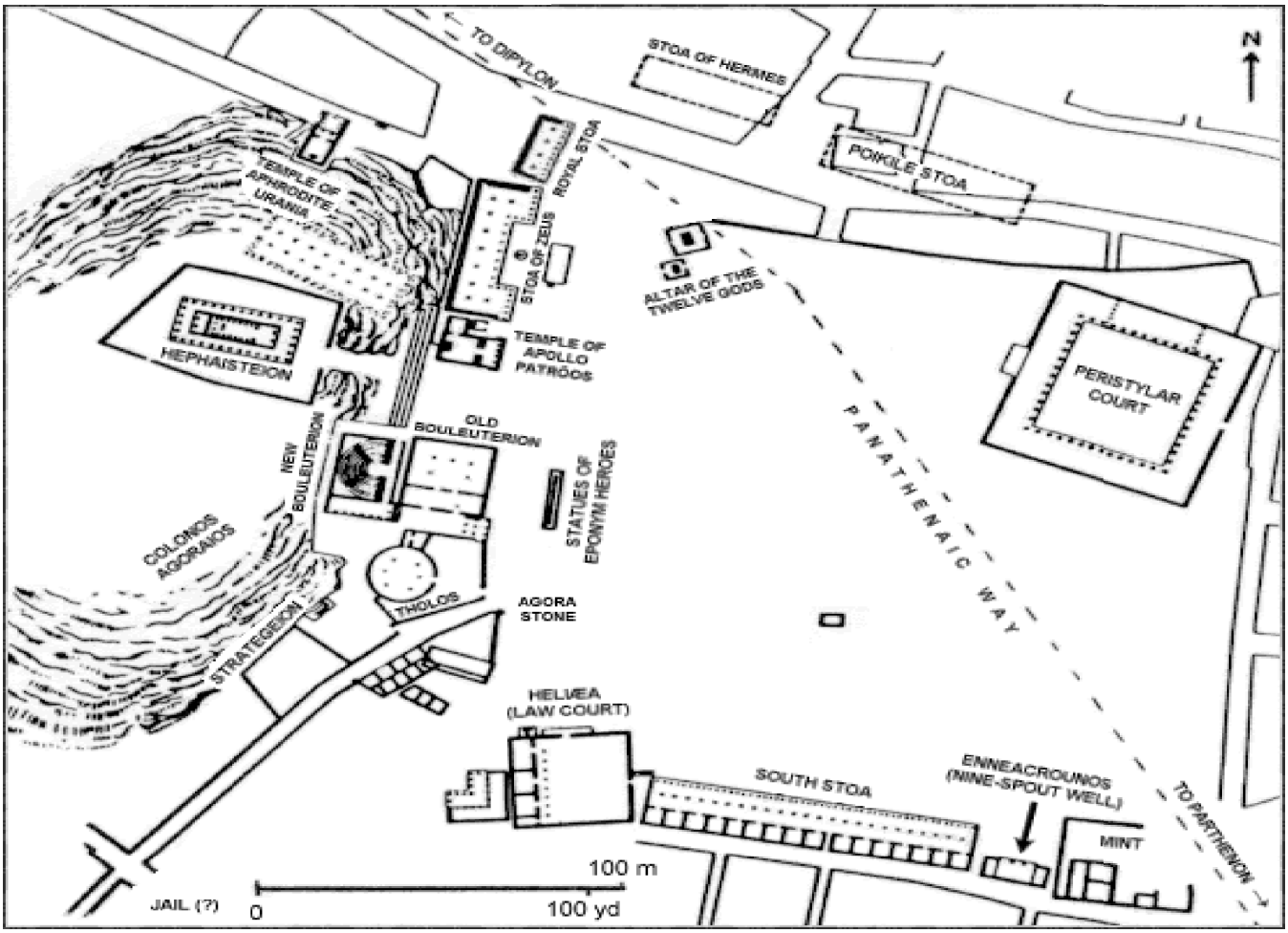


Figure 1. Map of the Agora of Athens in Socrates and Plato's time (Suzanne 1998) [12]

Similarly, according to some archaeological evidence, there is a Stoa on the south side of the Agora used by officials responsible for public affairs. On the east side of it is Enneacrounos, responsible for water supply, mistaken for a fountain by Pausanias in the 2nd century. At the southeast corner of the Agora is the Mint. In the northeast corner of the Agora, opposite the Mint, is the Peristylar Court, which was the court at the time and had a jury system and surrounded by vendors [13]. Through this Agora, fully displayed from the establishment of beliefs in ancient Greek culture-various temples and monuments to functional buildings- the court and the water supply, The Agora in ancient Greece provided various buildings to develop its democracy.

Figure 2. A model of the Agora of Athens at its maximum extension during the 2nd century CE is exhibited in the Athens Agora Museum. [17]

2.3 The Roman Evidence in The Athens Agora

Everything was traceable in the early Empire. The Romans paid tribute to the Hellenistic civilization through various public buildings and monuments while also implanting their culture and beliefs. Starting from the Augustus period (30-14BCE), the Classic Agora's appearance changed dramatically, leaving marks of the Roman rule (**Figure 2.**). Augustus the Great ordered the entire classical temple to be relocated from other areas to the Classic Agora in Athens and dedicated to Ares, the god of war in Greek mythology. This behavior was called "Itinerant temples," and it can also be regarded as the scars left by Augustus the Great to repair the Sulla looting of Athens (86BCE) during the Roman Civil War [14]. Later, due to the donations of Romans and local nobles, this Agora was filled with various public buildings and statues. Roman general Marcus Vipsanius Agrippa donated the Odeion of Agrippa during his visit to Athens (16-14BCE). At the beginning of its construction, it was used as a theatre for musical performances. However, the reducing audience capacity caused by the collapse and reconstruction; hence the Odeion of Agrippa was used for philosophical speeches. In 98-102CE, the Athenian Titus Flavius Pantainos built The Library

of Pantainos. According to archaeological inscriptions, he and his family dedicated the building to Emperor Trajan, and there was a South-East Stoa to serve this library located on the eastern border. During Emperor Hadrian's reign, more buildings were built in this ancient Agora, such as The Basilica, which is a product of typical Roman culture, used for meetings or commercial trade, and it also has a Nymphaeum, a beautifully carved construction with a water storage function, also used to decorate the classic Agora. Therefore, the statues of this period are also vibrant, mainly the portraits of famous Romans and Athenians. One of the most prominent figures is Emperor Hadrian, and the most beautiful is the head of an old priest of Isis. Although a Greek engraver made this statue, it also reflected Roman and Egyptian techniques and skills [15]. According to archaeological evidence, some statues used to worship heresy were erected here during this period [16].

3 Transformation of The Classic Agora in Athens

3.1 Reshaping the Significance of The Classic Agora

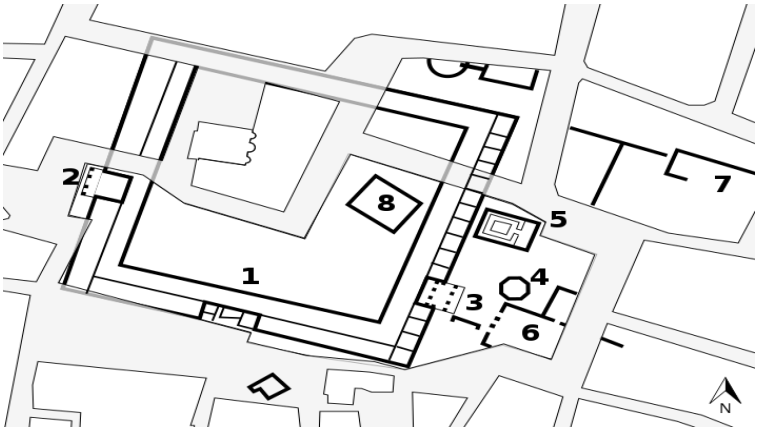
The Hellenistic Agora was a gathering place, and all the activities that took place here were made public. In other words, it requires the participation and witness of citizens, such as displaying the verdict or showing the copy of city laws, which implies that all the citizen needs to abide by the principles of urban policies and regulations. During this period, the commercial activities gave the space vitality and admitted that all citizens had the right to enter this space to a certain extent, demonstrating the spatial nature of democracy. The Altar of the Twelve Gods existed on the people's functional beliefs, and the Monument of the Eponymous Heros was also a typical Athenian democracy. Whether they exist to pray for “asylum” or emphasize the spirit of democracy, there is no worship of the ruling class, rights, and individuals. What cannot be denied is that in the early Roman Empire, this Agora in Athens was continually being destroyed and reshaped.

Nevertheless, at that time, Athens was still a place of artistic and cultural pilgrimage for the Roman elite, so they continue to provide funds to support the “repairing.” Some new public buildings and monuments have been built to maintain sacredness and commemorate past flourishing civilizations. However, Alcock [18] believes that this phenomenon is ironic because such a “new” memorial space is very ancient. If people compare the floor plan of this Agora in the 4-5th century BC with the 2nd century AD, they can find that the layout of this place has undergone tremendous changes. The existence of the Odeion of Agrippa marks the entry of leisure and entertainment into this place that once symbolized democracy, the meaning of the Agora had been changed, and it has gradually become an art center and entertainment venue. Those realistic portrait sculptures of characters have also entered this space to commemorate donors or commemorate the royal and nobility. As mentioned earlier, the statue of Emperor Hadrian was built in this Agora. Dickenson [19] believes that the existence of these statues, their placement, and the preserved statues of gods in the ancient Greek period, the connection within them played a function of reshaping memory. These links allow these respectable people who were still alive and shared the urban public space with other gods, heroes and mythical figures and shared the people's memories. Although the injected form seems to be a tribute to past civilizations, it just makes this Agora look more like an antique. Does the imperially ruled Athens still need democracy? No, it does not need, because the Empire has already ruled it.

3.2 From the Aspect of Architectural Form to The Roman Forum

As previously mentioned, Athens has always maintained its status as an educational center in the early Empire, and the old “Agora” sacredness must be preserved, which means that it needs to undergo a functional transfer. Due to this old urban heart is full of new temples and new monuments; it is enough to maintain its function used for pilgrimage if it survives. At the end of the first century BC, to ensure enough

space in the Agora to build new buildings, small shops and houses in the north were demolished. However, how to maintain its commercial functions? It was true that this behavior will result in lacking commercial spaces for the Athenians, so they need a new place. This fact happened simultaneously with the establishment of the nearby Roman Agora [20]. This Roman Agora (**Figure 3.**), located on the north side of the Acropolis, connected to the old one via a paved street. It was proposed by Caesar the Great but was built during the Augustus period. Thus, the Roman Agora in Athens is an extension of the commercial functions of the ancient Agora. According to archaeological evidence, it has been the commercial center of Athens since its completion, and it has been preserved until the Post-Classical era. However, in terms of architectural form, the middle of the site was open-air, surrounded by a colonnade to enclose this area, and it is indeed a closed public space [22]. Another thing worth noting is that at the same time, Caesar the Great built a similar enclosed building in Italy, the "Forum" (**Figure 4.**). From a connection point of view, the Caesar Forum and this new Roman Agora are very similar in construction and structural evolution. The only difference is that the Italian forum's function was more established for public affairs, and this Roman Agora is just a trading center. Therefore, when many scholars talk about it, they also call it a Roman Forum in Athens. After all, if they only talk about architectural form, there is undeniable trace and relationship.



1. Columned agora
2. Gate of Athena Archegetis i.e West Propylon
3. East Propylon
4. Tower of the Winds
5. Vespasianae
6. Agoranomeion
7. Pantheon (exact location not known)
8. Fethiye Mosque

Figure 3. Plan of Roman Agora at Athens [21]

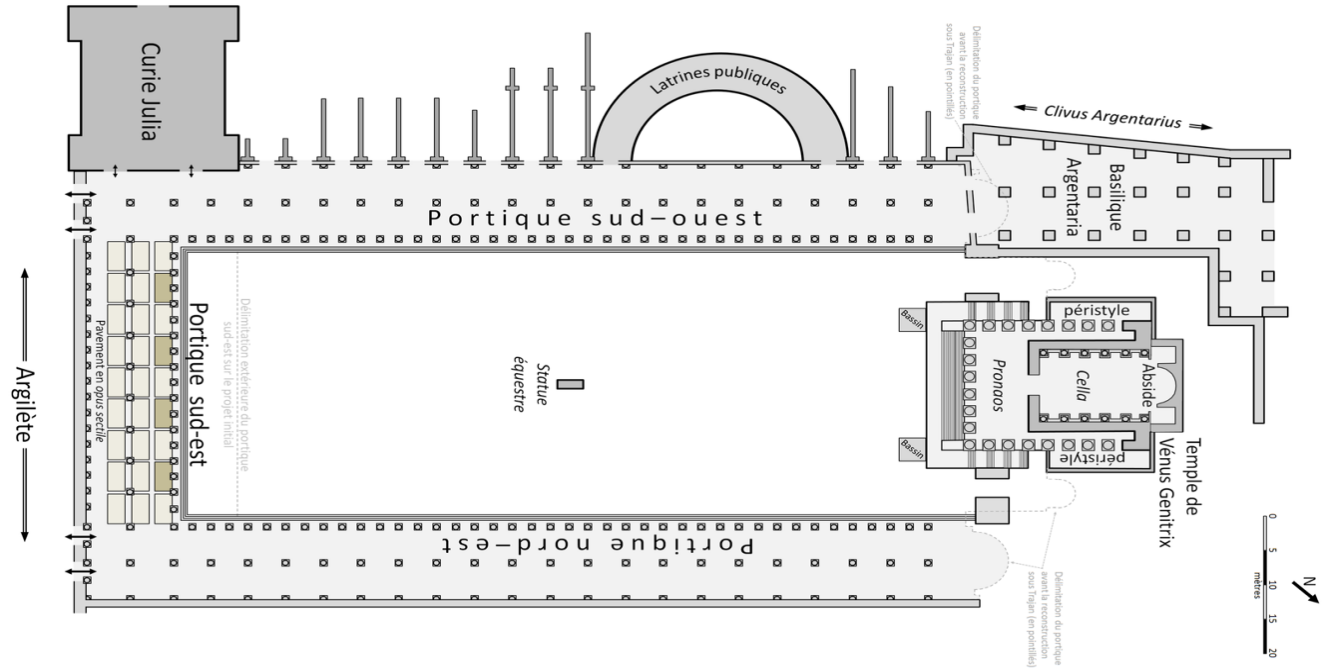


Figure 4. Plan of the Forum of Caesar [23]

4. Conclusion

Alcock believes that these behaviors can be interpreted as the expulsion of commercial activities from its homeland, and the imperial power and class are injected into this site for the classic Agora in Athens [24]. As a result, the site functions experienced dual changes. Based on the early Roman Empire, this article analyses the variations in the classic Agora and its surroundings in Athens during that period and believes that establishing these new public buildings and monuments led to the transformation of the Agora at Athens to a large extent. Specifically, this transformation can be called "from the Agora to the Forum" in architectural performance. In other words, if people talk about the new public building built by Caesar and Augustus, can it be called The Agora? The author is skeptical of calling it Roman Agora because it has lost the democracy that emerged from the Agora. Likewise, can it be called The Forum in Athens? It seems that it has not become a classic Roman Forum, a public space with a similar architectural form.

To some extent, it is more like a complex part of the function of "Agora" and the architectural expression of "Forum." Nevertheless, its archaeological research and excavation work has not been wholly completed. Therefore, the author hopes that people can find a clear answer to the link between "Agora" and "Forum" from future archaeological work.

Disclosure statement

The author declares no conflict of interest.

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Summary of Slope Ecological Protection Technology

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Abstract: It is an important issue for sustainable economic development to give consideration to both project development and environmental protection. At present, we must confront and seriously deal with the problems of rational utilization of resources, protection of the environment and beautification of the environment in engineering construction. This paper describes a variety of slope plant protection technology, which can not only play a good role in slope protection, but also improve the engineering environment and reflect the beauty of natural environment, so as to provide reference for slope ecological protection.

Keywords: Slope; Ecological protection; Theory; Technology

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1. Introduction

Highway, railway, water conservancy and other engineering construction are closely related to the natural environment. The project has large scale, many projects and wide coverage. A large number of exposed earth rock slopes formed by the earth rock filling and excavation project destroy the existing vegetation and have a great impact on the local ecological environment. In the past, simple engineering protection was usually used, such as mortar (dry) rubble, shotcrete and anchor protection, etc. These engineering measures all led to the original vegetation damage, soil erosion, landslide, landslide and so on slope instability and a series of ecological environment and engineering problems [1]. Over the past decade, people have developed a variety of new slope ecological protection technologies, which can not only play a good role in slope protection, but also improve the engineering environment and reflect the beauty of the natural environment. Together with the traditional slope engineering protection measures, the slope engineering plant protection system has been widely used in all kinds of rock slopes and soil slopes.

2. Principle and function of slope ecological protection

Slope ecological protection refers to the use of green vegetation or green plants with auxiliary materials instead of traditional stone and other engineering measures for slope protection [2]. In this way, plant roots and soil particles are bonded to form a large area of aggregates, which can increase the anti-erosion ability of soil, effectively stabilize soil, protect soil and conserve water, and reduce water and soil loss. Moreover, the construction speed is fast, the investment per unit area is small, and the effect is fast, so that the local environment of the slope area can be quickly improved.

3. Three commonly used slope ecological protection technology

3.1. Slope protection by spraying and sowing of foreign soil

The slope protection by spraying and sowing of foreign soil is a kind of slope plant protection measure, in

which the soil or substrate (foreign soil) and seeds with a certain thickness suitable for plant growth are mechanically sprayed and filled (or manually laid) by hanging nets on the slope surface. The technology is suitable for soil slope with slope ratio less than 1:1 and height less than two meters, and road slope with height less than 4 meters or more than four meters and engineering measures. It is characterized by low cost, simple construction and fast speed. Generally, greening protection function can be initially formed from January to February, and has wide adaptability. As the soil can be mixed by machinery, it is easy to implement, so the degree of mechanization of construction is required to be higher. However, it has obvious advantages over mortar rubble and hanging net shotcrete in terms of efficiency and cost, and has obvious greening protection effect, low maintenance requirements and strong adaptability to plant growth. At present, the technology has been widely used in highway slope protection.

3.2. Slope protection by spraying mixed vegetation

Spray mixed planting greening slope protection is a kind of construction technology of using foreign soil mixed with adhesive and anchor rod to reinforce wire mesh on stable rock slope, using special jet machine to spray evenly mixed planting base material on the slope, plants rely on "base material" to grow and develop, forming plant slope protection. It has the dual functions of slope protection and vegetation restoration, and can replace the traditional spray anchor protection Stone masonry slope protection and other construction technologies. The planting base material used in this technology is composed of soil, mixed grass and shrub seeds, organic matter, fertilizer, bonding material, water retaining material, stabilizer, pH release agent, water, etc. the proportion of the mixing material is the key factor of the technology. It can be used on the rock slope with a slope steeper than 1:0.75, which can effectively increase the slope protection strength and the ability to resist rain erosion, and keep enough porosity and fertility to ensure plant growth. This technology realizes the perfect combination of slope protection and landscape greening, which is a breakthrough in environmental protection and land greening engineering. It has been widely used in highway, railway, water conservancy and other rock slope greening protection projects.

3.3. Honeycomb grid grass planting for slope protection

Honeycomb grid grass slope protection is similar to dry rubble slope protection technology. It is a slope protection measure that after paving regular hexagonal concrete frame bricks on the finished slope surface to form honeycomb grid, planting soil is paved in the grid, and then grass is planted or planted in the brick frame. Before the construction of this technology, the key is to do a good job in slope dressing to prevent the grid laying cracking and collapse caused by the uneven slope. At the same time, it is necessary to set up a drainage system. Generally, the transverse spacing of slope drainage ditch is 40 ~ 50 cm. The grid used in this technology can be mass produced in the prefabrication yard, and its stress structure is reasonable. It can effectively disperse the rainwater runoff on the slope, slow down the flow speed, prevent the slope erosion, and protect the growth of turf. This kind of slope protection has the advantages of simple construction, neat appearance, beautiful appearance, double effects of slope protection and greening, and the construction cost is higher than that of mortar gravel skeleton slope protection. This technology is mostly used for the protection of fill slope.

3.4. Hydraulic spray seeding and grass planting for slope protection

Hydraulic spray seeding grass slope protection is a new slope plant protection measure implemented in recent years abroad. The method is to mix grass seed, adhesive, fertilizer, soil conditioner, pulp and pigment in the mixing box according to a certain proportion of water, and then spray them to the slope by mechanical pressure to achieve the purpose of grass slope protection. Hydraulic spray seeding is usually carried out in spring and autumn, and construction in rainstorm season should be avoided as far as possible. Slope leveling

→ drainage facilities construction → spray seeding construction → cover non-woven fabric → maintenance. This method has the advantages of simple construction, fast speed, wide applicability, low engineering cost, high quality, neat germination rate and good protection effect [3]. In general, the plant coverage rate of spray seeding slope can reach more than 70% after one month, and the function of protection and greening can be formed after two months. At present, hydraulic spray seeding grass slope protection has been widely used in highway, railway, urban construction and other slope protection and greening projects.

3.5. Geonet planting grass for slope protection

Geonet planting grass slope protection is a composite slope protection measure which integrates the reinforcement of geonet and plant protection. The geonet used in this technology is a kind of three-dimensional net produced by special technology. It is a product of high-density polyethylene extruded into square, rhombic and hexagonal grid shape. It has certain tensile strength, durability, chemical stability, weatherability, corrosion resistance and other properties. After implementation, it not only has the function of reinforcing the slope, but also has the function of strengthening the slope, In the early stage of sowing, it can also ensure that the surface is free from direct rain erosion, keep the soil to help grass seed germination, protect young grass growth, easy to fix the vegetation roots on the slope, gradually make the slope covered by plants, make the vegetation and triangular network form a whole, and then play the role of slope reinforcement together. It is necessary to pay attention to the selection of grass species, the specification of geonet and the treatment of slope foundation surface. At present, geonet planting grass slope protection is mainly used in highway and dam slope protection engineering.

4. Problems and solutions of slope ecological protection technology

At present, with the popularization and application of different slope plant protection technology in highway, railway, water conservancy and other construction, all kinds of slope plant protection technology have developed into an important means of slope reinforcement, but there are also some difficult problems.

4.1. Grass degradation is obvious

In different engineering construction, due to the small investment in slope greening protection, and the large area and partial location of some slopes, the slope lawn is basically in a natural growth state in the case of low investment, low maintenance or no maintenance in the later stage, and it is easy to cause vegetation degradation and death in case of drought, diseases and pests. With the passage of time, if the supply of nutrients and water is not timely, there will be different degrees of vegetation degradation. If the degradation problem cannot be solved in time, it will not only cause a waste of funds, but also fail to achieve the effect of slope protection, and eventually lead to soil erosion, slope collapse and other problems.

4.2. Selection of plant seed ratio and plant community structure

Different types of slopes have different requirements on the structure and morphology of plant community, and the selection of vegetation seed ratio is also different [4]. In order to restore the excavated slope to the natural state in a short time, it is necessary to determine the proportion of plant seeds, combine with the structural characteristics of the local dominant community, and study and determine the dynamic relationship between the plant proportion and the final formed plant community during spraying and sowing. Only after the investigation and analysis of the above problems, can we correctly guide the construction and ensure the smooth succession of plant growth from artificial greening to original plant community.

4.3. Drought is a threat to slope plants

After rock slope excavation, due to the thick rock layer, good integrity, generally high and steep slope, after the implementation of plant ecological greening, with the extension of time, hot summer and summer, drought in autumn and winter, soil nutrients of vegetation base soil slowly lose, and soil fertility gradually decreases. How to effectively solve the state of no soil, water shortage, fertilizer shortage of slope and the drought and drought faced by slope vegetation The threat of extreme heat is an important factor to determine the final greening effect and ecological benefits of the slope.

4.4. Maintenance management difficulties

Ecological slope protection mainly relies on vegetation production to achieve ecological restoration and beautify the environment. Sufficient water and nutrient supply are the key to the survival and growth of plants, especially in high and steep rock slopes, where the soil matrix of vegetation is thin, water shortage and poor nutrient conditions make it difficult for plants to grow. The slope greening measures cannot achieve long-term stable effect. Moreover, in some areas, less rainfall or large seasonal differences also make the natural growth of slope green plants more difficult. Methods to improve the maintenance measures, enhance the effectiveness of maintenance, timely give sufficient water and nutrients during plant growth, is the key factor to ensure the rapid growth of plants and play the role of slope protection.

5. Conclusion

At present, hydraulic spray seeding, soil spray seeding and mixed planting are the most typical ecological protection construction technologies, which are widely used. How to implement the concept of sustainable development of slope greening engineering, we need to carry out a series of research and Analysis on the difficult problems in the aspect of slope ecological protection, increase scientific research investment, introduce advanced technology and equipment, and cultivate professional talents, so as to provide a firm foundation for thoroughly solving the sustainable development of slope ecological protection.

Disclosure statement

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Research on Key Technologies of Solar Photovoltaic Building Integration

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Abstract: On December 21, 2020, The State Council Information Office issued a white paper titled "China's Energy Development in the New Era," in which the installed capacity of hydropower, wind power, photovoltaic power and biomass power generation in China ranked first in the world [1]. Solar photovoltaic power generation is the most important development direction of clean energy in the world. It is an important energy strategy to combine it with the field of construction in China. This paper mainly introduces the characteristics and problems of the key technologies of solar photovoltaic building integration, and explores its future development direction and ways, in order to constantly promote the industrialization of new energy technology in China.

Keywords: Solar photovoltaic building; Clean energy; Integration; Key technologies

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1. Introduction

As the name suggests, the key technology of solar photovoltaic building integration is to organically combine solar photovoltaic power generation and buildings. The combination here is not a simple addition of functions, but to reflect the idea of "building energy production." The most common practice is to build photovoltaic power generation equipment on the exterior structure of the building construction in time to improve the design sense of the building while providing it with additional power energy, so that the building and photovoltaic power generation technology form a unified whole, and the two complement each other. Since 2009, China has issued a series of important documents to promote the development of photovoltaic power generation projects, represented by the Implementation Opinions on Accelerating the Application of Solar Photovoltaic Buildings [2]. Since then, the research on the integration of solar photovoltaic buildings has developed rapidly. It has become a key research topic of renewable energy development and utilization in China.

2. The characteristics of the key technologies of solar photovoltaic building integration

2.1. The integration of solar photovoltaic buildings can realize the rational utilization of resources

The use of solar photovoltaic building integration key technology can effectively utilize the external structure of the building while using solar photovoltaic power generation, such as directly laying photovoltaic power generation equipment on the roof or wall. It does not occupy land resources other than the building itself, nor does it need to build other power generation facilities. Especially for the first-tier and second-tier cities, the population is becoming more and more dense, making land resources become scarce and expensive. In this case, the integrated design of solar photovoltaic building integration can give full play to the function of photovoltaic power generation and maximize the rational utilization of resources. At the same time, the solar photovoltaic power generation function can provide additional power demand

on the basis of the internal electricity of the building, especially in the hot summer, or when large factory buildings need to run air-conditioning, refrigeration equipment or large machinery and equipment, which can fully meet the power demand of the building. While alleviating the power supply pressure during the peak period of construction, it can solve the summer power load, or temporarily increase the power consumption of more resources, and provide sustainable and stable power supply for the building, so as to maximize the resource efficiency and economic benefits.

2.2. The integration of solar photovoltaic buildings can reduce the cost

The key technology of solar photovoltaic building integration can reduce the cost of additional electricity equipment in building construction, and the cost of solar photovoltaic power generation is lower than that of grid power supply or grid connection support. It is mainly based on the installation of photovoltaic array power generation equipment, which can fully supplement the power consumption of buildings and reduce the cost of electricity consumption. At the same time, solar photovoltaic array can also serve as a high-rise building shading facility, avoid building external structure caused by high temperature and other problems, improve the indoor temperature with light environment, reduce air conditioning, refrigeration equipment electricity costs, reduce extra shading and cooling facilities installation cost, eliminating the peripheral building maintenance materials of construction, further reduce the cost of construction.

2.3. Integration of solar photovoltaic buildings can give full play to the economic effects of environmental protection

As a major power demand country, China's electricity consumption is increasing every year. In 2020, China's electricity supply and demand gap has reached nearly 11%, and the proportion of clean energy generation is not high [3]. As human beings become more active on the earth, the adverse impact on the environment is becoming more serious. The key technologies of solar photovoltaic building integration use solar energy for photovoltaic power generation. Solar energy is inexhaustible compared with other power sources such as coal, oil and water power. Additionally, the use of solar power generation, will not produce thermal power generation, fossil fuel power generation caused by air pollution, solid pollution, can reduce the air emissions of various greenhouse gases, so as to alleviate the urban greenhouse effect. At the same time, solar energy belongs to clean energy, which can produce better environmental and economic effects, and embodies the concept of green and sustainable development.

3. The key technology of solar photovoltaic building integration is insufficient

3.1. The key technology of solar photovoltaic building integration is not mature

With the introduction of the national policy of supporting the research on key technologies of solar photovoltaic building integration, the research process of solar photovoltaic building integration in China has been gradually accelerated in recent years. However, China has joined the field of solar photovoltaic building for a short time, and the research on key technologies is still not mature enough. First, there is no unified and recognized system for the technical standards and specifications of the integrated construction of solar photovoltaic buildings. Research on photovoltaic building technology is relatively scattered, and most of the funding is supported by government subsidies. As an emerging technology, the research intensity and depth of the key technology of solar photovoltaic building integration in China are not as strong as those of western countries represented by Germany. Therefore, there are not many building cases that truly realize the integration of photovoltaic buildings in recent years. Second, the construction of solar photovoltaic building integration needs not only the maturity of photovoltaic power generation technology, but also the organic combination of photovoltaic power generation and architectural design and the production of related accessories. Additionally, it can produce photovoltaic array component of domestic

enterprises is not much, and the technical level is not high, especially solar photovoltaic building integrated involving curtain wall, outer shading building materials design, installation and other technical requirements, the related demand of domestic can realize company is relatively small, still need to be imported from abroad for key technology. Therefore, the development of the key technology of solar photovoltaic building integration is not only an issue of its own technical level, but also requires considerable progress in architectural design, component quality, process and structure to promote the rapid development of photovoltaic building integration technology in an all-round way [4].

3.2. At present, the power generation efficiency of photovoltaic cells in China is low

At present, solar photovoltaic power generation in China is mainly carried out by using battery modules. Domestic commonly used battery modules include monocrystalline silicon, polysilicon, amorphous silicon film, copper indium gallium selenium and so on. In comparison, the most widely used and widely accepted battery components are crystalline silicon. Crystalline silicon can be divided into monocrystalline silicon and polycrystalline silicon, both on the sun light is very high, pervious to light quality is not strong, crystalline silicon itself if hair form a complete set of solar photovoltaic components of light transmittance is also not strong, and photovoltaic building integrated design, the shading rate factor comprehensive enough, will significantly affect the efficiency of the crystalline silicon. However, because the crystalline silicon battery has been applied in China for a long time, the technology has been relatively mature, and the power generation is stable, the market is still the most recognized.

In contrast, amorphous silicon thin film cells, which are relatively new in recent years, are cheaper to build than crystalline silicon cells and are smaller and easier to assemble and use. However, the technology of amorphous film is relatively complex, and few companies can master it, which cannot form a wide range of promotion and use. Moreover, heavy metal pollution is easy to occur in the production process, which does not meet the green environmental protection and energy saving requirements in the field of solar photovoltaic building integration. Moreover, the power generation of amorphous silicon thin film cells is not as stable as that of crystalline silicon cells, and its application technology still needs further development and research. Therefore, in general, the power generation rate of domestic solar photovoltaic cells cannot meet the development needs of photovoltaic building integration.

3.3. High requirements for integrated design of photovoltaic buildings

If you want to carry out the integrated construction of photovoltaic buildings, you should carry out the overall construction design from the beginning, and take full account of the appearance and internal functionality and other comprehensive factors. For example, whether the size and color of solar photovoltaic power generation modules are coordinated with the building itself, whether it affects the beauty of the building; Whether the installation position can give full play to the function of its components to convert solar energy into electric energy, and whether the function of shading and modification can be realized. At the same time, it should not affect the load-bearing, windproof, waterproof and other functions of the building. Especially in the current market, the buildings that can use the integrated construction of solar photovoltaic buildings are generally high-rise buildings in cities, with more light time and greater power demand [5]. This puts forward strict requirements on the pipeline safety of the integrated design of photovoltaic buildings, and the ability of the battery components to withstand rain, snow, hail and wind. But also facilitate future maintenance, repair, replacement and system maintenance and upgrade. In general, it is on the basis of giving full play to the role of solar photovoltaic power generation and forming an organic combination with the function, beauty and overall style of the building.

4. The development trend of key technologies of solar photovoltaic building integration

4.1. Gradually replace thermal power, fossil and other traditional energy sources for power generation

At present, the international on the disadvantages of traditional energy sources such as coal and fossil power generation has a very profound understanding, in addition to the consumption of non-renewable resources, its produce all kinds of pollution has seriously affected the normal life of mankind, as a result, the clean energy such as solar power generation technology, will become the development trend of energy in the future, especially with the deepening of the research. With the maturity of technology, the use of green energy such as solar photovoltaic building integration will gradually replace the traditional energy generation.

4.2. The trend of large-scale application

At present, the application scope of domestic solar photovoltaic building integration is not wide, and the market acceptance is not high enough. However, the advantages of the key technology of photovoltaic building integration are obvious. With the deepening of research, the shortcomings and disadvantages will be gradually overcome and reduced. The key technology of solar photovoltaic building integration will be promoted and applied in the market on a large scale to promote the development of China's new energy technology.

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Contribution of Revived Heritage on Contemporary Social Interaction: The Case of Paddington Reservoir Garden

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Abstract: Reviewing and further reviving the historical landscape have significant impacts on developing this field for the designers [1]. It is useful for contemporary designers to learn from the past. They can practice analyzing the strengths and weaknesses of diverse past examples, recognizing the success criteria of contemporary designed landscapes, and exploring new ways to design sustainable public spaces for the future. This article will examine the Paddington Reservoir Garden, in Paddington, Sydney, Australia. This is as a successful and influential example as a heritage redesigned as a contemporary public open space.

Keywords: Revived heritage; Historical landscape; Contemporary social interaction

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1. Introduction

Based on the vital role that heritage plays in history of human art, culture and architecture, contemporary designers should to deliberate what is vital to modern society on producing a usable past. Start from this question, this article aims to explore how people revive the discarded heritage, improving its functions and creating new meaningfulness on modernity values. This article selects a typical heritage work, the Paddington Reservoir Garden (PRG), in Sydney, Australia. This is a heritage which display a combination of contemporarily creative intervention and original old construction. By analyzing the significance and effect in terms of social, environmental and aesthetic values, the effective ways to revive the heritage could be summarized and put forward.

2. Analysis progress

The Paddington Reservoir Garden was a significant water source catering to the rapidly growing population in the 19th century and ceased operations in 1899. Tonkin Zulaikha Greer and JMD Design redesigned this place and construction spanned from 2006 to 2009 [2]. Nowadays it is an outstanding public space integrating historical foundations and contemporary elements to provide the visitors with multiple opportunities. It reflects how a historical space can become a vital contemporary space, also create precious opportunity for the contemporary designer to rethink the historical landscape works functioning in the future.

3. Social value analysis

The discussion starts with its social values. The social value of one public space is exhibited by its ability of social connection [3]. It implies that a successful contemporary designed landscape should have the capacity to form a strong social connection between the visitors and itself. One approach is to provide

multiple facilities and services to cater the public's needs of their physical and mental aspects, for example, infrastructure, amenities and natural view [3]. These factors can inform, inspire and link people and the environment effectively [4]. Taking the PRG as an example, its highly social value is displayed by its comfortable and safe infrastructures, diverse cultural facilities and artistic natural elements.

3.1. Benefits

There are two main features facilitating the achievement of the high social value of this heritage. Afford of fundamental infrastructure play a vital role in strengthening social interaction. By providing the society's basic requirements is to cater the convenient and comfortable experience. The installed infrastructures in PRG are considered to cater to the users' multiple needs, including the elevator, the wide boardwalk, and benches (**Figure 1.**). Through using them, the interaction between the visitor and this public space could be strengthened.

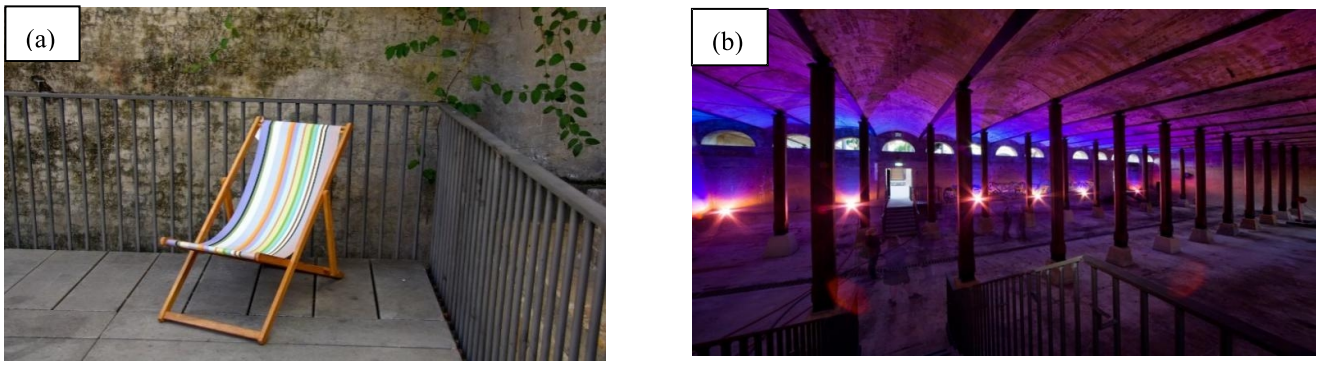

Figure 1. (a) Leanne Barnett as shown in Knowing where to stand, 2013; (b) Eric Sierens as shown in "tonkinzulaikhagreer" Architects, n.d. [5-6]

3.2. Weaknesses

Although applying the former two reviving techniques on this historical space can prove its highly social values in the contemporary period, there are still two shortcomings with hindering the further improvement of the values. Firstly, the garden still exists under-maintained infrastructure [7]. For example, the elevator with poor cleanliness for a long time is reducing the visitors' desire to use it. The second negative factor is the unobvious signage displayed on the garden entry gate. Its design ought to have the noticeable characteristics to gather social groups to this site [8]. The signage of the gardens' name on the gate is too inconspicuous to be noticed by the visitor (**Figure 2.**). This weakness could deprive the common guests' opportunities to engage in this site, and impede them to connect with more social groups.

Figure 2. Jim as shown in Sydney-City and Suburbs, 2013 [9]

4. Environmental value analysis

The application and expression of sustainability ethics in designed landscapes could have vital impacts on environmental protection [10]. Based on the design teams of the Paddington Reservoir Garden, Tonkin Zulaikha Greer, and JMD Design's sustainable design concept, this public open space has become a typical contemporary example that involves advanced sustainability ethics. There are two applied approaches in this site to strengthen its environmental values, decreasing the waste of materials through reusing past resources and maintaining a local ecological system with scientific humanistic intervention.

4.1. Benefits

Firstly, as water storage in the past, PRG had to be closed in 1899 because of collapsed roof and lack of primary functions (**Figure 3.**). Nevertheless, it escaped from the fortune of being discarded and revived with new functions and innovative styles since being redesigned. Their major approaches are to repair its original framework and reuse its old materials, including historic brick, cast iron and timber.

Secondly, proper anthropogenic intervention to natural resources could be more beneficial to the ecology cycle in a designed landscape [11]. In the PRG, there are multiple natural ornaments, such as plant collections, lawns, and ponds. The placement of these natural components is an artificial way to increase the richness of nutrition and necessary energy of the public space, for example, the pond. It provides this space adequate water resources.

Figure 3. Sally cited in Sydney Daily Photo, 2009 [12]

4.2. Weaknesses

Lundholm argues that the vegetation coverage could impact the sustainable development of the urban environment positively [13]. However, in the PRG, the density of green plants is one limitation of its environmental value. The major function of the vegetation in this public open space is decoration.

5. Aesthetics value analysis

Displaying precious cultural scenes to the visitors is a vital aspect to illustrate the aesthetic value of a contemporary garden [14]. PRG is a typical example.

5.1. Benefits

Firstly, the historical aesthetics value of the Paddington Reservoir Garden is its heritage. The vital original framework in this public open space is preserved completely by designers, such as major linear structures, vaulting, and walls with distinctive curved characteristics (**Figure 4.**). Secondly, the cultural aesthetics values of the designed landscape also are presented in terms of its contemporary design of roof-top, architecture structure, and artifacts. The obvious instance is the roof-top with a sunken characteristic is inspired by the Baths of ancient Caracalla, now becomes a modern feature and applied

widely in contemporary public space [15].

Figure 4. Christopher Yardin as shown in Something for Kiki and the Pok, 2013 [16]

5.2. Weaknesses

A few infrastructures breaking the aesthetic harmony of this space. Some details in their design could not match the major aesthetics style of this designed landscape. For example, the structure of the garden fences, texture of stair pavement and the color of deck chairs are discordant compared with other elements in this space (**Figure 5, 6**).

Figure 5. Lauran Vohmann as shown in hEAdoN photo festival, 2017 [17]

Figure 6. Alex Promios as shown in flickr, 2009 [18]

6. Discussion

Based on the analysis for this garden in terms of social value, environmental value and aesthetic value, there is no doubt that this space which has a highly meaningfulness for the contemporary as a heritage. As

the discussion, in these three aspects, this space still has a high value which can improve. However, the value and impact of this landscape still worthy to be analyzed and emphasized. The most vital benefits for this site include that the instalment of the artificial equipment and the recreation of the ecological system. The combination of the contemporary elements and the historical construction can create a new experience journey for the visitors.

7. Conclusion

In conclusion, former contemporary gardens exist advantages which are worthy to be learnt for future designers. They also have several disadvantages which could be avoided and improved. The author selected the Paddington Reservoir Gardens, an old reservoir which is revitalized through being redesigned as an example. Its strengths and weaknesses were analyzed in three aspects, including social values, environmental values and aesthetics values. Even though this contemporary public space still has several aspects which need to be promoted in the future, it does inspire and encourage designers to design a contemporary landscape with benefits in terms of social interaction, environmental sustainability and aesthetics values, just like itself, even better.

Disclosure statement

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Dynamic Management and Control Strategy of Highway Engineering Cost

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Abstract: The rapid economic development has promoted the construction of infrastructure, such as highways and water conservancy projects. The establishment of highways has facilitated people's lives and made the distance between regions shorter and shorter. However, the construction of highway engineering is a big project, which not only has a long cycle, but also has a high economic cost. During the construction process, a large number of construction materials and personnel will be applied. If the project cost management is not implemented for the highway construction, it will easily affect the final quality and profit of the entire project. This article expounds the significance of dynamic management and control of highway engineering cost, and analyzes the strategy of dynamic management and control of highway engineering cost.

Keywords: Highway; Engineering cost; Dynamic management; Control strategy

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1. Introduction

In recent years, various regions in our country have developed rapidly. In order to meet people's pursuit of a higher quality of life, the country has also begun to build a large number of highway projects to promote better social development. Due to the characteristics of the project itself, it is necessary to pay attention to the management of its project cost in the construction of highway projects. However, the cost of traditional highway engineering is inconsistent with the development of existing highway engineering, and there are many problems. For example, the awareness of the whole process of cost control is not strong, the lack of sound rules and regulations, and the quality of employees are not high. Therefore, it is necessary to strengthen the strategy of exploring highway engineering cost management to improve the quality and efficiency of highway construction.

2. The significance of dynamic management and control of highway engineering cost

Project cost refers to the project cost that is estimated or actually spent during the construction period of the project. Project cost management refers to the comprehensive application of management, economics, etc., and a series of processes such as forecasting, planning, controlling, and analyzing the cost of the entire project [1]. By implementing dynamic management and control of cost in highway projects, it is conducive to complete the content of the highway project within the specified time and avoid delays. The dynamic management of cost includes the management of manpower, material resources and materials in the project development process. Through scientific management, the orderly operation of the project can be ensured, and the cost of the road construction can also be reduced. Funding is an element in the whole process of highway construction. Through dynamic project cost management, the use of funds can be predicted, monitored and analyzed to avoid waste, which increases profits to a certain extent. In addition, the dynamic management and control of highway cost will involve all aspects of highway construction, such as

manpower, material resources, and financial resources. When these important elements are controlled, the quality of the highway is also guaranteed.

3. Analysis of the main factors affecting the cost of highway engineering

Highway engineering is the infrastructure construction of our country, and it has played a very important role in the economic development of various regions. In the process of highway construction, project cost is an important factor that cannot be ignored. The following describes several factors that affect project cost.

3.1. Changes in highway engineering

In the process of highway engineering construction, there will be engineering changes, which means that within the scope of the contract, the contractor makes changes in accordance with the documents issued by the supervisor and the change instructions, including changes in the amount of work in the contract, adding or subtracting work content, or adding content outside the contract. The reason for the changes in the cost of highway projects is closely related to insufficient surveying efforts and inaccurate data acquisition. Of course, it may also be related to unforeseen circumstances during the construction process. Once there is a change in the highway project, it will have a direct impact on the cost of the highway project.

3.2. The impact of construction materials and equipment

Many mechanical equipment and raw materials are used in the construction of the highway. These machinery and equipment are usually relatively special, such as the two-liner trolley, which has a relatively high technological content. Whether it is directly purchased or rented, the cost is not negligible. If there is an accident in these construction equipment's during the construction process, for example, it cannot be used normally, it will affect the entire construction schedule of the highway, which will inevitably affect the cost of the entire project. In addition, raw materials are a very important part of the construction process, which will determine the quality of highway projects and account for most of the cost of railway construction. If the procurement of materials is not well controlled during the entire construction process, poor quality materials are purchased and rework is caused, or the price of the purchased materials is higher, the cost of the project will increase.

3.3. The influence of design and construction

The design link of highway construction is a means to effectively control the construction cost. Therefore, it is usually necessary to determine the section, geology and parameters of the highway before designing, design a reasonable construction plan, and select appropriate construction materials. However, if the designers did not design the highway project based on the actual situation in the design phase, the later organization will inevitably appear to be inadequate, which will affect the cost of the highway project. What's more, there are many influencing factors in the construction process. If the construction technology is not in place, it will affect the quality and cause later rework. The construction efficiency is not well controlled during the construction process, which will result in not being completed within the specified construction period. Failure to do a good job of financial control in the construction process will result in a waste of funds. All these will have an impact on the cost of highway projects.

4. Strategies for dynamic management and control of highway engineering cost

Through the analysis of the main factors affecting the cost of highway engineering, it can be seen that in the management of highway engineering cost, changes in highway engineering, design factors, construction factors, construction materials and equipment, etc., will affect the cost of highways. Therefore, it is

necessary to implement dynamic control of these contents in order to reduce the capital loss caused by uncertainty and improve the efficiency of highway engineering management. The following specifically analyzes the strategies implemented by dynamic management in the project cost from four perspectives, namely the design phase, the bidding phase, the construction phase, and the completion phase.

4.1. Application of dynamic management of project cost in the design phase

In highway engineering, engineering design is the prerequisite for all projects, and it will affect the reasonable arrangements of manpower, material resources and financial resources for later construction. Therefore, it is necessary to integrate the dynamic management of the project cost reasonably in the design phase.

(1) Specify design standards to reduce errors in the implementation process. Pay attention to the cost control of the design link, focus on the expected goal in the design, and rationally incorporate new methods and technologies. The parameters involved must be tested and scientifically demonstrated, so as to reduce the economic benefits of the entire project cost.

(2) Carry out standardized highway engineering design management. The construction company can set up a special department to control the quality of highway construction, and compare the error between the established result and the actual result according to the unified highway index, so as to ensure the reasonable operation of the entire highway construction.

(3) Implement quota design. From the beginning of construction, it is necessary to analyze funds and set quotas reasonably. In short, incorporating dynamic engineering cost management in the design stage can better avoid a series of excess problems caused by insufficient accuracy in the later phase [2].

4.2. Application of dynamic management of project cost in the bidding phase

The project cost in the bidding phase can not only realize the preliminary estimate in the design process, but also effectively control the scale and quality of the later project development. The specific dynamic management is reflected in the following points. The first point is to analyze the relevant factors of the project cost on the premise of fully collating the content of the entire highway project to ensure the accuracy of the entire tender document. Secondly, before the start of the bidding activities, it is necessary to organize the bidding documents to ensure their quality. Thirdly, after the start of the bidding activities, it is necessary to screen and filter the construction plans and materials provided by some construction units, analyze the bidding documents among them, and select high-quality bidding companies and plans. In the whole process, a stricter bidding management system must be established to clarify the person in charge of each project in bidding and bidding management and their responsibilities, so as to avoid bribery and other situations. Once such a situation is discovered, severe penalties will be imposed. Through such a strict dynamic management of the project cost, the smooth operation of the bidding phase can be guaranteed.

4.3. Application of dynamic management of project cost in the construction phase

In the entire highway project, the construction phase is a very important part, the effect of the construction phase will directly affect the quality of the entire project and the final cost. However, the manpower and technology involved in the construction phase are relatively large, so it will also be affected by various factors. At this phase, reasonable cost control must be done to ensure the quality of the entire construction process.

(1) Construction materials are a very important part of the entire highway construction process. The price and quality of construction materials will have a great impact on the entire highway construction. In the current building materials market, prices are constantly changing. Therefore, as

a highway construction purchaser, it is necessary to measure the quality and price of materials to avoid low purchase prices and serious material problems. At the same time, we should not pursue materials too much and ignore the cost, but should be reasonably controlled.

(2) To avoid a series of cost changes and quality problems caused by man-made problems. Therefore, it is necessary to manage the construction contract during the entire construction process, sign labor contracts with the constructors in accordance with corresponding laws and regulations, and timely stipulate various changes, so that man-made changes can be effectively avoided.

(3) The management of construction technology should be strengthened. Construction technology will not only affect the construction schedule, but also have a direct impact on the quality of the highway. Therefore, it is necessary for the construction staff to review the design drawings in advance, and formulate the construction process and technology in advance according to the design to avoid technical inconsistencies. If we need to change the project temporarily, we need to submit it in accordance with the regulations, and ensure the consistency of the highway design and before and after the construction as much as possible [3].

4.4. Application of dynamic management of project cost at the completion phase

Project settlement is the final link of highway engineering, which will also affect the cost of the entire project, so reasonable control is required. Firstly, after the completion of the project, it is necessary to sort out and analyze a series of designs and data during the construction process, so that various costs can be calculated with justification. Secondly, accurately calculate the engineering quantity, check the engineering quantity on the list in detail and comprehensively, and improve the accuracy of the data. In addition, review the measurement and payment work, carefully and accurately measure, if problems are found, they must be resolved in time to improve accuracy. When calculating the final payment, each period should not be accumulated, and the quantity of the entire project should be fully calculated starting from the as-built drawings. Finally, a ledger is established to record and check the changes in various projects in the construction process in a timely manner to ensure the accuracy of the entire record.

5. Conclusion

All in all, the highway project itself involves manpower, material resources and capital. To ensure the rational operation of the entire project, it is necessary to implement dynamic management of the cost and reasonably control it. Specifically, in the management and control, comprehensive management should be carried out in the design phase, bidding phase, construction phase, and completion phase, so as to reduce the cost of highway engineering in the construction process, ensure quality, and improve efficiency.

Disclosure statement

The author declares no conflict of interest.

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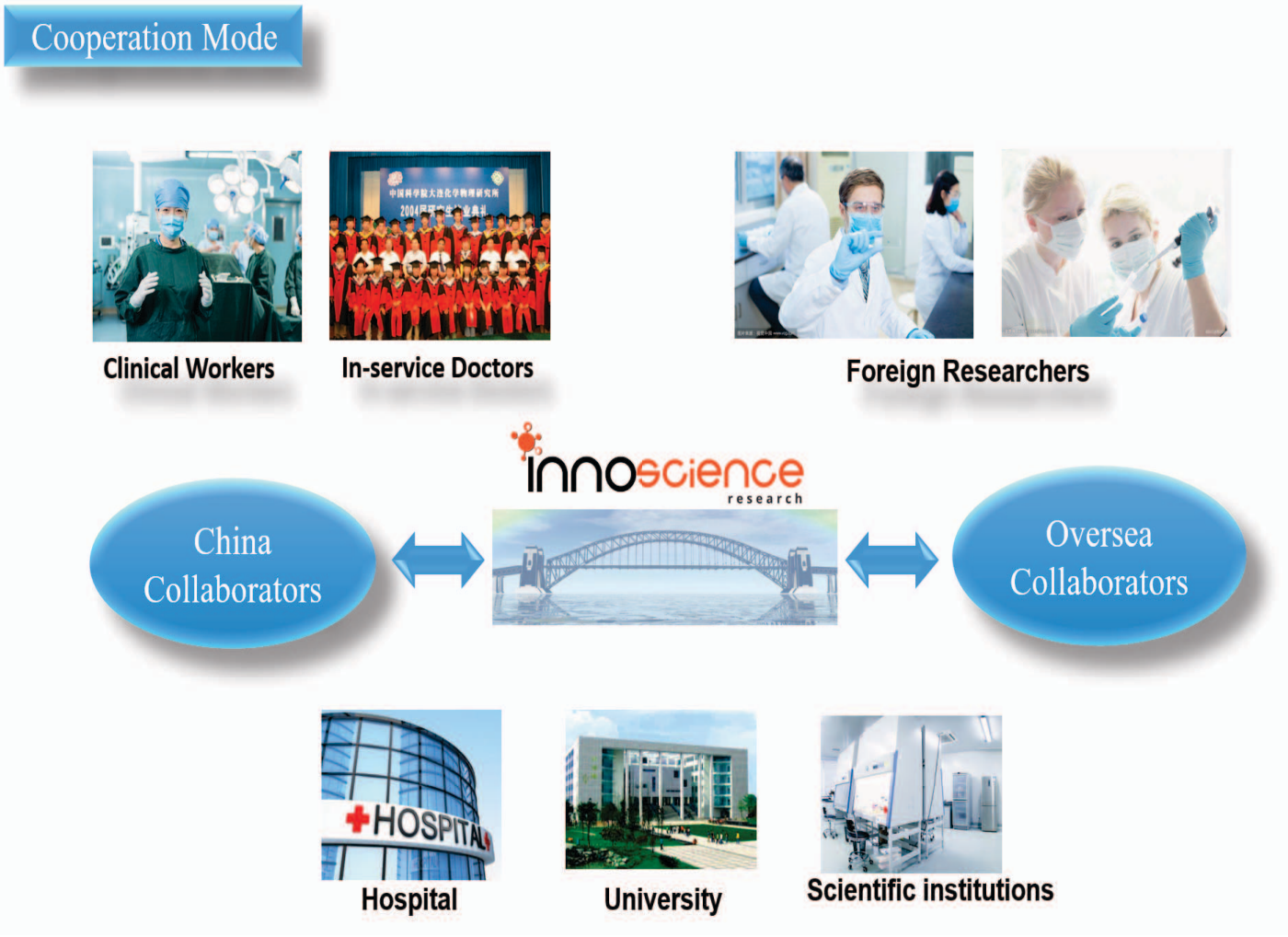

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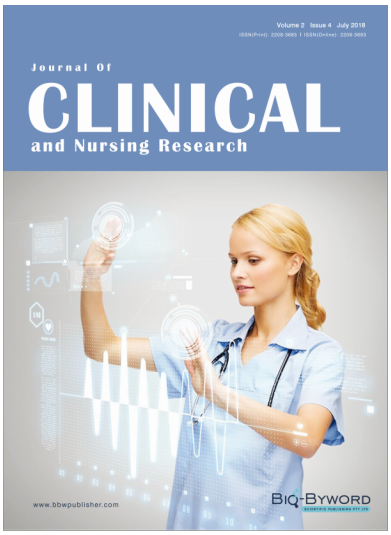

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