Waterfront Space Utilization in Coastal Metropolitans: An Empirical Study Based on Quantitative Analysis

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Abstract:

For most coastal metropolitans, the waterfront areas provide various valuable resources, However, reasonable arrangement and utilization of different resources, scientific distribution of diverse functions and efficient management of various urban elements with the limited space are major difficulties for urban planners. This study chooses 14 famous coastal cities over the world as the research objects, to conduct a quantitative analysis. Researchers have demarcated a 10-km^2 waterfront area (10-kilometer-long coast, 1-kilometer-wide outspread urban space) in each case city with a screenshot software based on Google Earth, then marked different components on the map with different colours, and calculated the ratios of buildings and lands with different functions. Moreover, this study has elaborately analysed the qualities, functions and heights of buildings through the open-source platform Openstreetmap and Geographic Information System, for answering three questions: (1)the proportions and percentages of various types of lands; (2) the types, forms and heights of constructions and buildings; (3)the organization of road net system. The result of the study has concluded key elements of coastal-waterfront space planning, utilization and management.

Keywords: coastal metropolitans, waterfront spaces, quantitative analysis,

1 Introduction

1.1 Waterfront Space: the Revitalizing Engine of Coastal Metropolitans

Waterfront space of a city refers to the urban land or dockland district which is alongside a body of water. Giovinazzi (2008) suggested that the waterfront should not be considered as a line, but should be more correctly envisaged as a network of places, functions, additions and hinges between the coast and the city[1] Compared with most inland cities, coastal metropolitans usually have much more longer and broader waterfront area, which is a substantial proportion of urban space. Nowadays, coastal cities and its waterfront spaces have played a significantly important role in the process of global urbaniz 21 , which was published on UNCED Earth Summit of Rio de Janeiro in 1992, st Sixty percent of the world s population already lives in coastal areas, whi cities with populations above 2.5 million are located along the world coasts in the Chapter

1 Giovinazzi, O., 2008. Waterfront planning: a window of opportunities for post-disaster reconstruction. 4th international i-Rec conference, Christchurch 30 April-2 May 2008.

17 Protection of the Foreshore[2] For most coastal metropolitans, waterfront areas have various valuable treasures, such as sightseeing, resort, biological, cultural, business and other public activities etc. As A.C. Moore said, a waterfront is a significant resource ad a challenging opportunity for a city, chance to be an escape for the pressure-cooker of crowded city life, a chance to be a bright breathing edge of city living.[3]

In the ancient ages, the utilization of sea and coasts was limited. Waterfront areas of coastal cities were always only used as ports, wharfs, fishery industry facilities or manufacturing factories. The urban centres and downtowns of those cities were usually not adjacent to their coasts or seashores. However, after the Second World War, the functions of sightseeing, residence, commerce, entertainment and other various functions besides transportation and industries had been developed in waterfront areas of coastal cities all over the world. In 1964, the government of Baltimore, a major metropolitan of the U.S. State of Maryland which is located in the east coast of America, operated an ambitious plan to re-use the maritime waterfront for tertiary facilities, middle-class and tourist settlements, therefore rejecting the conventional organisation based on manufacturing plants and traditional residential buildings.[4] Since that time, coastal-waterfront spaces have become a kind of public resources for the residents and tourists of cities. As Jauhiainen (1995) mentioned, waterfront redevelopment became a widely spread and largely accepted tool against urban dereliction of inner city areas close to water in North America. This development stared in the 1960s in the United States and about a decade later it spread to Europe where it was a key factor in inner city redevelopment during the 1980s and 1990s.[5] Today, coastal waterfront has become the stage of newly-emerging industries such as tourism, hotel and resort, real estate, MICE (meetings, incentives, conferences and exhibitions) as well as other public services projects. Those industries and projects make the engine that revitalize the coastal city.

1.2 Question: How do we make use of coastal urban waterfront?

Since urban coastal waterfront area provides a large amount resources and opportunities which can be used for various functions, we are facing to a major question that how we can distribute, arrange and manage those different functions in limited space. What are the proportions and percentages of each kind of land? Are there any waterfront space use models in coastal metropolitans? In this paper, we have raised three questions about the utilization of coastal-waterfront space: (1) ratios of various types of land; (2) ratios of various types of constructions and buildings; (3) the organization of road net system. For these targets, we

2 The United Nations Conference on Environment and Development, 1992. Agenda 21 [online] Available at: <http://habitat.igc.org/agenda21/index.htm> [Accessed 1 May 2015].

3 Moore, A.C. and Childs, P.P., 1971. Bright, Breathing Edges of City Life: Planning for Amenity Benefits of Urban Water Resources. Washington: Arthur Cotton Moore Associates.

4 Vallega, A., 2001. Urban Waterfront Facing Integrated Coastal Management, Ocean & Coastal Management, 44, pp. 379-410.

5 Jauhiainen, J. S., 1995. Waterfront redevelopment and urban policy: The case of Barcelona, Cardiff and Genoa. European Planning Studies, 3(1), pp. 3-21.

have designed this research which focuses on case study and empirical research based upon quantitative analysis.

2 Case Study

2.1 Overview of 14 Coastal Metropolitans

This study chooses 14 coastal metropolitans which have various characteristics and are located in 9 countries as the research case cities. We demarcates a 10-km^2 waterfront area in each case city as our survey sample. Then we compare and analyse these samples quantitatively in terms of the function categories of land use, building density and road traffic density etc. Through the comparison and analysis, we finally conclude key elements of planning and the model of coastal-waterfront space utilization.

As the table 1, the chosen cities are New York City, Los Angeles, Seattle, Baltimore, San Francisco, Barcelona, Benidorm, Fukuoka, Busan, Lisbon, Rio de Janeiro, Rotterdam, Marseilles and Vancouver. They are located in Continents of Asia (2), North America (6), South America (1) and Europe (5) (see Figure 1). In summary, every city of 14 chosen coastal metropolitans is of great importance in the aspects of economy, policy and culture in its region or country. Meanwhile, all of them are adjacent to sea, ocean or great lake, and each of them has huge and continuous body of water, long shoreline and port or harbour. Therefore, these 14 cities are the suitable cases of typical coastal metropolitans.

Figure 1. 14 Case cities on the World Map

Table 1. Case Cities and Their Locations, Characteristics, Population and Adjacent Waterbody

Nr.	City	Country	Characteristic	Population(million)	Sea/Ocean/lake

1	New York City	U.S.A	The largest city of the United States.	19.7	Atlantic Ocean
2	Los Angeles	U.S.A	The second largest city of the United States, the largest port of the United States.	3.9	Pacific Ocean
3	Seattle	U.S.A	The largest city of North-western U.S.	0.6	Pacific Ocean
4	Baltimore	U.S.A	The largest city in the U.S. state of Maryland.	0.6	Atlantic Ocean
5	San Francisco	U.S.A	The second largest city in the U.S. state of California	0.9	Pacific Ocean
6	Barcelona	Spain	The second largest city of Spain, the largest port of Spain.	1.6	Mediterranean Sea
7	Benidorm	Spain	The famous tourism destination of Spain.	0.07	Mediterranean Sea
8	Fukuoka	Japan	The capital city of Fukuoka Prefecture and is situated on the northern shore of the island of Kyushu in Japan.	1.5	Pacific Ocean
9	Busan	Korea	The second largest city of South Korea, the largest port of South Korea.	3.5	Pacific Ocean
10	Lisbon	Portugal	Capital city and the largest port of Portugal.	2.7	Atlantic Ocean
11	Rio de Janeiro	Brazil	The second largest city in Brazil, the sixth largest city in the Americas and the world's thirty-fifth largest city by population.	6.5	Atlantic Ocean
12	Rotterdam	Netherlands	The largest port of Europe	1.0	North Sea
13	Marseilles	France	The second largest city of France, the largest port of France.	0.9	Mediterranean Sea
14	Vancouver	Canada	The third largest city of Canada, the largest port of West Canada.	2.3	Pacific Ocean

2.2 Study Methodologies

In this study, we cut out the satellite image of each case city with a screenshot software based on Google Earth, a virtual globe, map and geographical information program (see Figure 2).[6]

6 http://en.wikipedia.org/wiki/Google_Earth

According to the 14 satellite maps we demarcated a 10-km^2 waterfront area (10-kilometer-long coast, 1-kilometer-wide outspread urban space) in each case city. On the maps, we mark different functional lands and main buildings with different colours. With the marked maps of the case cities, we can divide and distinguish the different components of the waterfront spaces, and calculated the ratios of lands and buildings with different functions (see Figure 3). Through the database of the open-source website Openstreetmap , we can estimate the heights buildings in the research areas. Meanwhile, we use Openstreetmap , Autodesk CAD and Geographic Information System to calculate the road traffic density of the coastal space of each case city.

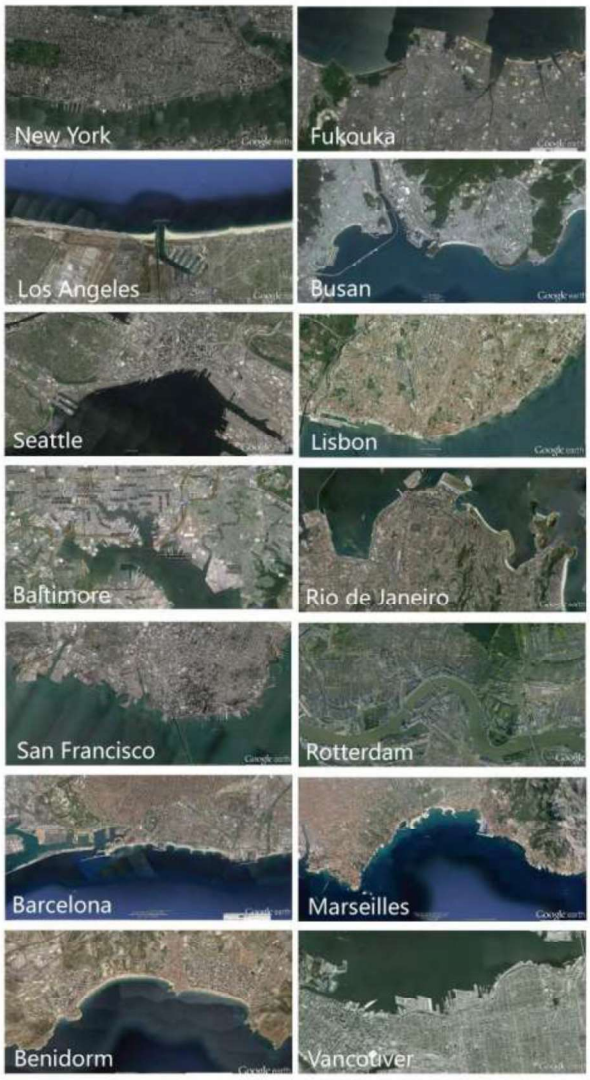


Figure 2. The Satellite Images of 14 Case Cities and Their Waterfront Area

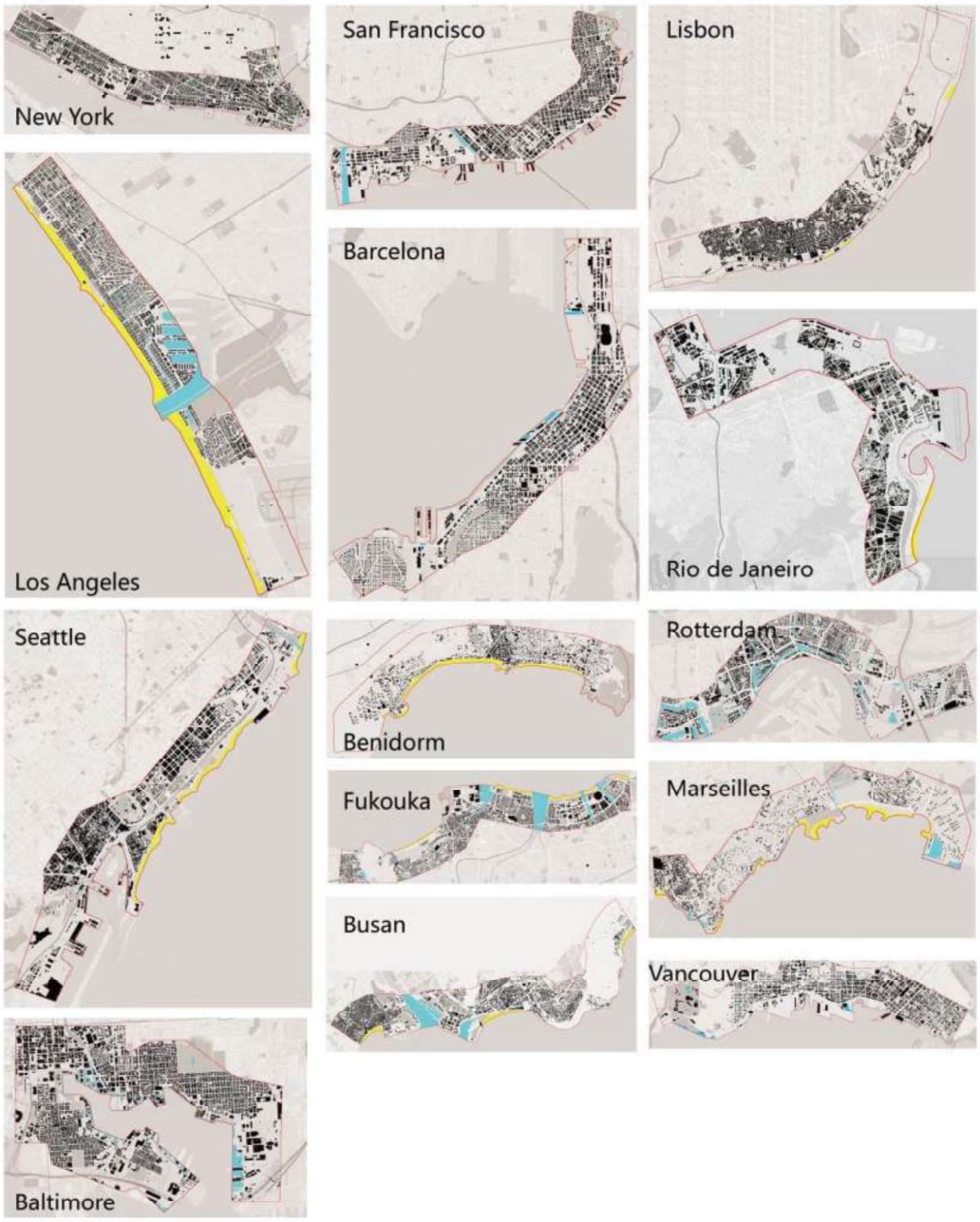


Figure 3. The Marked Maps Which Distinguished Different Components of the Coastal Area of the Case Cities.

2.3 Analysis on Land Use

The pie charts in below Figure 4 show the land use ratios of waterfront areas of 14 case cities. The red parts of the charts refer to the lands used for buildings. The green parts refer to the lands used for roads and green spaces. The orange parts refer to sand beaches. The blue parts refer to water bodies.

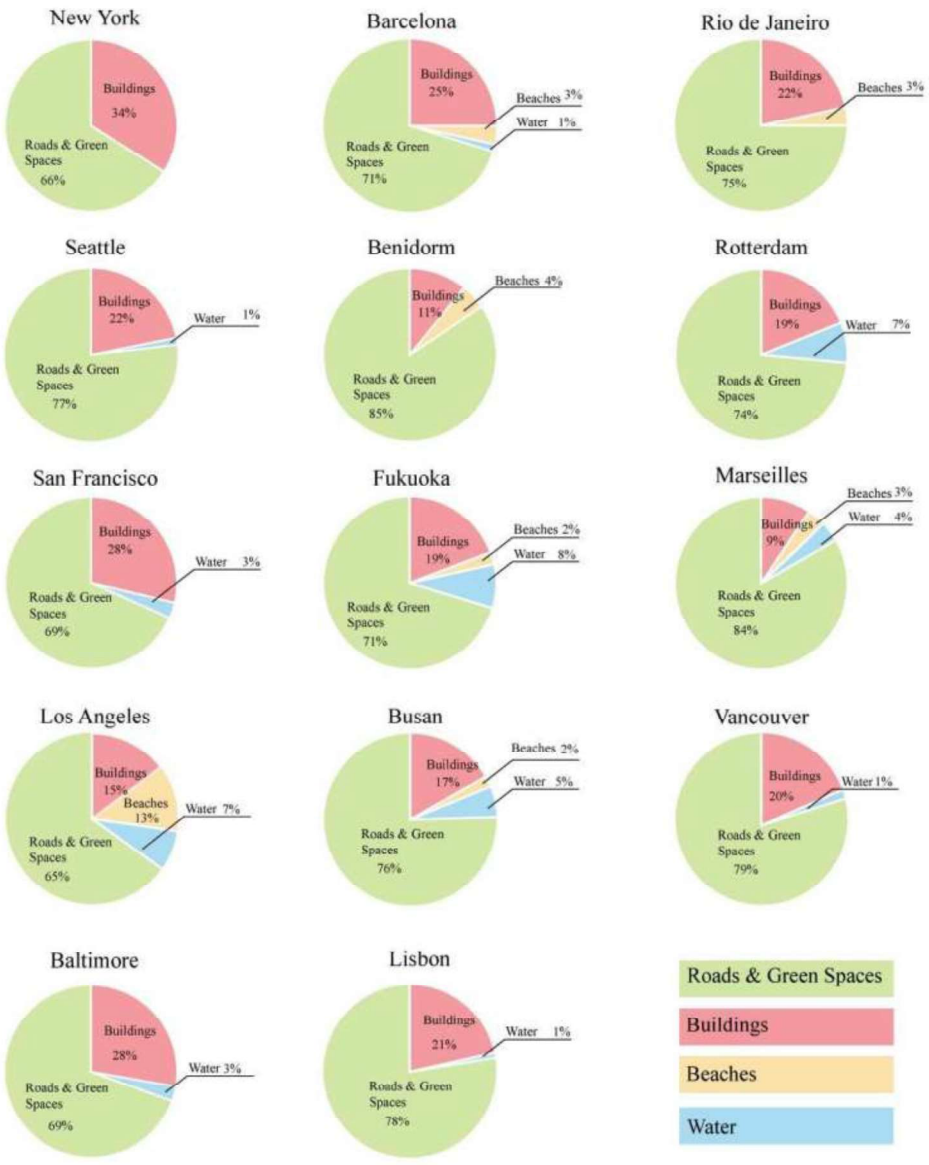


Figure 4. The Pie Charts about Land Use Ratios of the Waterfront Areas of the Case Cities

Generally speaking, the most lands of waterfront areas are used for roads and green spaces, which cover about three-fourth (74.2%) of all in average. The lands used for buildings occupy about one-fifth (20.7%) of all in average. The lands used as sand beaches cover about 2.1% in average. Besides, the small water bodies (such as rivers, small lakes or pools) occupy some 2.9% in average (See Figure 5).

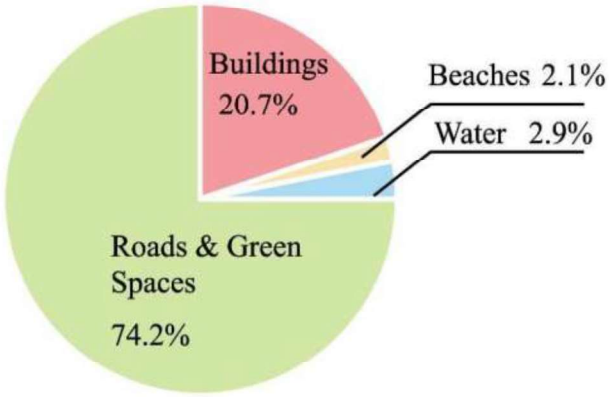
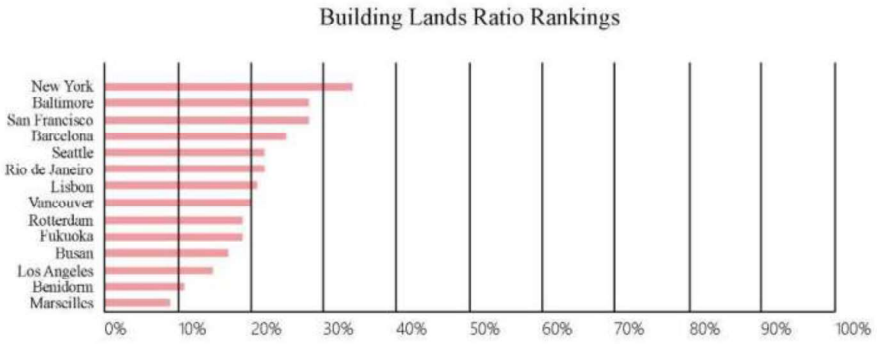


Figure 5. Average values of the percentages of different lands

As we see in the charts, in all 14 case cities the top three cities with highest ratio of buildings are New York City (34%), Baltimore (28%) and San Francisco (28%) (See the rankings of different types of lands in figure 6). And their rankings of roads and green spaces are relatively low. Except these three cities, all the case cities lands for buildings are le the whole waterfront areas. And this ratio is less than one-third even in New York City, the global commercial centre, financial centre, cultural centre, transportation hub and a world-class comprehensive metropolitan which has the most population in 14 cases. These statistics demonstrate that a large amount of outdoor open spaces and public facilities are necessary and the most important components of waterfront areas of coastal cities.



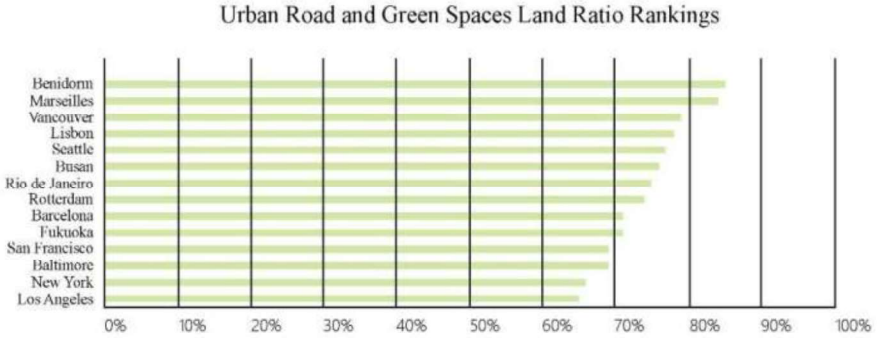


Figure 6. Building Land Ratios Rankings and Urban Road & Green Space Ratio Rankings

2.4 Analysis on Buildings

Through the planar shapes of the buildings on the satellite maps and the building information data come from the open-source platform Openstreetmap , we can estimate the heights the buildings on the waterfront areas of 14 case cities. We classify those buildings as low-rise buildings, multi-story buildings and high-rise buildings. Their percentages of each type of buildings of 14 case cities are shown in the figure 7.

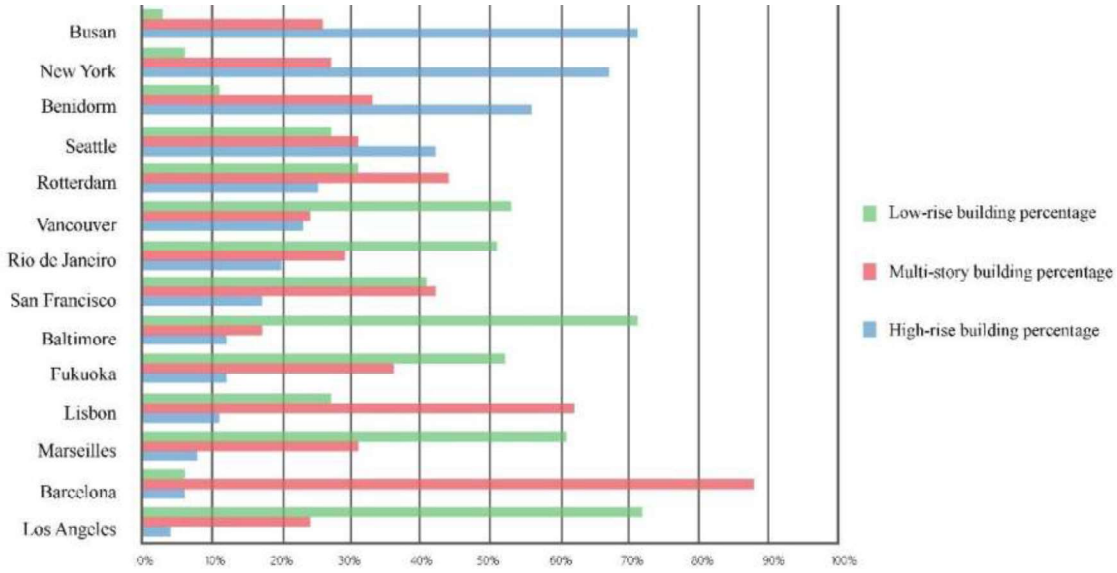


Figure 7. Percentage of Each Type of Buildings of 14 Case Cities

2.4.1 High-rise buildings

As we see in the Figure 8, among 14 case cities, Busan, New York City and Benidorm have relatively high percentages of high-rise buildings. Their percentages are 72%, 71%, 67% and 56%, which are all above 50%. Among them, Busan is the most important industrial centre in South Korea. New York City is the most populous city in the United States and the centre of the New York City metropolitan area, one of the most populous urban agglomerations in the world and a global power city.[7] Benidorm is the new town which is regarded as a vital seaport and an attractive tourism and resort city located in the Mediterranean coast. Benidorm is known for its hotel industry, beaches and skyscrapers.[8] In fact, it has the most high-rise buildings per capita in the world.[9]

7 Wikipedia. Benidorm. [online] Available at: <http://en.wikipedia.org/wiki/New_York_City> [Accessed 10 May 2015].

8 Wikipedia. New York City. [online] Available at: <http://en.wikipedia.org/wiki/Benidorm> [Accessed 10 May 2015].

9 Burdett, R. and Sudjic, D., 2008. The Endless City. London: Phaidon Press Ltd.

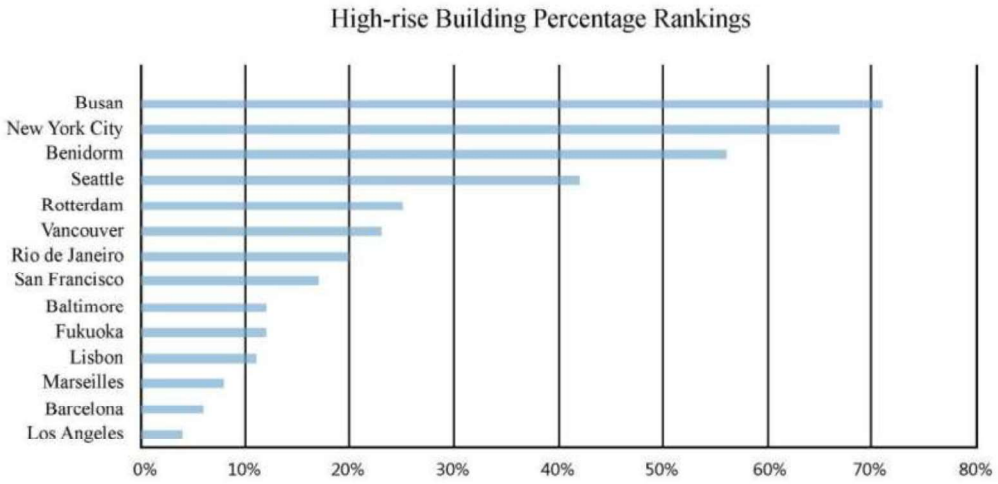


Figure 8. High-rise Building Percentage Rankings

2.4.2 Multi-story buildings

As we see in the Figure 9, Barcelona has the highest percentage of multi-story buildings. One reason might be the terrain of the city. It is located in the hilly region where multi-story buildings are more adaptive. Another reason is that the historic communities and architectures. As an ancient coastal city whose old down town is very close to the seashore, Barcelona has a large number of old building in the waterfront area, and most of those buildings are multi-story. Lastly, compared with other cities, Barcelona s coastal areas have mor communities, and the dwelling houses are almost multi-story.

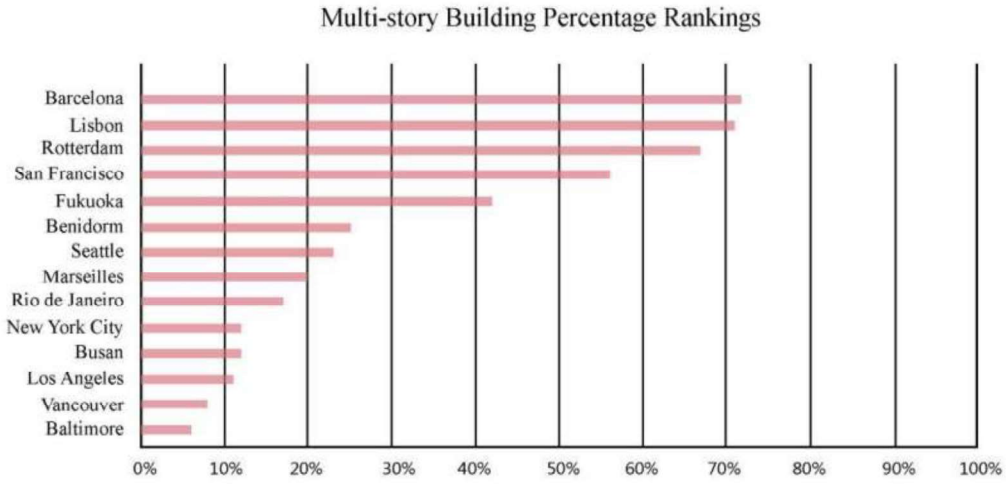


Figure 9. Multi-story Building Percentage Rankings

2.3.3 Low-rise buildings

As we see in the Figure 10, Los Angeles, Baltimore and Marseilles are in the top rank of the percentage of low-rise buildings. Their percentages are 72%, 71% and 61% in all the buildings

of the coastal areas.

Los Angeles has the highest percentage of low-rise buildings. That is because that Los Angeles is located in the seismic zone and earthquake disasters happen frequently. For instance, more than 2500 buildings were damaged in the 1994 Northridge earthquake. Therefore, single story buildings and low-story buildings are the main types of the architectures in coastal area of Los Angeles.

Baltimore ranks second in this percentage. Frequent natural calamities is also the main reason. Since 1980, 56 known hurricanes, tropical storms and tropical depressions have affected the U.S. state of Maryland, which state Baltimore is located in.[10] Hurricane Isabel submerged the whole Inner Harbour, the historic seaport, tourist attraction, and landmark of the city of Baltimore. Low-rise buildings are more easily preserved in severe weather.
Hence, natural conditions and geologic hazards are nonnegligible factor in the planning and design for the waterfront areas of coastal cities, which always are the frontlines of the disasters and the ecological sensitive areas as well.

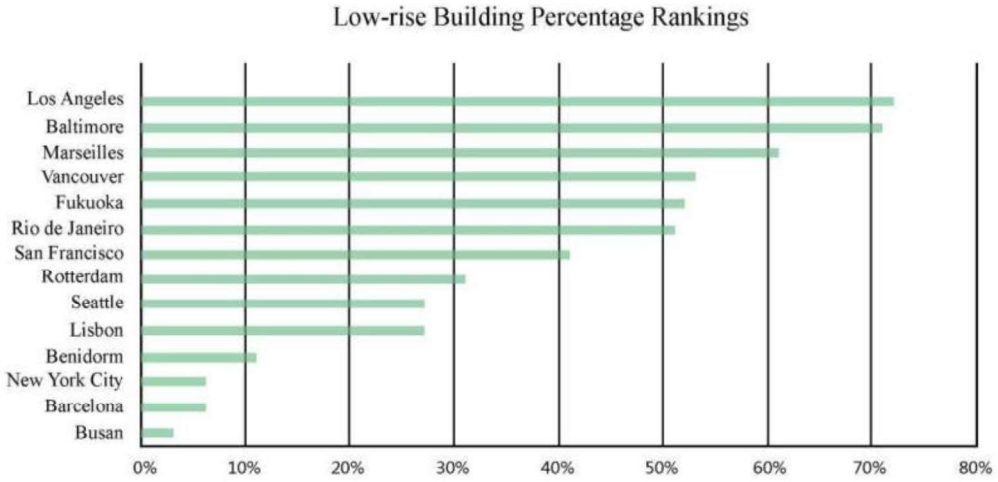


Figure 10. Low-rise Building Percentage Rankings

2.5 Analysis on linear density of road net

We exported data of networks of roads within all the study areas of 14 case cities through the open-source platform Openstreetmap . These data are in the file format of OSM. Via the geographic information system ArcGIS, we parsed these data files and turned them to DWG files which can be analysed in Autodesk CAD. By the analysis of Autodesk CAD, we finally educe the linear density of the networks of roads in the research areas of 14 case cities (See Table 2. The List of the Linear Density of Road Net and the Figure 12. Linear Density of Road Net Rankings) .

10 Wikipedia. List of Maryland Hurricanes. [online] Available at: <http://en.wikipedia.org/wiki/List_of_Maryland_hurricanes_(1980%E2%80%93present)> [Accessed 10 May 2015].

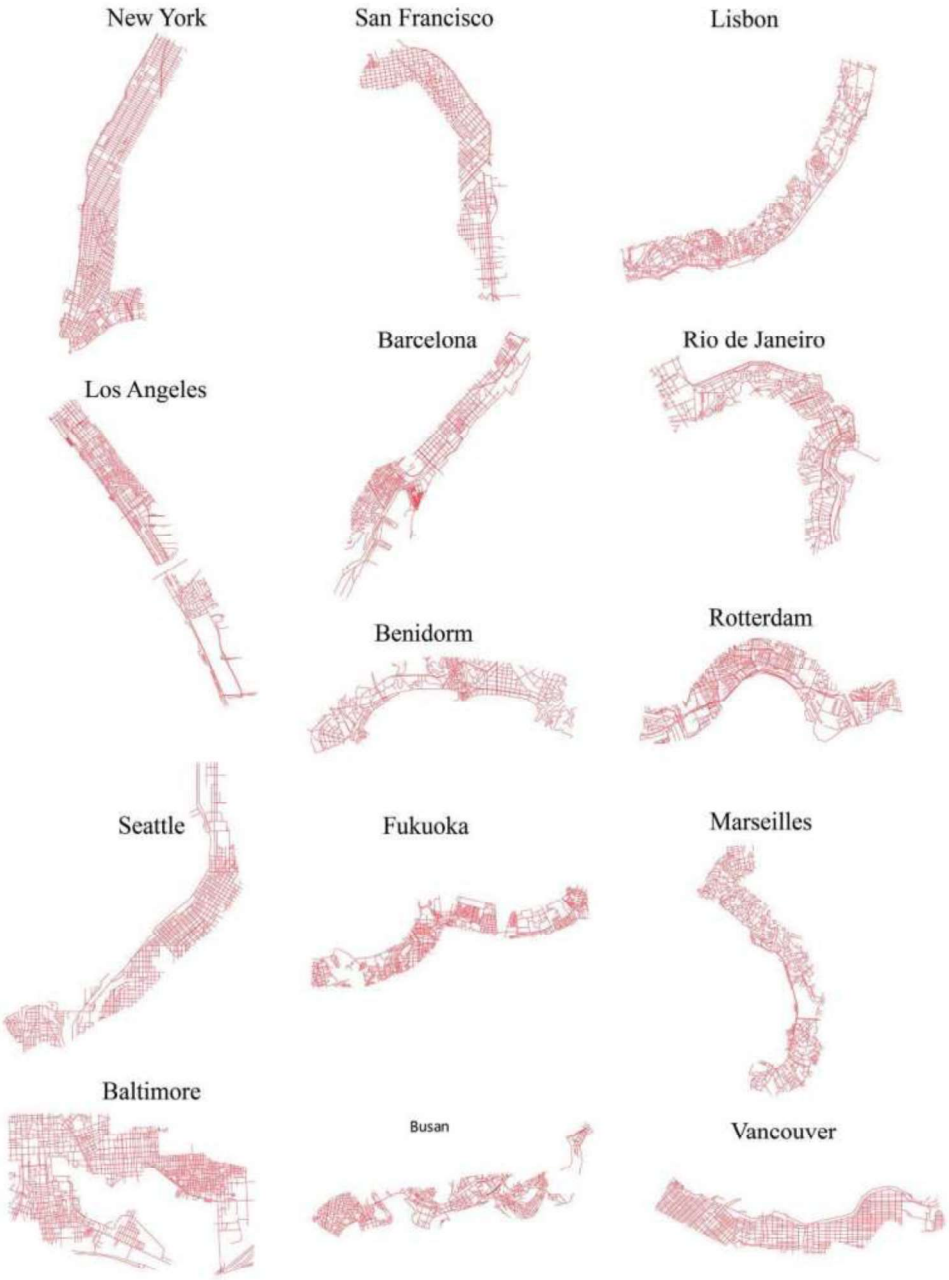


Figure 11. The Road Networks of 14 Case Cities

Table 2. The List of the Linear Density of Road Net of Each Case City

Nr.	City	Linear Density of Road Net km/km^2
1	New York City	19.8

2	Los Angeles	13.8
3	Seattle	14.2
4	Baltimore	21.4
5	San Francisco	15.7
6	Barcelona	16.9
7	Benidorm	12.2
8	Fukuoka	17.8
9	Busan	14.4
10	Lisbon	16.3
11	Rio de Janeiro	15.8
12	Rotterdam	17.7
13	Marseilles	14.6
14	Vancouver	14.7

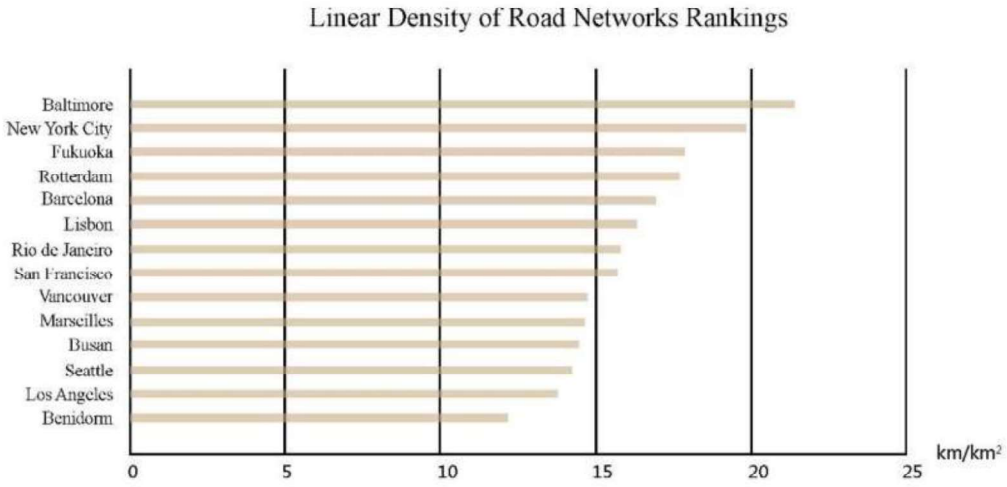


Figure 12. Linear Density of Road Net Rankings

As we see in the figure above, all case cities linear density of road net are ex
and the average linear density of the 10-km^2 waterfront areas 14 case cities is about 16 km/km^2, which means that all the waterfront areas in those cities have relatively good accessibility. Among them, Baltimore ranks the first in the road networks linear density, which is about 21 km/km^2, and New York City has the second highest linear density of road networks, which is close to 20 km/km^2. While Benidorm has the lowest road networks linear density. Compared with each percentage of building lands of case cities (New York City and Baltimore rank in the top and Benidorm ranks in the bottom), we can conclude that there is interrelated between building density and the linear density of road networks.

3 Conclusions

Through the case study and empirical research based upon quantitative analysis, we discover several regular phenomena about the waterfront space use in coastal metropolitan.

3.1 Land Use Division and building density

As we found in the case study, roads and green lands occupy the largest proportion of the coastal waterfront space (about 74% in average), while the lands of buildings averaged in one-fifth. The largest building density is about one-third of the whole area (New York City). This phenomenon tells us the importance and heavy demand of outdoor public activities in coastal-waterfront areas. Therefore, we must balance the scale of open space and indoor construction with rigid control over the construction quantity, avoiding to misappropriate the green lands and other public infrastructures by blind expansion of buildings.

3.2 Type and Height of the Building

In the case analysis, we can see that the types and heights of the buildings vary in different cities. There are three decisive factors for this phenomenon. The first one is the functional role and development orientation of the coastal-waterfront area as well as the city. For example, Busan, New York City and Seattle are the industrial centres, commercial centres and transportation hubs in their regions, while Benidorm is a well-known tourism and resort destination which is famous for its beach sceneries and coastal landscape. In other words, in all of those cities, the density of population is comparatively high in the waterfront area, since a large number of people live, work, communicate or travel in this area. Hence, the proportions of high-rise buildings in those cities are much higher than the proportions of other cities. The second reason is the natural environmental conditions, including terrain condition, geologic condition and natural disasters etc. For example, the regions of Barcelona, Marseilles and San Francisco are hilly and uneven, thus skyscrapers are not proper for the terrain of those places. Another instance is Los Angeles and Baltimore, these two cities often encounter severe natural catastrophes, like earthquakes and hurricanes. The threads come from nature force them abandoning high-rise buildings. The third reason is the historical background of the city. Old cities which have long history, and whose old downtown are near the waterfront areas, always have higher percentage of low-rise buildings and multi-story buildings.

When we plan a new coastal city s waterfront, we much synthetically consider the functions and development orientation, natural environmental condition and history background of this city, for design and arrange the forms and heights of the new-constructed buildings.

3.3 Organization of the traffic and road networks

In our research, the linear density of the case cities are relatively high. The average value is 16.1 km/km^2, and the highest value is 21.4 km/km^2. In all the case cities of different types and scales, dense roads guarantee the connectivity, openness, publicity and accessibility of the

coastal-water areas. All case cities have special promenades in their water front. In fact, the cities with higher building density, always have correspondingly higher linear density of road net (like New York City and Baltimore). This phenomenon shows that even in high building density cities, most buildings in the coastal-waterfront areas are not private properties. When we plan or design for the urban coastal waterfront area, it is required to ensure the accessibility and necessary to increase the linear density of branch road net.

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