A FRAMEWORK FOR THE ADAPTIVE REUSE FEASIBILITY OF PARKING GARAGES IN THE LESS-DRIVING FUTURE: A CASE STUDY OF DOWNTOWN ORLANDO, FLORIDA

By

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To my family for their selfless love
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LIST OF ABBREVIATIONS

IBC   International Building Code
ICC   International Code Council
IRC   International Residential Code
MEP   Mechanical, Electrical, and Plumbing
SCAD  Savannah College of Art and Design
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As the global population increases and cities become denser, many of them are developing public transportation systems to cope with road congestion and air pollution. With further development of technology and the emergence of autonomous vehicles, citizens' transportation choices are expected to change significantly. For instance, the pattern of private cars as the preferred means of transportation may change, and more people might use new modes of transportation in the future. Under these circumstances, the parking garage, once an essential functional building in the dense downtown areas, may become underused or even abandoned. Parking garages take up a lot of valuable land in the downtown areas of cities, and they are usually built of durable concrete, so knocking them down will increase pollution and economic costs. If we can reuse them adaptively, they can still serve the city.

This thesis uses downtown Orlando as its study area and classifies nine publicly owned parking garages. Their structures constrain their possibilities for reuse, as different building functions need to refer to different building codes. In this thesis, I study different policies to narrow down the reuse possibilities of Orlando’s parking garages. I
use comparative case studies to identify current adaptive reuse methods and their advantages, and I develop an adaptive reuse feasibility framework for publicly owned parking garages using downtown Orlando as a case study. The study will hopefully give urban planners, urban designers, government agencies, and developers ideas for handling challenges with parking garages in a future of less-driving.
CHAPTER 1
INTRODUCTION

1.1 Background

How to build sustainable cities and transportation systems has been a hot topic internationally for many years because of the world’s growing population and environmental problems. About 82% of Americans live in cities now, according to the United Nations, up from 60% in 1950. By 2050, 90% of Americans will live in cities (United Union, 2018). High-density urban form is considered a solution for allocating the larger population of the future.

As a result, some buildings that cannot meet high-density requirements are being phased out and abandoned. The obvious thing to do is demolish these building and construct new ones. But if a building is historically significant or even just structurally sound, it could be a colossal waste to tear it down. Adaptive reuse takes existing building structures and transforms their use to fit new developments. This strategy is often used with old industrial sites, grey sites, and abandoned buildings. In the following chapters, I detail the benefits of adaptive reuse.

Due to continual changes in urban form, future transportation patterns will also be different. First, Shoup & Manville (2005) argued that congestion in downtowns is high because the number of roads does not keep pace with the number of automobiles. On the other hand, too many roads would mean that people would have not enough space to live in. Therefore, cities need to reduce parking in urban areas to reduce congestion. Second, autonomous vehicles will also reduce urban congestion and the need for parking in cities. Third, due to increased investment, public transportation has become more and more popular. These trends mean that cities need to re-examine their existing
parking facilities to cope with future changes. For example, they might relocate parking areas to near public transit hubs or even reduce the overall parking space in downtown areas.

Parking garages often occupy large areas of a city, especially downtown. Parking facilities in city centers are used mainly during working hours, and at a lower rate during evenings and weekends. These large structures thus appear to waste valuable urban land. This is inconsistent with the goal of building sustainable, high-density cities.

For these reasons, the use of the existing large parking facilities in urban centers is likely to be lower in the future. However, as they are built to store cars, parking structures are usually of high quality. If they are abandoned in the future, we may be able to reuse them instead of demolishing them. The question, then, is what potential these structures have for being adaptively reused.

1.2 Research Questions and Purpose

The purpose of this study is to provide a framework for deciding how to reuse independent parking garages by analyzing the current situation of these garages in downtown Orlando. The different types of garages, their different constructions, and the city’s policies would limit their reuse, so this framework would allow municipalities and developers to see more directly the reuse potential of various kinds parking garages and how they can be designed for sustainably future use.

I chose downtown Orlando as the study area is because it has a lot of historical buildings and a pleasant street scale. However, a great deal of floor space in this area is occupied by parking garages; Figure 1-1 shows their building footprints. If we can develop and reuse these buildings, more vitality could be brought into the area.
Because there are few research articles on this topic, I hope this research can give future planners and urban designers a better understanding of the adaptive reuse of parking garages and new parking garage projects.

**1.3 Organization of the Paper**

Chapter 1 introduces the topic and explains the necessity of the adaptive reuse of downtown parking garages. Chapter 2 is a review of the literature. This chapter mainly analyzes current parking issues in the United States, development trends of future cities, and the advantages of adaptive reuse as described in previous studies.
This review provides strong support for the following chapters. Chapter 3 introduces the methods and procedures I used to complete this research. Chapter 4 is a presentation of the research findings and results. In Chapter 5, I explain the limitations of the research and give an extended discussion of the results. Chapter 6 is a summary of the entire paper.
CHAPTER 2
LITERATURE REVIEW

This literature review focuses on the problem of excessive parking in the United States and future transportation development patterns. These problems play a large role in the underuse of parking garages, and an understanding them can improve our grasp of the current situation. This review also defines adaptive reuse and summarizes its environmental and social benefits to lay a foundation for the follow-up research.

2.1 Parking Issues in the U.S.

2.1.1 Parking Spaces are Oversupplied

The United States is known as the “nation on wheels.” Because of its large number of cars, the demand for parking spaces is also very high. Extensive parking lots can be seen in cities almost everywhere in the United States.

Scharnhorst (2018) looked at how parking consumes land and money five U.S. cities: New York; Philadelphia; Seattle; Des Moines, Iowa; and Jackson, Wyoming. The study considered parking occupancy in these cities and found that in Jackson, 68% of parking spaces in residential areas were empty, as were 61% in the midtown area. One of the main public parking garages in Des Moines had a vacancy rate of 92%. Parking occupancy rates have also been declining annually according to the available data for Seattle and Philadelphia. Even in New York, only the cheapest parking garages are fully utilized. This implies that parking is oversupplied in the U.S; cities appear to provide more parking spaces than they actually need.

Another study revealed the crucial problem that no cities consider their actual parking supplies and wasted costs of parking (Scharnhorst, 2018; Shoup, 2017). Manville and Shoup (2005) revealed that many people, including professionals and
academics, usually ignore parking in the study of traffic patterns. Furthermore, most automobiles are parked 95% of the time on average (Greenblatt, 2016), but researchers focus mainly on times when the car is moving.

2.1.2 Excessive Parking Is an Economic Burden on Drivers and Cities

When you look at parking in terms of time and money, some of the numbers are shocking. INRIX (2017) released a study of how much parking costs drivers and cities after analyzing a survey of 6,000 American drivers. They found that American drivers spend an average of 17 hours a year looking for parking spots and $345 on wasted time, gas, and emissions. Moreover, Americans pay $20 billion annually for parking.

Shoup (2000) argued that it is unreasonable to set minimum parking requirements without considering parking costs and construction costs. In another study, he explained in detail that 99% of car trips in the U.S. involve free parking. Although minimum parking requirements can increase parking demand and reduce parking prices, they will not reduce the cost of the parking space itself. Conversely, cities that offer more free parking also offer more expensive goods and services. The costs of parking also include land development fees, such as those for building parking lots. Scharnhorst (2018) highlighted the fact that each structured parking space in the U.S. costs $60,000 or more to develop. Parking spaces in downtown areas may cost more because they occupy valuable urban land.

2.2 Future Urban Forms

Technology is moving so fast that we cannot keep up with it, but we can see many clues about how cities and transportation will change in the future. These trends tell us that city governors and planners need to alter their urban planning methods to accommodate future changes.
2.2.1 The New Urbanism Future

Since the massive development of suburbanization, downtown areas have been gradually forgotten. How to revitalize city centers has been a topic of discussion for a long time. The new urbanism seems to offer some hope.

The new urbanism aims to redefine communities by strengthening the design of neighborhoods. The core idea is to build walkable communities and public urban spaces with a pleasant human scale. However, the new urbanism was mostly used in the design and development of suburbs in the past (Bohl, 2000), while downtown areas were neglected. Bohl mentioned that applying the new urbanism to revive inner city areas has become increasingly common in recent years, however. Restoring and reusing old buildings is also part of a strategy for boosting the economies of downtown areas. Robertson (1997) also mentioned the growth of street retail as a means of reviving downtown economies.

2.2.2 The Less-Driving Future

Changes in traffic patterns and travel choices point to a future with less driving. Research has shown that people of younger generations, such as millennials, own fewer cars and drive less (Klein & Smart, 2017). A study of older people’s travel behavior also showed a tendency toward less driving (Alsnih & Hensher, 2003). And the number of Americans who get drivers’ licenses each year has been shrinking (Sivak & Schoettle, 2012). These figures suggest that there will be fewer cars in the future.

The popularity of transportation sharing, such as carpooling, car sharing, and bicycle sharing, is another reason there is likely to be less driving in the future. One study noted that it took Uber six years to reach its first billion trips, but only six months to reach the second billion in 2016 (Dias et al., 2017). Bike sharing has also seen huge
growth in the last decade. More than 400 cities around the world now have bike-sharing services, mainly in Europe and Asia (Faghih-Imani, Hampshire, Marla, & Eluru, 2017). Bike-sharing trips in the U.S. have also continued to grow, though, with the number taken in 2017 up 25% from 2016. By the end of 2017, five major bike-sharing companies were operating in 25 U.S. cities providing not just bicycles but electric bikes and scooters (NACTO, 2019).

Transportation sharing can ease traffic congestion and air pollution, but modern cities have other ways to solve these problems. Studies have shown that investment in public transportation can effectively relieve urban congestion and improve air quality (Beaudoin, Farzin, & Lawell, 2015). Due to increases in population, many cities have begun investing in developing their public transportation to cope with a more crowded future. Coupled with research into self-driving cars, this strengthens the case for a future of less driving. Fagnant and Kockelman (2015) also showed that autonomous vehicles can reduce traffic congestion, improve safety, and even reduce parking in central urban areas, as they can park themselves elsewhere and avoid crowded areas.

2.3 The Argument for Adaptive Reuse

2.3.1 Definition

Adaptive reuse is a strategy for giving buildings new functional uses while maintaining their historical structures and features. Extending the life of a building by reusing all or part of its original structure has been seen as a sustainable development strategy. From the perspective of urban planning, adaptive reuse can reduce urban sprawl and environmental hazards (Joachim, 2002).
2.3.2 Benefits

According to Bunnell (1977), the adaptive reuse of existing buildings can provide several benefits. First, it can save on costs of construction: not tearing down a building can save up to a tenth of the building’s cost. Second, the walls and structures of the original building can be reused to save on building materials. Third, less new construction means reduced labor costs. Obviously, time costs will also shrink as construction work is reduced. Moreover, less investment in new materials means less energy to produce them, and adaptive use is suitable for energy conservation as well. In addition, some states offer tax incentives for the reuse of historical or old buildings.

Langston (2008) showed that it usually takes only half to three-quarters as much time to restore an old structure as it takes to demolish it and build a new one. Not having to build a foundation, and being able to reuse existing building elements, can also save considerable time and money. From an environmental point of view, if the structural elements of an old building are of good quality, then reusing them can save energy and reduce construction waste. Moreover, construction waste needs to be transported after demolition, which also increases traffic congestion. One calculation found that in Seattle, demolishing a concrete building cost $1 million and generated 1,200 truck trips to transport construction waste (Brown, 2011). These trips not only increase the burden of urban transportation but also produce substantial carbon emissions.

The reuse of old buildings can also bring social benefits. Langston (2008) described several: First, old buildings sometimes have heritage value, and they are usually set in pleasant streetscapes with beautiful views. Second, old buildings are usually located in what is the center of the city today, so they are usually surrounded by
excellent public transportation systems. Their reuse is quite feasible. Third, the reuse of abandoned buildings can reduce criminal and unsocial behavior and improve the living environment of the streets. Adaptive reuse can also ease urban sprawl, and because it can directly use the existing infrastructure, such as water, drainage, electricity, cities do not have to use new land resources to provide this (Langston, 2008).

2.3.3 Adaptive Reuse of Standalone Parking Garages

The literature suggests that we will enter an era of less driving, or perhaps of only self-driving vehicles. If we need to reduce the parking supply, it would be most useful to reduce the number of independent parking garages. There are millions of these in the U.S., and their average vacancy rate is 33% (Koch, 2004; Brown, 2011). In the current urban development situation, they are underused and are likely to be abandoned entirely in the future, in which case they could become unsafe. Independent parking garages usually occupy entire city blocks and are generally dark, lifeless, and used only for storing cars. In urban centers, where land is valuable, these places could be better used by being developed for other purposes suited to medium-sized urban buildings.

From the perspective of architectural structure, a parking garage is very suitable for renovation and reuse. The core components of a building are its foundations, columns, beams, and floor slabs. After these are put together, space planning, interior design, facade decoration, and other follow-up work are carried out. Parking garages are easier to reuse than other buildings because they can be directly repurposed with new space planning, interior design, and facade decoration.
CHAPTER 3
METHODOLOGY

To explore the adaptive reuse of the parking garage, I conducted qualitative research, including research analysis, site visits, comparative case studies, and policy analysis. Due to the limited literature, comparing existing cases was one way to identify practical methods of dealing with different kinds of old buildings. The policy analysis provided a basis for the research and limited its results to reasonable norms. After that, I took independent parking garages in downtown Orlando as my primary research objects. I sorted the garages into types according to building structure and finally developed a feasibility framework for their adaptive reuse.

3.1 Case Study Analysis

In this thesis I take advantage of four completed cases of adaptive reuse to study current methods, especially those used with parking garages. Understanding how the site, scale, and function of the project can be transformed and the means of design used, can provide a theoretical and practical basis for the feasibility report.

The first case is the Broadway Autopark in downtown Wichita, Kansas. This case involved the transformation of a historic preserved parking garage into a mixed-use residential building. Autopark is one of the few places in the United States where garages have been completely adaptively reused. It was opened in 2018, and its leases were fully booked in advance. As this is a leading project in its field, studying its advantages and disadvantages can let us draw lessons for future projects.

The second case is the SCADpad in Atlanta. This is a new form of housing in a garage. The Savannah College of Art and Design (SCAD) developed a new approach to adaptive reuse by inventing a residential unit to put into the old parking garage instead
of reconstructing the old structure, and the concept was tested in an underused parking garage in midtown Atlanta, near the campus. The units were prefabricated and fully equipped with living facilities. Every part of it was designed for sustainability and energy conservation. This is a promising project, as the world faces climate change and growing energy consumption. With the advent of driverless cars, we may no longer need downtown parking garages but may face more severe pollution and overpopulation problems, and SCADpad may be an economical solution. Learning about it helped me gain a better knowledge base on sustainable development and set my sights further.

The third case is a project on the main campus of Northwestern University called The Garage. As incubators of new technologies, many universities are working on driverless cars and using their campuses as testing grounds. The transformation of this parking garage into a creative student center was well tested and successful. Although campuses are different from urban environments, a main campus is like the downtown of a university. It would be a great benefit if parking garages could be converted into other places students could use.

The fourth case is a mall renovation project called Arcade in downtown Providence, Rhode Island. This was once the oldest indoor mall in the U.S., and after it was closed, it went through several unsuccessful development attempts. The most recent finally brought it back to the forefront as a prime example of adaptive reuse. Although it was not a parking garage, it was a medium-sized urban building like most parking garages. It is now an adaptive reuse project in the city center, and its successful
transformation supports the more general reuse of old buildings in downtown areas. This is why I chose it as a case study.

3.2 Study Area Selection and Data Collection

The study area was set up in downtown Orlando, Florida. This is the historic and commercial center of the city. According to one report (Downtown Orlando, 2018), the residential population here grew from 10,559 in 2000 to 17,870 in 2018. The report predicted that Orlando's population will continue to grow over the next few years. There are 13,054 units with a 94.4% occupancy rate and an average rental cost of $1,781 (Downtown Orlando, 2018). These data also show that many commuters live outside the city center and need to travel in using different kinds of transportation.

From the literature, we know that a good geographical location and convenient public transportation are conducive to the adaptive reuse of old buildings. Downtown Orlando has a good public transportation infrastructure: the local bus service LYNX serves 88 routes in the metropolitan area, and its central station is downtown. More than 30 bus routes run from here to the entire Orlando metropolitan area. In addition, LYMMO operates four fare-free circulator routes under LYNX that provide convenient access around the downtown area. LYMMO is the first free downtown bus system operating in the U.S. In addition to public buses, Sunrail, a commuter rail system in central Florida, has four stations in downtown Orlando.

Downtown Orlando also has many beautiful historic buildings, along with pleasant city blocks and architectural scales. Bike-sharing is becoming more popular in the area, and when people walk on the street, they often see cyclists and other pedestrians. For these reasons, Orlando's downtown has shown a trend of changing traffic patterns.
As the population grows and cities become denser and invest more in public transportation, people will come to depend less on private cars and thus require less parking. The Economic Development Department discussed this in a 2015 study on reducing minimum parking requirements. They found that parking facilities built with minimum parking requirements were occupied at 30% below the required number of parking spaces. The opinions in the report are also consistent with those in the literature: First, minimum parking requirements need to vary between locations. Second, an oversupply of parking facilities increases costs to the city, reduces useable land, and increases the cost per unit. Third, downtown Orlando’s parking problems reflect those of the nation, as other states are also trying to reduce minimum parking requirements so that downtown areas can better develop other modes of transportation.

I chose downtown Orlando as the research area on the basis of these points. In light of current development trends, it has been speculated that downtown parking garages will be underused or abandoned in the future. Although cities could tear them down and put up new buildings, the literature reports a lot of negative effects of tearing down an old building. If a city knocks down ten parking garages, these negative effects will be multiplied tenfold.

I focus just on the publicly owned garages because their data are more accessible. Figure 2-1 shows twelve downtown Orlando public parking facilities. Nos. 7 and 12 are flat parking lots, and no. 8 is not an independent garage, so they aren’t included in this study. I collected most of the data through field trips and observation; some data were obtained from the Orlando government’s website. Modeling software (Sketchup), satellite maps, and pictures were also used to help with the research.
Figure 3-1. Map of publicly owned parking facilities in Orlando (Source: City of Orlando).
CHAPTER 4
FINDINGS AND RESULTS

4.1 Case Studies

The United States currently has only minimal cases of adaptive reuse of parking garages. The reviewed cases include only one completely renovated downtown parking garage case, two cases of partial reuse, and one case of reusing an old shopping mall. In this thesis, I make a comparative study of these cases to analyze their advantages and disadvantages. Because of the limited literature on the adaptive reuse of parking garages, this comparison of actual examples can enrich the foundation of the research. It can also bridge the gap between research theories and real cases to allow a more comprehensive and detailed analysis.

4.1.1 Broadway Autopark, Wichita, Kansas

**Background.** Broadway Autopark in downtown Wichita is now a 44-unit high-end residential and commercial complex (Figure 4-1). A few years ago, however, it was a forgotten garage: Knightley’s Parking Garage (Figure 4-2). This 101,000-sq.ft., five-story garage was a product of the explosion of the postwar automobile industry and could store 500 automobiles. It is a good representative of American multi-story parking garages, with modern architecture, an open-air design, cement structure, twin spiral ramps, and an exposed horizontal-bandng skeletal structure. It was a bustling spot in the downtown area after being built in 1949. Customers enjoyed valet parking, restrooms, small storage spaces, and even air-conditioned waiting areas. However, it was completely closed in the early 1980s due to increasing suburbanization and a lack of demand for valet services. After that, it became an abandoned garbage dump. Its
unique appearance and important status, however, landed it on both the national and state registers of historic places in 2016.

Like most parking garages, this one has large beams and columns, low floor heights, and hard-to-use ramps. It would be difficult to turn it into a residential building under the constraints of the original structure. Moreover, because it was registered as a historic building, its renovation faced higher requirements; for example, it could not destroy the features of its façade. Similarly, changing the land use from a parking structure to an R-2 residential use required the approval of the city, which needed to recognize a strong sense of identity in the building. This added further restrictions to the rebuilding. As a result, the project cost $5 million and did not save much money, according to the developer. It was opened on April 1, 2018.

Figure 4-1. Broadway Autopark building after reconstruction (Source: https://sheldenarchitecture.com/portfolio_item/broadway-parking-garage/)
Reuse solution. The overall design of the project is based on the idea of mixed use. The ground floor is used for public parking, administrative offices, amenities, and small retail. Because the building is in Wichita’s downtown area, retail use maximizes the advantages of the ground floor. The other four levels have about ten one-bedroom units each on the east side, and a single uniquely shaped unit on the west side. These last units take advantage of part of the ramp and are very popular due to their unusual shape and large area. What makes these apartments even more attractive is that the spaces on each floor between the apartments still retain their parking function. This kind of front-door parking is rare in traditional apartment buildings (Figure 4-3).

The mix-used design also maximizes the structural and location advantages of the building. All the units are one-bedroom apartments with complete kitchens and restrooms. Beams need to be exposed to the ceiling due to floor-height restrictions, so
the overall interior design style follows a theme of cement and industry, which is also in line with a parking garage.

The project takes advantage of the existing structure of the building, in which walls are erected to separate spaces. The electricity, plumbing, and HVAC have been redesigned and fitted to the structure using exposed design methods, as shown in Figure 4-4. Because the original MEP system of the garage only conformed to the code for parking garages, it had only a simple plumbing system to supply electricity and water for lights, elevators, and fire sprinklers. The entire MEP system was thus redesigned by MEP engineers to accommodate residential and other uses.

Figure 4-3. Parking spaces in the Broadway Autopark building (Source: https://sheldenarchitecture.com/portfolio_item/broadway-parking-garage/)
Figure 4-4. Interior design of an apartment (Source: https://sheldenarchitecture.com/portfolio_item/broadway-parking-garage/)

**Lessons.** This parking garage was preserved because it was listed in the Register of Historic Places. But we should not only focus on historic buildings; buildings without great significance but with good structural qualities should also receive attention, as it takes a lot of labor and financial resources to protect and reconstruct a building under the strict requirements of historical preservation. Second, most of the tenants said in their feedback that because the units use the original walls and ceilings of the structure, they are not as well insulated as current residential buildings. This has led to a heavy electricity use for air conditioners. This project indicates that more economical and efficient renovation methods are needed for parking garages.

4.1.2 SCADpad, Atlanta, Georgia

**Background.** SCADpad is a parking garage housing model designed by the Savannah College of Art and Design to cope with an increasingly crowded urban
environment. It is a sustainable and efficient solution to the growing demand for urban housing units around the world.

SCAD set up a cross-disciplinary team and spent ten months completing the project, from engineering to architecture and interior design. They created dwelling units that perfectly accommodate standard $9 \times 18$ ft. parking spaces. According to their findings, the units they developed could be accepted by the next generation. The design was applied in an underused garage on the SCAD campus in midtown Atlanta as a test project (Figure 4-5). The usage of some parking garages in Atlanta is in decline because of the development of mass transit and shared transportation.

**Reuse solution.** This garage has five stories, and the project used part of the fourth floor as a test area. Three micro dwelling units were placed, and some public spaces were also planned (Figure 4-6). Each micro unit is 135 sq. ft. and has an additional green space to extend the living area. Figure 4-8 shows the floor plan for this project. The cost per unit ranges from $40,000 to $60,000, which qualifies them as affordable housing.

The walls, ceilings, and floors of the units are made of special insulation material. The units are designed to generate electricity using solar panels. Each is equipped with LED lights and low-power appliances. At the bottom of each unit is a large storage tank to supply water for domestic use; it can be replenished by connecting pipes. The water supply to the garden is recycled from domestic wastewater to reduce waste. The designers argued that a limited water supply can reinforce residents’ awareness of sustainability, because unlike ordinary houses the taps cannot run indefinitely. The HVAC is installed on the ceiling, and the kitchen has ventilation holes.
The whole indoor environment is equipped with advanced technology, including an iPad that controls the electrical appliances. Residents can use this to control the temperature or even whether items are delivered directly to the door. Due to the small size of the units, this project included a lot of public spaces, including recreation areas, rest areas, and even a garden where vegetables can be grown. Residents can rest and sleep in the unit and go out for leisure activities and meals.

Figure 4-5. SCADpad in Atlanta (Source: https://www.mnn.com/your-home/remodeling-design/blogs/scadpad-a-micro-housing-community-founded-on-big-ideas-launches-in).
Figure 4-6. Public space in Atlanta SCADpad (Source: http://www.scadpad.com/).

Figure 4-7. SCADpad’s green garden (Source: https://weburbanist.com/2014/07/21/scadpads-parking-garage-turned-tiny-house-village/).
Lessons. In this project, each living unit was prefabricated and then placed in the garage. Unlike the Autopark apartments, the independent design of the units means they do not use the walls of the existing structure, so they can be self-insulated to save energy. Second, underneath each unit are wheels to let it move around, making it look like a mobile home that can be put in a garage (Figure 4-9). The low building cost and ease of movement make the unit economical and efficient. When a building can no longer be used, the unit can be easily removed rather than demolished. This housing model has the potential to address shortages in affordable housing, especially in urban centers with large numbers of low-income residents.

The disadvantage of this model is that the space in the unit is limited, as are the electricity and water consumption, which means a decline in quality of life. The designers used technology and public space to make up for this. It is more like
everyone has a private bedroom, but they share a bigger public living room. Residents’ model of living undergoes a huge shift when they live in SCADpad.

Figure 4-9. SCADpad construction process (Source: https://www.scad.edu/event/2019-04-22-scad-sustainable-journey-scadpad-earth-day-lunch-and-learn).

4.1.3 The Garage, Northwestern University

Background. The Northwestern University campus has a great entrepreneurial community called “The Garage,” inspired by Bill Gates’ garage startup. The 11,000-square-foot creative space reuses part of a parking garage in the main campus area to provide students with a cross-disciplinary meeting space where they can communicate and gather to inspire each other’s innovations.
Reuse solution. Because this is a creative space, its floor plan design is flexible. It has small offices that can be changed by lifting and lowering the doors. There are also studios, a 3D-printing room, a VR experience lab, some private booths, a meeting room, and a kitchen. Figures 4-11 and 4-12 show the environment inside The Garage.
Lessons. These reused spaces, such as the meeting room, discussion space, printing rooms, and VR lab, can be very flexible in design, as they must meet fewer spatial standards and require less natural light than other living spaces. There are other architectural spaces in our lives that have flexible natural light and height requirements, such as exhibition and projection spaces. Such areas could be considered in future adaptive reuse design. Second, this project only uses part of the parking garage space. As the United States is still a car-leading society, phased development is a good reuse solution for garages that are underused but not completely abandoned.

4.1.4 Related Case: Arcade, Providence, Rhode Island

Arcade is not a reused garage, but it is a building in a downtown area similar in size to a normal parking garage. Its successful renovation could also inspire the reuse of downtown parking garages.
Background. Arcade, in downtown Providence, was once the oldest indoor mall in the United States. It was built in 1828. The 53,440-square-foot building has three stories, a glass skylight over an atrium, and an ancient Greek–styled façade (Figure 4-14). As suburbanization increased, many tenants relocated their businesses to the suburbs. The numbers of customers on the second and third floors also decreased because there was no elevator. Eventually the building was abandoned, but it remained a landmark for residents. With three universities—Brown, Rhode Island School of Design, and Johnson & Wales University—the city’s economy has shifted toward education and research, but what students need most is affordable housing.

Figure 4-13. Interior of the old mall (Source: https://www.arcadeprovidence.com/).
Reuse solution. A developer bought the building and redesigned it as a commercial and residential complex in 2013. The ground floor now has seventeen retail and public rest spaces. The second and third floors contain 48 micro-apartments. Figure 4-15 shows the new section of the building. These micro units range from 425 to 600 square feet and are fully furnished (Figure 4-16). They have become very popular; most of the tenants are students and young professionals.
Figure 4-15. Graphic of the new section of the building (Source: https://www.cnu.org/what-we-do/build-great-places/micro-lofts-arcade-providence).

Figure 4-16. One of the micro-apartments (Source: https://www.cnu.org/what-we-do/build-great-places/micro-lofts-arcade-providence).
**Lessons.** Reusing a building instead of abandoning it is the best way to preserve it and to bring it back to life. It is possible to convert a medium-sized urban building into a mixed-use complex of micro-apartments and ground-floor retail. The geographical location of this building has great advantages, which can save transportation time and costs for commuters in the city center. The micro-apartments are also affordable and suitable for young individuals and couples. Finally, the model of upper-floor apartments and ground-floor retails makes life simple.

**4.2 Summary of the Case Studies**

To better compare the basic information between the cases, Figure 4-17 shows a summary. It can be concluded that these buildings are no longer single-use but are mixed-use after the application of adaptive reuse design. Structures that were abandoned have been completely retrofitted. Structures with low or expected low usage rates have been partially retrofitted as a test project. The three mixed-use projects are located in urban centers, and The Garage is located in the main area of a university campus. Conversion to mixed residential use was selected for the three urban projects and has been tested to be relatively successful. Each project shows some advantages and disadvantages of adaptive reuse. These are summarized in Figure 4-18.

Broadway Autopark is a good example of mixed-use redevelopment of a stand-alone parking garage. The facilities on the ground floor are a convenience for residents and also increase the rental income and revivify the street economy. The residential units on the upper floors have open-door parking and comfortable dwelling spaces. However, the walls of the original structure are used as walls of the residential units, which leads to low insulation efficiency and noise resistance. The new MEP system also
adds high costs to the project, and the design does not consider energy conservation.

Each floor has only eleven units, so the structure is not being used efficiently.

Figure 4-17. Case studies summary (edited by the author).

Figure 4-18. Strengths and weaknesses of cases (edited by the author).

I believe that SCADpad solves the problems of Broadway Autopark. Its prefabricated micro-housing units can be easily placed in different parking structures. The precast wall systems also address the noise, insulation, and other problems using new lightweight materials. Prefabrication and low building costs also make this economical and affordable. For example, if the parking structure is demolished for some reason, the mobile living units can be put in other places. The units have sustainable
designs, including low-power appliances and water storage tanks. Moreover, one building can hold many micro-units, so the reuse efficiency of the floor area is high. All these points are consistent with the concept of sustainable development.

These cases show that people have begun to look for ways to reuse independent parking garages and found some success. They also show a trend toward the adaptive reuse of old buildings through vertical and mixed-use development of urban spaces.

The Garage at Northwestern University shows how parking garages can be transformed partially at first. Then if necessary, phased development can be carried out in the future. The structure of the parking garage is also suitable for flexible uses, such as innovation spaces. Adaptive reuse programs in universities are also educational and make more students aware of the importance of sustainability. For garages that are not suitable for renovation to regular use, creative spaces may thus be a good choice because they have few requirements for space planning. However, this project uses a space without natural light or ventilation, which leads to more energy consumption.

Arcade is not a garage-reuse project, but it is a success story in the conversion of old downtown buildings into micro-apartments. It shows that the housing demand in downtowns is huge, and its success shows that the younger generations care more about the conveniences of daily life than the size of housing space. This project makes good use of the original structure of the building, and the historical façade is well protected. Commercial use on the ground floor provides convenience to residents and neighbors and strengthens the downtown economy.
4.3 Parking Garage Structures in General

The primary purpose of the parking garage is to allow cars to move vertically to reach parking places. Parking garages may look similar, with simple facades, columns, and floors, but their inside structures can be very different. Due to site conditions and cost requirements, designers use different methods and structures to maximize parking efficiency. The internal vertical traffic patterns are the key to differentiating these structures. Three main forms of vertical transportation are used: (1) staggered floors with one- or two-way circulation slopes; (2) flat floors with one- or two-way circulation slopes or helical ramps; and (3) sloping floors with one- or two-way circulation. The circulation slopes in the second and third types can be used for both circulation and parking spaces. Because ramps and slopes cannot be reused, however, the area of flat floor determines the reuse area of the whole parking structure. Gensler (2018) noted that the more flat floor there is, the higher the building’s potential for repurposing.

Figure 4-19. Types of parking garage structure (Source: http://www.polarinertia.com/nov04/parking01.htm).
4.4 Publicly Owned Parking Garages in Downtown Orlando

This section is an analysis of nine parking garages in Orlando regarding their original structures. The purpose is to explore the limitations and possibilities of the reuse of parking garage buildings, as transforming the original building for different functions depends on the condition of the structure itself. Both new and renovated buildings in the U.S. need to follow the International Building Code (IBC), which provides detailed specifications on the use of buildings, basic dimensions, and related matters. The model building code was published by the International Code Council (ICC). Similarly, residential buildings need to comply with the International Residential Code (IRC). So the analysis will refer to the criteria of the IBC, IRC, and related standards. This will let us determine what uses garages can be converted to within the constraints of their original structures. The main concerns in this section are the form of the floor, the load of the floor, and the height of the floor. These are the basic normative components of a building. This section also provides a brief analysis of daylight and ventilation based on the standards.

For ease of reading, the names of parking garages are replaced by the serial numbers in Figure 4-21. This table summarizes the basic information about all nine garages, including the number of floors, garage clearance height, and building area.
Ramps. The key to distinguishing garage styles is the means of vehicle circulation—the different ways of combining ramps and floors. In general, these parking garages fall into five types, as Figure 4.4-1 shows. They also use two kinds of ramps: those wide enough to accommodate parking spaces, and non-parking ramps. Most of them (garages 1, 2, 4, 5 & 6) use a central ramp system to circulate traffic; each of these is structured as a combination of flat floors with parking ramps. Garage 3 has half continuous parking ramps and half flat floors. Garage 7 uses a continuous sloped floor system. Garage 8 has a flat floor with helical non-parking ramps. Garage 9 has non-parking flat floors with ramps on one side only.

According to Kimley Horn’s parking structure design guidelines (2016), parking ramps are more common because they are more economical, and their ramps usually have a slope of about 5%. Non-parking ramps are common in airports, casinos, large retail locations, and special event structures. They usually have lower parking efficiency,
and the garages’ construction costs per space are greater because of the lower number of spaces per square foot. Their slopes are usually between 12% and 14%.

Figure 4-21 also shows the proportion of slopes and ramps to total garage area. This lets us identify the maximum reusable floor area of the garage. Seven of the garages have ramps or slopes accounting for between 10% and 22% of the total area, while garage 3 is 45% ramps, and in garage 7, all the floors are slopes. Garages 3 and 7 are thus likely to pose greater challenges to adaptive reuse. The ramps and slopes in the other nine garages can be retained for circulation or removal, depending on the overall reuse design.

Figure 4-22. Five types of publicly owned parking garages (edited by the author).

**Floor load.** Generally speaking, the bearing capacity of a building is divided into live loads and death loads. According to the IBC definition, a live load is the dynamic weight a building needs to bear. The dead load is the permanent weight the structure needs to bear, such as the weight of the walls themselves. It might seem that parking garages need to bear a lot of weight, but in fact their loads are similar to those of residential buildings. According to the IBC (2018, 1607.1), the floor load of a garage should be 40 pounds per square foot (psf). Similar load requirements are for office use (50 psf) and residential use (40 psf). This means that the most suitable reuse of parking garages is residential. If the structures are reinforced to bear 50 psf, they might also be
transformed into office buildings. Economically, however, residential use is the first choice, which is consistent with the reuse solutions in the case studies.

**Floor height.** The height of the floors is also an important dimension of a building. Of the nine parking garages, all but garage 7 (6 feet 10 inches) have clearance heights between 7 feet and 8 feet 2 inches. Clearance height is usually measured as the distance from the floor to the beam. In places with no beams, it is usually 2 to 2.5 feet higher. The ground floor is typically 1 to 3 feet higher than the upper floors. The number of beams and columns differs between garages. In other words, the minimum ceiling height of these spaces is between 7 feet and 8 feet 2 inches. According to the IBC (2018, 1207.2) and the Florida Building Code, all occupiable interior spaces should have ceiling heights of at least 7 feet 6 inches, except bathrooms, storage rooms, and laundry rooms, which should be at least 7 feet. Garages 1, 2, 5, and 6 have a clearance height of 7 feet, which means converting them to other uses is difficult.

![Figure 4-23. Typical annual life-cycle costs of different construction methods (Source: https://ieiusa.com/how-long-will-my-parking-structure-last/).](image-url)
**Durability.** Parking garages are usually made of concrete. The main advantage of this is that they are very durable. Concrete structures use two main building methods: pre-cast and cast-in-place. Most of Orlando’s parking garages are pre-cast concrete structures. A concrete structure typically has a design life of around 50 years, but with proper maintenance they can last more than 100 years without problems. According to one article (Weiland, 2018), cast-in-place buildings have lower maintenance costs.

**Daylight and ventilation.** According to the IBC, generally speaking, the net glazed area should not be less than 8% of the room floor area. Open-air parking garages can easily meet this specification. Some parking garages with façade decoration will block the effective lighting area, which must be considered in subsequent design. However, due to the low height of parking garages, the depth of daylight penetration into the interior is low, so only a limited area on the periphery can be effectively used for residential and similar purposes.

Natural ventilation is also required, but mechanical ventilation can be used instead in some areas if necessary. Ventilation efficiency must meet different specifications depending on the area’s use.

**Water, electricity, and plumbing.** These parking garages all have lighting and sprinklers, so they also have access to water and electricity. However, the connections for both must be redesigned if the buildings are to be reused, and the case studies show that this is a system that can be redeployed in the structures.

**Life safety.** The fire and life safety requirements for parking garages are different from those of other structures. If they are to be reused, the existing fire and life safety systems need to be redesigned and modified. Similarly, enhancements to the egress
system are needed as density increases. These modifications should accord with the Life Safety Code.

4.5 Adaptive Reuse Feasibility Framework for Each Garage Type

Given the current situation of downtown Orlando, our analysis suggests that if the garage’s building conditions meet the requirements, the best reuse pattern will be mixed use, redeveloping the ground floor for commercial use and the upper floors for residential use. However, shopping and office modes have changed; for example, we can do almost everything through the internet now. We may also face exploding populations in the future. So this feasibility study will also consider extreme case of converting all the reusable floors into living units. Under these two reuse solutions, mixed-use and maximum residential, the advantages and disadvantages of adaptive reuse of different type of garages will be analyzed.

4.5.1 Garage Type I

Figure 4-24 shows a typical model of the first type of parking garage; five of the nine garages (1, 2, 4, 5 & 6) were built in this form. It has a big ramp system in the central part, accounting for 17% to 22% of the total floor area, with two driving lanes in the middle and parking spaces on both sides of the ramp on each floor. Stairs and elevators are usually placed at four corners of the building.
Mixed use. According to the analysis of the original structure, the most suitable redevelopment mode is the reuse of the ground floor as commercial or office space, as the ground floor is higher than the others and has no floor load limit. The upper floors can be reused as living spaces. Figure 4-25 shows a cross-section of such a building. The design of the dwelling units has been discussed in the previous chapters; the SCADpad’s many advantages make it stand out among this group. Because this type of parking garage is surrounded by four narrow rectangle spaces, it is suitable for the SCADpad’s micro units.

Figure 4-25. Cross-section of mixed-use building (edited by the author).
Ramps cannot be reused, but the ramps in this type of garage have parking spaces, which we could consider preserving. As we saw with Broadway Autopark, this gives residents easy access to parking spaces. Due to the natural light and ventilation, the units are more suitable for arrangement along the peripheries of the floors but not in the inner areas around the slopes. Car circulation could be arranged in this area to allow on-ramp parking. A typical floor plan example is shown in Figure 4-26.

Figure 4-26. Typical mixed-use floor plan for garage type I (edited by the author). The small blue boxes represent dwelling units.

**Maximum residential use.** Maximizing residential use means placing dwelling and related functional units on 83% to 78% of the total floor area excluding the ramps. Some changes could be made to add dwelling units. This garage type usually has a circle of structural columns on the outer wall and another around the slope. The ramps are directly attached to the columns in the inner circle. It is technically possible to remove these ramps, in which case the central area could be used as an atrium or enclosed garden, or for ventilation and lighting, and the structure could be maximally reused (see Figure 4-27).
Challenges. The floor height (beam to floor) of the upper stories in this kind of garage is relatively low. Among the five cases, only garage 4 has floors high enough to meet the IBC’s requirements for residential use. The solution is to avoid the beams when arranging the units. In places with no beams, however, stories are typically 2–3 feet taller. The density of the beams is depends on different factors of structures, so the specific layout planning method should be developed according to the beam system. Figure 4-28 shows a possibility of the floor plan with low beams.
4.5.2 Garage Type II

**Mixed use.** Only garage 3 has this type of structure. Nearly half of the floor space in these garages consists of ramps, so the reusable area is minimal. Figure 4-29 shows a typical case. The ramp structure is similar to that of type I garages: the middle is a two-way driving space, and the sides hold parking spaces. So the redevelopment model can be the same as for type I: the ground floor for commercial space, the upper floors for residences, and the ramps maintained as parking spaces.

![Typical model of garage type II (edited by the author).](image)

**Maximum residential use.** Because only three sides of the flat floor are open to the air, there are few places to arrange living spaces, as Figure 4-30 shows.

**Challenges.** Because of its limited reusable space, the reuse value of these garages is limited. To improve this, we would need to study possibilities for ramp reuse, which this research does not include. For residential use, the original structure cannot be reused maximally, so I would suggest that this type of garage be considered for flexible reuse, for instance with large areas like studios, creative spaces, or even
community centers. However, the floor load requirements also demand careful consideration of the design and possibly strengthening of the structural supports.

Figure 4-30. Maximum residential reuse of garage type II (edited by the author)

4.5.3 Garage Type III

Only garage 8 belongs to this type. Each floor of this kind of garage is a gradual, continuous slope. Slopes are difficult to reuse, so the reuse value of these garages is relatively low. This research, however, did not investigate the reuse of slopes; there may be new solutions available in the future.

4.5.4 Garage Types IV & V

These two types are treated together because their ramps are only for traffic (they do not contain parking spaces) and thus take up a low percentage of the total floor area. Garages 8 and 9 belong to these two types, respectively. Some studies have suggested that a garage with a large flat floor area can be easily renovated. However, it turns out that building codes restrict the reuse options of these garages. Their floor loads cannot satisfy most architectural functions, and the requirements for ventilation and lighting limit their division into small spaces. Figure 4-31 shows satellite images of two such garages.
Figure 4-31. Satellite views of garage types IV & V (Source: Google Maps).

**Mixed use.** Redevelopment can take the form of both commercial and residential use. Because of the huge size of these garages, SCADpads can be placed only on the sides in relatively small area. Therefore, other approaches to space planning are necessary, such as retrofitting the original walls, as in Broadway Autopark. Because of their large area, though the buildings can also be considered for a greater variety of other uses, such as exhibition space, office spaces, and other flexible spaces.

**Maximum residential use.** It is hard to fully utilize the floor of such a garage while meeting residential building codes. We might consider the redesign and re-planning of the space. For instance, parts of the slabs could be demolished to admit light and create ventilation shafts. Alternatively, one could apply for exceptions to the building codes to accommodate reuse, for example by allowing full mechanical ventilation in such spaces.

**Challenges.** The difficulty with these garages is their size: Garage 8 is 462,098 sq. ft, and GEICO Garage is 983,178 sq. ft. It might be best to consider phased development to make the transition to reuse.
CHAPTER 5
DISCUSSION

5.1 Research Limitations

This study was based on a limited literature review and case studies. First, it was developed with respect to parking garage types in downtown Orlando. We did find that within the constraints imposed by parking garages’ structures, they can be reused in limited ways. However, an actual development project would need to consider many other factors, such as the surrounding land-use and traffic conditions.

Second, this study provides a general research framework for different types of parking garages. Within this framework, though, more research into adaptive reuse is needed—for example, fire escapes, architectural design, space planning, structural design, utility arrangement, and energy saving. These components all need careful but different professional cooperation in each garage type.

The study also includes only nine garages in one city; it is a feasibility study with limited coverage. But due to varying lot sizes and conditions, there are many types of parking garages. A complete city-wide feasibility report would require a more detailed study of garages.

5.2 Problems Encountered in the Research

The best way to study a building is using drawings of its structure. But because these garages were built at different times, it was often difficult to obtain these documents. I could also only conduct a field trip with a laser measuring instrument due to lack of funds and manpower, so I could not make a detailed survey myself.
While surveying, I also encountered problems of inaccessibility. Permission was required to enter two parking buildings (those of the courthouse and the administration building). I could only observe these two structures from the outside.

The variety of parking garages and the number of ways they are built went beyond my expectations. Due to the different sizes of the lots, different structural forms have been adopted to maximize parking efficiency in different lots and achieve other economic benefits. In my analysis, I pointed out that possibilities for adaptive reuse are tightly limited by the conditions of the original structure. This means that different types of parking garages may be suitable for different methods of adaptive reuse. There are five forms of construction among the nine garages in Orlando, so it would be hard to invent a reuse method that could accommodate all the garages in one area.

Because of the differences in the structures of the garages, I cannot propose detailed designs when developing feasibility plans. A complete, feasible design requires a lot of professional cooperation, which it would be impossible to include in one study. Instead, I only present several of the many possibilities for adaptive reuse based on the findings in the previous parts of the thesis.

5.3 Considering the Use of Transitional Periods

As best I can tell, the occupancy rate of parking garages in downtown Orlando is very high on weekdays and very low on weekends and at night. On weekdays, I observed that almost all the parking garages were more than 95% occupied. As things stand, most Americans, especially in warm, rainy places like Florida, have a hard time switching from private cars to other models of transportation. People still love their cars and suburban life.
When the era of driverless cars will really arrive is not yet known, and it may still be a long time. Transitions are always the hardest times to go through, and it is worth studying now how these old parking garages can be reused during the transition period to limit confusion. In addition to the phased development approach mentioned above, another option is adding time controls for different uses of parking garages. For example, community activities and markets could be held in parking garages on weekends. Mixed use could be controlled at different times.

5.4 Garage Design for Future Adaptive Reuse

The difficulties of garage reuse mentioned above affect the development of the whole research field. Awareness of the need to transform parking garages has increased, but little research and few completed cases exist in this area at the moment.

Because of the growth in traffic, cities may continue to build new parking structures. While designing those garages, professionals must consider whether their structures can be easily reused. For example, concrete structures can last longer, an increased floor load capacity can accommodate a wider range of uses, and space can be reserved for light and ventilation wells.

Many international cases can also be used for reference on this matter. Many of the world’s high-density cities are built vertically to allow more development. The TOD model in Hong Kong is a good representative. High-rises tend to mix all urban functions in a single building: the subway runs underground for public transportation; the lower floors provide commercial centers and parking, the middle floors are used as offices, and the upper floors are used as residences. This vertical development mode can provide more usable area for high-density cities.
When designing future buildings, we can make it easier to transform them for different functions. For example, parking floors can be easily converted into office or residential use to adapt to the needs of different times, as we found that the biggest constraint on adaptive reuse is the original structure of the building. If designers make structures flexible, the adaptive reuse process will become much easier.
CHAPTER 6
CONCLUSION

According to the literature, the current oversupply of parking in the United States is likely to be phased out in the less driving future. A large number of building facilities, including independent parking structures, will then be underused or abandoned; we are already seeing this trend. For the purposes of energy conservation and environmental protection, the adaptive reuse of these structures is the best choice. Many people think that parking garages are firm and stable because vehicles are heavy, but in fact the floor load of parking garages is similar to those of residential and office spaces. Many specific codes also need to be followed for residential and office application, such as IBC. Therefore, it is not possible to judge whether a parking garage can be maximally reused just by looking at its flat floor areas. Whether a structure can be usefully transformed depends on the following points: (1) the construction of the ramps, (2) the height of floors, (3) the spacing between the beams and pillars, (4) the lighting and ventilation conditions, and (5) the life of the cement structure.

The study will hopefully give urban planners, urban designers, government agencies, and developers ideas for handling challenges with parking garages in a future of less-driving. This is an environmentally friendly, affordable way to live, and is beneficial to the development of other traffic modes. These old parking garages will have a new life in the less-driving future.
LIST OF REFERENCES


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BIOGRAPHICAL SKETCH

Ruchen Zhou was born in Shanghai, China in 1990. She graduated from Shanghai university in 2014 with a bachelor's degree in architecture. Since then she has worked in Shanghai as an architect and participated in some urban planning projects, which stimulated her interest in urban planning. In 2017, she began the graduate study in University of Florida and received a degree of Master of Urban and Regional Planning in 2019.