Green Mobility Taipei City:
With the Arrival of Mobility-on-Demand System With Ultra Small Electric Vehicles

by
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Abstract
Urban form always transforms when new transportation technology is deployed. Urban form and transportation technologies always
coevolve. Many new technologies have been developed to solve the problems of greenhouse gas emission, air pollution, energy effi-
ciency, high gas prices, traffic congestion, etc. Electric vehicles (EVs) and Mobility-on-Demand systems are two of these technologies.
With the advancement of battery technologies, EVs are become the next mainstream product for Automobile industry. Meanwhile,
there are many new concepts about various alternative types of car ownership, such as Mobility-on-Demand (MoD) systems, a one-
way rental car sharing systems, for which the Smart Cities group of MIT Media Lab is doing research. The regulation and infrastructure
of current cities are mainly designed to accommodate gasoline-powered and private owned vehicles. This thesis addresses how will
urban fabric and space transform with the arrivals of EVs and MoD systems and what kind of service and urban infrastructure can be
integrated when individual vehicles become a node of mobility network. The thesis focuses on Taipei City as a case study city and
develops varies scale design strategies, ranging from charging infrastructure, street, sidewalk, curb, parking infrastructure, to building
type. The thesis also discusses the benefit of EVs and MoD system may bring to a city.

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1.0 INTRODUCTION
Numerous burgeoning technologic developments in urban transportation and automobile industry will totally transform the transportation network when they are fully implemented. City form and transportation technology are always coevolving hand in hand. This thesis examines when transportation undergoes an overall technological improvement, how will urban form transform itself accordingly and what will that be.

According to United Nation Population Division Report, over half of the world population now reside in urban area. The urban population will keep growing from 6.7 billion in 2007 to 9.2 billion in 2050. However, the speed of urbanization cannot match up with the speed of population growth and developed and undeveloped lands are both finite. Therefore, most of the metropolitan areas will definitely grow in its size and density in the future. Higher population in urban areas means that there will be more urban trips. At this moment, a lot of cities already suffer from air pollution, noise pollution, heat island effect, high gas prices, traffic congestion, parking shortage, and streetscape discontinuation. The current transportation system and its vehicles caused many of these issues. How to make cities greener, more energy efficient, less congested, and more human-centric are very important to future city designer, planner, and inhabitant.

In order to make a city greener and more energy efficient, it requires a closer look at the current design of gasoline-powered vehicles. The current transportation energy consumption is 34% of the total world energy consumption. The gasoline-powered automobiles contribute about two-third of the total transportation energy consumption. Even after a century of technological advancement, the fuel efficiency of gasoline vehicles still has a lot of room to improve. The Henry Ford Model T had better fuel efficiency than most automobiles right now. Gasoline-powered vehicles are not energy efficient in nature. The energy conversion rate from gasoline to people on board is actually very low. About 80% of energy is lost and wasted in the internal combustion engine when it is running. Only 20% of energy contributes to vehicle’s movement. Moreover, in this 20%, 19% of the energy is consumed to move the vehicle’s own weight; only 1% of the total energy is consumed to move passengers and drivers’ body weight. For example, the gas price skyrocketed in the summer of 2008. If one gallon of gas is $4 U.S. dollars, 1% of the total energy contributes to your body weight movement means only 20 cents contribute to your actual body movement. A tremendous amount of energy is wasted. Although there are a lot of attempts to overcome this problem, comparing the growth rates of fuel efficiency to car ownership, the positive effects will be relatively small. However, the world is facing imminent problems, such as petroleum exhaustion, greenhouse gas emission, global warming, etc. The world needs a different system other than gasoline-powered automobiles to untangle all
In order to make a city less congested and more human-centric, it requires a closer look at the overall transportation system. Take the U.S. cities for example, whose developing pattern is followed and favored by a lot of giant developing countries, such as India and China. From 1982 to 1999, in 75 metropolitan areas, the average percentage of daily traffic congestion, rising from 17% to 33%, nearly doubled during 17 years. The Texas Transportation Institute also states in its annual traffic congestion analysis in 1999 that the average traffic congestion time, rose from two to three hours a day in 1982, to five to six hours a day in 1999. These traffic congestion patterns not only take place in the U.S., but also in any other metropolitan area around the world as well. Especially the size and population densities of most the U.S. metropolitan areas are lower than the cities in Asia or South American. It is not too hard to imagine how these metropolitan areas will look like when they are following the lead of the U.S. and become developed countries.

Besides the problems caused by moving vehicles, parked vehicles caused problems too. The average percentage of car-driving-time in the U.S. is fifty-six minutes out of twenty-four hours in a day; it's only 4% of the total time. It means 96% of the time these vehicles are stationary either at work place or at home. Therefore, a lot of cities need to convert lots valuable urban real estates into parking lots to provide spaces for these vehicles when they are not in use. People also spend money to pay parking fees, purchase or rent parking spaces, or build garages for their vehicles. These vehicles are not only inefficient, with only 4% of the usage time, occupying valuable urban spaces, and spending people's money, but also affecting the whole urban form and development.

It is a reasonable assumption that the quality of life in urban areas will deteriorate more in the future, because of population growth and if there is no major improvement to the current transportation system and planning policies. A lot of these urban problems are caused by the current transportation systems and policies and cannot be solved by traditional urban design or planning methods. Therefore, as urban designers and planners, we need new types of thinking to tackle these problems within the realm of transportation itself.

The ideas of tackling these problems are replacing gasoline-powered automobiles with electric-powered ones and adapting sharing car ownership instead of private car ownership. It is already happening in the real world. More and more automobile manufacturers are turning their focus from muscular, gasoline vehicles to small, electric vehicles. At the same time, more and more vehicle sharing programs, including bikes and cars, are widely spread across the continents. Transportation and cities are closed related and coevolve together. These new transportation inventions will
have an implication for urban form when are fully implemented. How to move is an urban issue. The invention of steam engine train expanded the urbanized area boundaries and people’s perception of time and space. Cities can be more expanded and concentrated at the same time, because the resources and labors can move in and out very fast. The elevator enabled the later invention of skyscrapers. The escalator encouraged the ground floor retail stores transformed into multi-stories department stores. Not to mention the later inventions of gasoline-powered vehicles and highways; they created urban sprawl all over the world. The minimum street width was determined by the width of a fire truck. Transportation always plays an important role in urban form and leads urban development in new directions. Although transportation and urbanism have close relationships, most of transportation issues were only discussed among specialists of transportation professions, urban designers and planners just took their conclusions to form urban design theories and policies. However, urban designers and planners cannot deal with a lot of urban problems which caused low quality of urban life because the causes of these problems were not discussed in their fields. For instance, more population means more cars and more highways. If traffic jams still happened, there would be more highways or more lanes in construction. These endless highways cannot stop the endless time people spend on traffic delays and commutes. They also create a never ending suburbia. More people need to drive their cars to works; more space will become parking lots to accommodate parking needs. It makes urban fabric and activities disconnected and scattered. A lot of transportation problems were solved from technical or economical points of view, not design or cultural oriented. Sometimes they create urban fabric separation and low quality streets and needs a project like Big Dig spent millions of dollars over many years to fix it. Cities are for people to live in and enjoy their urban life. Urban designers and planners like to depict an imagined urban life from a person’s walking experience perspective. Ironically, people tend to spend more time experiencing urban space in their cars than on their feet. The most popular public spaces are highways and roads. The purpose of these most popular “Public Spaces” is to pass by, not to stay. To serve this purpose, a lot of time urban designers would sacrifice real urban public space for these “Public Spaces.” If the current transportation planning logic does not change, a lot of urban planners and designers’ efforts are still in vain. If a lot of urban space problems were caused by transportation, maybe urban designers need to address the urban issues from transportation point of view rather than urban design point of view. This thesis will talk about how can a city be transformed and people’s life quality can be improved with the helps of new green urban mobility.
2.0 MOBILITY-ON-DEMAND SYSTEM
2.1 Mobility-on-Demand System

Mobility-on-Demand (MoD) system is a personal transportation system, developed by the Smart City/Changing Places Group, at MIT Media Lab. The system includes fleet management system, charging infrastructure, special vehicles, urban implementation strategies, etc.

MoD system is a public but personal green transportation system for dense, mixed-used, contemporary cities. MoD system creates a new rental model, a one-way rental service, which allows users to pick up electric vehicles from any charging station and return them at any other charging station. Users only need to pay the time they are using the vehicles. Users can find MoD stations linked with the existing civic structure throughout a city. The purpose of establishing MoD system is not to replace the existing transportation network. On the contrary, it is complementary to the existing transportation network. MoD system helps the existing transportation network to solve the first mile and the last mile problems, which most of public mass transit systems do not have the flexibility and capacity to deal with. By adapting different pricing strategies, MoD system can encourage users to use its service to connect to mass transit networks, such as subway or buses.

MoD systems are a mixed modality transportation system. MoD systems provide users with green vehicles, such as electric cars, electric scooters, electric bicycles, etc., in their stations throughout an urban area. One station may have only one type of vehicles, but others might have more than one types of vehicles. Users can choose what ever vehicles which fit their purposes the most. For example, if the weather permits, people do not have to rent a car to go to supermarkets. They can ride a bike to a supermarket and pick up a car and drive it back with groceries. They do not need to pay for the time when vehicles were parking in a station and save some parking fees. These electric MoD vehicles are constantly charging themselves inductively when they are parked in MoD stations for next users to pick up.

MoD systems can use any type of electric vehicles, but in order to achieve the greatest benefit out of MoD system, it will be best to use MoD vehicles, which are specially designed for MoD system. These MoD vehicles are CityCar, Roboscooter, and GreenWheels. These vehicles are developed by Smart City/Changing Places Group, at MIT Media Lab. They are all electric, have small footprints, and two of them even are foldable. These vehicles are designed to do inductive charging, meaning wireless charging; unlike most of other electric vehicles need to plug in to a power source. Therefore, when these MoD vehicles are folded and parked in the station, they only occupy a small space and are constantly charging wirelessly themselves. Users do not have to worry about the power level of the vehicles. Just like an electric toothbrush, when it is not in use, it is always charging on its stand, without plugging anything. Therefore, each MoD vehicle can maintain its optimal power level for the next trips. Moreover, MoD system will only allow user to pick up MoD vehicles which have enough power for average urban trips.

MoD system rental process is very easy. Users can go to any of these stations and simply use a membership card to pick up any available vehicle in a station and drive it away. They can return their MoD vehicles to any other station, if there is an available parking space, and then walk away. MoD System is both public and personal. Anyone with a membership card could use this service, so it is public, like taking a bus. However, because users can use the MoD service at any time, in any place, without any route limitation, point-to-point commute, it is like taking a taxi but you are your own driver. Therefore, it is personal. The best of all, users do not have to pay for the time they are not using these vehicles, such as parking fee, insurance fee, and depreciation. For users, it is even better than owning a private vehicle themselves.

With the traditional car rental service, such as Hertz, or Avis, users can only rent cars by days. Most of the time users have to return their cars to the original stations or they may need to pay different rates in the first place. With the recent car sharing rental service,
Figure 1. Mobility-on-Demand system in urban area, provides different types of vehicles for one-way vehicle rental service.
such as Zipcar, users can rent cars by hours, but they have to return the cars to the same parking spots. Unlike these services, with MoD System, it only charges its users for the time or the distance they are actually using or driving these vehicles. They can pick up any MoD vehicle from any station, in any time, as long as it is available.

MoD system is not the first vehicle sharing system in the world, which is providing large-scale, citywide one-way rental service, but it is one of the several systems, which are using automobile as the main vehicle for vehicle sharing system. Velib is the bike sharing system in Paris. It provides a large-scale, citywide one-way rental bike service. Users can pick up any bike from any station and return to any other station. The system is doing well, but when it comes to fleet management, it does not do so well. The supply and demand of bicycles may be imbalance after daily operation. Some stations may have too many bikes and some stations may not have any bike left. Velib has to hire employees to manually move bikes around on their trucks throughout the city at night, in order to let users to have bikes to pick up in the next morning. MoD system is trying to tackle this problem using a different approach. MoD system is developing the dynamic pricing strategy to use price incentive to encourage users to pick up or drop off MoD vehicles as the system wanted. If a user wants to pick up a vehicle, and system tells him if he picks up a vehicle from a station, which is two blocks away from the station he wants to pick up, he will have 50% off of the rental price. If this user has time, he might be willing to do it. By implementing this pricing strategy, MoD system can balance its fleet.

Unlike the bike sharing system, many bikes can be moved around at once on a truck. However, MoD system are using cars. It would be really difficult to move around cars throughout the city in a short period of time. The cost will also be very expensive and not practical.

The most important thing about MoD system for users, except MoD vehicles, is where to find MoD stations to rent or return MoD vehicles. The location and identity of MoD stations will be the key factor to make this system work. First, MoD stations will be placed nearby the existing major mass transit hubs. The MoD stations will provide extended mobility for passengers to go to their destinations from the existing stations. Second, the stations will be placed near places with clear identities and also the presence of these places need to be distributed evenly throughout a city. Therefore, people will have no problem to find MoD stations, even in unfamiliar areas.

The second most important things about MoD system for users, will be how MoD stations interact with users. The drop-off and pick-up process need to be very simple. It should be as simple as driving a car on the street. Users do not need to be trained or require a lot of prerequisite knowledge in order to use MoD system. Therefore, the design of a MoD station will be crucial to the large implementation of MoD system in a dense city area.

The last but not the least, the important thing for MoD system operators, will be how to build a modular station in different types of urban environment. MoD system will assemble these modular components to customize MoD stations for each individual site. Thus, MoD system can be widely distributed throughout a city.

Figure 2. Citycar and Roboscooter in a MoD station.
2.2 CityCar: Ultra Small Electric Vehicles for Mobility-on-Demand System

There are three different types of vehicles specially designed for MoD system; however, the thesis will only use CityCar as the sole vehicle in MoD system. It is because when comparing cars with scooters and bikes, cars do have more impact on the urban environment. The larger the vehicle size is, the larger space it will occupy. The thesis will address the impact of MoD system have on urban environment. Therefore, CityCar is the better candidate than the other two vehicles.

Ultra small vehicle is a new automobile trend in dense urban area, especially in a place when the traffic condition is bad. There are more than half of the world population now reside in urban areas. When more and more population move into cities; at the same time, the land area of cities will not grow and the urbanization speed cannot catch up with the population growth speed. Therefore, the urban population density will become higher and higher. There will be more high-rise buildings to accommodate more people, and more people means more commuting needs. However, in a place where the traffic is already bad, how can two-dimensional streets accommodate more transportation needs, when buildings can accommodate more people in three-dimensional space? Therefore, cities need to utilize the existing transportation infrastructure, not to make roads bigger and wider, but to make them work more efficiently. Ultra small vehicle can be the solution to these kind of cities.

The existing transportation system, especially private gasoline vehicle, is not working efficiently. In Taipei City, the average occupancy of private vehicles during morning rush hours and afternoon rush hours, are 1.48 people per vehicle and 1.64 people per vehicle. Most of the vehicles are designed to sit at least four to five people. However, the average occupancy is below two people per vehicle. In other words, these vehicles waste a lot of public and private real estate, when they are on the roads and when they are parking. If most of these vehicles, one day become two-seater vehicles, like Mercedes-Benz Smart, It is not too hard to imagine how good the traffic will be, if that day really comes.

In order to make dense and congested cities a good place to live, these cities need a revolutionary vehicle design to meet their needs. This vehicle should accommodate no more than two people on board, this number is already higher than the average vehicle occupancy in Taipei City. The vehicle footprint should be very small, in order to reduce the road surface and parking space it occupies, and also improve the fuel efficiency. This vehicle should be electric, in order to prevent the tailpipe emission, air pollution, and noise pollution, which the current gasoline vehicles are making right now. This vehicle should be a ultra small electric vehicle.

CityCar fulfills all the requirements of ultra small electric vehicle. It is clean, green, silent, and compact. It also has more features other than the requirements of ultra small electric vehicle to solve the urban congestion problems. Therefore, the thesis will use CityCar as the sole MoD vehicle for MoD system urban implementation in Taipei City.

Figure 3. Citycar designed by Will Lark, Smart Cities, MIT Media Lab
Features of CityCar
The CityCar is a lightweight, folding, electric 2-passenger 4-wheeled vehicle. It is developed by Smart City/Changing Places group, MIT Media Lab. The followings are its features.

Wheel Robots
The most important enabling technology of CityCar is the wheel robot technology. Wheel Robot is a modularized wheel, which contains electric motor, suspension, steering, and braking. CityCar is drive-by-wire and it uses digital signal to control the vehicle instead of mechanical steering. A wheel robot is an independent unit, like an USB thumb drive, it can connect to the vehicle chassis quickly and also unplug quickly. It is good for vehicle sharing system. The maintenance team can fix a stall vehicle quickly, by replacing the bad wheel with a good one. The team can take the bad wheel back to the factory for further examination later.

Drive-by-Wire
CityCar is totally drive-by-wire. Except the mechanical connection between wheel and chassis, there are only electric power cable and data cable running between chassis and wheel. The vehicle is totally controlled by digital signal.

Full Electric Powertrain
CityCar is an four wheel drive electric vehicle. It is powered by four electric motors in its four wheels.

Maneuverability
The independent, omni-directional wheel robots provide extraordinary maneuverability. CityCar can drive like the current gasoline vehicle. Moreover, CityCars can spin on their own wheelbases. They can make O-turns instead of making U-turns. They can parallel park by slipping in sideways.
Figure 5. Different modes of CityCar
Foldability
The most significant benefit of using wheel robots is that it enables foldability for CityCar, because the elimination of the traditional engine and drive train. A CityCar can fold or unfold in a very short time, even when users still on board. A folded CityCar still have the full driving function of an unfolded CityCar.

Micro Footprint
When a CityCar is unfolded, the length is about the same length of a Mercedes-Benz Smart car, about 262cm / 103 inches. However, when it is folded, the length is about 198cm / 80 inches. It reduces its original footprint by 25%. A CityCar is already smaller than a conventional gasoline car. A CityCar is even smaller when it is folded and parked in MoD stations. Depending on context, up to three folded and stacked CityCars can fit in one traditional parking space. MoD system is intended to do a large scale urban implementation. There will be a lot of cost in acquiring real estate for parking and charging. When a CityCar is folded can save 25% of its footprint, it means that it will save a lot of money for system operator. In Taipei City, sometimes a parking space is even more expensive than a car is parking above it. 25% of saving is pretty good.
Our team has created two light weight electric vehicles designed for Mobility-on-Demand: The CityCar and the RoboScooter. We have submitted them as two separate entries into the ID Competition Student Work Category.

Figure 7. CityCar exploded diagram of components
Front Ingress and Egress
By removing the traditional engine in front of a vehicle, users can enter and exit a CityCar in a front, rather than on the sides. When a CityCar is folded, the chairs inside the CityCar will also be lifted. When the front door opens, users will be in half standing position and make going out and coming in of a CityCar easier. The feature of front ingress and egress totally transforms the relationship between vehicle and streets. Users can directly step onto sidewalks, without the danger of hitting by approaching cars from the back. Users can directly get into a CityCar from sidewalks, without obstructing the moving traffic if users get into a vehicle from its side on the street.

Inductive Charging Ability
CityCar is developing the inductive charging ability. Vehicles can automatically recharge themselves wirelessly while they are parked in MoD stations. The constant charging can also reduce the need for massive amounts of batteries on-board the vehicle and also improve the fuel/power efficiency.

Dynamic Front Impact Dampening
CityCar can take advantage of its foldability to emulate the crumple zone of the present vehicles. When a CityCar hit something in the front, it can use its foldable frame to reduce the impact force and decelerate passengers inside the CityCar.

Autonomous Driving Ability
The most important assumption of CityCar's feature in the thesis, is that CityCar will equip with autonomous driving ability. CityCar is totally drive-by-wire. It means that CityCar is driven by digital signal rather than mechanical or physical force. Right now, the driving interface of CityCar interprets drivers' input into digital signal to control the vehicle. The vehicle will not care about what is the original source of the input. Therefore, a computer can easily send out digital signal to take over control of a CityCar. A CityCar is equipped with a lot of sensors on board. CityCar can use it sensors to navigate itself in a physical environment, without hitting anything. In the thesis, autonomous driving ability is only using as autonomous valet parking inside MoD stations. Therefore, it greatly reduce the chance of hitting anything or anyone. It is the fundamental assumption of the thesis, that a CityCar can drive and park itself.
Figure 8. CityCars on a narrow urban street
3.0 TAIPEI CITY
3.1 Introduction
The thesis is using Taipei City as a case study city for Mobility-on-Demand system urban implementation studies. The pick-up and drop-off process typologies and three stages of Mobility-on-Demand system, the portal stage, the interface stage, and the system stage, present in later parts of the thesis, are specially designed for the existing urban conditions of Taipei City. The design strategies are proposed by using data and studies gathered and analyzed for this thesis. The Taipei City urban analysis part of this thesis is based on the previous research works, which I did for my previous thesis, “Taipei Mobility: Gone in Less Than 300 Seconds-Mixed Modality Transportation System in Dense Mixed-Use Urban Fabric, Take Taipei City For Example,” in Department of Architecture, MIT, 2008. It is presented in chapter 6.0 appendix. The Taipei City urban analysis is the foundation of this thesis. There are fourteen aspects of Taipei City urban analysis and they are listed in the following.

6.1 Taipei City
6.1.1 Introduction of Taipei City
A brief introduction of Taipei city. Please see more detail in P.175.
6.1.2 Pilot Program of Mobility-on-Demand
Reasons of why chose Taipei City as the candidate for Mobility-on-Demand pilot program. Please see more detail in P.175.
6.1.3 Location and Geography
Introducing the location and geographical features of Taipei City and its neighboring areas. Please see more detail in P.177.
6.1.4 Administrative Zones
Introducing the administrative zonings and its surface area in Taipei City and Taipei County. Please see more detail in P.179.
6.1.5 Population and Density
Introducing the population and population density of Taipei City and Taipei County. Please see more detail in P.180.
6.1.6 Urbanized Area of Greater Taipei
Introducing the seven different types of urbanized area of greater Taipei City. Please see more detail in P.183.
6.1.7 Road Systems
Introducing the road systems in Taipei City, including high-speed rail, railways, highways, expressways, main streets, and Mass Rapid Transit (MRT). Please see more detail in P.189.
6.1.8 Public Transportation
Introducing the public transportation system in Taipei City, including MRT and public buses. Please see more detail in P.190.
6.1.9 Transfer Types
Introducing the transfer types between different transportation modes in Taipei City. Please see more detail in P.191.
6.1.10 Private Vehicles
Introducing the private vehicle ownerships, including cars and scooters, in Taipei City. Please see more detail in P.193.
6.1.11 Parking in Taipei City
Introducing the parking in Taipei City and also cars, scooters, and parking spaces densities. Please see more detail in P.195.
6.1.12 Home versus Work Trips Matrix
Introducing the home to work or work to home commuting patterns in Taipei City. Please see more detail in P.196.
6.1.13 Urban Interface
Introducing how to categorize streets based on its urban interface features. This is the basis of the thesis and many chapters are based on these eight different types of urban interface to develop its design strategies and proposals. Please see more detail in P.200.
6.1.14 Streets in Greater Taipei Area
Introducing the communal street and main street typologies of Taipei City. Please see more detail in P.201.
Figure 9. Thesis book cover of "Taipei Mobility: Gone in Less than 300 Seconds."
4.0 THREE STAGES OF MOBILITY-ON-DEMAND SYSTEM IN TAIPEI CITY
4.1 The Anatomy of Mobility-on-Demand Stations

The Mobility-on-Demand station manages the Mobility-on-Demand vehicles from the time that they have been returned until the next users pick them up. During this period of time, the core functionality of Mobility-on-Demand station can be divided into three stages: the portal stage, the interface stage, and the system stage. Each stage will be responsible for a certain job. The portal stage is about where to locate a MoD station. The interface stage is about how users pick up and drop off a MoD vehicle at a MoD station. The system stage is about how a MoD station handles its vehicle charging tasks, vehicle flows, and the station spatial layout in different urban environments.

The Mobility-on-Demand system provides a one-way rental service, during which users may only be charged for the period of time from when they pick up a MoD vehicle at one station, to when they return the MoD vehicle at another station. The pickup and drop-off stations can be the same station or can be different stations. During the time interval lasting from when a user picks up a vehicle till he or she returns it, he or she will be driving the vehicle on his or her trip. During this period of time, the Mobility-on-Demand system is focusing on the MoD vehicles on the roads and how users interact with their MoD vehicles. However, from the time that users return their vehicles to the time that the next users pick up these vehicles is the period of time that the entire Mobility-on-Demand system is focused on Mobility-on-Demand stations.

The Mobility-on-Demand system in Taipei City will focus on the Mobility-on-Demand station design and user scenarios from when users return their MoD vehicles to when the next user picks it up and drives it away. The sequence of the user scenarios will consist of the MoD users trying to find a station to drop off the MoD vehicles, the portal stage; the MoD users interacting with the station to drop off the vehicles, the interface stage; the vehicles entering a station, charging themselves, exiting the charging spots to the parking spaces for the next user to pick up, the storage stage; the vehicles parking at the station and a user interacting with the

![Diagram of Mobility-on-Demand station stages](image-url)
The Portal Stage
The portal stage is about distributing MoD stations for users of the MoD service. The locations of stations will have crucial impacts on how users use the MoD system. The MoD system takes advantage of six existing established places or locations to build their stations nearby or at. These places are Mass Rapid Transit (MRT) stations, schools, convenient stores, bus stops, gas stations, and car parks. The MoD system will synergize its service with these six locations and provide more convenience to the city. Please see chapter 4.2 for more detail.

The Interface Stage
The interface stage is about how the appearance and functionality of the MoD station including vehicle pick-up and drop-off process in the MoD station. The users will either take control of the MoD vehicles from the MoD system or give control back to the system during this interface stage. The interface of the MoD systems has three major components, the MoD Smart kiosk, the Smart Curbstone, and the Smart Docking Pad. Each of these components is specially designed for the Taipei MoD system and plays an important role in the interface stage. Please see chapter 4.3 for more detail.

The System Stage
The system stage is about, between the time that after a MoD vehicle returned to a station and before the time that vehicle has been picked up by the next user, how a MoD station handles its vehicle charging tasks, vehicle flows, and the station spatial layout in different urban environments. The system stage can be divided into three phases; the entrance, the storage, and the exit phases. After a MoD vehicle entered the system stage, it will move and charge itself autonomously inside the realm of the MoD station, based on the MoD system optimization for different locations. Please see chapter 4.4 for more detail.
4.2 The Portal Stage: The Placing Solution for Mobility-on-Demand Stations in Taipei City

4.2.1 The Portal Stage: Introduction

The task of locating a Mobility-on-Demand station to pick up or to drop off a MoD vehicle is the key issue for the Mobility-on-Demand system urban implementation. If the MoD stations are not distributed properly, it will prevent many users from utilizing the system because they may find it confusing to find a station. However, if the MoD stations are not distributed evenly, the users may also find it confusing because they might not be able to find the MoD station to return their vehicles after they arrive at their destination, or a station nearby their origins to pick up a vehicle.

The portal stage is about where to locate a MoD station. The portal stage means that the users can go to certain locations and places, which are suitable for building Mobility-on-Demand stations, for their MoD vehicles. The Mobility-on-Demand service is a new kind of service so it will be difficult to establish its own location without connecting to the existing urban context. Therefore, the Taipei Mobility-on-Demand system will build the MoD stations in the existing locations or places, where the services they are providing have common interests with the MoD system. In the greater Taipei City area, there are six different types of places or locations that the Mobility-on-Demand service can suitably tap into. All of them have their own social functions, spatial characteristics, and special services. They all play important and irreplaceable roles in Taipei City. These places are Mass Rapid Transit (MRT) stations, schools, convenient stores, bus stops, gas stations, and car parks. Each of these places has its own function and role in an urban environment and their distribution in the urban area is dense, wide, and uniform. They play roles as transportation hubs, transportation nodes, community centers, places where people converge, etc. After adding the Mobility-on-Demand features to their functions, their original functions will prosper and expand their influence and the MoD system will synergize with these places and their services to improve their coverage and service to provide greater convenience to city dwellers.
The Mobility-on-Demand System in Taipei City

- **Backbone System**: MRT Station
  - Backbone system is illustrated in chapter 6.3, P.219.

- **Ubiquitous System**: School, Convenience Store, Bus Stop
  - Ubiquitous sub-system I is illustrated in chapter 6.4, P.225.
  - Ubiquitous sub-system II is illustrated in chapter 6.4, P.229.
  - Ubiquitous sub-system III is illustrated in chapter 6.5, P.233.

- **Supporting System**: Gas Station, Car Park
  - Supporting sub-system I is illustrated in chapter 4.2.2, P.41.
  - Supporting sub-system I is illustrated in chapter 4.2.3, P.45.
Figure 16. A gas station in Taipei City
4.2.2 Supporting Sub-System 1:
Gas Stations

Schools, convenient stores, and bus stops are locations, which distributed evenly throughout Taipei City. They are the ubiquitous system. However, except schools, the locations of convenient stores and bus stops do not have much space to establish a bigger size MoD station. Therefore, there should be another supporting system to support MoD system in Taipei City, with greater capacity to store more vehicles. In Taipei City, gas stations can be the supporting sub-system. If MoD system has a successful launch in Taipei City, it means that the traffic condition should be better, because more people will use the public transportation system, instead of driving their own gasoline vehicles. If the number of private gasoline vehicle ownerships goes down, the city might not need so many gas stations, because the demand for gas also drops. However, as long as there are gasoline vehicles, gas station should exist in the city. Therefore, gas station should start to serve both gasoline vehicles and electric vehicles, when electric vehicles are becoming more popular.

Instead of just using gas station to serve private vehicle, the location of the gas station can actually be a very good MoD station location. In greater Taipei area, within the city center, there are not many gas stations. Most of the gas stations are located in the perimeter of the city center and also located on major avenues in suburbs. Gas stations can be the MoD warehouse stations in those locations. Unlike the ubiquitous system locations, gas stations have space, both above ground and underground. MoD system can build autonomous parking structures in this location. To absorb overflow MoD vehicles or to dispense MoD vehicles when they are needed by the nearby users. There are 258 gas stations in greater Taipei area.
Gas Station Distribution Diagram in Greater Taipei Area

Figure 17.
Gas Stations Density per Square Kilometer Diagram in Greater Taipei Area
Figure 19. A car park in Taipei City
4.2.3 Supporting Sub-System 2: Car Park

In Taipei City, besides gas stations, car parks can be the other supporting sub-system. When more people start to use MoD system, the less of them will own their private vehicles. In Taipei City, most of people do not have their own garages. Although there are a lot of car parks, most of the people park on street at night to avoid parking fees. There are a lot of areas restricted for parking, but they are open for parking at night times. Unlike gas stations, the density of parking structures is higher when it is closer to the city center. Car parks also have a lot of space. If there are less and less people drive their own cars, there will be more empty space in car parks. Since car park locations are complementary to location of gas stations, and car parks also have a lot of space, car parks can become the MoD warehouse station in city center. It can play the role of balancing the MoD vehicles supply and demand the nearby areas. They are currently 1,211 car parks in greater Taipei area.
Figure 20.

Car Park Distribution Diagram in Greater Taipei Area
4.3 The Interface Stage: The Design Solution for Mobility-on-Demand Stations in Taipei City

4.3.1 The Interface Stage: Introduction

After locating a Mobility-on-Demand station, the next step for users is to physically interact with the MoD system to pick up a MoD vehicle or to return one. The interface stage is illustrating the interface of the Mobility-on-Demand station on how the station interacts with its users. Many of the MoD stations are on the street level and many of the MoD vehicles are charging in an open environment. With the autonomous driving capability, the MoD system can move the cars around among its vehicle drop-off point, user drop-off point, charging point, vehicle pick-up point, and vehicle take-off point, based on the system's needs. These points will explain in detail in Chapter 3.4.6. Not all of the vehicles, which users see on the street, can be pick up at any time. The same to, not all the available parking and charging spots, which users see on the street, can drop off their MoD vehicles. It would be very confusing if there is no simple rule for users to recognize where to pick up or to drop off a car. Therefore, the MoD station should act like the McDonald's yellow sign. Everyone sees it knows what it means. Moreover, the pick-up and drop-off points should act like the counter in McDonald's. Everyone enters a MoD station knows where to pick up or to drop off a MoD vehicle, just like buying a hamburger in McDonalds. Therefore, the interface should be very clear, after the users arrived at the stations, they should be able to tell immediately where to go to that they can pick up a vehicle or drop off one.

The interface stage shows clear design guidelines of a station and its conceptual prototypes. The prototype of the Mobility-on-Demand station has three major components, the MoD Smart kiosk, the Smart Curbstone, and the Smart Docking Pad. Each of these components are specially designed for the MoD system in Taipei City and plays an important role in the interface stage. The design guidelines need to reflect the dynamic nature of the MoD system, which stations might need to redistribute from time to time, based on the trip supply and demand trends. These components are very easy to transport, deploy, install, and relocate. They are an autonomous system and can stand and work by themselves. All they need is a power supply, not too much existing infrastruc-
ture modification needed. Their universal and adaptive design are good for all kinds of urban environment. They will create an intuitive and standard user scenarios for all MoD users. During this stage, the vehicle control will be either handed back from the users to the system, or handed to the users from the system. The driving mode will be switched back and forth between the manual driving mode to autonomous driving mode. The MoD station need to deal with this transition to make it easier for users to use and the system to operate.

Figure 23.
4.3.2 The Mobility-on-Demand Station Components Design Guidelines and Prototypes

There are a lot of things need to be considered when it comes to designing the Mobility-on-Demand station. The charging station consists of several major components to fulfill its jobs, which are interacting with users and also providing information, directing incoming traffic and users queuing line for vehicle pick up, wireless charging the MoD vehicles no matter how they parked, providing power connection and power supply to all the components, etc. In order to achieve these goals, the following design guidelines need to be met to have a successful MoD station implementation. These design guidelines will help the MoD charging station to distribute widely in a vary and dense urban environment.

The Station Design Challenges from the Users and System Operators’ Perspective

There are two dimensions need to address when it comes to the Mobility-on-Demand station design. One is for the users and the other is for the Mobility-on-Demand system operator.

From the users’ perspective, they do not know and did not care about the technicality of how vehicles are charging themselves and how do they move around inside the charging systems. They only care about how to pick up a vehicle and how to drop them off after they finished using it. Therefore, this is what they should know. The users only need to know about the pickup and drop off process. The pickup and drop off process will be standardized in every stations. It does not matter how a station looks like or how a station handles its vehicle storage and charging process. The pickup and drop-off process will be the same.

From the Mobility-on-Demand system operators’ perspective, each station is facing different challenges when it comes to build a new charging station in the existing urban environments in different locations. The design guidelines need to be flexible to accommodate all kinds of urban environments in order to widely distribute the Mobility-on-Demand station in urban area. Therefore, the charging process and the way the system stores its vehicles will be different from one station to another based on the urban environment the station is situated in.
Four Design Guidelines for the Mobility-on-Demand Station Design
The following are the four design guidelines in designing a MoD station. Each of these guidelines is very important to the overall success of the Mobility-on-Demand system urban implementation.

Easy to Transport, Deploy, Install, and Relocate
The first design criteria of these components is that they must be mobile and flexible. They should be more like urban furniture than infrastructure. If there is a large-scale implementation of MoD system in Taipei City, there will be thousands of MoD station cover the entire city. If the system is not easy to transport, deploy, and install, it will take a long time to implement the first pilot program. It is not efficient and it is not economical. Moreover, the Mobility-on-Demand system is evolving and improving itself when the time progresses. The system can optimize itself when it gathers more data of the urban traffic supply and demand. The system would need to relocate the MoD station to a better location to better meet these demands. The Mobility-on-Demand station is not a permanent settlement. It will grow and evolve with the city. Therefore, after the first implementation, there will be a lot of adjustment of the locations of the stations. Moreover, there will be constant adjustment if the system is running. The system should be able to uninstall easily, without damaging the existing infrastructure or a lot of repair works after it is removed, and relocate to the next location. Hence, the first design guideline is very important to designing the Mobility-on-Demand station components.

Autonomous System, Not Much Existing Infrastructure Modification Needed
The second design criteria of these components is that they do not need a lot of modification on the existing infrastructure for a large scale, city-wise implementation and they can work autonomously by themselves. The current transportation infrastructure is actually tailor-made for the current transportation means, which mainly are gasoline vehicles and scooters. It took many years to evolve to the stage it is at right now. The Mobility-on-Demand system is a brand-new concept, which breaks the traditional concepts of private car ownership and gasoline-powered vehicles. It will certainly influence the way we interact with the current transportation infrastructure. It will need a different infrastructure to support the system. However, if we need a total transformation of the current infrastructure, it will be an impediment for implementation of the Mobility-on-Demand system. Therefore, designing Mobility-on-Demand station components which can work with the current infrastructure is a requirement in order to make the system viable and successful. These components should blend into the current urban space and also fit into the current using scenarios of the traffic infrastructure. These components should also be able to function autonomously with little or no outside resources. These components should supply power, power connection, and structural supports to themselves. They should be able to communicate and work as a single system, despite of the fact that, in one station, they might locate in different places and not physically linked together.
Universal and Adaptive Design for All Kinds of Urban Environment

The third design criteria of these components is that they should be a modular design but with a great ability to adapt to any kind of urban environment. In a large scale urban implementation scenario, it will need hundred of thousands pieces of these components to build a Mobility-on-Demand station network citywide. If the designs of these components are not modularized, but tailor-made for each location, the numbers of variations of these components will prevent this project from happening. Therefore, the design of these components need to be simple but with the flexibility to accommodate and cover all kinds of dense urban environment. The system operator should be able to handle hundreds of different station site conditions with a few combinations assemble from these components. With the intention to scale up the Mobility-on-Demand system, standardized and modularized designs will be very important. The designs of these components should be more like industrial design than architectural design. The architecture design is custom-made for each site. Different site will require different spatial solution. However, the vehicle design is universal. It could handle all kinds of terrain and roads with the exact same four wheels. One design fits all is crucial to the Mobility-on-Demand system.

Intuitive and Standardized User Scenarios

The fourth design criteria of these components is that they should be intuitive for users to use it without any or with little prerequisite training or knowledge. Despite of hundreds of different site conditions and all the different various combinations generated from these components, users should be able to follow simple rules to pick up a vehicle and drop it off after using it. These intuitive and standardized user scenarios should be set up like traffic rules. No matter how different each road or each intersection looks like, a driver should be able to follow simple driving rules to guide him or her safely through these different situations. Therefore, a universal design and rules for users to know how to interact with the system without too much thinking will be very important for the Mobility-on-Demand system implementation.

The Three Major Components of the MoD Station

Based on the design guidelines, this thesis presents a conceptual design prototype for the Mobility-on-Demand station. The design divides the station into three major parts; the MoD Smart kiosk, the Smart Curbstone, and the Smart Docking Pad. Each of them has all the design guideline features and they work together as one single system.
The MoD Smart Kiosk
The MoD Smart Kiosk is the interface between users and the MoD system. Users can pick up vehicles at these kiosks and also learn about nearby local information. The MoD Smart Kiosk also displays real-time queuing information for users who want to drop-off or pick-up vehicles. The MoD Smart Kiosk also plays the role as a control module for the MoD station and wire/wirelessly communicates with Smart Curbstone and Smart Docking Pad. Please see chapter 4.3.3 for more detail.

The Smart Curbstone
The Smart Curbstone is the base piece for the MoD stations. It provides electricity and structural connection for the MoD Smart Kiosk and the Smart Docking Pad. Each Smart Curbstone can connect to each other and provide power connection throughout the whole charging station. It also provides vehicle information for users who want to pick up vehicles and parking instructions for users who want to drop-off vehicles. It is mobile, easy to assemble and fit nicely into the current street environment. Please see chapter 4.3.4 for more detail.

The Smart Docking Pad
The Smart Docking Pad provides wireless charging capability to the MoD vehicles and also directs users where to drop off their vehicles. The Smart Docking Pad is designed both for nose-to-curb and curb-parallel parking. The curving shape increases the efficiency of inductive charging. The displays on the pads are working together with the Smart Curbstone side display forming a visual direction for users who want to return their vehicles. Please see chapter 4.3.5 for more detail.
4.3.3 The MoD Smart Kiosk
The MoD Smart Kiosk is the major interface to interact with users when they want to pick up a vehicle for their trips and find out more information after they finish their trips. The MoD Smart Kiosk can be divided into three major parts and they are the upper unit, the lower unit, and the transparent touchscreen.

The upper unit has four large displays, displaying supply and demand, news, time, location information, etc, to users and pedestrians, and one of these four displays is a touchscreen interface. The upper unit also provides lights, sunshade, rain cover, and wireless communication equipment for users. The lower unit has a physical user interface for users to conduct a transaction and print out the things they need. Both of these two units have mechanical mechanisms to lift the upper unit to the fully open position and close it when situation needs it. The upper unit can stop at any height to accommodate the needs of different sites. The transparent touchscreen is the main interface for users to use. It will not block the views of the street and it can give users, car drivers, and pedestrians a better view of their surroundings. For most of the user scenarios, the front of the smart MoD kiosk is facing toward the street, and the back of it, which has the physical interface, is facing towards sidewalk for people to use it. While people are using the kiosk, they still have a good view of what is happening on the street.
The Exterior of the MoD Smart Kiosk
The MoD Smart Kiosk is made out of stainless metal to accommodate the humid and rainy climate in Taipei City. It comprises of three major components; the upper unit, the lower unit, and the transparent touchscreen. The footprint of the kiosk is 80 cm x 30 cm. The design principle is to shrink the kiosk footprint as much as possible in order to blend into the existing streetscape. The heights of the kiosk will depend on the position of the upper unit. When it is fully closed, it is 210 cm; when it is fully opened, it is 300 cm. Although the kiosk looks pretty much the same from each direction, it has a front side and a back side. The front side of the kiosk is generally facing the street and providing information for car drivers in the traffic and the users who want to return their vehicles to the station. The back side of the kiosk is generally facing the sidewalk and providing information for the passing by pedestrians and the users who want to pick up vehicles at the station. The difference between front side and back side is that the back side has a physical user interface. Users can conduct transactions by using the keypad and print out the receipts.
The Transparent Touchscreen Display
The main interface of the MoD Smart Kiosk is the transparent touchscreen display. The users can use it when the kiosk is in the open position. In order to fit into the street environment nicely, it is better to minimize the footprint of the kiosk and not to block the views for the street users as much as possible. However, the kiosk needs its visibility for the MoD system to work. The solution is to make the mid section of the kiosk transparent, which is the transparent touchscreen display. It will not block the view of pedestrians and car drivers from their eye levels. When a user is using the system, he can still see the street traffic through the touchscreen. The augmented reality technology can also be used on this display to overlap information on top of the real thing to provide more information. The last but not the least, the transparent touchscreen display will not block the view of the buildings or stores’ facade behind it. It is very important to promote commercial activities from an economic point of view and to prevent the unnecessary rejections from of these building and store owners for setting up something between their properties and streets.

The Upper Unit Displays
The upper unit has four large displays facing each direction. Each display is customized to show specific information to each direction. The displays are showing information about the latest MoD vehicles supply and demand information in green or red, station number, news, latest headline, location information in Mandarin and English, local time, travel and commute information, etc. The most important one is the MoD vehicles supply and demand information. It is very important for users to make decisions about picking up or returning MoD vehicles. The supply and demand information in green means, at this location, the supply of MoD vehicles is greater than the demands of users want to pick up; the red means vice versa. For example, if a user wants to pick up a MoD vehicle, when he sees a green number on the MoD station displays, he will know that there are that number of vehicles available for pick up at that station. On the contrary, if he sees a red number, he will know that there are that number of users queuing up for MoD vehicles at that station. Users can also use this information to help them returning their vehicles. When the MoD Smart Kiosk is in the fully open position, the display facing the street, the lower figure in the middle, is showing supply and demand information in bigger size. It helps the driver to see in a far distance and in a faster speed. The display facing the pedestrian, the lower figure on the left, is showing more detail information for user to pick up a vehicle. When the kiosk is in the closed position, the display facing the pedestrian, the lower figure on the right, becomes a touchscreen display, replacing the transparent touchscreen, for users to interact with.

Figure 28.
Figure 29, 30, 31.
The Adjustable Height of the MoD Smart Kiosk

The height of the MoD Smart Kiosk is adjustable based on the condition of each site and is determined by the position of the upper unit, ranging from 210 cm to 300 cm. The upper and lower units have the mechanical mechanisms, to use the transparent touchscreen frame as a track, to lift the upper unit up or down. There are several benefits when the kiosk has the ability to adjust its height. First, when the upper unit is lifted to the fully open position, it will fully reveal the mid section of the kiosk, the transparent touchscreen, in order to not block the views of the street users as much as possible. By doing so, it can also give the upper unit displays a better position for users to see from far away. Second, the ability to open and close the kiosk gives the system operator the ability to deal with the climate in Taipei City. Taiwan is famous for its typhoons, hot, rainy, humid weather. The kiosk can be fully opened during the normal days. However, during the extreme weather conditions, the system operator can command the outdoor kiosks to close. The upper unit and lower unit will seal the gap in between. When it is fully closed, the most fragile part, the transparent touchscreen, is protected inside the case. The stainless metal case can withstand the extreme weather conditions. However, at the same time, the kiosk will not lose its functionalities. When the upper unit is in the closed position, the display which is facing the sidewalk will become the main interface for users to conduct a transaction and inquiries. This display is also a touchscreen display. Users can use it the same way they are using the transparent touchscreen. Third, the adjustable heights of these kiosks can give them the ability to fit into different urban environment. In the mass implementation phase of the MoD system, it is a very important to create a modular system to fit into different urban environment. Since the kiosk can adjust its height, it can be placed in outdoor, semi-outdoor, even indoor. The system operator only need to adjust its height accordingly to the situation it is situated in. This one design fits all strategy will save a lot of time and money for the operation of the MoD system.
The Lower Unit of the MoD Smart Kiosk
The lower unit of the MoD Smart Kiosk is the base unit of the MoD Smart Kiosk system. It physically connects to the ground units, which is the Smart Curbstone, to have structural supports and power supply. It also connects and communicates to the rest of components by wire. It has a mainframe in its unit to handle the computing for this station and connects to the server of the MoD system in Taipei City. The motors, which provide power to lift the upper unit up and down, is located in the lower unit to reduce the weight of the upper unit. Besides the transparent touchscreen being the main user interface for the kiosk, the lower unit also has a physical user interface for users to use. It has keypad, credit card reader, receipt and information printer, and a wireless membership card reader. Users can conduct transactions regarding the MoD trips and other transactions which are provided by the MOD kiosks by using this user interface. Users can simply tap their MoD membership cards to activate their MoD accounts and log in the MoD kiosk. The password is needed before logging in the system. The users can use the physical keypad to input the numbers to avoid being seen by others on the transparent touchscreen.

The Upper Unit of the MoD Smart Kiosk
The upper unit of the MoD Smart Kiosk not just has four large displays, but also has other functions when it is in the fully open position. First, it has several lights beneath the units. When it is opened, the lights can help users to see things clearly when they are using the system. It can also function as a street lighting when it is needed. Second, the upper unit can also act as a sunshade when the weather is too hot and a rain cover when it is raining. It will offer some kind of comfort and convenience to users when they are using the transparent touchscreen. When it is in the semi-closed or fully closed position, one of the four large displays, which is facing the sidewalk, can function as a touchscreen for users to use. This way, the system operators doesn’t need to worry about the trade-off when he makes a decision to close the kiosk. Both this display and the transparent touchscreen will offer the same functionalities to users. The upper unit is also a communication unit at the station. It can take advantage of its height to provide and receive better wireless singles to and from other components.
The Mod Kiosk Placing Strategy

The location of where to place the MoD kiosk is crucial for Mobility-on-Demand stations. It will affect the way how users interact with the systems and how the system transform the urban space. There are five different types of placing strategies for the MoD kiosk. These types can cover the majority of the urban environment scenarios where the stations are situated in. The system operator can decide where to place the MoD kiosk based on the local site condition. Moreover, each of these types also forms a different spatial relationship with the location they are at and might need different pre-work to make this to happen.

Type 1

The MoD kiosk can connect with the Smart Curbstone and directly place on top of it, which is facing parallel to the street. This is a more mobile solution.

Type 2

The MoD kiosk can connect with the Smart Curbstone and directly place on top of it, which is facing perpendicular to the street. This is a more mobile solution.

Type 3

The MoD kiosk can be placed on any part of the sidewalk. This is a more fixed placing solution. Without the Smart Curbstone to provide power supply and structural connection, the MoD kiosk would need some modification on the existing infrastructure to supply power and structural supports.

Type 4

If there is a cut on the sidewalk for the MoD station, the MoD kiosk can be placed on the Smart Curbstone extension platform, facing parallel to a street. This is a more mobile solution.

Type 5

The MoD kiosk can be placed on the Smart Curbstone extension platform, facing perpendicular to the street. The users will see the MoD vehicles through the transparent touchscreen. The screen can provide augmented reality information. This is a more mobile solution.
4.3.4 The Smart Curbstone

The Smart Curbstone is the key component for the MoD stations. It is responsible for providing structural supports and power supply to the other two components, the MoD Smart Kiosk and Smart Docking Pad. The Smart Curbstone has two displays: one on the side and the other on the top. The side display provides instructions for users who want to docking in the stations and the top display provides information for users who want to pick up vehicles and gives out warning signs to the passing by pedestrian about moving vehicles in the stations. Each Smart Curbstone is a modular design which is easy to transport, deploy, and installed on-site. It can connect to one another and form a charging infrastructure for a MoD station without too much modification on the existing environment. All the Smart Curbstones need is a power supply and that is all. Therefore, this is also very convenient to relocate a station and redeploy. Although the Smart Curbstone is a modular design, it can very in display contents and other colors to accommodate all kinds of urban environment and user scenarios. These modular designs will give this system a greater opportunity to reach an economy of scale when the MoD system is going to mass implementation. With the help of the color codes of the Smart Curbstone and the displays on it, it is very easy to design a pick-up and drop-off process for the MoD system. These user scenarios will also work very well with the present urban environment.
The Exterior of the Smart Curbstone

The Smart Curbstone is a 20 cm x 20 cm x 120 cm metal bar, which was made out of reinforced stainless metal to withstand the climate in Taipei City, and also the weight of a MoD vehicle, which may occasionally bump into the Smart Curbstone, because it is functioning as a car stop. The Smart Curbstone is actually the same size of an existing concrete curbstone. Therefore, it is very convenient to replace a present one with a Smart Curbstone, or to place a Smart Curbstone in front of an existing one. One standard parking/charging space for a MoD vehicle requires two Smart Curbstones and four Smart Docking Pads, which is demonstrated on the lower left side figure of this page.

There are two displays on the Smart Curbstone; one is on the side and the other is on the top. The Smart Curbstone side display is designed to direct the incoming traffic to the stations. The Smart Curbstone side display also works with the Smart Docking Pad display to give out directions at the same time. These two displays are meant to be seen from a driver’s perspective when he is on the roads. It is designed to give drivers of the MoD vehicles quick information about where to park. The screen can show green or red light, just like traffic light. The green light means this parking space is ready for the MoD vehicles to drop off. The red light means the reverse. The Smart Curbstone top display is designed for people who are standing on the sidewalk to see. Therefore, the screen is facing the sidewalk rather than facing the streets. The Smart Curbstone top display shows information for users who want to pick up a vehicle, the status of a vehicle which is parking at this space, and messages to the passing by pedestrian.
Modular, Mobile and Flexible
The Smart Curbstone is a modular design. It is mobile and easy to transport and deploy. Although it is a standard design, it can fit into most of the urban environment, no matter it is on the street, on the sidewalk, inside the arcade, in the basement, or even inside a regular building. It is easy to assemble. The MoD system team can take the Smart Curbstone to the site and assemble it on-site. All the team needs is a power outlet. After they assembled the Smart Curbstones and fixed them on the ground, they can connect a power outlet to any of these Smart Curbstones and the system will be ready to work.

Connection to Other Smart Curbstones
Each Smart Curbstone is a complete unit. Any Smart Curbstone can take the power source in and distribute the power to other Smart Curbstones in the same station. Each Smart Curbstone has the power wires to handle different type of charging, either standard charging or rapid charging. When one Smart Curbstone connects to another, their power wires can establish cascades to make power transferring from one unit to another possible. No matter what types of variation of the Smart Curbstone is, these power wires are a must have in any unit. Therefore, in a station, if there is one Smart Curbstone has power, the rest will have it to. This will make the installation of MoD station much less difficult.

Connection for the MoD Smart Kiosk
The Smart Curbstone provides the power supply and structural supports to the MoD Smart Kiosk. The Kiosk can connect with the Smart Curbstone through the connection point on top of the Smart Curbstone. The kiosk can be placed exactly on top of the Smart Curbstone, either facing streets or sidewalk; or the kiosk can also connect with the Smart Curbstone on one side and place perpendicular to the Smart Curbstone. The system operator does not need to worry where to place the MoD Smart Kiosk when the Smart Curbstones are installed in place.

Connection for the Smart Docking Pad
The Smart Curbstone provides the power supply, structural supports, and information computing and processing power to the Smart Docking Pad. The Smart Curbstone is responsible for the whole charging process of a vehicle and the Smart Docking Pad is a power adapter responsible for transferring power to vehicles. The Smart Docking Pad can connect with the Smart Curbstone to form a complete vehicle charging unit. One unit requires two Smart curbstones and four Smart Docking Pad. The installation of the Smart Docking Pad can be assembled on site. These pads are modular units and can be attached to any of the Smart Curbstones. These modular curbstones and pads will make the transportation and deployment much easier.
**Smart Curbstone Placing Strategy**

Because the Mobility-on-Demand system needs to work with the existing urban environment, how the Smart Curbstone can integrate into the present streetscape would be a key factor to a successful urban implementation. They have five different types of placing strategies for the Smart Curbstone. These types can cover the most parts of the urban environment where the MoD stations are located in. The system operator can decide how to layout these Smart Curbstone, based on the assumption that if the station is permanent, or temporary, and also on the site condition. Each type will form a different spatial relationship amount users, the MoD vehicles, and the streets.

**Type 1**
The Smart Curbstone can place next and parallel to the existing curbstones. This is a more mobile solution.

**Type 2**
The Smart Curbstone can place on the position of the existing curbstones to replace them. The existing curbstones need to be removed. This could be a mobile or permanent solution.

**Type 3**
The Smart Curbstone can place against and parallel to a wall. The Smart Curbstone is acting as a car stop. This is a more mobile solution.

**Type 4**
The Smart Curbstone can place on any part of a sidewalk. The gray one means that it is for autonomous parking only, users cannot drop off their vehicles here. It is acting as a car stop. This is a more mobile solution.

**Type 5**
The Smart Curbstone can place on any part of a ground surface, outdoor or indoor, to form a car park or a car garage. It is acting as a car stop. This could be a mobile or permanent solution.
The Smart Curbstone Top Display
The Smart Curbstone top display is located on the top side of the Smart Curbstone. This is a major communication channel for users who want to pick up a MoD vehicle and for pedestrian who are passing by the station. Because the display is for people to see when they are standing on the sidewalk, no matter they are MoD users or other pedestrian, the direction of the screen will be facing the sidewalk. From the streets, the users will only see upside down information. The display shows the information and status about the MoD vehicle, which is charging in front of this Smart Curbstone, information including parking space number, charging status, battery capacity, capable driving range, capable driving time, message to users, etc. The display also use specific background color to represent certain kind of information. The followings are the more detail descriptions of the content which it is showing.

A. Parking Space Number
It shows the number of parking spaces in a MoD station. Each parking space has its own number. When a user is trying to pick up a vehicle, the kiosk will show the number of the parking space which the vehicle is currently at, then the user can find his or her vehicle from the parking space number shown on the top display of the Smart Curbstone.

B. Charging Status
When the charging sign appears on the Smart Curbstone top display, it means this parking space equips with charging capacity and the vehicles can be charged at this location.

C. Battery Capacity
The color strip inside the battery icon and the percentage number represents the charging status. There are two colors of this color strip, green and red. Green means this vehicle is ready for users to pick up and red means this vehicle is not ready for pick up. The criteria of deciding whether this vehicle can be picked up or not will be based on the system operators’ decision. The system will set up a minimum charge number to satisfy most of the trips to prevent users running out of power in the middle of their trips.

D. Capable Driving Range
The capable driving range shows the distance this vehicle can drive with the current battery power capacity. However, this number is not a fixed number. It will fluctuate depend on the current traffic conditions and the current urban traffic speed. All this information will be gathered and reported back to the system from the fleet on the roads. It will give users a sense of security if they know the battery power capacity of the vehicle is enough to carry them to their destination. The system operator can also use this information to decide in what charging percentage the vehicle will be switching from rapid charging to standard charging. The more accurate the data is, the more energy the system operator can manage to sell to the grid.

E. Capable Driving Time
The capable driving time shows the time which vehicles can drive non-stop at the current urban traffic speed. At any given time, the urban traffic speed is different. Therefore, even with a fully charged bat-
tery, the capable driving time will be different at different times of day. This will help user to have a sense in their mind whether the battery capacity in their vehicles is enough for their trip or not. Most people can give a pretty accurate estimation of the time it takes from point A to point B if they travel often on this route before. However, most people cannot give an accurate estimation of the distance from point A to point B. This feature can give users more security when they pick up their vehicles. However, when a user inputs his or her destination on the screen of a kiosk, the system should be able to choose a vehicle, for him or her, which has enough power for his or her trips.

F. Color Representation
There are four different types of color representation shown on the Smart Curbstone top display. They are green, red, black, and yellow. Green means the vehicle is ready for pickup; red means the vehicle is not ready for pickup; black means messages to users; and yellow means standby and warning signs. They will give users a quick sense of which vehicle is ready for pick up even just at a quick glance. The system will decide which vehicle is ready for use and which is not. The users do not need to care about the battery capacity in any given vehicles. The system will make sure the users arrive at their destination with power left in their vehicles’ batteries.

G. Message
The Smart Curbstone top display will show information which is customized for users who are using the MoD system and people nearby the station. For example, each user can select his or her own username. When he or she wants to pick up a vehicle and chooses one in the MoD station kiosk, the Smart Curbstone top display, which in front of the vehicle he or she is going to pick up, will show his or her username and welcome message. When the MoD vehicles are approaching, leaving, or moving, the display will show warning sign and beeping sound to notify the nearby pedestrian to watch out for the vehicles. The Smart Curbstone top display will be a direct message board between the MoD system and users when things are in motion.
The Variations of the Smart Curbstone Top Display
The following shows different types of display content which the Smart Curbstone top display is showing to users and passing by pedestrians.

1. **Charging, Fully Charged, Ready for Pick up**
The display shows the vehicle is charging at this space and is fully charged. The green color means that it is ready for users to pick up.

2. **Fully Charged, Ready for Pick up**
The display shows the vehicle is not charging at this space but it is fully charged. The green color means that it is ready for users to pick up.

3. **Charging, Partially Charged, Ready for Pick up**
The display shows the vehicle is charging at this space and is partially charged, but power level of the battery is enough to handle an average trip. The green color means that it is ready for users to pick up.

4. **Partially Charged, Ready for Pick up**
The display shows the vehicle is not charging at this space and is partially charged. However, the power level of the battery is enough to handle an average trip. The green color means that it is ready for users to pick up.

5. **Charging, Partially Charged, Not Ready for Pick up**
The display shows the vehicle is charging at this space and is partially charged, but the MoD system indicates that the power level of the battery is not enough to handle an average trip. The red color means that it is not ready for users to pick up.

6. **Charging, Fully or Partially Charged, Not Ready for Pick up**
The display shows the vehicle is charging at the space and may be partially or fully charged. However, the MoD system indicates that there might be a malfunction of this vehicle and it is not suitable for any trip and should wait for the service to come. The red color means that it is not ready for users to pick up.
Pick up Message
The display shows the welcome message and the username to user who is picking up the vehicle. The black color means that it is a specific message to that user.

Drop off Message
The display shows the farewell message and the username to user who is dropping off the vehicle. The black color means that it is a specific message to that user.

Standby Display
The display shows nothing but a yellow background. It is a standby display for the Smart Curbstone which has no current or expected activities. The yellow color means that it is a general message to users and the people passing by.

Vehicle Approaching Warning Message
The display shows the vehicle approaching warning message to warn the people near the Smart Curbstone to pay attention for the incoming vehicle. The yellow color means that it is a general message to users and the people passing by.

Vehicle Leaving Warning Message
The display shows the vehicle leaving warning message to warn the people near the Smart Curbstone to pay attention for the vehicle about to leave. The yellow color means that it is a general message to users and the people passing by.

Vehicle Moving Warning Message
The display shows the vehicle moving warning message to warn the people near the Smart Curbstone to pay attention for the vehicle about to move. The warning message often displays during the vehicles doing autonomous switching charging. The yellow color means that it is a general message to users and the people passing by.
The Smart Curbstone Typologies

The Smart Curbstone is a modular and universal design; however, there are ten different types of Smart Curbstones for ten different user scenarios. Their sizes are the same, but they are different in side display, top display, outer colors, etc. These Smart Curbstones can be divided into two groups; one is the yellow Smart Curbstone group and the other is the grey Smart Curbstone group. The yellow Smart Curbstone group is for users to pick up or drop off the MoD vehicles. The grey Smart Curbstone group is for the MoD system to autonomously drive from or park in the MoD vehicles.

The Yellow Smart Curbstone Group

The yellow Smart Curbstone is for user to pick up their MoD vehicles from or to drop off their MoD vehicles at. In order to simplify the pick-up and drop-off procedures for users to use the MoD systems without difficulties or other prerequisite knowledge, to establish a simple rules, like traffic lights, would be very important to the MoD system urban implantation. In the Taipei MoD system, the yellow Smart Curbstone is the first rules for users to understand. There are many different kinds of Smart Curbstones in the city, some are for vehicle pick-up and drop-off, and some are for the MoD system internal use only. It is very hard to know which space is the right space to drop off a vehicle or which vehicle is the right vehicle to pick up. The yellow Smart Curbstone rule is going to solve these problems. The MoD users, when he or she wants to pick up a MoD vehicle, he or she would approach to a vehicle parking in front of a yellow Smart Curbstone. After arriving at their destination, he or she would find a yellow Smart Curbstone to drop off their vehicle. This would be very useful, especially within one MoD station, there might be several types of Smart Curbstones, some are good for drop off and some are not. The MoD users only need to recognize the yellow Smart Curbstone to return their cars. The yellow Smart Curbstone side display and Smart Docking Pad display will also show green or red light to indicate if this parking space is suitable to drop off a vehicle or not. The yellow Smart Curbstone is also extended to the Smart Docking Pad. If the Smart Curbstone is yellow, the Smart Docking Pad will be yellow too; vice versa.
The Grey Smart Curbstone Group

The grey Smart Curbstone is for the MoD system internal use only and not for users to pick up or drop off their vehicles. All of the MoD vehicles have the autonomous driving ability. The system can move a MoD vehicle from one parking space to another without a driver onboard. There is a possibility that where the MoD vehicle is heading to does not need to interact with any user. For example, in a MoD station, there are three rows of parking spaces; Row A, Row B, and Row C. Row A is the place for users to drop off their MoD vehicles. Row B is the place where the system is charging all the MoD vehicles. Row C is the place for users to pick up their MoD vehicles. After users returned their vehicles at Row A, the system will move these vehicles autonomously to Row B for charging. After some of these vehicles reach to a power level enough for an average trip, the system will move these vehicles autonomously to Row C for users to pick up. Both Row A and Row C will have users coming and going. However, Row B will only have the MoD vehicles coming in and going out autonomously without any user’s presence or people nearby. Therefore, the Smart Curbstones in Row B will be the grey Smart Curbstone, to indicate that these are not for users to interact with. The Smart Curbstones in Row A and Row C will be the yellow Smart Curbstone, to tell users to come here for returning or picking up their MoD vehicles. There are other user scenarios which will need the grey Smart Curbstones, such as the user drop-off point, the vehicle take-off point, even the Smart Curbstone connector, etc.
The Smart Curbstone Typologies with the Possible Contents of the Smart Curbstone Top Display

The following illustrations are showing all the Smart Curbstone typologies, including side display with green light or red light, and also giving a description of the role of each Smart Curbstone plays in the MoD system. It is also showing the possible Smart Curbstone top display content for each Smart Curbstone typology.

Y Type 1
The Y Type 1 Smart Curbstone is for the parking space, which is a vehicle drop-off point, a user drop-off point, a vehicle pick-up point, and a vehicle take-off point at the same time, with charging capability.

Y Type 2
The Y Type 2 Smart Curbstone is for the parking space, which is a vehicle drop-off point, a user drop-off point, a vehicle pick-up point, and a vehicle take-off point at the same time, without charging capability.

Y Type 3
The Y Type 3 Smart Curbstone is the base for the MoD Smart Kiosk.

Y Type 4
The Y Type 4 Smart Curbstone is for the parking space, which is both a vehicle drop-off point and a user drop-off point, or a vehicle drop-off point only, without charging capability.

Y Type 5
The Y Type 5 Smart Curbstone is for the parking space, which is both a user drop-off point and a vehicle pick-up point, with charging capability.
**Y Type 6**  
The Y Type 6 Smart Curbstone is for the parking space, which is both a user drop-off point and a vehicle pick-up point, or a vehicle pick-up point only, without charging capability.

**G Type 1**  
The G Type 1 Smart Curbstone is for the parking space, which is an autonomous vehicle charging point, with vehicles driving in and driving out by themselves, with charging capacity.

**G Type 2**  
The G Type 2 Smart Curbstone is for the parking space, which is a user drop-off point, without charging capability.

**G Type 3**  
The G Type 3 Smart Curbstone is for the parking space, which is a vehicle take-off point, without charging capability.

**G Type 4**  
The G Type 3 Smart Curbstone is the Smart Curbstone connector. It can connect one Smart Curbstone to another when they need to form a cascade. It does not have charging capacity.
4.3.5 The Smart Docking Pad

The Smart Docking Pad is the component, which connects to the Smart Curbstone, to provide wireless charging capability to the MoD vehicles. The display of the Smart docking pad also works with the Smart Curbstone side display to show instructions for incoming MoD vehicles about where to park and how to park. A standard MoD parking space for MoD vehicle needs two Smart Curbstones and four Smart Docking Pads. When a MoD vehicle is fully folded and parked at the space, the entire footprint will stay within the boundaries of the four Smart Docking Pads, no matter it is nose-to-curb or parallel to curb parking. The design of the Smart Docking Pad is universal and standardized. Any Smart Docking Pad can be connected to any Smart Curbstone to form a parking space for charging. The Smart Docking Pads are easy to transport and assemble on-site. This is especially important for the MoD system operation. The MoD station might need to be relocated from time to time based on the supply and demand of different areas. The Smart Docking Pad provides the mobility to achieve this goal. The Smart Docking Pad gets its power from the Smart curbstone. Once the pads are connected and provided with power, a charging station is good to go. The Smart Curbstone will do most of the computing work, such as how to achieve the fastest charging time, when to charge at the maximum speed, when to sell the power back to the grid, etc. The Smart Docking Pad will execute the charging works. The Smart Docking Pad is an universal design and it can be deployed to any urban environment, such as on the street, on the sidewalk, inside the arcade, indoor, etc, as long as there is a flat surface. The Smart Docking Pad display will provide users an intuitive user experience, similar to the traffic light, to direct them how to park their vehicles to a station without too much training or prerequisite knowledge. Not all the Smart Docking Pads have charging capability by default, it will depend on what kind of smart curbstone they are connected to.

Figure 194.
The Exterior of the Smart Docking Pad
The Smart Docking Pad is a 60 cm x 185 cm curving shape metal panel with plastic finished, which was made out of reinforced stainless metal and plastic to withstand the climate in Taipei City. These pads also need to withstand the weight of the MoD vehicles, which are nonstop coming in and out, throughout the day and the night. The highest point of the Smart Docking Pad is 12 cm. It is good for wireless charging efficiency. The Smart Docking Pad may come in two colors, yellow and grey, depend on what types of Smart Curbstone they are connected to. A standard charging unit requires four Smart Docking Pads and they will show in the same color. There is a large LED display on top of the Smart Docking Pad. It will work with the Smart Curbstone side display at the same time to show driving instruction for incoming MoD vehicles.

The Smart Docking Pad Side Ramp
The Smart Docking Pad is a standardized design. When they are connected with the Smart Curbstones, these pads can form a very long charging strip. However, because the Smart Docking Pad has certain thickness, if a station just operates like this, every car drives in and drives out will hit a bump, because of the high difference. The Smart Docking Pad side ramp is the accessory to overcome these problems. When the MoD system team is deploying the MoD station, they can just bring the standard Smart Docking Pads and two types of side ramps, one for going up and the other for going down. They can assemble all the Smart Docking Pads and place the side ramp on both side of these pads. And then, these Smart Docking Pads good for car to park.
The Mini Version of the Smart Docking Pad
The standard version of the MoD parking space needs two Smart Curbstones and four Smart Docking Pads. However, the mini version of the MoD parking space only needs one Smart Curbstone and two Smart Docking Pads. When a MoD vehicle wants to park in the mini version of this MoD parking space, the driver can park on top of the Smart Docking Pads, with four wheels landing on the ground.

Connection to other Smart Docking Pads
The Smart Docking Pad can connect to one another to form a linear charging strip. They only need one Smart curbstones to provide the power. It is very convenient for deployment in a large surface area or indoor space.

The Yellow Smart Docking Pad and the Grey One
There are two types of Smart Curbstone, the yellow ones and the grey ones. The same principle applies to the Smart Docking Pad. For example, if the Smart Curbstone the pad connected to is yellow, the Smart Docking Pad will be yellow too. Vice versa. If the Smart Curbstone does not have the charging capability, neither does the Smart Docking Pad, when it is connected to that Smart Curbstone.

Designed for Both Parking Directions
The Smart Docking Pad is designed for both parking directions, parking nose-to-curb and parking parallel to curb. No matter in which directions, the MoD vehicle will have a flat and continue surface to drive without the feelings of hitting a bump.

Wireless Charging
The Smart Docking Pad is designed for efficient wireless charging. The hump of the Smart Docking Pad contains an inductive charging adapter. The closer this adapter can get to the vehicle chassis, which has a wireless charging receiver, the better power transfer rate the system will get. No matter the car is parked nose-to-curb or parallel to curb; no matter the car is folded or unfolded; the hump of the Smart Docking Pad can have a good position for efficient power transferring.
The Smart Docking Pad display
There is a large LED display on each of the Smart Docking Pad. It will work with the Smart Curbstone side display to show instructions for incoming traffic. Once a Smart Docking Pad is connected to a Smart Curbstone, the pad is connected to the MoD station system and the pad will know its location and in which parking space number it is at and also what to display. Each station will have different parking strategies, some are parking nose-to-curb and some are parking parallel to curb. The Smart Curbstone side display will only show green light or red light to show the users to park or not to park in this parking space. However, the Smart Docking Pad display will show in which direction that the users should park their MoD vehicles. When the display is showing the green arrow strip, it tells users the direction they need to park their vehicles. When the display is showing the red tire-mark strip, it means that the users need to stop at that pad.

Parking Nose-to-Curb
The Smart Docking Pad display shows that the vehicle should park nose-to-curb. The green pad means the parking space for the current incoming vehicle.

Parking Parallel to Curb
The Smart Docking Pad display shows that the vehicle should park parallel to curb. The green pad means the direction that the driver should follow until he or she hit the red pad.
Figure 86.

**Vehicle Drop-off Point ≠ User Drop-off Point**

**Type 4: Local Storage Charging**

- A (Local Storage) — A
- A (Local Storage) — A

**Type 5: Two Way Remote Storage Charging**

- A (Remote Storage) — A
- A (Remote Storage) — A

**Type 6: One Way Remote Storage Charging**

- A (Remote Storage) — B
4.3.6 The Interface Stage:

MoD Vehicle Drop-off and Pick-up Process Types

The MoD vehicle drop-off and pick-up process at the MoD station is fairly simple. The whole process can be divided into seven steps. When a user is driving a MoD vehicle and wants to return it. First, the user should find a vehicle drop-off point to drop off his or her vehicle. Second, after the vehicle is parked, the vehicle will drop-off the user at the user drop-off point. Third, the vehicle will enter the storage stage for charging and parking autonomously, controlled by the MoD system. Fourth, after the vehicle has enough power level for the next trip, the MoD system will drive this vehicle autonomously to the vehicle pick-up point for the next user to pick up. Fifth, the next user can pick up the vehicle and enter the vehicle. Sixth, the vehicle will be ready for the user to drive away after the vehicle is at the vehicle take-off point. Seventh, the user drives away the vehicle manually to his or her destination.

There are six different types of pick-up and drop-off process when users are interacting with the Mobility-on-Demand stations. These six types can be divided into two major kinds: one is the vehicle drop-off point is the same as the user drop-off point, and the other is the vehicle drop-off point is not the same as the users drop-off point. Each of these two kinds can be divided into three different types, based on different parking strategies. These three types are local parking strategy, two-way remote parking strategy, and one-way remote parking strategy.

The drop-off and pick-up process can be divided into two major kinds. The first one is the vehicle drop-off point is the same as the user drop-off point. This means that after a user drops off his or her vehicle, he or she will leave the vehicle at the same time. In the pick-up scenario, it means that right after a user picked up and entered his or her vehicle, the MoD system will still remain in control of the vehicles and drive the vehicle autonomously to the vehicle take-off point and stop, and then the MoD system will give the control back to the users and users will drive their MoD vehicles away manually.

In either of these two major kinds of drop-off and pick-up process, they can be divided into three different types, based on different parking strategies. The first one is the local parking strategy. The local parking strategy means that when users dropped off their vehicles at the Point A, the vehicles will be charging at the same station and wait for the next users to pick them up. The second one is the two-way remote parking strategy. It means that after users dropped off their vehicles at the Point A, the system will drive these vehicles autonomously to other locations for charging and parking. After the power level of these vehicles are good for the next trips, the system will drive these vehicles autonomously back to the Point A for the next users to pick up. The third one is the one-way remote parking strategy. This means that after users dropped off their vehicles at the Point A, the system will drive these vehicles autonomously to other locations for charging and parking. After the power level of these vehicles are good for the next trips, the system will drive these vehicles autonomously to another Point B for the next users to pick up.

During the drop-off and pickup process, the whole MoD station, including the MoD Smart Kiosk, the Smart Curbstone, and the Smart Docking Pad, will work together to send out the right instructions for users to drop off or to pick up a vehicle. These instructions will be shown through the displays on these three components and also the lights from other parked MoD vehicles. These instructions will also be broadcasted through the speakers inside and outside of the vehicles and the speakers at the MoD station. These six types of drop-off and pick-up process are illustrated step by step in more detail in the following pages.
The Mobility-on-Demand Station Diagram Graphic Index

If there are many MoD stations on the streets, some parking spaces are for charging, and some parking spaces are for vehicle drop off only, how can users distinguish each function from one another, when they just simply want to pick up or to drop off a vehicle. In the MoD system in Taipei City, the way to pick up or to drop off a vehicle is very simple. Users only need to find a yellow parking space. That is all.

The MoD stations can be divided into four location points and one function point. The four location points are vehicle drop-off point, user drop-off point, vehicle pickup point, and vehicle take-off point. When parking spaces are vehicle drop-off point and vehicle pickup point, they will be yellow. When parking spaces are user drop-off point and vehicle take-off point, they will be grey. However, the characteristics of a parking space may be more than one. For example, a parking space could be a vehicle drop-off point and a user drop-off point at the same time, which means when user stops the vehicle at the parking space, he or she will exit the vehicle at the same very spot. However, the color codes for these two points are different. Therefore, when a parking space needs to yellow and grey at the same time. It will be yellow. The one function point is charging point. Any of the previous four points can be a charging point and a charging point can also be independent from those four points. It is just a difference between local charging and remote charging, which is mentioned in the previous page.

Drop-off a Vehicle

Users can drop off their vehicles in these two types of yellow parking spaces. One is with MoD Smart Kiosk and the other is without. Users can follow the green light or red light, which are showing on the side displays of Smart Curbstones.

Pick-up a Vehicle

Users can pick up their vehicles in this type of yellow parking space, the one with MoD Smart Kiosk on the side.

System Internal Use Only

The grade parking space is for the MoD station internal use only, including charging and storage. It is not designed to have any interaction with users.

Choose Vehicle at Kiosk

Vehicle Pick-up

User Drop-off

Manual Driving Mode

Autonomous Driving Mode

Figure 87. The diagram graphic indexes
Figure 88. The diagram shows how these graphic indexes are applied on a station layout diagram
**Vehicle Drop-off Point = User Drop-off Point**

**Type 1: Local Storage Charging**

At the Point A

User A drives a MoD vehicle manually to the station at Point A.
User A drops off the MoD vehicle.
User A exits the MoD vehicle and leaves the station.
The MoD vehicle starts charging at the station.
Vehicle Drop-off Point = User Drop-off Point

Type 1: Local Storage Charging

Type 1-2

At the Point A
The MoD vehicle finishes charging at the station.
User B arrives at the station and chooses a MoD vehicle at the MoD Smart Kiosk.
User B picks up the MoD vehicle.
User B drives the MoD vehicle manually away from the station at Point A.
Type 2-1

At the Point A
User A drives a MoD vehicle manually to the station at Point A.
User A drops off the MoD vehicle.
User A exits the MoD vehicle and leaves the station.
The MoD vehicle drives itself autonomously to the vehicle charging location at Point X.

At the Point X
The MoD vehicle arrives at the vehicle charging location at Point X.
The MoD vehicle starts charging at the vehicle charging location.
Type 2-2

At the Point X
The MoD vehicle finishes charging at the vehicle charging location. The MoD vehicle drives itself autonomously to the station at Point A.

At the Point A
The MoD vehicle arrives at the station at Point A. User B arrives at the station and chooses a MoD vehicle at the MoD Smart Kiosk. User B picks up the MoD vehicle. User B drives the MoD vehicle manually away from the station at Point A.
**Vehicle Drop-off Point = User Drop-off Point**

Type 3: One Way Remote Storage Charging

**At the Point A**
User A drives a MoD vehicle manually to the station at Point A.
User A drops off the MoD vehicle.
User A exits the MoD vehicle and leaves the station.
The MoD vehicle drives itself autonomously to the vehicle charging location at Point X.

**At the Point X**
The MoD vehicle arrives at the vehicle charging location at Point X.
The MoD vehicle starts charging at the vehicle charging location.
Type 3-2

At the Point X
The MoD vehicle finishes charging at the vehicle charging location. The MoD vehicle drives itself autonomously to the station at Point B.

At the Point B
The MoD vehicle arrives at the station at Point B. User B arrives at the station and chooses a MoD vehicle at the MoD Smart Kiosk. User B picks up the MoD vehicle. User B drives the MoD vehicle manually away from the station at Point A.
Vehicle Drop-off Point ≠ User Drop-off Point

Type 4: Local Storage Charging

Figure 101.

At the Point X
User A drives a MoD vehicle manually to the station at Point X.
User A stops at the station and drops off the MoD vehicle.
User A passes the control of the MoD vehicle to the MoD system.
**Type 4-2**

**At the Point X**
The MoD vehicle drives itself autonomously to the vehicle charging location at Point A.

**At the Point A**
The MoD vehicle arrives at the vehicle charging location at Point A. User A exits the MoD vehicle and leaves the station. The MoD vehicle starts charging at the station.

---

**Vehicle Drop-off Point ≠ User Drop-off Point**

**Type 4: Local Storage Charging**

![Diagram](image)

**Figure 103.**

**Figure 104.**
Type 4-3

At the Point A
The MoD vehicle finishes charging at the station.
User B arrives at the station and chooses a MoD vehicle at the MoD Smart Kiosk.
User B picks up and enters the MoD vehicle.
The MoD vehicle drives itself autonomously to the station at Point Y.

At the Point Y
The MoD vehicle arrives at the station at Point Y.
The MoD vehicle stops at the station.
**Vehicle Drop-off Point ≠ User Drop-off Point**

**Type 4: Local Storage Charging**

<table>
<thead>
<tr>
<th>Vehicle Drop-off Point</th>
<th>User Drop-off Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

Local Storage

**Vehicle Vehicle**

**Enter Phase / Storage Phase / Exit Phase**

**Type 4-4**

**At the Point Y**

User B takes over the control of the MoD vehicle.
User B drives the MoD vehicle manually away from the station at Point Y.
**Vehicle Drop-off Point ≠ User Drop-off Point**

**Type 5: Two Way Remote Storage Charging**

**At the Point X**

User A drives a MoD vehicle manually to the station at Point X. User A stops at the station and drops off the MoD vehicle. User A passes the control of the MoD vehicle to the MoD system.
**Vehicle Drop-off Point ≠ User Drop-off Point**

**Type 5: Two Way Remote Storage Charging**

At the Point X
The MoD vehicle drives itself autonomously to the vehicle charging location at Point A.

At the Point A
The MoD vehicle arrives at the vehicle charging location at Point A.
User A exits the MoD vehicle and leaves the station.
The MoD vehicle drives itself autonomously to the vehicle charging location at Point Y.

At the Point Y
The MoD vehicle arrives at the vehicle charging location at Point Y.
The MoD vehicle starts charging at the vehicle charging location.

*Figure 111.*
Type 5-3

At the Point Y
The MoD vehicle finishes charging at the vehicle charging location. The MoD vehicle drives itself autonomously to the station at Point A.

At the Point A
The MoD vehicle arrives at the station at Point A. User B arrives at the station and chooses a MoD vehicle at the MoD Smart Kiosk. User B picks up and enters the MoD vehicle. The MoD vehicle drives itself autonomously to the station at Point Z.

At the Point Z
The MoD vehicle arrives at the station at Point Z. The MoD vehicle stops at the station.
Vehicle Drop-off Point ≠ User Drop-off Point

**Type 5: Two Way Remote Storage Charging**

- **Remote Storage**

<table>
<thead>
<tr>
<th>Vehicle Drop-off Point</th>
<th>User Drop-off Point</th>
<th>Enter Phase</th>
<th>Storage Phase</th>
<th>Exit Phase</th>
<th>Vehicle Pick-up Point</th>
<th>Vehicle Take-off Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 115.**

**Figure 116.**

**Type 5-4**

**At the Point Z**

User B takes over the control of the MoD vehicle.
User B drives the MoD vehicle manually away from the station at Point Z.
Vehicle Drop-off Point ≠ User Drop-off Point

Type 6: One Way Remote Storage Charging

<table>
<thead>
<tr>
<th>Vehicle Drop-off Point</th>
<th>User Drop-off Point</th>
<th>Enter Phase</th>
<th>Storage Phase</th>
<th>Exit Phase</th>
<th>Vehicle Take-off Point</th>
</tr>
</thead>
</table>

![Diagram of Vehicle Drop-off Point ≠ User Drop-off Point]

**Type 6-1**

At the Point X
User A drives a MoD vehicle manually to the station at Point X.
User A stops at the station and drops off the MoD vehicle.
User A passes the control of the MoD vehicle to the MoD system.
Vehicle Drop-off Point ≠ User Drop-off Point

Type 6: One Way Remote Storage Charging

Figure 119.

Vehicle Drop-off Point ≠ User Drop-off Point

Figure 120.

Type 6-2

At the Point X
The MoD vehicle drives itself autonomously to the vehicle charging location at Point A.

At the Point A
The MoD vehicle arrives at the vehicle charging location at Point A. User A exits the MoD vehicle and leaves the station. The MoD vehicle drives itself autonomously to the vehicle charging location at Point Y.

At the Point Y
The MoD vehicle arrives at the vehicle charging location at Point Y. The MoD vehicle starts charging at the vehicle charging location.
Vehicle Drop-off Point ≠ User Drop-off Point

Type 6: One Way Remote Storage Charging

The MoD vehicle finishes charging at the vehicle charging location. The MoD vehicle drives itself autonomously to the station at Point B.

At the Point B
The MoD vehicle arrives at the station at Point B. User B arrives at the station and chooses a MoD vehicle at the MoD Smart Kiosk. User B picks up and enters the MoD vehicle. The MoD vehicle drives itself autonomously to the station at Point Z.

At the Point Z
The MoD vehicle arrives at the station at Point Z. The MoD vehicle stops at the station.
Vehicle Drop-off Point ≠ User Drop-off Point
Type 6: One Way Remote Storage Charging

Figure 123.

<table>
<thead>
<tr>
<th>Vehicle Drop-off Point</th>
<th>User Drop-off Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Storage</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>User</th>
<th>Enter Phase</th>
<th>Storage Phase</th>
<th>Exit Phase</th>
<th>Vehicle</th>
<th>Take-off Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop-off</td>
<td>Drop-off</td>
<td></td>
<td></td>
<td></td>
<td>Pick-up</td>
<td></td>
</tr>
<tr>
<td>Point</td>
<td>Point</td>
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<td></td>
<td>Point</td>
<td></td>
</tr>
</tbody>
</table>

Type 6-4

At the Point Z
User B takes over the control of the MoD vehicle.
User B drives the MoD vehicle manually away from the station at Point Z.
4.4 The System Stage: The Spatial Solution for Mobility-on-Demand Stations in Taipei City

4.4.1 The System Stage: Introduction

The system stage is about handling the MoD vehicles inside the MoD stations, between the vehicles have been dropped off by users and until the next users pick them up. After the MoD users returned their vehicles to a MoD station, these vehicles will need to be recharged in order to maintain enough power levels for the next trips. The interface stage illustrates the interaction between users and the MoD stations. The system stage demonstrates the interaction between the MoD vehicles and the MoD stations and its internal working mechanisms with the MoD vehicle. However, these interactions do not have any human involvement. Because the vehicles have the autonomous driving ability, the MoD system can move any vehicle freely without human supervision. The system stage describes how the MoD system handles, the arrival, the charging, and the departing vehicles internally and autonomously.

The system stage can be divided into three phases; the enter phase, the storage phase, and the exit phase. Since the MoD vehicles have the autonomous driving capability, they will not necessarily stay in the same parking space where the users left them at, the MoD station will move these vehicles around automatically based on the their charging levels and the supply and demands of the vehicles. These three phases are used to describe the MoD vehicle movement inside a station.

The enter phase means the process from a user entering the MoD station and he or she leaving MoD vehicles at the available parking spaces to the vehicles reach to their final charging locations. The storage phase means the locations and process where the MoD vehicles will stay and begin charging themselves. The exit phase means the process of MoD vehicles moving out from the storage phase to locations for next users to pick up. These phases will be elaborated after two pages.

This chapter use four urban components to define the station spatial layout; they are street, under-street, building, and block. The system stage provides different enter, storage, and exit phases user scenarios and station layouts for the Mobility-on-Demand system in different urban components.
The Four Urban Components Defining the Station Spatial Layout

The system stage can be divided into three phases. Each phase is determined by the movement of the MoD vehicle when it is moving autonomously inside a MoD station. When a MoD vehicle is autonomously moving toward the charging point, this is the enter phase. When a MoD vehicle is charging at the charging point, this is the storage phase. When a MoD vehicle is autonomously moving toward the vehicle pick up point, this is the exit phase. The spatial layout of each phases is determined by the spatial characteristics of the location where the MoD vehicle is at during that phase. These spatial characteristics can be categorized into four urban components.

**Street Level**
Street level means, within a MoD station, the MoD vehicle is moving, parking, or charging at the street level. The street level is an outdoor or semi-outdoor space. Outdoor means the road surface and the sidewalk. Semi-outdoor means the street arcade or any place is covered by a roof.

*Figure 126.*

**Building level**
Building level means, within the MoD station, the MoD vehicle is moving, parking, or charging inside a building or the level right beneath it, but not entering the space under the building. The building level is mostly an indoor space, but could be outdoor or semi-outdoor space too. Indoor means inside the building. Outdoor means on top of the building. Semi-outdoor means on the terrace and covered by a roof.

*Figure 128.*

**Under-Street level**
Under-street level means, within the MoD station, the MoD vehicle is moving, parking, or charging at the level right beneath the street level, but not entering the building property line. The under-street level is an indoor space.

*Figure 127.*

**Block level**
Block level means, within the MoD station, the MoD vehicle is moving, parking, or charging at the level which is under both the street and building. The block level is an indoor space.

*Figure 129.*
### Pick-up/Drop-off Points on Streets (Outdoor/Semi-Outdoor)

<table>
<thead>
<tr>
<th>Arriving at MoD Station</th>
<th>Drop-off Point</th>
<th>MoD Station</th>
<th>Enter (Charging / Non-Charging)</th>
<th>Storage (Charging)</th>
<th>Exit (Charging / Non-Charging)</th>
<th>MoD Station</th>
<th>Pick-up Point</th>
<th>Departing from MoD Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street</td>
<td>Street</td>
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</tr>
</tbody>
</table>

### Pick-up/Drop-off Points in Under-streets, Buildings, and Blocks (Mostly Indoor)

<table>
<thead>
<tr>
<th>Street</th>
<th>Under-street</th>
<th>Under-street</th>
<th>Under-street</th>
<th>Under-street</th>
<th>Under-street</th>
<th>Under-street</th>
<th>Under-street</th>
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<th>Street</th>
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</thead>
<tbody>
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<td>Street</td>
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</tr>
<tr>
<td>Street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Building</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Street</td>
</tr>
<tr>
<td>Street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Block</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Under-street</td>
<td>Street</td>
</tr>
<tr>
<td>Street</td>
<td>Building</td>
<td>Building</td>
<td>Building</td>
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<td>Street</td>
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<td>Block</td>
<td>Building</td>
<td>Block</td>
<td>Block</td>
<td>Block</td>
<td>Block</td>
<td>Street</td>
</tr>
</tbody>
</table>
MoD System Spatial Sequence from Drop-off Point to Pick-up Point

MoD stations can be categorized into two types. The first type is MoD station on streets. The second type is MoD station under a street, inside a building, or beneath an urban block. The first type, MoD station on street, is the most important type, which the thesis intend to discuss. Because the thesis want to explore, when the city has a MoD system, what kind of impact MoD system will have on urban space. This type, users will pick up and drop off vehicles on streets. MoD station will also operate on street level. Therefore, this type of stations will have crucial influence on streetscapes.

The second type, MoD station under a street, inside a building, or beneath an urban block, will not be so important, regarding its influence on urban environment. Because MoD station is not locating on street, in this type, the driving experience will be very similar to the experience people have right now. It is just like people drive their cars inside a shopping mall and park their cars in the basement. The only difference is, instead of finding a parking space in the basement, people find MoD stations. The only impact this type has on urban environment, is the entrance and exit locations. Because it is the only interface which connects urban environment to indoor space. Therefore, the thesis will not discuss too much about this type of station.

The figure on left illustrates the spatial sequence of each step, from users drive MoD vehicles approaching stations, to users drive MoD vehicles leaving stations. Each color block and text represents the spatial characteristics of the MoD vehicle is situated in during that step. The figure lists all the possible spatial sequence during this process.
4.4.2 The Vehicle Flow Types and Station Spatial Layout Types of the System

The system has three phases; enter phase, storage phase, and exit phase. Any type of the system needs to have these components in order to make it work. In each phase, the way how vehicle flows in a station and the station spatial layout may be different. Each phase will have its vehicle flow types and station spatial layout types. The following descriptions are the three different types of vehicle flows and four different types of spatial layout of the system.

The System Types I, II, III

Based on the four urban components and the sequence of the enter, storage, exit phases, the system can be divided into three different types, System Type I, II, and III. Each type will have three phases and each phase will have its vehicle flow types and station spatial layout type.

<table>
<thead>
<tr>
<th>System</th>
<th>Enter</th>
<th>Storage</th>
<th>Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop-off/Pick-up Point on Streets (Outdoor/Semi-outdoor)</td>
<td>Flow Type Space Type</td>
<td>Flow Type Space Type</td>
<td>Flow Type Space Type</td>
</tr>
<tr>
<td>A 1 + A 1 + A 1 = System Type I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop-off/Pick-up Point in Under-street, Buildings, Blocks (Mostly Indoor)</td>
<td>Flow Type Space Type</td>
<td>Flow Type Space Type</td>
<td>Flow Type Space Type</td>
</tr>
<tr>
<td>A 2 + B 3 + A 2 = System Type II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A 4 + B 3 + C 4 = System Type III</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The Flow Type A</th>
<th>The Flow Type B</th>
<th>The Flow Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>The flow type A shows how vehicle flows, when they on the street level, during the enter, storage, and exit phases.</td>
<td>The flow type B shows how vehicle flows when they are in the under-street, building, block levels, during the storage phase.</td>
<td>The flow type C shows how vehicle flows when they are in the under-street, building, block levels, during the storage to exit phases.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The Space Type 1</th>
<th>The Space Type 2</th>
<th>The Space Type 3</th>
<th>The Space Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The space type 1 shows the system is always operating on the street level, an outdoor or semi-outdoor environment, through the enter, storage to exit phases.</td>
<td>The space type 2 shows the system is operating from the street level to under-street, building, block levels, from an outdoor or semi-outdoor environment to indoor environment, during the enter phase to storage phase or the storage phase to exit phase.</td>
<td>The space type 3 shows that the system is operating from under-street, building, block levels to other under-street, building, block levels, from an indoor environment to another indoor environment, during the storage phase.</td>
<td>The space type 4 shows that the system is operating from under-street, building, block levels to other under-street, building, block levels, during the enter phase to storage phase or the storage phase to exit phase.</td>
</tr>
</tbody>
</table>
**MoD Vehicle Flow Types during the System Stage**

During the system stage, MoD vehicle will drive themselves autonomously to charging location and recharge themselves. There are four types of MoD vehicle flow during this stage. They are autonomous moving, standstill charging, autonomous switch charging, and autonomous progressive charging. These four different vehicle movement and charging types will have its own strategy to deal with rapid charging space and standard charging space.

**Autonomous Moving**

MoD vehicles move autonomously from point A to point B without charging.

**Standstill Charging**

After MoD vehicles parked in the charging spaces, these vehicles will remand in the same charging space until power reaches a certain level. The vehicles will not move around during charging.
Autonomous Switching Charging
The system will decide which vehicle to park in the rapid charging space first, based on power levels of each car. The car with the lowest power level can use the rapid charging space first. When the power level of this car reaches a certain level, which is enough for an average urban trip, the system will switch this vehicle with another low power level vehicle. The system will constantly switch vehicles, in order to distribute power evenly among its fleet.

Autonomous Progressive Charging
A linear charging formation, one MoD vehicle follows another. Vehicles are moving slowly and charging at the same time. Autonomous progressive charging does not differentiate power levels of each car. It charges the MoD vehicle on the first-come first-served basis. Every vehicle will have a chance to use the rapid charging space.
4.4.3 The Flow Type A

**Autonomous Switching Charging on Streets**

**Autonomous Progressive Charging on Streets**

**Standstill Charging on Streets**
4.4.4 The Flow-Space Type: A-1 (Enter->Storage->Exit) = The System Type I

The flow-space type A-1 means the MoD vehicles are moving autonomously as the vehicle flow type A within the station spatial layout type 1. The A-1 type is representing three phases, the enter phase, the storage phase, and the exit phase, of the system stage. It means that during the enter and the exit phases, the MoD vehicles are moving at the street level, and during the storage phases, the MoD vehicles is moving and charging also at the street level. The street level represents an outdoor or semi-outdoor environment.

The System Type I (Enter/Storage/Exit Phases)

The three phases of the system type I are all the A-1 type. It means that after the users returned their vehicles at the station on the street, the vehicles are still moving and charging at the station on the street before they get pick-up at the station on the street again. This chapter shows the different variations of the system type I in different urban environment. They are eight different types of streets in Taipei City, based on the presence of sidewalk and arcade. The street can also be divided into main streets and communal streets. Most of the communal streets in Taipei does not have sidewalk and the widths vary from 4 m to 10 m wide. The chart on the right covers all the urban component scenarios in Taipei City, taking into consideration of the four urban components defining the station spatial layout, the communal and main streets, and streets with or without sidewalk and arcade. The numbers in the chart represents the different types of station layouts and user scenarios of the system type I, under that particular urban condition. These types are illustrated in the following pages. Because the street level only covers the outdoor and semi-outdoor space, the system type I typologies are only showing under these two categories.

The system type I is a very important typology, because it demonstrates the possible station layouts in communal street. The communal streets share 60% of the total street area of Taipei City. Therefore, the system type I can provide station layout solutions, at least, to 60% of the streets in Taipei City.
<table>
<thead>
<tr>
<th>Enter / Storage / Exit Phase Location</th>
<th>Parking Storage Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outdoor</td>
</tr>
<tr>
<td>4m Communal Street</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>6m Communal Street</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>8m Communal Street</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>10m Communal Street</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Main Street</td>
<td>1, 2, 7</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>6m Communal Street</td>
<td>8, 9, 10</td>
</tr>
<tr>
<td>8m Communal Street</td>
<td>8, 9, 10</td>
</tr>
<tr>
<td>10m Communal Street</td>
<td>8, 9, 10</td>
</tr>
<tr>
<td>Main Street</td>
<td>8, 9, 14, 15</td>
</tr>
</tbody>
</table>

**Table 2.** The urban condition categories were generated from urban interface types in P.200
Illustration Site Typology: Street without arcade without sidewalk, 4m communal street

Possible Sites:
- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main

- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m
  - w/ Arcade w/ Sidewalk 1.5~3.5m
  - w/ Arcade w/ Sidewalk >3.5m

Figure 141.
A-1 Type 2:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging
Possible Sites:

- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m 6m 8m 10m Main
- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction

Figure 142.
Illustration Site Typology: Street without arcade without sidewalk, 4m communal street

Figure 143.

A-1 Type 3:

- **Street Types:** Communal / Main Street
- **Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode:** Manual / Autonomous Driving
- **Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed:** Standard / Rapid Charging
- **Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:

- **Street w/o Arcade w/o Sidewalk**
  - 4m 6m 8m 10m Main
- **Street w/ Arcade w/o Sidewalk**
  - w/ Arcade w/ Sidewalk <1.5m
  - 6m 8m 10m Main
- **Sidewalk Divides Two Directions**
  - Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade without sidewalk, 4m communal street

Figure 144.

A-1 Type 4:
Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
Street w/o Arcade w/o Sidewalk 4m 6m 8m 10m Main
w/o Arcade w/ Sidewalk <1.5m 6m 8m 10m Main
Street w/ Arcade w/o Sidewalk w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade without sidewalk, 4m communal street

A-1 Type 5:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:

- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
  - w/o Arcade w/ Sidewalk <1.5m 6m 8m 10m Main

- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m

- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction

Figure 145.
Illustration Site Typology: Street without arcade without sidewalk, 4m communal street

Vehicle Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging
Possible Sites:
- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - 6m 8m 10m Main
- Sidewalk Divides Two Directions

Figure 146.
Illustration Site Typology: Street without arcade without sidewalk, 12m main street

A-1 Type 7:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
Street w/o Arcade w/o Sidewalk  w/o Arcade w/ Sidewalk <1.5m  w/o Arcade w/ Sidewalk 1.5~3.5m  w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main 6m 8m 10m Main
Street w/ Arcade w/o Sidewalk w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions Sidewalk Divides Same Direction
### Illustration Site Typology: Street without arcade with sidewalk < 1.5M, 6m communal street

**A-1 Type 8:**

**Street Types:** Communal / Main Street

**Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage

**Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off

**Vehicle Driving Mode:** Manual / Autonomous Driving

**Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging

**Vehicle Charging Speed:** Standard / Rapid Charging

**Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

**Possible Sites:**

<table>
<thead>
<tr>
<th>Street Type</th>
<th>Parking Area Size</th>
<th>Vehicle/Location</th>
<th>Driving Mode</th>
<th>Charging Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>w/o Arcade w/ Sidewalk &lt;1.5m</td>
<td>w/o Arcade w/ Sidewalk 1.5~3.5m</td>
<td>w/o Arcade w/ Sidewalk &gt;3.5m</td>
<td></td>
</tr>
<tr>
<td>4m 6m 8m 10m Main</td>
<td>6m 8m 10m Main</td>
<td>6m 8m 10m Main</td>
<td>6m 8m 10m Main</td>
<td></td>
</tr>
<tr>
<td>Street w/ Arcade w/o Sidewalk</td>
<td>w/ Arcade w/ Sidewalk &lt;1.5m</td>
<td>w/ Arcade w/ Sidewalk 1.5~3.5m</td>
<td>w/ Arcade w/ Sidewalk &gt;3.5m</td>
<td></td>
</tr>
<tr>
<td>Sidewalk Divides Two Directions</td>
<td>Sidewalk Divides Same Direction</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 149. Illustration Site Typology: Street without arcade with sidewalk < 1.5M, 6m communal street

A-1 Type 9:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
Street w/o Arcade w/o Sidewalk w/o Arcade w/ Sidewalk <1.5m w/o Arcade w/ Sidewalk 1.5~3.5m w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main 6m 8m 10m Main
Street w/ Arcade w/o Sidewalk w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade with sidewalk < 1.5M, 6m communal street

A-1 Type 10:

- **Street Types:** Communal / Main Street
- **Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode:** Manual / Autonomous Driving
- **Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed:** Standard / Rapid Charging
- **Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

**Possible Sites:**

- Street w/o Arcade w/o Sidewalk 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk 6m 8m 10m Main
- Sidewalk w/o Arcade w/ Sidewalk 1.5~3.5m
- Sidewalk w/ Arcade w/ Sidewalk >3.5m

Figure 150.
Illustration Site Typology: Street without arcade with sidewalk < 1.5M, 6m communal street

A-1 Type 11:
- **Street Types:** Communal / Main Street
- **Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode:** Manual / Autonomous Driving
- **Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed:** Standard / Rapid Charging
- **Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m
  - 6m 8m 10m Main
- Sidewalk w/o Arcade w/ Sidewalk
  - w/ Arcade w/ Sidewalk 1.5~3.5m
  - w/ Arcade w/ Sidewalk >3.5m
- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade with sidewalk < 1.5M, 6m communal street

A-1 Type 12:

- **Street Types**: Communal / Main Street
- **Station Spatial Characteristic**: Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point**: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode**: Manual / Autonomous Driving
- **Vehicle Charging Location**: Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed**: Standard / Rapid Charging
- **Vehicle Charging Mode**: Standstill / Autonomous Switching / Autonomous Progressing Charging

**Possible Sites:**

- Street w/o Arcade w/o Sidewalk 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk 6m 8m 10m Main
- Street w/o Arcade w/ Sidewalk w/o Arcade w/ Sidewalk <1.5m w/o Arcade w/ Sidewalk 1.5~3.5m w/o Arcade w/ Sidewalk >3.5m
- Street w/ Arcade w/ Sidewalk w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m
- Sidewalk Divides Two Directions Sidewalk Divides Same Direction

Figure 152.
Illustration Site Typology: Street without arcade with sidewalk < 1.5M, 6m communal street

A-1 Type 13:

- **Street Types:** Communal / Main Street
- **Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off
- **Vehicle Driving Mode:** Manual / Autonomous Driving
- **Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed:** Standard / Rapid Charging
- **Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

**Possible Sites:**

- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m 6m 8m 10m Main
- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction
- w/o Arcade w/ Sidewalk 1.5~3.5m
- w/ Arcade w/ Sidewalk >3.5m
Illustration Site Typology: Street without arcade with sidewalk < 1.5m, 12m main street

Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging
Possible Sites:
- Street w/o Arcade w/o Sidewalk
- w/o Arcade w/ Sidewalk <1.5m
- w/o Arcade w/ Sidewalk 1.5~3.5m
- w/o Arcade w/ Sidewalk >3.5m
- 4m 6m 8m 10m Main
- 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
- w/ Arcade w/ Sidewalk <1.5m
- w/ Arcade w/ Sidewalk 1.5~3.5m
- w/ Arcade w/ Sidewalk >3.5m
- Sidewalk Divides Two Directions
- Sidewalk Divides Same Direction

Figure 154.
Illustration Site Typology: Street without arcade with sidewalk < 1.5m, 12m main street

A-1 Type 15:

- **Street Types:** Communal / Main Street
- **Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode:** Manual / Autonomous Driving
- **Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed:** Standard / Rapid Charging
- **Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

**Possible Sites:**

- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m
  - w/ Arcade w/ Sidewalk 1.5~3.5m
  - w/ Arcade w/ Sidewalk >3.5m
- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade with sidewalk 1.5~3.5m, 12m main street

A-1 Type 16:

- Street Types: Communal / Main Street
- Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
- Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- Vehicle Driving Mode: Manual / Autonomous Driving
- Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
- Vehicle Charging Speed: Standard / Rapid Charging
- Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
- Street w/o Arcade w/o Sidewalk
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m
  - w/ Arcade w/ Sidewalk 1.5~3.5m
  - w/ Arcade w/ Sidewalk >3.5m
- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction

Figure 156.
Illustration Site Typology: Street without arcade with sidewalk 1.5~3.5m, 12m main street

A-1 Type 17:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging
Possible Sites:

Street w/o Arcade w/o Sidewalk  w/o Arcade w/ Sidewalk <1.5m  w/o Arcade w/ Sidewalk 1.5~3.5m  w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main 6m 8m 10m Main
Street w/ Arcade w/o Sidewalk  w/ Arcade w/ Sidewalk <1.5m  w/ Arcade w/ Sidewalk 1.5~3.5m  w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions  Sidewalk Divides Same Direction

Figure 157.
Illustration Site Typology: Street without arcade with sidewalk >3.5m, 18m main street

Figure 158.

A-1 Type 18:
Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging
Possible Sites:
Street w/o Arcade w/o Sidewalk w/o Arcade w/ Sidewalk <1.5m w/o Arcade w/ Sidewalk 1.5~3.5m w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main 6m 8m 10m Main
Street w/ Arcade w/o Sidewalk w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions Sidewalk Divides Same Direction
A-1 Type 19:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:

Street w/o Arcade w/o Sidewalk w/o Arcade w/ Sidewalk <1.5m w/o Arcade w/ Sidewalk 1.5~3.5m w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main 6m 8m 10m Main
Street w/ Arcade w/o Sidewalk w/ Arcade w/ Sidewalk <1.5m w/ Arcade w/ Sidewalk 1.5~3.5m w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions Sidewalk Divides Same Direction
4.4.5 The Flow-Space Type: A-2
(Enter->Storage, Storage->Exit)

The flow-space type A-2 means the MoD vehicles are moving autonomously as the vehicle flow type A within the station spatial layout type 2. The A-2 type is representing two phases, the enter phase and the exit phase, of the system stage. The A-2 type suggests that during the enter phase, the MoD vehicles are moving from the street level to other levels, such as under-street level, building level, and block level; and during the exit phase, the MoD vehicles are moving out from these three levels to street level. The A-2 type represents the MoD vehicles are moving from an outdoor or semi-outdoor environment to an indoor environment or vice versa.

The System Type II (Enter/Exit Phases)

The enter phase and the exit phase, which the A-2 type is representing, are the enter phase and the exit phase of the system type II. It means that after the users returned their vehicles at the station on the street, the vehicles will drive themselves autonomously to the charging locations, which are located in either under-street, building, or block levels, most of these levels are indoor environment. Or after the MoD vehicles finished charging, the vehicles will drive themselves autonomously to the MOD station on the street level for the next users to pick up. The chart on the right covers all the urban conditions in Taipei City. The numbers in the chart represents the different station layouts and user scenarios of the system type II, during the enter phase and the exit phase, in that particular urban condition. These types are illustrated in the following pages. The A-2 type typologies are only showing under the indoor category, because the vehicles are either going to an indoor space or coming from an indoor space.
<table>
<thead>
<tr>
<th>Enter / Exit Phase Location</th>
<th>Parking Storage Location</th>
<th>Outdoor</th>
<th>Semi</th>
<th>Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>4m Communal Street</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6m Communal Street</td>
<td></td>
<td></td>
<td>1, 2, 3, 4</td>
<td></td>
</tr>
<tr>
<td>8m Communal Street</td>
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<td></td>
<td>1, 2, 3, 4</td>
<td></td>
</tr>
<tr>
<td>10m Communal Street</td>
<td></td>
<td></td>
<td>1, 2, 3, 4</td>
<td></td>
</tr>
<tr>
<td>Main Street</td>
<td></td>
<td></td>
<td>1, 2, 3, 4</td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>Street w/o Arcade w Sidewalk 1.5m-3.5m</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk &gt;3.5m</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk &lt;1.5m</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade w Sidewalk 1.5m-3.5m</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade w Sidewalk &gt;3.5m</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade w Sidewalk &lt;1.5m</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade in the middle of different direction</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street w/o Arcade in the middle of same direction</td>
<td>Main Street</td>
<td>5, 6, 7, 8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 3.*
Illustration Site Typology: Street without arcade without sidewalk, 6m communal street

A-2 Type 1:

- **Street Types**: Communal / Main Street
- **Station Spatial Characteristic**: Outdoor / Semi-Outdoor / Indoor / Storage
- **Vehicle/User Drop-off Point**: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode**: Manual / Autonomous Driving
- **Vehicle Charging Location**: Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed**: Standard / Rapid Charging
- **Vehicle Charging Mode**: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:

- **Street w/o Arcade w/o Sidewalk**: w/o Arcade w/ Sidewalk <1.5m / w/o Arcade w/ Sidewalk 1.5~3.5m / w/o Arcade w/ Sidewalk >3.5m
- **4m 6m 8m 10m Main**: 6m 8m 10m Main
- **Street w/ Arcade w/o Sidewalk**: w/ Arcade w/ Sidewalk <1.5m / w/ Arcade w/ Sidewalk 1.5~3.5m / w/ Arcade w/ Sidewalk >3.5m
- **Sidewalk Divides Two Directions**: Sidewalk Divides Same Direction

Figure 162.
Illustration Site Typology: Street without arcade without sidewalk, 6m communal street

A-2 Type 2:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:

Street w/o Arcade w/o Sidewalk  w/o Arcade w/ Sidewalk <1.5m  w/o Arcade w/ Sidewalk 1.5~3.5m  w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main  6m 8m 10m Main
Street w/ Arcade w/o Sidewalk  w/ Arcade w/ Sidewalk <1.5m  w/ Arcade w/ Sidewalk 1.5~3.5m  w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions  Sidewalk Divides Same Direction

Figure 163.
A-2 Type 3:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:

Street w/o Arcade w/o Sidewalk  w/o Arcade w/ Sidewalk <1.5m  w/o Arcade w/ Sidewalk 1.5~3.5m  w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main  6m 8m 10m Main
Street w/ Arcade w/o Sidewalk  w/ Arcade w/ Sidewalk <1.5m  w/ Arcade w/ Sidewalk 1.5~3.5m  w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions  Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade without sidewalk, 6m communal street

Figure 165.

A-2 Type 4:

- **Street Types**: Communal / Main Street
- **Station Spatial Characteristic**: Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point**: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode**: Manual / Autonomous Driving
- **Vehicle Charging Location**: Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed**: Standard / Rapid Charging
- **Vehicle Charging Mode**: Standstill / Autonomous Switching / Autonomous Progressing Charging

- **Possible Sites**:
  - Street w/o Arcade w/o Sidewalk: 4m 6m 8m 10m Main
  - w/o Arcade w/ Sidewalk: 1m 2m 3m 4m
  - w/o Arcade w/ Sidewalk: 1.5m 2.5m 3.5m 4m
  - w/o Arcade w/ Sidewalk: 5m 6m 7m 8m
  - w/o Arcade w/ Sidewalk: 1.5~3.5m
  - w/o Arcade w/ Sidewalk: >3.5m

- **Sidewalk Divides**:
  - Two Directions
  - Same Direction
Illustration Site Typology: Street without arcade with sidewalk, 6m communal street

Possible Sites:
- Street w/o Arcade w/o Sidewalk
- w/o Arcade w/ Sidewalk <1.5m
- w/o Arcade w/ Sidewalk 1.5~3.5m
- w/o Arcade w/ Sidewalk >3.5m
- 4m 6m 8m 10m Main
- 6m 8m 10m Main

Street w/ Arcade w/o Sidewalk
- w/ Arcade w/ Sidewalk <1.5m
- w/ Arcade w/ Sidewalk 1.5~3.5m
- w/ Arcade w/ Sidewalk >3.5m

Sidewalk Divides
- Two Directions
- Sidewalk Divides Same Direction

A-2 Type 5:
- Street Types: Communal / Main Street
- Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
- Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- Vehicle Driving Mode: Manual / Autonomous Driving
- Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
- Vehicle Charging Speed: Standard / Rapid Charging
- Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Figure 166.
Illustration Site Typology: Street without arcade with sidewalk, 6m communal street

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
- Street w/o Arcade w/o Sidewalk
- w/o Arcade w/ Sidewalk <1.5m
- w/o Arcade w/ Sidewalk 1.5~3.5m
- w/o Arcade w/ Sidewalk >3.5m
- 4m 6m 8m 10m Main
- 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
- w/ Arcade w/ Sidewalk <1.5m
- w/ Arcade w/ Sidewalk 1.5~3.5m
- w/ Arcade w/ Sidewalk >3.5m
- Sidewalk Divides Two Directions
- Sidewalk Divides Same Direction
Illustration Site Typology: Street without arcade without sidewalk, 6m communal street

A-2 Type 7:

- **Street Types:** Communal / Main Street
- **Station Spatial Characteristic:** Outdoor / Semi-Outdoor / Indoor Storage
- **Vehicle/User Drop-off Point:** Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
- **Vehicle Driving Mode:** Manual / Autonomous Driving
- **Vehicle Charging Location:** Local / One Way Remote / Two-Way Remote Charging
- **Vehicle Charging Speed:** Standard / Rapid Charging
- **Vehicle Charging Mode:** Standstill / Autonomous Switching / Autonomous Progressing Charging

**Possible Sites:**

- Street w/o Arcade w/o Sidewalk
  - w/o Arcade w/ Sidewalk <1.5m
  - w/o Arcade w/ Sidewalk 1.5~3.5m
  - w/o Arcade w/ Sidewalk >3.5m
  - 4m 6m 8m 10m Main
- Street w/ Arcade w/o Sidewalk
  - w/ Arcade w/ Sidewalk <1.5m
  - w/ Arcade w/ Sidewalk 1.5~3.5m
  - w/ Arcade w/ Sidewalk >3.5m
  - 6m 8m 10m Main
- Sidewalk Divides Two Directions
  - Sidewalk Divides Same Direction

**Figure 168.**
A-2 Type 8:

Street Types: Communal / Main Street
Station Spatial Characteristic: Outdoor / Semi-Outdoor / Indoor Storage
Vehicle/User Drop-off Point: Vehicle Drop-off = User Drop-off / Vehicle Drop-off ≠ User Drop-off Point
Vehicle Driving Mode: Manual / Autonomous Driving
Vehicle Charging Location: Local / One Way Remote / Two-Way Remote Charging
Vehicle Charging Speed: Standard / Rapid Charging
Vehicle Charging Mode: Standstill / Autonomous Switching / Autonomous Progressing Charging

Possible Sites:
Street w/o Arcade w/o Sidewalk  
w/o Arcade w/ Sidewalk <1.5m  
w/o Arcade w/ Sidewalk 1.5~3.5m  
w/o Arcade w/ Sidewalk >3.5m
4m 6m 8m 10m Main  
6m 8m 10m Main
Street w/ Arcade w/o Sidewalk  
w/ Arcade w/ Sidewalk <1.5m  
w/ Arcade w/ Sidewalk 1.5~3.5m  
w/ Arcade w/ Sidewalk >3.5m
Sidewalk Divides Two Directions  
Sidewalk Divides Same Direction

Illustration Site Typology: Street without arcade without sidewalk, 6m communal street
4.4.6 The Flow-Space Type: B-3 (→Storage→)

The flow-space type B-3 means the MoD vehicles are moving autonomously as the vehicle flow type B within the station spatial layout type 3. The B-3 type is representing the storage phase of the system stage. The B-3 type suggests that during the storage phase, the MoD vehicles are moving from any of the four levels, to under-street level, building level, and block level to charge themselves. The B-3 type represents the MoD vehicles are moving from an outdoor, semi-outdoor, and indoor environment to an indoor environment and stay there for charging and parking.

The System Type II and III (Storage Phase)

The storage phase, which the B-3 type is representing, is the storage phase of the system type II and III. It means that after the users returned their vehicles at the station on the street or under a street, inside a building or at a urban block, the vehicles will drive themselves autonomously to the charging locations, which are located in either under-street, building, or block levels and most of these levels are indoor environment, for charging and parking. The chart on the right is a different than the previous two charts in A-1 type and A-2 type. The configuration of a street has limited variables, such as the width of a street and a sidewalk, with or without a sidewalk or an arcade, a main street or a communal street, etc. Therefore, it is possible to list out most of these urban condition scenarios in a chart. However, the configuration of an indoor space such as the space inside a building, under a street, or under a street block, has thousands of variables and results in thousands of variations. These variations can all be considered as the station spatial layout type 3. It is impossible to list every one of them. Instead of listing out all the possible spatial layout typologies of the storage phase of the system type II and III, the thesis is showing the possible vehicle flow type B scenarios in the possible station spatial layout type 3. Therefore, in the chapter 3.5.6, the vehicle flow type B and the station spatial layout type 3 are presenting together. The flow type B is demonstrating by using the space type 3.
The Flow Type B and the Space Type 3

In the B-3 type, there are 27 different types of vehicle flows. During the storage phase, the MoD vehicles are coming from one place for charging and going to another place after finished charging or when they are needed, there are three type of vehicle flows in each the enter phase and the exit phase. The storage phase has four type of vehicle flows, including the standstill charging type. Therefore, the total combination of the vehicle flows in B-3 type are 27 different types of vehicle flows. Some of these types are illustrated with the possible station spatial layout type 3 in the following pages.
B-3 Type 1: Charging in Building Level

Autonomous Moving

Autonomous Switching Charging

Autonomous Moving

Figure 171.
B-3 Type 3: Charging in Under-street Level

Figure 172.
B-3 Type 7: Charging in Building Level

Autonomous Moving

Autonomous Progressive Charging

Autonomous Moving

Figure 174.
B-3 Type 9: Charging in Under-street Level

Figure 175.
B-3 Type 7: Charging in Building Level

Autonomous Moving
Autonomous Progressive Charging
Autonomous Progressive Charging

Figure 176.
B-3 Type 14: Charging in Block Level

Autonomous Switching Charging

Standstill Charging

Autonomous Switching Charging

Figure 177.
B-3 Type 15: Charging in Block Level

Autonomous Switching Charging  Standstill Charging  Autonomous Progressive Charging

Figure 178.
B-3 Type 27: Charging in Under-street Level

Autonomous Progressive Charging

Figure 179.
B-3 Type 27: Charging in Building Level

Autonomous Progressive Charging

Figure 180.
4.4.7 The Flow-Space Type: C-4
(Enter->Storage, Storage->Exit)

The flow-space type C-4 means the MoD vehicles are moving autonomously as the vehicle flow type C within the station spatial layout type 4. The C-4 type is representing two phases, the enter phase and the exit phase, of the system stage. The C-4 type suggests that during the enter phase, the MoD vehicles are moving from under-street level, building level, and block level to other under-street level, building level, and block level; and during the exit phase, the MoD vehicles are moving out from any of these three levels to any other of these three levels. The C-4 type represents the MoD vehicles are moving from a mostly indoor environment to another mostly indoor environment. The vehicle flow type C is very similar to the vehicle flow type A. The only difference is that in the vehicle flow type A, the vehicle is driving on the street environment, which is not too hard to provide specific spatial solutions for each possible urban condition. However, in the vehicle flow type C, the vehicle is driving in any possible indoor space, which has countless variations and it is very hard to provide specific spatial solutions for specific spatial conditions. Therefore, the vehicle flow type C is different than the vehicle flow type A.

The System Type III (Enter/Exit Phases)

The enter phase and the exit phase, which the C-4 type is representing, are the enter phase and the exit phase of the system type III. It means that, first, the users will drive their vehicles into the under-street level, the building level, or the block level and they will see a MoD station located in these levels. Second, the users will return their vehicles at the station in these levels and the vehicles will drive themselves autonomously to the charging locations, which are located in either of these levels and most of stations are in an indoor environment. After the MoD vehicles finished charging, the vehicles will drive themselves autonomously to a MoD station on any of these three levels, excluding the street level, for the next users to pick up. However, the spatial configurations in an indoor environment, such as a space inside a building, under a street, or under a street block, are impossible to list them all. Therefore, this chapter is showing the possible vehicle flow type C scenarios with the possible station spatial layout type 4.
4.4.7 The Flow-Space
Type: C-4

Autonomous Switching Charging
under Streets
inside Buildings
beneath Urban Blocks

Figure 182.

Autonomous Progressive Charging
under Streets
inside Buildings
beneath Urban Blocks

Figure 183.

Standstill Charging
under Streets
inside Buildings
beneath Urban Blocks

Figure 184.
5.0 CONCLUSION
The Mobility-On-Demand System in Taipei City: A Glossary of Mobility-on-Demand Station Typologies

The thesis divided the process, from the time a MoD vehicle has been dropped off to a station to a vehicle has been picked up again, into three stages. Each stage plays its own role during this process. The portal stage is to identify the possible locations to build MoD stations. In other words, portal location is the actual location of a MoD station. The MoD vehicle is driving manually during this stage. The interface stage is about the physical MoD station design. It talks about the major components of a MoD station and the design guidelines for each component. It also provides the possible combinations of these components, when they are deploying to the existing urban environment. During this stage, the MoD vehicle is between manual driving mode and autonomous driving mode. The system stage is the internal working mechanisms, which is dealing with vehicle charging and storage, of a MoD station. It talks about the possible station layouts in different urban conditions. During this stage, the MoD vehicle is on autonomous driving mode.

When putting these three stages together, it shows an overall picture of how the system works. From the portal stage, you will know the exact locations of the MoD stations. From the interface stage, you will know how does a station look like and work. From the system stage, you will know the possible station layouts for each specific urban condition and also what kinds of MoD station components will be used in which types of station spatial layouts.

However, the thesis can show the possible station typology by using only two variables, the portal and the system, because the interface variable is already embedded in the diagrams of the system stage. Just by combining the research findings of the portal stage and system stage, it will show what types of MoD stations can be built in what locations and what kinds of MoD station components will be needed. Therefore, the system type will define the possible station typology and the portal locations will be the locations of MoD stations.

In the system stage, there are three different types of station layouts, the system type I, II, and III, as the table shows on top of this page. The system type I can be divided into two sub-types, outdoor type and semi-outdoor type. Therefore, there are total four types of station layouts in the system stage. The system type I outdoor station means that users drop off and pick up vehicles on streets, and vehicle are charging on streets. The system type I semi-outdoor station means that users drop off and pick up vehicles on streets, and vehicle are charging on the streets, but in a semi-outdoor environment. The system type II indoor station means that users drop off and pick up vehicles on streets, but vehicle are charging inside a building, under a street, or beneath an urban block, in an indoor environment. The system type III indoor station means that both users drop off and pick up points and vehicle charging locations are inside a building, under a street, or beneath an urban block, in an indoor environment. These four types will be illustrated in more detail in the following pages.

In the portal stage, there are six different types of locations are suitable for building MoD stations. However, based on the spatial characteristics and requirements of these six locations, they are distributed throughout the city in different urban environment. From the table on the right page, it shows the possible portal locations in different urban condition.

<table>
<thead>
<tr>
<th>System</th>
<th>Enter</th>
<th>Storage</th>
<th>Exit</th>
<th>= System Type I</th>
<th>= System Type II</th>
<th>= System Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop-off/Pick-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point on Streets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Outdoor/Semi-outdoor)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Type</td>
<td>Space Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>1</td>
<td>A</td>
<td>1</td>
<td>System Type I</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>3</td>
<td>B</td>
<td>2</td>
<td>System Type II</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>3</td>
<td>B</td>
<td>4</td>
<td>System Type III</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. See Table 1. in P.103
<table>
<thead>
<tr>
<th>Enter / Storage / Exit Phase Location</th>
<th>Parking Storage Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outdoor</td>
</tr>
<tr>
<td></td>
<td><img src="1" alt="Diagram" /></td>
</tr>
<tr>
<td>4m Communal Street</td>
<td><img src="4" alt="Diagram" /></td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td><img src="7" alt="Diagram" /></td>
</tr>
<tr>
<td>6m Communal Street</td>
<td><img src="10" alt="Diagram" /></td>
</tr>
<tr>
<td>8m Communal Street</td>
<td><img src="13" alt="Diagram" /></td>
</tr>
<tr>
<td>10m Communal Street</td>
<td><img src="16" alt="Diagram" /></td>
</tr>
<tr>
<td>Main Street</td>
<td><img src="19" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td><img src="22" alt="Diagram" /></td>
</tr>
<tr>
<td>6m Communal Street</td>
<td><img src="25" alt="Diagram" /></td>
</tr>
<tr>
<td>Street w/o Arcade w Sidewalk &lt;1.5m</td>
<td><img src="28" alt="Diagram" /></td>
</tr>
<tr>
<td>8m Communal Street</td>
<td><img src="31" alt="Diagram" /></td>
</tr>
<tr>
<td>10m Communal Street</td>
<td><img src="34" alt="Diagram" /></td>
</tr>
<tr>
<td>Main Street</td>
<td><img src="37" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Table 6.
The System Type I Outdoor Station
The system type I outdoor station is one of the most common station typologies of the Mobility-on-Demand system in Taipei City. It represents that MoD stations are locating on the street, an outdoor environment, not covered by any kind of structure. Users pick up and drop off their vehicles on the street levels. From the figure second on the left, it shows that the three phases of the system stage, they all belong to the flow-space type A-1. It means that during these three phases, MoD vehicles are all moving as the flow type A in a station spatial type 1 layout. In other words, after vehicles returned to MoD stations, these vehicles enter the system for charging, recharge, and exit the system after charging, all of these phases are on street levels of an outdoor environment. The table on the right shows the locations of the system type I outdoor stations, under specific urban conditions. The portal icons represent the types of locations the MoD stations are associated with. The system type I station typologies are shown in numbers. These numbers represent A-1 type station layouts and they are illustrated in detail in the chapter 4.4.4. The table illustrates that, under which kinds of urban condition, which types of station layouts can be built in and associated with which types of the locations.

The top figure on the left shows the spatial characteristics sequence of the MoD vehicles are in, from coming to station from users’ origins to driving away to users’ destinations.
<table>
<thead>
<tr>
<th>Enter / Storage / Exit Phase Location</th>
<th>Portal</th>
<th>System (Outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>4m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>6m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>8m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>10m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>Main Street</td>
<td>![Image]</td>
</tr>
<tr>
<td>Street w/o Arcade w Sidewalk</td>
<td>6m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>8m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>10m Communal Street</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>Main Street</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

Table 8. From Table 6 in P.157 and Table 2. in P.109
The System Type I Semi-outdoor Station

The system type I semi-outdoor station is also one of the most common station typology of the Mobility-on-Demand system in Taipei City. It represents that MoD stations are locating on the street, a semi-outdoor environment, which is covered by any type of structure or is simply under a roof. Users pick up and drop off their vehicles on the street levels. From the figure second on the left, it shows that the three phases of the system stage, they all belong to the flow-space type A-1. It means that during these three phases, MoD vehicles are all moving as the flow type A in a station spatial type 1 layout. In other words, after vehicles returned to MoD stations, during the enter phase, the storage phase, and the exit phase, these vehicles are on street levels, a semi-outdoor environment, or from an outdoor to semi-outdoor environment for storage and charging.

The table on the right shows the locations of the system type I semi-outdoor stations, under specific urban conditions. The portal icons represent the types of locations the MoD stations are associated with. The system type I station typologies are shown in numbers. These numbers represent A-1 type station layouts and they are illustrated in detail also in chapter 4.4.4. The table illustrates that, under which kinds of urban condition, which types of station layouts can be built in and associated with which types of the locations.

The top figure on the left shows the spatial characteristics sequence of the MoD vehicles are in, from coming to station from users’ origins to driving away to users’ destinations.
<table>
<thead>
<tr>
<th>Enter / Storage / Exit Phase Location</th>
<th>Portal</th>
<th>System (Semi-outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td>4m Communal Street</td>
<td></td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>6m Communal Street</td>
<td></td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>8m Communal Street</td>
<td></td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>10m Communal Street</td>
<td></td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>Main Street</td>
<td></td>
<td>4, 5, 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11, 12, 13</td>
</tr>
<tr>
<td>6m Communal Street</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8m Communal Street</td>
<td></td>
<td>11, 12, 13</td>
</tr>
<tr>
<td>10m Communal Street</td>
<td></td>
<td>11, 12, 13</td>
</tr>
<tr>
<td>Main Street</td>
<td></td>
<td>11, 12</td>
</tr>
</tbody>
</table>

Table 10. From Table 6. in P.157 and Table 2. in P.109
The System Type II Indoor Station

The system type II Indoor station is designed for situations when there is not enough space to build a whole MoD station, including every charging spaces, on a street. This type represents that MoD stations are locating on the street, either an outdoor or a semi-outdoor environment, and the vehicles will be charging in an indoor environment, either under a street, a building, or an urban block. From the figure second on the left, it shows that the enter and the exit phases of the system stage, they both belong to the flow-space type A-2, and the storage phase belongs to the flow-space type B-3. It suggests that, after users returned the MoD vehicles, these vehicles will go from street level to either an under-street, a building, or a block level. These vehicles will go from an outdoor or a semi-outdoor environment to an indoor environment for charging and storage. The enter and the exit phases represent these transitional phases.

The table on the right shows the locations of the system type II Indoor stations, under specific urban conditions. The portal icons represent the types of locations the MoD stations are associated with. The system type II station typologies are shown in numbers in different phases. The numbers under the enter and the exit phases, represent A-2 type station layouts, they are illustrated in more detail in chapter 4.4.5. The numbers under the storage phase, represent B-3 type station layouts, they are elaborated in chapter 4.4.6.
<table>
<thead>
<tr>
<th>Enter / Exit Phase Location</th>
<th>Portal</th>
<th>System (Indoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A-2</td>
</tr>
<tr>
<td>4m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>6m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>8m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>10m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>Main Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>6m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>8m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>10m Communal Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
<tr>
<td>Main Street</td>
<td>![image]</td>
<td>27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
</tbody>
</table>

Table 12. From Table 6. in P.157, Table 3. in P.131, and Table 4. in P.141
The System Type III Indoor Station

The system type III Indoor station is using the portal locations as its enter and exit point for its interface and system stages. The MoD stations are locating in an indoor environment, either under a street, inside a building, or under an urban block. When users see a MoD station enter point on the street level, they need to drive manually into the enter point to an indoor environment, in the previous three levels, and find MoD stations to return their vehicles. Unlike the previous system type I and II, after users returned vehicles on street level, these vehicles will stay in the same locations for charging or will move themselves autonomously into the system for charging and storage. Users do not need to drive into an indoor space, like we drive our cars to a basement for parking right now. This type can be applied in the scenarios, such as MoD stations inside or under a big shopping mall, a convention center, a stadium, a residential high-rise, an urban block, etc. When the situations are more convenient and comfortable for users to drop off and pick up vehicles in indoors rather than outdoors. However, the system type III Indoor station has countless variations and does not have major impact on urban environment. The portal location on the street is for entering and exiting only, just like tunnels or ramps, it does not affect the streetscape too much. Therefore, the thesis will not discuss this typology in detail. The various combinations are showing in the table on the right page.
Table 13. From Table 6. in P.157, Figure 182, 183, 184. in P.153, and Table 4. in P.141

Table 14. The C-4 type can be found in chapter 4.4.7 and the B-3 can be found in chapter 4.4.6.
5.2 A Handbook for Urban Implementation of the Mobility-on-Demand System

The thesis is designed as a handbook for urban implementation of the Mobility-on-Demand system in Taipei City. After the research works have been done for the three stages of the Mobility-on-Demand system in Taipei City, these works can combine and become a handbook for practical urban implementation purposes. The thesis is laying out a structure for urban implantation studies. This structure is not only good for my present studies, but also good for the future planners or designers who are doing this type of researches. Their works can follow the structure and find a place to fit in. After that, these accumulated works can be searched and provide references and possible solutions when the MoD system is doing a real urban implementation.

The thesis is not intended to show every possible station layouts for every urban conditions. However, the thesis wants to give enough possible station layouts and diagrams to show what this thesis is for and how can this thesis work as a handbook. There are two ways to use this handbook when the MoD system is doing urban implementation. The first one is when the system operators know an existing physical location, like a 7-11 convenience store, which the MoD system wants to build a MoD station at this location. The second one is when the system operators know, based on the traffic supply and demand, the MoD system needs a MoD station in a certain area. The followings are the two examples of how to use this thesis as a handbook for urban implantation.

Implementation Scenario I: With a Known Portal Location

If the system operators know an existing physical location, which the MoD system wants to build a MoD station at this location. For example, the MoD system needs to be build a station in the location of the 7-11 convenience store, which its image is showing on the top right-hand side of the left page. Firstly, the MoD system needs to find out what type of the street of this convenience store is on. In this case, this 7-11 is located on a 8 meter-wide, communal street, without a sidewalk and an arcade. Secondly, the system operators can search this handbook for the possible MoD station layouts for this location. They just need to find the possible station layouts of system type I, II, and III, under the urban condition of a 8 meter-wide, communal street, without a sidewalk and an arcade, in chapter 5.1. The followings are the possible outdoor, semi-outdoor, and indoor station layouts for this 7-11 location.
The System Type I Outdoor Station Possibilities
The diagrams below are showing the possible outdoor station layouts under the category of 8 meter-wide, communal street, without a sidewalk and an arcade.

<table>
<thead>
<tr>
<th>Exit / Storage / Enter Phase Location</th>
<th>Portal</th>
<th>System (Outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m</td>
<td>Communal Street</td>
</tr>
<tr>
<td></td>
<td>1, 2, 3</td>
<td><strong>A-1</strong></td>
</tr>
</tbody>
</table>

A-1 Type 1

Figure 191. Detailed in P.141

The System Type I Semi-outdoor Station Possibilities
The diagrams below are showing the possible semi-outdoor station layouts under the category of 8 meter-wide, communal street, without a sidewalk and an arcade.

<table>
<thead>
<tr>
<th>Exit / Storage / Enter Phase Location</th>
<th>Portal</th>
<th>System (Semi-outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m</td>
<td>Communal Street</td>
</tr>
<tr>
<td></td>
<td>4, 5, 6</td>
<td><strong>A-1</strong></td>
</tr>
</tbody>
</table>

A-1 Type 4

Figure 194. Detailed in P.144

A-1 Type 2

Figure 192. Detailed in P.142

A-1 Type 5

Figure 195. Detailed in P.145

A-1 Type 3

Figure 193. Detailed in P.143

A-1 Type 6

Figure 196. Detailed in P.146
The System Type II Indoor Station Possibilities

The diagrams on the left on the left page are showing the possible indoor station layouts, during the enter and the exit phases, under the category of 8 meter-wide, communal street, without a sidewalk and an arcade. Users drop off and pick up their vehicles on the street and the vehicles move autonomously to an indoor environment for charging and storage. The diagrams on the right on the left page is showing the possible MoD vehicle charging flow types during the storage phase. Therefore, a possible station layout of this type will be picking up one diagram from the left and one diagram from the right and combining them together as one possible type.

**A-2 Type 1**  
*Figure 197. Detailed in P.132*

**A-2 Type 2**  
*Figure 198 Detailed in P.133*

**A-2 Type 3**  
*Figure 199. Detailed in P.134*

**A-2 Type 4**  
*Figure 200. Detailed in P.135*

<table>
<thead>
<tr>
<th>Exit / Enter Phase Location</th>
<th>Portal</th>
<th>System (Indoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter</td>
<td>Storage</td>
<td>Exit</td>
</tr>
<tr>
<td>A-2</td>
<td>B-3</td>
<td>A-2</td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m Communal Street</td>
<td>1, 2, 3, 4</td>
</tr>
</tbody>
</table>

**Table 17. From Table 12. in P.163**

**Table 34. From Table 20. in P.219**
The System Type III Indoor Station Possibilities
The table below is showing the possible indoor station layouts under the category of 8 meter-wide, communal street, without a sidewalk and an arcade. First, this type of station layout does not have much impact on urban environment, because it only uses the portal location as an enter and exit point for driver to manually drive into an indoor environment, such as a parking lot entrance. Unlike the system type I and II station layouts have physical stations on the street level and vehicles only drive themselves autonomously into an indoor space. Second, this type has unlimited spatial configuration and can not be listed one by one. Please see chapter 4.4.7. Therefore, the thesis will not discuss too much about this typologies, but lists it in order to maintain the station spatial layouts structure.

<table>
<thead>
<tr>
<th>Portal Stage Location</th>
<th>Portal</th>
<th>System (Indoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A-2</td>
</tr>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m Communal Street</td>
<td>3 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
</tbody>
</table>
Implementation Scenario II: with a Known Urban Area

The other implementation scenario is, if the system operators know the MoD system needs a station in an area in order to sustain sufficient MoD vehicles supply and demand, but they do not have a physical location in mind. The planners and designers can look at this handbook to have a good idea what kind of station and location choices they can have in this area. For example, the MoD system wants to be build a station within the area covered by the white circle, because the system operators know if they build a station in the area, it will balance the supply and demand of the MoD fleet. First, within the area, planners and designers can choose a suitable street to build their station. In this case, they chose a 8 meter-wide, communal street, without a sidewalk and an arcade. Second, the planners and designers can look up this handbook for the possible MoD station layouts for this type of street. They can find the possible station layouts of system type I, II, and III, under the urban condition of a 8 meter-wide, communal street, without a sidewalk and an arcade, in chapter 5.1. The followings are the possible outdoor, semi-outdoor, and indoor station layouts for this type of street. Therefore, the planners and designers can have a good repertoire of locations and station types, which can be built within this area. It will shorten the planning and design process.

Figure 201. The white circle shows the area which the system operators want to build a MoD station in
The System Type I Outdoor Station Possibilities

<table>
<thead>
<tr>
<th>Exit / Storage / Enter Phase Location</th>
<th>Portal</th>
<th>System (Outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m Communal Street</td>
<td>1, 2, 3</td>
</tr>
</tbody>
</table>

The System Type I Semi-outdoor Station Possibilities

<table>
<thead>
<tr>
<th>Exit / Storage / Enter Phase Location</th>
<th>Portal</th>
<th>System (Semi-outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m Communal Street</td>
<td>4, 5, 6</td>
</tr>
</tbody>
</table>

The System Type II Indoor Station Possibilities

<table>
<thead>
<tr>
<th>Exit / Enter Phase Location</th>
<th>Portal</th>
<th>System (Indoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m Communal Street</td>
<td>1, 2, 3, 4, 27 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
</tbody>
</table>

The System Type III Indoor Station Possibilities

<table>
<thead>
<tr>
<th>Portal Stage Location</th>
<th>Portal</th>
<th>System (Indoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street w/o Arcade w/o Sidewalk</td>
<td>8m Communal Street</td>
<td>3 Vehicle Flow Types / Unlimited Spatial Types</td>
</tr>
</tbody>
</table>

A Crucial Factor for a Large-Scale Mobility-on-Demand System Urban Implementation

By using the thesis as a handbook for the Mobility-on-Demand system of urban implementation, a possible outdoor, semi-outdoor station, or indoor station can be found or generated for the system operator. Through exploring the potential station layouts, planners and designers of the MoD system can have a repertoire of types of the MoD station might be suitable for a location or an area. A key of success of the MoD system urban implementation, the most crucial factor is how fast the system can adapt and optimize to the dynamic urban environment. This handbook will not only give the designers and planners the station types to choose from, but will also speed up the design and planning process for large-scale MoD system urban implementation. It will be crucial for urban implementation. However, even the planners and designers come up with new station spatial layouts, it can always be added on to the repertoire. The handbook will be more useful for the future urban implementation. The more the MoD stations the system builds, the better station spatial types repertoire the system will have.
6.0 APPENDIX
6.1 Taipei City
Taipei city is the capital city of Taiwan. It is also the social, economical center of the country. It is located in the northern part of Taiwan and surrounded by Taipei County, Taiyuan City and Keelung City. Taipei City, Taipei County and Keelung City is the so-called Greater Taipei Area. Most parts of Taipei city and Taipei County are situated in the Taipei basin and surround by hills and mountains.
6.1.1 Introduction of Taipei City
Taipei City is located in the northern part of Taiwan, which is situated in the bottom of Taipei basin and surrounded by hills and mountains. Taipei City is the capital city and social, economic and political center of Taiwan. Taipei City has 2,630,515 residents and relation density is 9,678 people per square kilometers. It is ranked as the seventh highest population density city in the world. Combined with Taipei County, together they have 6,409,734 residents in Greater Taipei Area. Taipei City is the typical East Asia city, as well as Taipei County. That land-use zoning system is not monotonic or single-purpose, it has traditionally been multipurpose. Taipei is generally characterized as a mixed-use city. Commercial and residential areas can easily be seen mixed together in the same street or in the same block. Because of the mixed-use characteristics and high density, it creates a very convenient city in the world. People can buy or do basically anything within three to five minutes driving distance in Taipei urban area. A lot of stores are running 24 hours a day and convenience stores are ubiquitous. Sometimes people can see the same brand convenience stores open across the street and face each other. Taipei City also faces a lot of traffic problems. Every 1000 people have 218 cars and 406 motorcycles in Taipei City; 222 cars and 570 motorcycles in Taipei County. Taipei city ranked the second most congested city in Asia. What makes things worse is that motorcycles pollute more than cars. It is not hard to imagine that people almost choked in traffic congestion with a lot of smoke. The traffic issue needs to be addressed in order to improve the living quality in Taipei City.

6.1.2 Pilot Program of Mobility-on-Demand
Taipei City will be a good candidate city to test out the pilot program of Mobility-on-Demand transportation system. It will not only solve the traffic problems, but also can integrate the existing transportation system and make it work more efficiently. It could also address environmental issues. Many Taipei City residents have high-income levels and are typically open to new technologies, new ideas and new services. They will be interested in this service if it can save more time and money. Also because of the mix-used urban fabrics, it will make Mobility-on-Demand fleet management easier. The traffic of Taipei City already used to cars and scooters mixed together roaming down the same street and the same land, it will not be a problem to introduce the mixed modality MoD service to Taipei City.
Aerial Photos of Metropolitan Taipei Area

Figure 205.
6.1.3 Location and Geography
Taipei City is located almost at the northern tip of Taiwan and surrounded by Taipei County, Keelung City, and Taoyuan County. The Greater Taipei Area often refers to Taipei City and Taipei County together. The metropolitan area of Taipei includes Taipei City, Taipei County, Keelung City, Taoyuan County, Hsinchu City, Hsinchu County, and Yilan County. Taipei City and Taipei County are located in the alluvial plain of Taipei basin. The perimeter of basin is about 70 square kilometers in length and the slope is pretty steep so it is not suitable for any kind of construction. Within Taipei basin, there are 243 square kilometers in area under 20 meters height above sea level, 19 square kilometers are water area. Tamsui River is running through the middle of the basin and cut it into two half. The left side is Taipei County and the right side is Taipei City. Taipei City has 272 hectares and Taipei County has 2053 hectares. The 55 % of Taipei City are hills and mountains, only 45% are plains. Taipei County only has 11.65% plains, the others are hills and mountains. The urban development is basically within the plains of the Taipei basin.

Figure 206. View of Taipei Basin
Aerial Photos of Greater Taipei Area

Figure 207.
6.1.4 Administrative Zones
Taipei City has 12 districts and Taipei County has 10 township-level cities, 4 urban townships and 15 rural township, total 29 cities and townships. The Taipei County actually surrounds and encloses Taipei City entirely.

**Table 23. Area of Each District**

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Name</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taipei City</td>
<td>271.80</td>
<td>Sijhih City</td>
<td>71.24</td>
</tr>
<tr>
<td>Shihlin District</td>
<td>62.37</td>
<td>Rueifang Township</td>
<td>70.73</td>
</tr>
<tr>
<td>Beitou District</td>
<td>56.82</td>
<td>Danshuei Township</td>
<td>70.66</td>
</tr>
<tr>
<td>Neihu District</td>
<td>31.58</td>
<td>Sanjhih Township</td>
<td>65.99</td>
</tr>
<tr>
<td>Wunshan District</td>
<td>31.51</td>
<td>Wanli Township</td>
<td>63.38</td>
</tr>
<tr>
<td>Nangang District</td>
<td>21.84</td>
<td>Linkou Township</td>
<td>54.15</td>
</tr>
<tr>
<td>Jhongshan District</td>
<td>13.68</td>
<td>Shihmen Township</td>
<td>51.26</td>
</tr>
<tr>
<td>Daan District</td>
<td>11.36</td>
<td>Jinshan Township</td>
<td>49.21</td>
</tr>
<tr>
<td>Sinyi District</td>
<td>11.21</td>
<td>Baishihu Township</td>
<td>39.49</td>
</tr>
<tr>
<td>Songshan District</td>
<td>9.29</td>
<td>Wugu Township</td>
<td>34.86</td>
</tr>
<tr>
<td>Wanhu District</td>
<td>8.85</td>
<td>Shulin Township</td>
<td>33.13</td>
</tr>
<tr>
<td>Jhongjheng District</td>
<td>7.61</td>
<td>Tucheng City</td>
<td>29.56</td>
</tr>
<tr>
<td>Datong District</td>
<td>5.68</td>
<td>Xindian City</td>
<td>23.14</td>
</tr>
<tr>
<td>Taipei County</td>
<td>2,052.57</td>
<td>Yingge Township</td>
<td>21.12</td>
</tr>
<tr>
<td>Wulai Township</td>
<td>321.13</td>
<td>Shenkeng Township</td>
<td>20.58</td>
</tr>
<tr>
<td>Sansia Township</td>
<td>191.45</td>
<td>Jhonghe City</td>
<td>20.14</td>
</tr>
<tr>
<td>Pinglin Township</td>
<td>170.84</td>
<td>Sinjhuang City</td>
<td>19.74</td>
</tr>
<tr>
<td>Shuangsi Township</td>
<td>146.25</td>
<td>Taishan Township</td>
<td>19.16</td>
</tr>
<tr>
<td>Shihding Township</td>
<td>144.35</td>
<td>Sanchong City</td>
<td>16.32</td>
</tr>
<tr>
<td>Sindian City</td>
<td>120.23</td>
<td>Lujhou City</td>
<td>7.44</td>
</tr>
<tr>
<td>Gongliao Township</td>
<td>99.97</td>
<td>Yonghe City</td>
<td>5.71</td>
</tr>
<tr>
<td>Pingsi Township</td>
<td>71.34</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.1.5 Population and Density

The greater Taipei urbanized area ranked the seventh highest population density city in the world with about 15,200 people per square kilometer in urban area. Within the Taipei City and Taipei County boundaries, Taipei City population density is 9,682 people per square kilometer and Taipei County population density is 1,854 people per square kilometer. However, because most urbanized areas of Greater Taipei are located in the alluvial plain of Taipei basin, the population densities in urbanized areas are actually much higher than the statistics showed. There is one district the population density is higher than the most highest population density city; there are two districts higher than the second place city, but lower than the top one; they are nine districts higher than the third place city, but lower than the second place one. The aerial photos below show the same scale comparison between Manhattan and Taipei. Manhattan has 87.5 square kilometer in area, 1,620,867 residents and population density is 27,256 people per square kilometer. Although Greater Taipei Area doesn’t have so many skyscrapers like Manhattan, but the population density of many districts are close to this number. The population density is very high in Greater Taipei Area.

<table>
<thead>
<tr>
<th>Name</th>
<th>Population</th>
<th>Density</th>
<th>Name</th>
<th>Population</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taipei City</td>
<td>2,631,605</td>
<td>9,682</td>
<td>Yingge Township</td>
<td>85,891</td>
<td>4,066</td>
</tr>
<tr>
<td>Daan District</td>
<td>315,511</td>
<td>27,770</td>
<td>Taishan Township</td>
<td>74,670</td>
<td>3,897</td>
</tr>
<tr>
<td>Songshan District</td>
<td>211,540</td>
<td>22,776</td>
<td>Sijihh City</td>
<td>181,195</td>
<td>2,544</td>
</tr>
<tr>
<td>Datong District</td>
<td>126,201</td>
<td>22,213</td>
<td>Sindian City</td>
<td>290,868</td>
<td>2,419</td>
</tr>
<tr>
<td>Wanhua District</td>
<td>192,040</td>
<td>21,694</td>
<td>Wugu Township</td>
<td>77,456</td>
<td>2,222</td>
</tr>
<tr>
<td>Jhongjeng District</td>
<td>159,829</td>
<td>21,011</td>
<td>Danshuei Township</td>
<td>132,804</td>
<td>1,880</td>
</tr>
<tr>
<td>Sinyi District</td>
<td>228,935</td>
<td>20,427</td>
<td>Linkou Township</td>
<td>68,296</td>
<td>1,261</td>
</tr>
<tr>
<td>Jhongshan District</td>
<td>218,705</td>
<td>15,985</td>
<td>Shenkeng Township</td>
<td>22,509</td>
<td>1,094</td>
</tr>
<tr>
<td>Neihu District</td>
<td>265,894</td>
<td>8,420</td>
<td>Bali Township</td>
<td>32,773</td>
<td>830</td>
</tr>
<tr>
<td>Wunshan District</td>
<td>261,915</td>
<td>8,312</td>
<td>Rueifang Township</td>
<td>43,434</td>
<td>614</td>
</tr>
<tr>
<td>Nangang District</td>
<td>113,726</td>
<td>5,207</td>
<td>Sansia Township</td>
<td>95,617</td>
<td>499</td>
</tr>
<tr>
<td>Shihlin District</td>
<td>287,177</td>
<td>4,605</td>
<td>Jinshan Township</td>
<td>22,249</td>
<td>452</td>
</tr>
<tr>
<td>Beitou District</td>
<td>250,132</td>
<td>4,402</td>
<td>Sanjihh Township</td>
<td>23,579</td>
<td>357</td>
</tr>
<tr>
<td>Taipei County</td>
<td>3,804,969</td>
<td>1,854</td>
<td>Wanti Township</td>
<td>20,732</td>
<td>327</td>
</tr>
<tr>
<td>Yonghe City</td>
<td>236,927</td>
<td>41,466</td>
<td>Shihmen Township</td>
<td>11,875</td>
<td>232</td>
</tr>
<tr>
<td>Lujhou City</td>
<td>192,515</td>
<td>25,893</td>
<td>Gongliao Township</td>
<td>14,020</td>
<td>140</td>
</tr>
<tr>
<td>Banciao City</td>
<td>548,816</td>
<td>23,720</td>
<td>Pingsi Township</td>
<td>5,602</td>
<td>79</td>
</tr>
<tr>
<td>Sanchong City</td>
<td>383,749</td>
<td>23,518</td>
<td>Shuangsi Township</td>
<td>9,937</td>
<td>68</td>
</tr>
<tr>
<td>Jhonghe City</td>
<td>409,846</td>
<td>20,346</td>
<td>Shihding Township</td>
<td>7,862</td>
<td>54</td>
</tr>
<tr>
<td>Sinjhuang City</td>
<td>396,762</td>
<td>20,101</td>
<td>Pinglin Township</td>
<td>6,582</td>
<td>39</td>
</tr>
<tr>
<td>Tucheng City</td>
<td>237,643</td>
<td>8,040</td>
<td>Wulai Township</td>
<td>5,427</td>
<td>17</td>
</tr>
<tr>
<td>Shulin City</td>
<td>165,333</td>
<td>4,991</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 25. Top Cities of Population Density (People/km²)

<table>
<thead>
<tr>
<th>Name</th>
<th>Country</th>
<th>Population</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai</td>
<td>India</td>
<td>14,350,000</td>
<td>29,650</td>
</tr>
<tr>
<td>Kolkata</td>
<td>India</td>
<td>12,700,000</td>
<td>23,900</td>
</tr>
<tr>
<td>Karachi</td>
<td>Pakistan</td>
<td>9,800,000</td>
<td>18,900</td>
</tr>
<tr>
<td>Lagos</td>
<td>Nigeria</td>
<td>13,400,000</td>
<td>18,150</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>China</td>
<td>8,000,000</td>
<td>17,150</td>
</tr>
<tr>
<td>Seoul</td>
<td>South Korea</td>
<td>17,500,000</td>
<td>16,700</td>
</tr>
<tr>
<td>Taipei</td>
<td>Taiwan</td>
<td>5,700,000</td>
<td>15,200</td>
</tr>
</tbody>
</table>
Urbanized Area of Greater Taipei

Zone 1: Core Com.
Zone 2: Second Com.
Zone 3: Newly Developed
Zone 4: Old City
Zone 5: Res. Inside City
Zone 6: Res. Outskirt
Zone 7: Organic Mix-Used
6.1.6 Urbanized Area of Greater Taipei
Because Greater Taipei is situated in the bottom of the Taipei Basin, the mountains and hills in the perimeter of basin become the physical boundary of urban development. Within the boundary, nearly all the areas are occupied by either by buildings and/or infrastructure. Based on different urban fabrics and development patterns, Greater Taipei can be divided into 7 zones. Each zone’s urban fabric and public transportation accessibility is different.

Zone 1:
Core Commercial Area
Public Transportation: Dense
Urban Fabric: Dense

The central business district of Taipei City. A lot of Tall office buildings situated along avenues and boulevards. Top 4 busiest MRT stations are located in this area. A lot of people come here for works more than the people who live here.
Zone 2:
Second Commercial Area
Public Transportation: Even
Urban Fabric: Dense

The residential and commercial areas are totally mix-used. Not as crowded as CBD and streets have more space for parking.

Figure 216.

Zone 3:
Newly Developed Area
Public Transportation: Even
Urban Fabric: Dense

One block equal one mega building. Most of the buildings are headquarter for international corporations. There are also a lot of department stores here. Taipei City Gov. is here, too.

Figure 218.
Zone 4:  
Old City Area  
Public Transportation: Even  
Urban Fabric: Dense  

The earliest developed area in Taipei, famous for its small alleys and organic growth pattern. There are a lot of ancient buildings, markets and temples in this area. A lot of traditional row-houses were also preserved.

Figure 220.

Zone 5:  
Residential Area inside City  
Public Transportation: Even  
Urban Fabric: Even  

It's situated around core com. and second com. areas. Mostly residential neighborhood, but commercial areas are also included. Most of them are 5-7 stories high buildings.

Figure 222.
Zone 6:
Outskirt Residential Area
Public Transportation: Even
Urban Fabric: Even

It’s situated between the central city and mountains of Taipei Basin. Most of them are 5-7 stories high buildings, but tall residential towers are also common.

Figure 224.

Zone 7:
Organic Mix-Use Fabric Area
Public Transportation: Loose
Urban Fabric: Dense

The Taipei County is belong to this area. It is very dense and famous for its organic growth pattern and green-less space. Most of the streets are very sinuous and hard to recognize.

Figure 226.
Road Systems Diagram in Urbanized Area of Greater Taipei Area
6.1.7 Road System

The red dotted line represents Taiwan High Speed Rail, which in capable of a top speed of 300 kilometers per hour. It connects Taipei City and Kaohsiung City in 90 minutes. The total route length is 345 kilometers. They are total eight stations in service right now and two of them are in Greater Taipei Area. The black dotted line represents Taiwan railroad, the ordinary train. Most of the routes overlap with Taipei High Speed Rail in city center. The orange solid lines represent highways. There are three major highways running across Taipei City. They cross over in the west side of the city. The solid color lines represent the current MRT system. It connects the major urbanized parts of Taipei City. The yellow thicker solid lines represent expressway and there are 13 expressways in Greater Taipei Area. The yellow thinner solid lines represent main streets. They are denser inside the urban area.

Figure 230. High Speed Rail, Railroad and Highways
Figure 231. Expressways and Main Streets
Figure 232. MRT Routes
Figure 233. Distance from City Center
6.1.8 Public Transportation
There are four different types of public transportation in Greater Taipei Area. They include public buses, Metropolitan Rapid Transit, known as MRT, Taiwan Railway, and taxis. Public buses and MRT are the most widely used public transportation systems in Taipei City. Public buses average 1,687,960 passengers per day and MRT has average 1,239,761 passengers per day. Even after MRT started to operate, buses passengers only 90,000 less after 10 years. A lot of people use railway to do intercity commute. There are 142,373 passengers per day in and out railway stations in Taipei City. There are 57,764 taxis in Greater Taipei Area and share 62.5% of the total taxis in Taiwan. There are estimated 1,156,305 passengers per day use this service in Greater Taipei Area and each taxi serves 20 passengers per day.

Table 26. Total Passengers of Public Transit in Each Year (10,000/year)

<table>
<thead>
<tr>
<th>Year</th>
<th>MRT</th>
<th>BUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>-</td>
<td>260</td>
</tr>
<tr>
<td>1986</td>
<td>-</td>
<td>254</td>
</tr>
<tr>
<td>1987</td>
<td>-</td>
<td>246</td>
</tr>
<tr>
<td>1988</td>
<td>-</td>
<td>238</td>
</tr>
<tr>
<td>1989</td>
<td>-</td>
<td>227</td>
</tr>
<tr>
<td>1990</td>
<td>-</td>
<td>216</td>
</tr>
<tr>
<td>1991</td>
<td>-</td>
<td>214</td>
</tr>
<tr>
<td>1992</td>
<td>-</td>
<td>211</td>
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<tr>
<td>1993</td>
<td>-</td>
<td>204</td>
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<tr>
<td>1994</td>
<td>-</td>
<td>190</td>
</tr>
<tr>
<td>1995</td>
<td>-</td>
<td>175</td>
</tr>
<tr>
<td>1996</td>
<td>17</td>
<td>178</td>
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<td>1997</td>
<td>10</td>
<td>186</td>
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<td>1998</td>
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<td>192</td>
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<td>1999</td>
<td>35</td>
<td>198</td>
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<td>2000</td>
<td>73</td>
<td>186</td>
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<td>2001</td>
<td>79</td>
<td>187</td>
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<td>2002</td>
<td>89</td>
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<td>2003</td>
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<tr>
<td>2004</td>
<td>97</td>
<td>171</td>
</tr>
<tr>
<td>2005</td>
<td>99</td>
<td>168</td>
</tr>
<tr>
<td>2006</td>
<td>105</td>
<td>169</td>
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</tbody>
</table>
6.1.9 Transfer Types

Public buses and MRT are the two major public transportation systems. Sometimes public buses have to assist MRT to solve the first mile and last mile problems. About 56.7% and 67.8% of the total MRT passengers arrived and left MRT stations on foot. It took them an average of 18.21 minutes to walk 1,457 meters in distance. About 23.5% and 26.2% of total MRT passengers arrived and left MRT stations by bus. Only 6.5% and 1.4% of the passengers used scooters. However, scooters traveled the longest distance in the shortest time. It took them 4.28 minutes to travel 2,565 meters in distance.21

<table>
<thead>
<tr>
<th>Transfer Types</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>1.457</td>
</tr>
<tr>
<td>Bus</td>
<td>2.360</td>
</tr>
<tr>
<td>Scooter</td>
<td>2.665</td>
</tr>
</tbody>
</table>

Table 27. Distance of Transfer Types

<table>
<thead>
<tr>
<th>Transfer Types</th>
<th>Arrive</th>
<th>Depart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>56.7%</td>
<td>67.8%</td>
</tr>
<tr>
<td>Taxi</td>
<td>1.3%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Bus</td>
<td>23.5%</td>
<td>26.2%</td>
</tr>
<tr>
<td>Car</td>
<td>2.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Scooter</td>
<td>6.5%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Bike</td>
<td>1.0%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Others</td>
<td>8.7%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>

Table 28. MRT Passengers Transfer Types
Figure 237. Traffic of Taipei in rush hours
### 6.1.10 Private Vehicles

Cars and motorcycles, most of them are scooters, are the major two types of private vehicles in Greater Taipei Area. They are total 1,417,576 cars and 3,234,760 scooters in Greater Taipei Area. Nearly every 1000 people have average 220 cars and 503 scooters. The table on the left shows in Taipei County, the scooter ownership is 50% more than Taipei City scooter ownership. In places that have denser urban fabric and higher population densities, people tend to have more scooters, but not always less cars. 25% of the total residents in Greater Taipei Area commute by their cars, 36% by their scooters. Because traffic is too congested in Greater Taipei Area, scooters actually are the cheaper and faster solution in this condition, especially with their small vehicle footprint, they can in and out the traffic without any problem. About 54.4% of the total scooters used for daily commute, from home to work or to school. About 80.4 % of scooter users ride their scooters directly to their destination without transferring. About 64.8% of the scooter users are male. About 90.2% of scooter users in Greater City center and 88.9% of scooter users outside the city center will buy another scooter if the current one is broken.

#### Table 29. Cars and Scooters numbers in Greater Taipei Area

<table>
<thead>
<tr>
<th>Name</th>
<th>Cars</th>
<th>Scooters</th>
<th>Cars/1000 people</th>
<th>Scooters/1000 ppl.</th>
<th>Name</th>
<th>Cars</th>
<th>Scooters</th>
<th>Cars/1000 people</th>
<th>Scooters/1000 ppl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taipei City</td>
<td>574,560</td>
<td>1,067,407</td>
<td>218</td>
<td>406</td>
<td>Taishan Township</td>
<td>17,941</td>
<td>42,709</td>
<td>240</td>
<td>572</td>
</tr>
<tr>
<td>Wanhu District</td>
<td>31,816</td>
<td>106,027</td>
<td>166</td>
<td>552</td>
<td>Wugu Township</td>
<td>21,246</td>
<td>44,253</td>
<td>274</td>
<td>571</td>
</tr>
<tr>
<td>Datong District</td>
<td>26,819</td>
<td>69,611</td>
<td>213</td>
<td>552</td>
<td>Shuangsi Township</td>
<td>1,865</td>
<td>5,454</td>
<td>188</td>
<td>549</td>
</tr>
<tr>
<td>Nangang District</td>
<td>24,651</td>
<td>52,951</td>
<td>217</td>
<td>466</td>
<td>Gongliao Township</td>
<td>2,903</td>
<td>7,400</td>
<td>207</td>
<td>528</td>
</tr>
<tr>
<td>Jhongzheng District</td>
<td>35,311</td>
<td>68,442</td>
<td>221</td>
<td>428</td>
<td>Pingsi Township</td>
<td>1,143</td>
<td>2,838</td>
<td>204</td>
<td>507</td>
</tr>
<tr>
<td>Jhongshan District</td>
<td>60,516</td>
<td>93,287</td>
<td>277</td>
<td>427</td>
<td>Sansia Township</td>
<td>23,328</td>
<td>47,458</td>
<td>244</td>
<td>496</td>
</tr>
<tr>
<td>Shihlin District</td>
<td>60,748</td>
<td>121,077</td>
<td>212</td>
<td>422</td>
<td>Yonghe City</td>
<td>42,982</td>
<td>115,840</td>
<td>181</td>
<td>489</td>
</tr>
<tr>
<td>Beitou District</td>
<td>51,487</td>
<td>105,110</td>
<td>206</td>
<td>420</td>
<td>Ruelfang Township</td>
<td>8,714</td>
<td>20,914</td>
<td>201</td>
<td>482</td>
</tr>
<tr>
<td>Sinli District</td>
<td>45,413</td>
<td>88,596</td>
<td>198</td>
<td>387</td>
<td>Danshui Township</td>
<td>31,914</td>
<td>62,982</td>
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<td>474</td>
</tr>
<tr>
<td>Neihu District</td>
<td>63,225</td>
<td>99,931</td>
<td>238</td>
<td>376</td>
<td>Wulai Township</td>
<td>1,076</td>
<td>2,553</td>
<td>198</td>
<td>470</td>
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<tr>
<td>Wunshan District</td>
<td>54,937</td>
<td>98,038</td>
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<td>374</td>
<td>Jinshan Township</td>
<td>5,253</td>
<td>10,175</td>
<td>236</td>
<td>457</td>
</tr>
<tr>
<td>Songshan District</td>
<td>50,011</td>
<td>72,871</td>
<td>236</td>
<td>344</td>
<td>Bali Township</td>
<td>9,144</td>
<td>14,909</td>
<td>279</td>
<td>455</td>
</tr>
<tr>
<td>Daan District</td>
<td>69,626</td>
<td>91,466</td>
<td>221</td>
<td>290</td>
<td>Sanjihh Township</td>
<td>6,601</td>
<td>10,502</td>
<td>280</td>
<td>445</td>
</tr>
<tr>
<td>Taipei County</td>
<td>843,016</td>
<td>2,167,353</td>
<td>222</td>
<td>570</td>
<td>Sindian City</td>
<td>69,075</td>
<td>128,513</td>
<td>237</td>
<td>442</td>
</tr>
<tr>
<td>Sanchong City</td>
<td>78,593</td>
<td>264,521</td>
<td>205</td>
<td>689</td>
<td>Pinglin Township</td>
<td>1,680</td>
<td>2,893</td>
<td>255</td>
<td>440</td>
</tr>
<tr>
<td>Sinjhuang City</td>
<td>86,877</td>
<td>250,401</td>
<td>219</td>
<td>631</td>
<td>Shihding Township</td>
<td>2,016</td>
<td>3,374</td>
<td>256</td>
<td>429</td>
</tr>
<tr>
<td>Banciao City</td>
<td>109,816</td>
<td>342,010</td>
<td>200</td>
<td>623</td>
<td>Sijihh City</td>
<td>49,473</td>
<td>77,584</td>
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<td>428</td>
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<tr>
<td>Shulin City</td>
<td>40,790</td>
<td>102,281</td>
<td>247</td>
<td>619</td>
<td>Shihmen Township</td>
<td>2,912</td>
<td>5,026</td>
<td>245</td>
<td>423</td>
</tr>
<tr>
<td>Lijhou City</td>
<td>38,531</td>
<td>117,546</td>
<td>200</td>
<td>611</td>
<td>Wanli Township</td>
<td>4,411</td>
<td>8,694</td>
<td>213</td>
<td>419</td>
</tr>
<tr>
<td>Tucheng City</td>
<td>50,822</td>
<td>143,665</td>
<td>214</td>
<td>605</td>
<td>Shenkeng Township</td>
<td>6,073</td>
<td>9,400</td>
<td>270</td>
<td>418</td>
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<tr>
<td>Jhonghe City</td>
<td>85,369</td>
<td>246,625</td>
<td>208</td>
<td>602</td>
<td>Linkou Township</td>
<td>19,178</td>
<td>25,965</td>
<td>281</td>
<td>380</td>
</tr>
<tr>
<td>Yingge Township</td>
<td>23,290</td>
<td>50,868</td>
<td>271</td>
<td>592</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 238. Tow trunk in Taipei streets
### 6.1.11 Parking in Taipei City

Parking in Taipei City is always an issue. There are 2,114 cars and 3,927 scooters per every square kilometer in Taipei City. However, there are only 1,911 car parking spaces and 1,562 scooter parking spaces in every square kilometer when we include public street parking spaces and private parking spaces. The lower table shows the vehicle density and parking space density comparison in every district in Taipei City. Although in some districts, parking spaces outnumber the numbers of vehicles. In reality, only a few people have their own private parking spaces and the rest have to pay for parking except street parking midnight. People tend to find any available free parking space all sides of this parking system to avoid paying money. It creates that cars and scooters are actually parking everywhere throughout the city. Because of parking space shortage, a lot of people will not use their cars unless necessary. It will be very hard to find another parking space especially when people were already returned home from work. There are three types of street parking for cars. If there is a red line on the curb, its means no parking; a yellow line means temporary parking; if there is no line means can park at any time. They are three different types of street parking for scooters. They are perpendicular curb parking, sidewalk parking, and scooter turn parking.

#### Table 30. Cars and Parking Spaces Density in Each District

<table>
<thead>
<tr>
<th>Name</th>
<th>Car density</th>
<th>Car Parking Density</th>
<th>Available Parking Space</th>
<th>Scooter Density</th>
<th>Scooter Parking Density</th>
<th>Available Parking Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taipei City</td>
<td>2,114</td>
<td>1,911</td>
<td>-203</td>
<td>3,927</td>
<td>1,562</td>
<td>-2,365</td>
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<tr>
<td>Jhongshan District</td>
<td>4,423</td>
<td>5,297</td>
<td>874</td>
<td>6,818</td>
<td>3,461</td>
<td>-3,358</td>
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<tr>
<td>Neihu District</td>
<td>2,002</td>
<td>2,808</td>
<td>806</td>
<td>3,165</td>
<td>2,825</td>
<td>-339</td>
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<tr>
<td>Jhongheng District</td>
<td>4,642</td>
<td>5,367</td>
<td>725</td>
<td>8,997</td>
<td>5,117</td>
<td>-3,880</td>
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<td>Nangang District</td>
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<td>1,153</td>
<td>25</td>
<td>2,424</td>
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<td>-1,411</td>
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<td>3,853</td>
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<td>Wunshan District</td>
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<td>1,450</td>
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<td>-2,243</td>
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<tr>
<td>Beitou District</td>
<td>906</td>
<td>580</td>
<td>-326</td>
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<td>456</td>
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<tr>
<td>Shihlin District</td>
<td>974</td>
<td>632</td>
<td>-342</td>
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<td>560</td>
<td>-1,382</td>
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<td>Songshan District</td>
<td>5,385</td>
<td>4,751</td>
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<td>7,846</td>
<td>2,901</td>
<td>-4,945</td>
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<td>Daan District</td>
<td>6,128</td>
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<td>4,085</td>
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<td>Datong District</td>
<td>4,720</td>
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<td>12,252</td>
<td>2,371</td>
<td>-9,882</td>
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<td>Wanhua District</td>
<td>3,594</td>
<td>1,813</td>
<td>-1,781</td>
<td>11,977</td>
<td>1,949</td>
<td>-10,029</td>
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</table>
### Table 31. Home versus Work Trips in Number between Districts

<table>
<thead>
<tr>
<th>District</th>
<th>Work</th>
<th>Home</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Work</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Songshan</td>
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<td></td>
<td>Total 94,056</td>
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<td>Sinyyi</td>
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<td>Da-an</td>
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<td>2,994</td>
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<tr>
<td>Jhongshan</td>
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<td>Datong</td>
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<td></td>
<td>6,422</td>
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<td>Tucheng</td>
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<td></td>
<td>3,015</td>
</tr>
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<td>Shihmen</td>
<td></td>
<td></td>
<td>991</td>
</tr>
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<td></td>
<td>466</td>
</tr>
<tr>
<td>Guangzhou</td>
<td></td>
<td></td>
<td>482</td>
</tr>
<tr>
<td>Shihmen</td>
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<td></td>
<td>1,202</td>
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<tr>
<td>Wanhua</td>
<td></td>
<td></td>
<td>1,875</td>
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<tr>
<td><strong>Total</strong></td>
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### Home versus Work Trips Matrix

<table>
<thead>
<tr>
<th>District</th>
<th>Work</th>
<th>Home</th>
<th>Total</th>
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<tbody>
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</tr>
<tr>
<td>Songshan</td>
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<td>Total 94,056</td>
</tr>
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<tr>
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<tr>
<td><strong>Total</strong></td>
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<td>94,056</td>
</tr>
</tbody>
</table>

This table shows the commute pattern from home to work of people who are over 15 years old with jobs. We can tell how many people live in which district and go to which district for work. The yellow represents the largest numbers of people live in this district that go to that district. For example, there are 94,056 workers live in Songshan district. 57,471 of them stayed in Songshan district for works. It is 61.1% of the total workers live in this Songshan District. The grey represents the second largest numbers of people. For example, there are 6,422 workers live in Jhongshan district go to Jhongshan District for works. It is 6.8% of the total workers live in this Songshan District. The yellow represents the third. The red ones show the top 5 largest numbers of people whose homes in one district but go to another district for works, except home and work in the same district.
### Table 32. Home versus Work Trips in Number between Cities

<table>
<thead>
<tr>
<th>City</th>
<th>Taipei County</th>
<th>Taoyuan County</th>
<th>HOME</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taipei City</td>
<td>1,204,382</td>
<td>1,018,002</td>
<td>121,429</td>
<td>1,481,635</td>
</tr>
<tr>
<td>Taoyuan County</td>
<td>1,727,197</td>
<td>814,996</td>
<td>1,227,076</td>
<td>2,959,273</td>
</tr>
<tr>
<td>Taipei City</td>
<td>1,204,382</td>
<td>1,018,002</td>
<td>121,429</td>
<td>1,481,635</td>
</tr>
<tr>
<td>Taoyuan County</td>
<td>1,727,197</td>
<td>814,996</td>
<td>1,227,076</td>
<td>2,959,273</td>
</tr>
</tbody>
</table>

### Data

<table>
<thead>
<tr>
<th>City</th>
<th>Taipei County</th>
<th>Taoyuan County</th>
<th>HOME</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1,204,382</td>
<td>1,018,002</td>
<td>121,429</td>
<td>1,481,635</td>
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<tr>
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<td>1,204,382</td>
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<td>121,429</td>
<td>1,481,635</td>
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<tr>
<td>Taoyuan County</td>
<td>1,727,197</td>
<td>814,996</td>
<td>1,227,076</td>
<td>2,959,273</td>
</tr>
</tbody>
</table>

### Notes

- The table shows the number of home versus work trips between Taipei City and the Taoyuan County, under the HOME and Total categories.
- Taipei City is represented with 1,204,382 and 1,727,197 respectively, and Taoyuan County with 1,018,002 and 814,996.
- The HOME category indicates the number of trips taken by residents within these areas, while the Total category combines both-home and work trips.
- There is a notable difference in the total number of trips between the two regions, highlighting the disparity in urban planning and commuting patterns.
## Table 33. Home versus Work Trips in Percentage between Districts

<table>
<thead>
<tr>
<th>District</th>
<th>Home</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Songshan</td>
<td>61.1%</td>
<td>38.9%</td>
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<tr>
<td>Shilin</td>
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<td>Shenekeng</td>
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<td>Sinhuang</td>
<td>68.9%</td>
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<td>Wanhua</td>
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<td>23.3%</td>
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</tbody>
</table>
松山區
Pinglin
坪林鄉
樹林市
深坑鄉
Sinjhuang
新莊市
萬華區
三芝鄉
Yingge
鶯歌鎮
龜山鄉
泰山鄉
文山區
Lujhou
蘆洲市
北投區
Shuangsi
南港區
土城市
Wugu
五股鄉
萬里鄉
Shihmen
貢寮鄉
內湖區
汐止市
平溪鄉
Pingsi
Taipei City
Taipei County
Taoyuan County

Total 1,481,635 1,409,659 814,996
Taipei City 66.7% 8.6% 3.2%
Taipei County 26.7% 87.0% 6.9%
Taoyuan County 2.1% 2.6% 88.3%

Table 34. Commute from Cities

Table 35. Commute to Cities
6.1.13 Urban Interface
Although the streets and roads have different widths, the things that affect the urban environment the most are the interfaces between streets and urban space are the sidewalks and arcades. These two elements are the only two parts of streets that residents will have to interact with while they are doing their daily activities except driving, the other parts of the roads just designed for cars to pass by. Based on different combination of arcades and sidewalks, they are eight types of basic street interfaces in Greater Taipei Area. From no arcade no sidewalk to arcade with sidewalk greater than 3.5 meters wide, different sizes of sidewalks and arcades will have different possibilities for pedestrian to use the space. The size of sidewalk is usually related to width of streets and roads. Most of the streets that are less than 10 meters wide usually do not have a sidewalk. Most of sidewalks start from minimum 1 meter to 1.5 meters wide. Up to 1.5 meters to 3.5 meters, trees are allowed to plant on sidewalks and scooters are allowed to park between tree rings. Greater than 3.5 meters, scooter parking turns can be constructed. Most of commercial and commercial mixed with residential streets have arcades, because of the rainy climate in Taipei. Arcades will be the major passages for pedestrian to walk by without getting wet. Sidewalks can be added on the sides.

**Figure 244. Sidewalk and Arcade**

**Figure 245. Different Types of Street Interface**
6.1.14 Streets in Greater Taipei Area

The ideal street section in Greater Taipei Area should look like the diagram the first on the left. Each type of vehicles should have its own lane and sidewalk is for pedestrian only. Because of the scarcity of the available land and high population density in Taipei, streets are typically multifunctional. The street section diagram is the second on the left. Only inner lanes are for cars only, the slow speed lanes are often both for cars and scooters. Sometimes street parking will also occupy some space from slow speed lanes. The traffic conditions in these lanes are chaotic. Scooter drivers not only have to watch out cars in the same lane, they also have to avoid the unexpected door swings from the parking cars. The car drivers also have to pay extra attention to scooter drivers to avoid collusion. It is never easy to drive on Taipei streets. Except highways and expressways, streets of Taipei can be divided into two categories, one is main and secondary streets, and the other is communal streets. Main and secondary streets are mostly full of commercial activities and the major arteries in connecting each part of the city. A lot of people go to these places to work and transfer. The communal streets usually have only a little commercial activity and the rest just all-residential areas. Because there were too many cars and especially scooters parked on the main and secondary streets and on the sidewalks which caused a lot of messy views of urban environment, this city government tried to ban parking in those areas, however, there are still a lot of demand for parking spaces instead of parking in those areas. These vehicles flooded into communal streets. These streets should be the major living space for local residents, but now they become free parking lots. These communal streets share 60% of the total street area of Taipei city. The ban actually made living space worse.

Figure 246.

Figure 247.

Figure 248.

Figure 249.

Figure 250.

Figure 251.
Communal Street Type 1:
4 meters wide street.
Communal Street Type 2:
6 meters wide street.

Figure 254.

Figure 255.
Communal Street Type 3:
8 meters wide street.
Communal Street Type 4:
10 meters wide street.

Figure 258.

Figure 259.
Main Street Type 1: Street without sidewalk.
Main Street Type 2:
Street with 1.5 meters wide sidewalk.

Figure 262.

Figure 263.
Main Street Type 3:
Street with 1.5~3.5 meters wide sidewalk.

Figure 264.

Figure 265.
Main Street Type 4:
Street with sidewalk greater than 3.5 meters in width.
Main Street Type 4:
Street with sidewalk greater than 3.5 meters in width.
Main Street Type 5:
Street with arcade without sidewalk.
Main Street Type 6:
Street with arcade with 1.5 meters wide sidewalk.
Main Street Type 7:
Street with arcade with 1.5~3.5 meters wide sidewalk.
Main Street Type 8: Street with arcade with sidewalk greater than 3.5 meters in width.
Main Street Type 8:
Street with arcade with sidewalk greater than 3.5 meters in width.
6.2 The Distribution of Mobility-on-Demand System in Greater Taipei Area

Everyone wants to have a very good car to drive, such as Porsche. The top speed of Porsche 911 GT2 is 328 kilometers per hour. However, the average Taipei city traffic speed is 27.2 kilometers in morning peak hours; 30.1 kilometers in morning off-peak hours and 25.9 kilometers in afternoon peak hours. Why bother to buy a Porsche to use in this kind of traffic? Although the top speed of MoD vehicles could not catch up with ordinary gasoline vehicles, the MoD vehicles will accelerate faster and are more environmental because they have a smaller footprint and they are fully electric. The MoD transportation system will not replace the existing transportation systems; on the contrary, it will supplement the current systems and make them work more efficiently. The existing transportation network has different systems, and they are now fully integrated. Today, it is often difficult to use one system and transfer to another one because the routes and schedules don't work together very well. By introducing the MoD transportation system, it not only solves the first mile and last mile problem but will also become the bridge and lubricant of different transportation systems. The integration of different transportation systems can make passengers' commute become more efficient and save more money and time. Because of the high density of vehicles and congested traffic in Greater Taipei Area, the MoD system will only introduce CityCar and Roboscooter as MoD vehicles in the first stage. It will be dangerous to use bikes and Segways while the traffic speed is very fast and there are currently few special lanes for these kinds of vehicles.
6.3 Backbone System: MRT Stations

The Taipei Rapid Transit System, also known as the MRT, Metropolitan Rapid Transit, is a rapid transit system connecting the Greater Taipei Area. After the MRT first began operating in 1996, passengers grew from 40,000 passengers per day to 1,239,761 passengers per day today. The MRT is the second most popular public transportation system in Greater Taipei Area. There are eight routes, 69 stations in service right now. The total routes length is 74.4 kilometers. There will be 135 stations and 154.1 kilometers routes length in 2014. The length of total routes will grow up to 270 kilometers in the future planning phase. Based on MRT’s characteristics, the growing number of passengers it carries, the distribution throughout the city, the size of stations, and landmarks which stations became to the neighborhoods, MRT Stations will be the perfect places to become MoD stations. MRT will serve to transport a large number of people to travel from one place to another in distance, while MoD will be responsible to take these people from MRT stations to their destinations. Therefore, MoD System is introduced to solve the first mile and last mile problems between the MRT Stations and people’s destinations. MRT stations will become the backbone system of the MoD System. MoD vehicles will be parked near the entrances of MRT stations or parking lots. People who use MoD vehicles from their origins can simply drop off vehicles in these places. Once passengers left the MRT Stations, they can also pick up of any available MoD vehicle near stations and drive them to their destinations, since a lot of times passengers’ destinations are not within walking distance. They can simply use the same MRT easy-cards to rent and activate MoD vehicles. When they arrive at the destinations, they can follow the Ubiquitous System to guide them to stations near their destinations.

![Figure 282. MRT Routes Map](image)
### Throughput Table of MRT in 2008

#### Table 36. Daily Passengers Numbers in Each Stations in May, 2008

<table>
<thead>
<tr>
<th>Station</th>
<th>Xiaoqitan</th>
<th>Xindian</th>
<th>Xindian City Hall</th>
<th>Qizhang</th>
<th>Dapinglin</th>
<th>Jingmei</th>
<th>Wanlong</th>
<th>Gongguan</th>
<th>Taipower Building</th>
<th>Guting</th>
<th>C.K.S. Memorial Hall</th>
<th>Dingdui</th>
<th>Yongan Market</th>
<th>Jingan</th>
<th>Nanshijiao</th>
<th>Xiaonamen</th>
<th>NTU Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>In</td>
<td>1,871</td>
<td>8,903</td>
<td>9,000</td>
<td>12,484</td>
<td>15,710</td>
<td>13,968</td>
<td>6,839</td>
<td>26,710</td>
<td>14,129</td>
<td>25,839</td>
<td>21,484</td>
<td>25,323</td>
<td>17,806</td>
<td>16,387</td>
<td>16,387</td>
<td>4,161</td>
<td>21,871</td>
</tr>
<tr>
<td>Out</td>
<td>1,903</td>
<td>8,161</td>
<td>9,065</td>
<td>11,935</td>
<td>15,129</td>
<td>13,903</td>
<td>6,548</td>
<td>26,452</td>
<td>13,516</td>
<td>25,903</td>
<td>21,226</td>
<td>26,774</td>
<td>17,484</td>
<td>16,097</td>
<td>15,645</td>
<td>4,484</td>
<td>22,129</td>
</tr>
<tr>
<td>People Trips/ Day</td>
<td>1,887</td>
<td>8,532</td>
<td>9,032</td>
<td>12,210</td>
<td>15,419</td>
<td>13,935</td>
<td>6,948</td>
<td>26,581</td>
<td>13,255</td>
<td>25,887</td>
<td>21,324</td>
<td>26,094</td>
<td>16,422</td>
<td>16,016</td>
<td>4,323</td>
<td>2,742</td>
<td>22,000</td>
</tr>
</tbody>
</table>

| Station                  | Taipei Main Station | Zhongshan | Shuangli an | Minquan W. Rd. | Yuanshan | Jiantan | Shinlin | Zhishan | Mingde | Shipai | Qilian | Qiyang | Beitou | Xinbeitou | Fuxinggang | Zhongyi | Guandu |
|--------------------------|---------------------|-----------|-------------|-----------------|----------|---------|---------|---------|--------|--------|--------|--------|--------|--------|-----------|-----------|--------|-------|
| In                       | 126,710             | 30,742    | 19,677     | 29,581          | 34,355   | 23,677  | 14,484  | 11,710  | 24,355 | 6,355  | 5,839  | 5,387  | 6,097  | 6,306  | 15,452    | 4,274     | 3,032  | 2,742 |
| Out                      | 122,613             | 31,903    | 21,258     | 29,613          | 33,935   | 23,968  | 14,613  | 11,097  | 25,419 | 5,839  | 5,387  | 6,097  | 6,306  | 15,452 | 4,274     | 3,032     | 2,742  | 11,065 |

<table>
<thead>
<tr>
<th>Station</th>
<th>Zhuweii</th>
<th>Hongshulian</th>
<th>Danshuil</th>
<th>Xinpu</th>
<th>Jiangzicui</th>
<th>Longshuan Temple</th>
<th>Ximen</th>
<th>Shandaotemple</th>
<th>Zhongxiaocixing</th>
<th>Zhongxiaofuxing</th>
<th>ZhongxiaoDunhuang</th>
<th>Sun Yetsen Memorial Hall</th>
<th>Taipei City Hall</th>
<th>Yongchu</th>
<th>Houxianpi</th>
<th>Kunyang</th>
<th>Zhongshana Junior High School</th>
</tr>
</thead>
<tbody>
<tr>
<td>In</td>
<td>8,677</td>
<td>5,742</td>
<td>35,065</td>
<td>37,032</td>
<td>19,355</td>
<td>22,323</td>
<td>49,258</td>
<td>16,000</td>
<td>18,129</td>
<td>40,839</td>
<td>28,710</td>
<td>17,484</td>
<td>41,677</td>
<td>16,677</td>
<td>15,968</td>
<td>28,065</td>
<td>16,194</td>
</tr>
<tr>
<td>Out</td>
<td>8,774</td>
<td>5,968</td>
<td>34,290</td>
<td>36,258</td>
<td>19,226</td>
<td>21,581</td>
<td>49,516</td>
<td>17,290</td>
<td>19,129</td>
<td>40,484</td>
<td>31,903</td>
<td>18,936</td>
<td>42,419</td>
<td>16,419</td>
<td>15,710</td>
<td>28,226</td>
<td>14,968</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station</th>
<th>Nanjing E. Rd.</th>
<th>Daan</th>
<th>Technolo gy Building</th>
<th>Liuzhang</th>
<th>Linguang</th>
<th>Xinhai</th>
<th>Wanfang Hospital</th>
<th>Wanfang Communl ty</th>
<th>Muzha</th>
<th>Taipei Zoo</th>
<th>Bangqiao</th>
<th>Fuzhong</th>
<th>Far Eastern Hospital</th>
<th>Haishan</th>
<th>Tucheng</th>
<th>Yongning</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>In</td>
<td>17,387</td>
<td>11,581</td>
<td>10,710</td>
<td>6,845</td>
<td>19,355</td>
<td>2,516</td>
<td>10,903</td>
<td>1,903</td>
<td>3,806</td>
<td>7,452</td>
<td>18,548</td>
<td>22,613</td>
<td>11,742</td>
<td>14,355</td>
<td>5,000</td>
<td>11,129</td>
<td>1,226,194</td>
</tr>
<tr>
<td>Out</td>
<td>18,613</td>
<td>12,161</td>
<td>10,677</td>
<td>8,581</td>
<td>19,226</td>
<td>2,355</td>
<td>11,548</td>
<td>1,548</td>
<td>4,065</td>
<td>7,613</td>
<td>20,226</td>
<td>21,194</td>
<td>10,258</td>
<td>14,161</td>
<td>5,000</td>
<td>11,129</td>
<td>1,226,161</td>
</tr>
<tr>
<td>People Trips/ Day</td>
<td>18,000</td>
<td>11,871</td>
<td>10,694</td>
<td>8,613</td>
<td>19,290</td>
<td>2,435</td>
<td>11,226</td>
<td>1,726</td>
<td>3,935</td>
<td>7,532</td>
<td>19,387</td>
<td>21,903</td>
<td>11,000</td>
<td>14,258</td>
<td>5,000</td>
<td>11,129</td>
<td>1,226,177</td>
</tr>
</tbody>
</table>
Throughput Diagram of MRT in 2008

Figure 283.
5 minutes Walking and 3 minutes Driving Distance from MRT Stations Diagram in 2008

- Existing Single Line Station
- Existing Crossing Lines Station
- Station after 2011
- 3 Minutes Car/Scooter Drive from Existing Sta. (1800m)
- 5 Minutes Walk from Sta. (400m)
5 minutes Walking and 3 minutes Driving Distance from MRT Stations Diagram in 2011

- 3 Minutes Car/Scooter Drive from Existing Sta. (1800m)
- 5 Minutes Walk from Sta. (400m)

Figure 285.
Figure 286. View of junior high school's field
6.4 Ubiquitous Sub-System 1: School Stations

Because Taipei City and Taipei County are mixed-use cities, there is no clear boundary among residential, commercial and industrial zones. Residential areas can be found anywhere inside and outside the city limits. Where there is a residential area, there are schools near by it. Furthermore, education for children from elementary school to junior high school is compulsory in Taiwan. Except for a small number of special and private schools, most of elementary schools and junior high schools are community schools. They are usually within walking distance for students who live in nearby neighborhoods to attend. Most parents in Taiwan don’t drive their children to schools like parents in United States do; instead, most students travel to their schools on feet or by bicycles. Elementary schools and junior high schools are a necessity for every residential area. These schools don’t just play roles in education systems, but can actually become community centers. For example, people go to schools to vote in every election. Similarly, many public lectures and local clubs take place in schools. Nearby residents always use schools like their own back yards to do exercise and sports. Schools even become shelters for nearby citizens when unexpected disasters taking place. Schools are very important to every neighborhood and they are ubiquitous throughout Greater Taipei Area. From university to elementary school, there are 309 schools in Taipei City and 345 schools in Taipei County, and a total of 654 schools in the Greater Taipei Area.\(^{489}\) Of them are elementary schools or junior high schools, nearly 75% of total schools. Since schools are ubiquitous and have their own campuses, the MoD System can take the advantage of their distribution, density, available space and the role it plays and turn it into Ubiquitous System Station for MoD System. People could pick up their desired vehicles from School Stations. Because schools are always within the walking distance for residents in the same neighborhood, people will have no problem to go to nearby schools either from home or work place in a short time. Parents could even walk their children to schools and pick up vehicles to go to work from School Stations. If users go to an unfamiliar area, they would have no problem to find a School Station to pick up a vehicle or to find a drop off parking space either by asking people or using on-board GPS. There are four different types of parking possibilities for School Station parking. They are parking near the school’s perimeter, parking inside certain areas of school, parking everywhere inside school, and parking under school. They can accommodate both CityCar and Roboscooter parking.

<table>
<thead>
<tr>
<th></th>
<th>Taipei City</th>
<th>Taipei County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities &amp; Colleges</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Junior Colleges</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>High Schools</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td>Vocational High Schools</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Junior High Schools</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>Elementary Schools</td>
<td>153</td>
<td>209</td>
</tr>
</tbody>
</table>

Table 37. Schools in Greater Taipei Area
Schools Distribution Diagram in Greater Taipei Area

There are 654 schools in Greater Taipei Area and approximately at least 582 schools are shown on this map. Most of schools are within urbanized area and still some are outside urban area. Within the urbanized area, schools are distributed evenly everywhere and ubiquitous. Where there are people, there are schools.

Figure 287.
From the density diagram, it can be seen that there is at least one school per square kilometer in the urbanized Greater Taipei Area. In some parts, there are up to six schools per square kilometer. The sheer density and even distribution of schools can be a very good characteristic for the Ubiquitous System of the MoD System.
<table>
<thead>
<tr>
<th>Country</th>
<th>Stores</th>
<th>Density (stores/km²)</th>
<th>People serving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>12,013</td>
<td>31</td>
<td>10,636</td>
</tr>
<tr>
<td>USA</td>
<td>5,863</td>
<td>1,642</td>
<td>51,443</td>
</tr>
<tr>
<td>Taiwan</td>
<td>4,807</td>
<td>8</td>
<td>4,781</td>
</tr>
<tr>
<td>Thailand</td>
<td>4,055</td>
<td>127</td>
<td>16,139</td>
</tr>
<tr>
<td>South Korea</td>
<td>1,433</td>
<td>70</td>
<td>34,211</td>
</tr>
<tr>
<td>Malaysia</td>
<td>843</td>
<td>391</td>
<td>32,230</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>600</td>
<td>1</td>
<td>8,704</td>
</tr>
<tr>
<td>Mexico</td>
<td>678</td>
<td>2,909</td>
<td>158,480</td>
</tr>
<tr>
<td>Canada</td>
<td>469</td>
<td>21,289</td>
<td>70,959</td>
</tr>
<tr>
<td>Singapore</td>
<td>400</td>
<td>2</td>
<td>11,210</td>
</tr>
<tr>
<td>Australia</td>
<td>366</td>
<td>21,239</td>
<td>58,283</td>
</tr>
<tr>
<td>China</td>
<td>341</td>
<td>28,152</td>
<td>3,876,398</td>
</tr>
<tr>
<td>Philippines</td>
<td>291</td>
<td>1,031</td>
<td>304,380</td>
</tr>
<tr>
<td>Norway</td>
<td>102</td>
<td>3,179</td>
<td>46,595</td>
</tr>
<tr>
<td>Turkey</td>
<td>79</td>
<td>9,881</td>
<td>891,316</td>
</tr>
<tr>
<td>Sweden</td>
<td>74</td>
<td>6,081</td>
<td>124,094</td>
</tr>
<tr>
<td>Denmark</td>
<td>61</td>
<td>706</td>
<td>89,767</td>
</tr>
<tr>
<td>Hawaii</td>
<td>53</td>
<td>535</td>
<td>22,859</td>
</tr>
<tr>
<td>Macau</td>
<td>26</td>
<td>1</td>
<td>20,885</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>14</td>
<td>650</td>
<td>282,713</td>
</tr>
</tbody>
</table>
6.5 Ubiquitous Sub-System 2: Convenience Store Stations
Taiwan has the highest density of convenience stores per person in the world. There are 9,029 convenience stores \(^{32}\) in Taiwan, serving 23 million population in an area of 35,801 m\(^2\), an average of 2,700 potential customers per one store and every 3.97 km\(^2\) serving area per one store. 80\% of urban household shoppers in Taiwan go to a convenience store every week.

The top four franchises convenience stores brands own 94.1\% of the total convenience stores in Taiwan. They are 7-11, 48.57\%; Family Mart, 22.28\%; Hi-Life, 13.96\% and OK, 9.29\%. Just 7-11 alone has 6 million customer visits per day, and nearly one out of four people in Taiwan shops in 7-11 everyday. Japan has 12,013 7-11 convenience stores, ranked 1st in the world; USA is in 2nd place, has 5,863 stores; Taiwan ranked 3rd, has 4,807 stores.\(^ {32}\) However, if you compare the size of Taiwan with Japan and USA, Japan is 11 times and USA is 275 times bigger than Taiwan, Taiwan is 2/5 of Japan’s store number and only 1,056 stores less than total number of stores which the USA has.

Convenience stores in Taiwan not only sell food, beverages, snacks, newspapers, and books, but also provide all kinds of service, such as movie and concert tickets, delivery service, on-line shopping pick up and payment service, ATM, Taxi, fax, printing, scanning, photo printing, video rental pick up, insurance, recycling, donation, etc. Furthermore, customers can even pay their bills such as cell phone, internet, credit card, utility, parking fee, traffic violation fine in these convenience stores. Convenience stores in Taiwan actually function like a community center. People go there to meet friends, find solutions, and feed their needs. Because all the convenience stores operate 24-7, people always feel secure mentally and physically that there is a place they can go anytime they choose to have anything they like.

Based on the wide distribution and density that convenience stores have, they can be a perfect place to become the Ubiquitous System for MoD System. People can go there not only buy all sorts of things and pay all kinds of bills, but also fulfill their need for mobility. Because the top four brands have 94.1\% share of the total convenience stores. It would be relatively easier to negotiate with just four franchises about implementing the MoD network. There are seven different general types of convenience stores in Taiwan. Each of them will have different parking strategies for CityCar and Roboscooter. These vehicles don't always need to park in front of stores, they can be parked near them. Convenience store can just provide a locating point for user to locate the station.
There are approximately at least 1,579 convenience stores in Greater Taipei Area. Most of convenience stores are within urbanized area and especially in central part of Taipei City. Within urbanized area, convenience stores are distributed evenly everywhere and ubiquitous. Where there are people, there are convenience stores.
Convenience Stores Density per Square Kilometer Diagram in Greater Taipei Area

From the density diagram, it can be seen that every square kilometer in urbanized Greater Taipei Area has more than one convenience store. In some parts, there are even 26, 24, 24 convenience stores per one square kilometer. The sheer density and even distribution of convenience stores is ideal for enabling the Ubiquitous System of MoD System.
Figure 292. Street View of Taipei City
6.6 Ubiquitous Sub-System 3: Bus Stop Stations

Public buses are always very important to public transportation in Greater Taipei Area. Since operating, public buses are the major commute method to Taipei citizens, even after MRT operating. There are more passengers using public buses to commute than using MRT. Public buses have an average of 1,687,960 passengers per day, while the MRT only has 1,239,761 passengers per day. There are 11 companies, running 287 routes, 3,877 buses per day. Bus stops are everywhere throughout the Greater Taipei Area. Almost everywhere can be reached by bus. Sometimes people don’t have to transfer to another route to their destinations, because every route tries to cover as many stops as possible. This makes the bus routes in Greater Taipei Area extremely complicated and even difficult to understand for some local residents. There are only a few routes that always stay on the same main roads and people can transfer to their destination by taking another these types of buses, known as a chessboard route. Based on the wide coverage, density and passenger trips per day, which bus stops have, they can be the perfect Ubiquitous System for MoD System. MoD System can also solve complex routes problem by giving passengers an extra mobility to link with MRT Stations or other bus stops, all they have to do is to pick up a vehicle and drive it to their transfer station or destination. There are two types of bus stops in Great Taipei Area: one is with bus route sign standing on the sidewalk, and the other is bus kiosk usually near the designated bus line.
Bus Stops Distribution Diagram in Greater Taipei Area

There are at least 4,261 bus stops, which belong to Taipei public bus system, in Greater Taipei Area. Most of bus stops are within urbanized area and especially in central part of Taipei City, though some stops are in mountain hills for tourists. Within the urbanized area, bus stops are distributed evenly everywhere and ubiquitous. Where there are people, there are bus stops.
Bus Stops Density per Square Kilometer Diagram in Greater Taipei Area

From the density diagram, it can be seen that every square kilometer in urbanized Greater Taipei Area has more than one bus stop. In the central part of Taipei, the average is over 30 bus stops and up to 44 in one square kilometer. One bus stop may have dozens of bus routes that service the stop. The sheer density and even distribution of bus stops is a perfect characteristic for Ubiquitous System of MoD System.
Ubiquitous System Stations Distribution Diagram in Urbanized Area

School
Convenience Store
Bus Stop

Figure 297.
6.7 Ubiquitous Systems
When School Stations, Convenience Store Stations and Bus Stop Stations all work together, they become the Ubiquitous System. There are a total at least 6,422 points that could possibly form the backbone for a Ubiquitous System Stations throughout the Greater Taipei Area, mainly in urbanized areas. Each Ubiquitous Sub-system is distributed evenly and covers near every corner of urbanized area. Although the density of potential Ubiquitous System is very high, each sub-system is not overlay with each other. Nearly every square kilometer in urbanized Greater Taipei Area has more than one school and dozens of convenience stores and bus stops. These Ubiquitous Stations can provide pick up and drop off spaces for MoD vehicles. Users can always pick up and drop off any MoD vehicles near their origins or destinations in no time. By synergy, all sub-systems can work as one and become a ubiquitous transportation network for Greater Taipei Area.

After users leave MRT Station, Backbone System, and take MoD vehicles to their desire destination, they will need stations to drop off their vehicles if there are no MRT Stations nearby and vice versa. Ubiquitous System Stations will be the stations which solve the first mile and last mile problems for MoD users. Therefore, the distance and time from users' origins and destination to the nearest Ubiquitous System Stations are very important and will affect users' decisions whether they want to use the MoD System or not. Accessibility to Ubiquitous System Stations can be measured by the distance between these stations to any point of urbanized area in Greater Taipei Area, since most of the commute will take place in this area. The accessibility to Ubiquitous System Stations can be shown on the diagrams of walking distance and time consumption from these stations.

The diagram on left page shows the location of Ubiquitous System Stations. The following diagrams in the next four pages show how much time it takes and how far it gets from stations. An average person in normal walking speed can walk 80 meters in one minute.
1 Minute Walking Distance/80 Meters
2 Minute Walking Distance/160 Meters
3 Minute Walking Distance/240 Meters
4 Minute Walking Distance/320 Meters
Walking Distance from Convenience Store

Walking Distance from School

Walking Distance from Convenience Store

Bus Stop

Walking Distance from Bus Stop

5 Minutes Walking Distance/400 Meters
5 Minutes Walking Distance from School Stations/ 400 Meters

5 Minutes Walking Distance from Convenience Store Stations/ 400 Meters
Synergy of Ubiquitous Sub-Systems

In just one minute of walking and 80 meters in distance from all the Ubiquitous System Stations, it could cover roughly 45% of the total urbanized area in Greater Taipei. Two minutes walking could cover 60%; Three minutes for 75%; Four minutes for 85% and five minutes walking from stations can cover up to 95% of the urbanized area in Greater Taipei. It suggests that users of MoD System could find a MoD Station anywhere in urbanized Greater Taipei Area in less than 300 seconds. People could pick up MoD vehicles from stations which near their origins in less than 300 seconds, 400 meters walking distance. People could drop off MoD vehicles to stations near their destinations and arrive at their destination in less than 300 seconds, 400 meters walking distance. The three diagrams on the left hand side show five minutes walking distance from each sub-system. Each sub-system could not cover 95% of the urbanized area in Greater Taipei just on its own, they have to work together as one to achieve it.
Ubiquitous System Stations Distribution Diagram in Greater Taipei Area

- **School**
- **Convenience Store**
- **Bus Stop**

Figure 306.
Ubiquitous System Stations per Square Kilometer Diagram in Greater Taipei Area
7.0 REFERENCE
Note
4. e2: Transport, DVD (PBS, 2008)
7. Ibid, 1.
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27.Ibid, 4-1.
30.http://140.111.34.54/statistics/content.aspx?site_content_sn=8869
33.Ibid.


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Figure 1. Smart Cities group, MIT Media Lab
Figure 2. Smart Cities group, MIT Media Lab
Figure 3. Will Lark
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Figure 7. Will Lark
Figure 8. Will Lark
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