ABSTRACT

Title of Document: URBAN SCAFFOLD FOR RENEWING DERELICT FABRIC

Lin Mao, Master of Architecture, 2011

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In a historic Italian town, opportune innovations in automated parking provide solutions to multifaceted challenges in urban renewal and economic revitalization. A single automated parking facility alleviates pressure in urban infrastructure, simultaneously stabilizing an endangered building shell, and becoming a catalyst for phased urban redevelopment. Strategic opportunities in geography and context are pursued to produce upfront and long-term project feasibility.

URBAN SCAFFOLD FOR NEWING DERELICT FABRIC

By

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Preface

It is important to understand 1) that this document is produced eighteen months after the original defense of the thesis. Since the defense, the author completed a Master of Science in Real Estate, and the experience obtained in the M.S.RE program has since informed the content of this document. The conceptual understanding of real estate has improved and reinforced the strength of the original thesis. 2) Unless otherwise noted, the author holds authorship for graphic content in this document.

In 2008, a fresh M.Arch candidate, who had been a commuter student throughout college, visited Gragnano for the first time. This architecture student was amazed but also saddened by the wide use of automobiles in Italy, especially in historic hillside towns where cars are unfit for the towns but still operate in the streets. So naturally, the M.Arch candidate decided to pursue a thesis to catalyze urban redevelopment via parking solutions. Based on his instincts as a commuter, this student held a seasoned belief that automotive forces drive urban development. Through this belief and his fascination for neglected spaces, he sought out architectural methods and design strategies to empower a declining historic town for renewal.

For this thesis, the scope of the design process has been limited to the design and engineering of the automated parking facility only. Phasing in urban redevelopment is suggested through the growth of the primary automated parking system.

Acknowledgements

I would like to acknowledge the generosity and support of the faculty at the School of Architecture, Planning & Preservation. Without them, this would not have been possible. Special thanks are given to my thesis committee, Garth, Dr. Vann and B.D., for their continued encouragement and friendship. Likewise, I am grateful for the production support by my dear friends, Artur Kalil, Rob Sanz and Jason Cheung at the final hours before my public defense.

Furthermore, I would like to offer special recognition to Martin Mattia of FATA Automation Inc. / FATA Skyparks, Steven Z. Cratin of Siena Corporation, and Franklyn E. DeFoe of Unitronics for their professional support, their special insight on the automated parking industry and their continued enthusiasm since 2009.

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Executive Summary

The technology of automated parking is used to stabilize an existing building shell and serves to catalyze urban revitalization. The insertion point is in Gragnano, a post-earthquake, historic Italian town that is in decline. The abandoned building shell is at the entry to Gragnano's congested downtown, where its narrow main street is burdened by traffic and parking. Effectively, automated parking will offer structural stabilization to the building shell while accommodating parking needs to stimulate phased downtown redevelopment.

This architectural thesis provides one, adaptable, tangible solution to address multiple challenges that are simultaneous in local and regional economic development, historic preservation, and urban redevelopment.

In Gragnano, NA, Italy, through four development phases, one design intervention in automated parking system will simultaneously:

Provide Primary Solutions in

1)	Preservation:	stabilize an endangered historic building shell
2)	Parking:	alleviate parking; improve the main street
3)	Development:	satisfy residential and retail demand criteria
4)	Impermanence:	prefab modules optimize facility expansion

With Sustainable and Economic Solutions in

1) Renewal Energy

   a. Solar Power: Mediterranean climate and sun

   b. Wind Power prevailing Bay of Naples wind

   c. Geothermal: regional hot spring of Campania

2) Value-add

   a. Cellular Towers: unique height in a low-rise context

   b. Advertising: prominent visibility for sponsors' marketing

   c. Public Relations: ideal visibility for public announcements

3) Joint Venture

   a. Café: capitalization of parking customers' wait time

   b. Car Rental: opportunistic utilization of excess parking racks

The phased solution explores the versatility in automated parking technology's potential in impermanent construction methods, while capitalizing on the construction's versatile modular system to accommodate evolving market demands.

The technology of automated parking offers significant possibilities in redevelopment strategies by applying opportune modifications to the conventional system. In fact, the prefabrication of structural modules allows phased implementation of site-specific and market-appropriate accommodations that are otherwise impossible in conventional structured parking. In fact, the historic siting of Gragnano is advantageous for the utilization of solar and wind-powered alternative energy systems, providing, independent and self-sustaining energy sources. Additionally, the finished construction is opportune for advertisement, public announcement, and cell tower enhancements as value-add for long-term debt service. Ultimately, a wholly prefabricated system is advantageous for the deconstruction of the entire structure for potential future relocation and reversion of the original property.

Within the endangered building shell, an enhanced automated parking system is most opportune to address Gragnano’s parking demand, needs in urban revitalization, and strategies in sustainable energy use and financing.

Chapter 1: The Hermit Crab

Figure 1-0-1. A hermit crab (public domain photo).

The hermit crab is a sustainable nomad. When hermit a hermit crab grows out of its shell, it finds a new one and adapt into it. In the moving process, the previous shell is passed on to another hermit crab. The shells that hermit crabs use are from sea snails, and certain species even rehabilitate hollow wood and stones as new shells. The hermit crab is perhaps one of the most versatile and resourceful creatures.

Humanity can learn a lot from hermit crabs' ability to re-use, to pass-on and to adapt. In the development of towns and cities, so much of humanity's history has been scraped away. Resources have been taken for granted in urban development, where upfront cost is conventionally cheaper through demolition and new construction. Unfortunately, much of the planet's environments have suffered in the process, while only inconsequential spreadsheets have benefited.

This thesis looks at a hillside Italian town of significant history, an endangered building in this town, and a multiple innovation in automated parking that will help this town restore its brilliance. This thesis focuses on the key principles of historic preservation, adaptive-reuse and impermanent architectural intervention; while simultaneously address challenges in derelict urban fabric, distressed real estate, and creative project financing to facilitate economic revitalization. This is a thesis that finds creative opportunities in overlaying, multidisciplinary challenges by providing a simple, multifaceted solution in car parking.

Humanity has much to gain by learning from nature

Chapter 2: Gragnano

Gragnano is Italy’s birthplace for pasta. It is where Italian pasta manufacturing began.

Gragnano’s geographic location is strategically advantageous to the process of pasta production. Gragnano is a hill town in Campania along the Amalfi Coast, nestled in to face the Bay of Naples, where the region is rich with natural springs and fertile volcanic soil. The running springs of the region powered the mills, the fertile earth grew the stocks, the natural spring water mixed the dough, and the prevailing breeze dried the pasta hung on the main street. The natural conditions gave Gragnano its success in pasta production.

The mills in Gragnano have existed since the Middle Ages (between the ninth and eleventh centuries). The first records of producers were from 1641, as only two Gragnano producers were registered with the guild of Neapolitan pasta-makers. By the late eighteenth century, 280 pasta shops were in Naples, which provided for a Neapolitan consumption rate of 31 pounds of pasta per person. By early nineteenth century, 110 pasta factories still operated even after the invention of competing hydraulic technology in pasta production. During the same century, railroad also began transporting goods from Gragnano to Naples. Gragnano continued to prosper in the nineteenth century, especially after the 1884 lifting of an oppressive flour tax, until the outbreak of World War I.

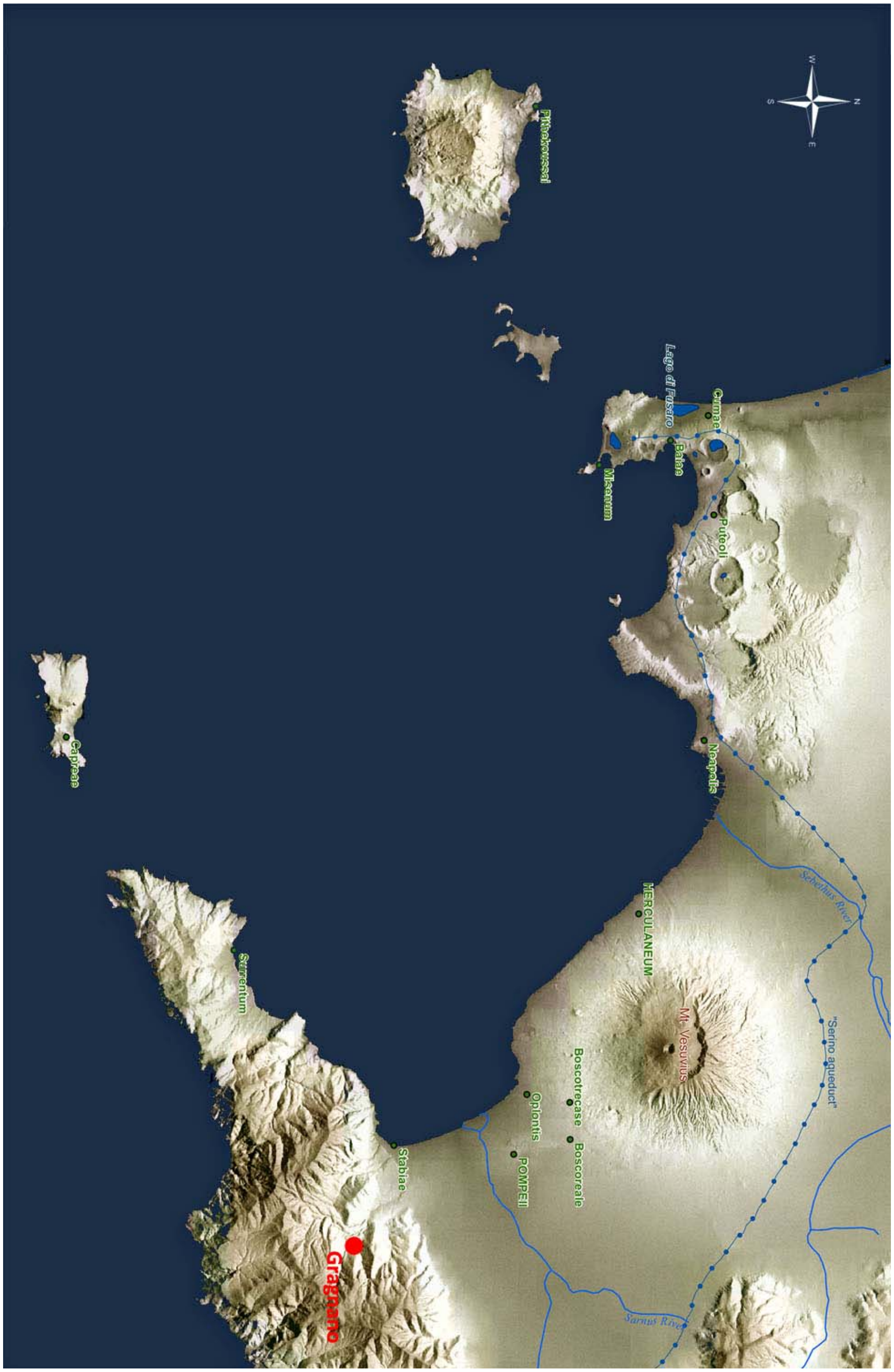
What also contributed to Gragnano's success is its tremendous access to local, regional, and international markets. In Gragnano's downtown is a railway that runs adjacent to the main street where pasta is dried. Railroad provides access to local and regional markets, where goods are further distributed around the world. Three miles towards the water from Gragnano is the historic shipyards of Castellammare di Stabia, where ship-building has existed since the Romans, and twenty miles to the northwest is the port city of Naples, where Gragnano's pasta is able to reach its international market. In 1815, Gragnano successfully delivered its first shipment of pasta to the U.S.

The industry of pasta manufacturing has been central to the vitality of Gragnano. As the industry has dwindled after World War II, so has the overall economic vitality of the town. Post-war depression and competing international pasta industries contributed significantly to the decline of pasta manufacturing in Gragnano. For instance, more progressive northern Italian industries became Gragnano's greatest national competitors. As of 1996 only twenty-two factories remained operational in Gragnano, responsible for 10% of Italy's national pasta production—a fraction of its historic glory.

Without its dominant industry, Gragnano has struggled to survive. The hill town’s fabric historically accommodated horses and wagons, but its infrastructure cannot adequately adapt to modern transportation needs. Furthermore, in the early 1980’s, a significant earthquake hit Campania, and many buildings in downtown Gragnano fell and became damaged. The town has not been able to heal its economy or its torn fabric. The long-term survival of the town is very much at stake.

Solutions to revitalize Gragnano are very tangible for both the near and far future. Economic challenges in the region provide ample opportunities for innovative solutions that will effective rebuild Gragnano’s global reputation. The simultaneous preservation, reconstruction, and redevelopment of downtown can be achieved through a single catalyzing insertion to stimulate regional economic vitality.

Figure 2-1-1. The driving of pasta on Via Roma in Gragnano. Photo reproduction of a displayed photograph. Photographic reproduction by author.



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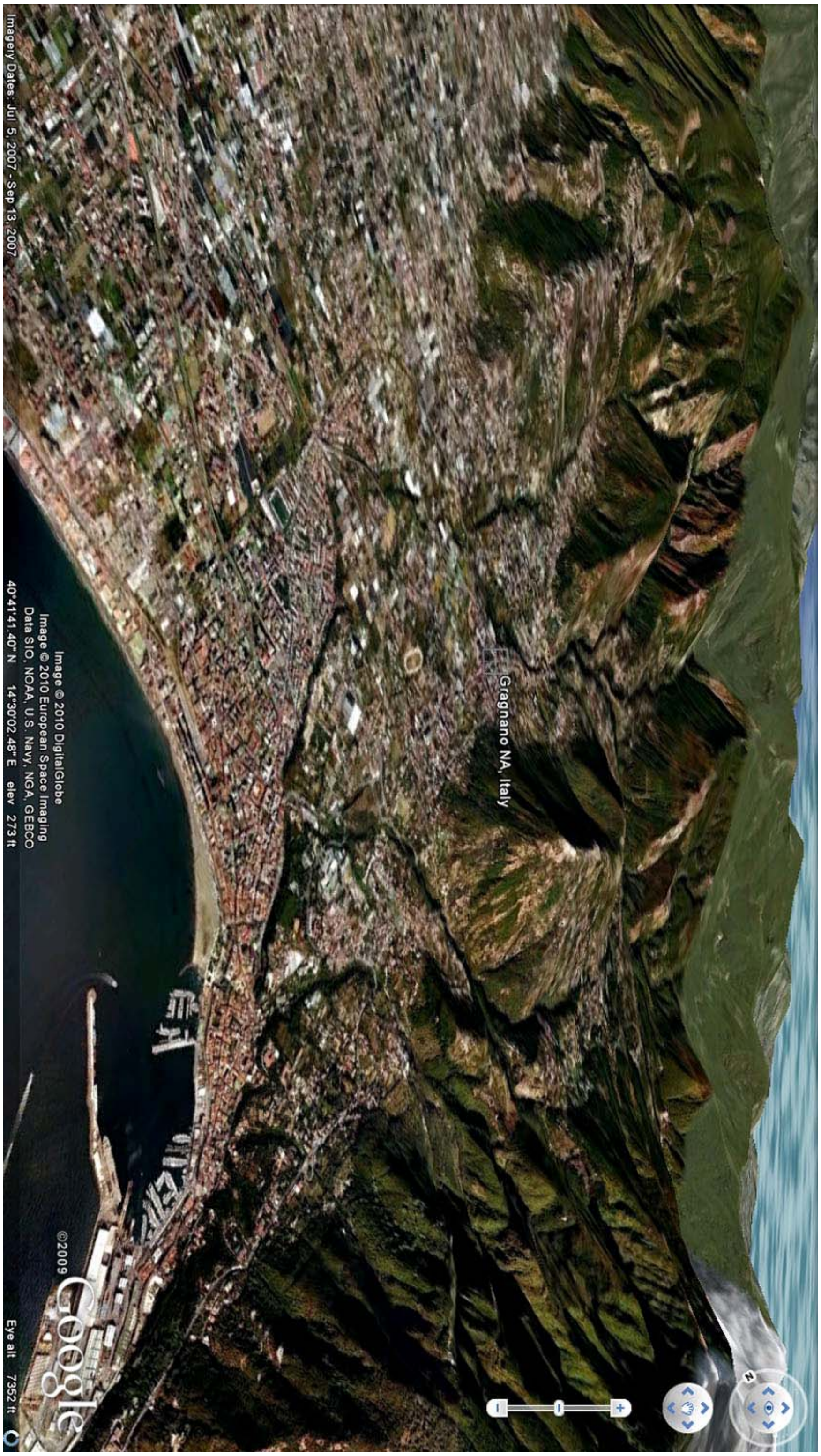

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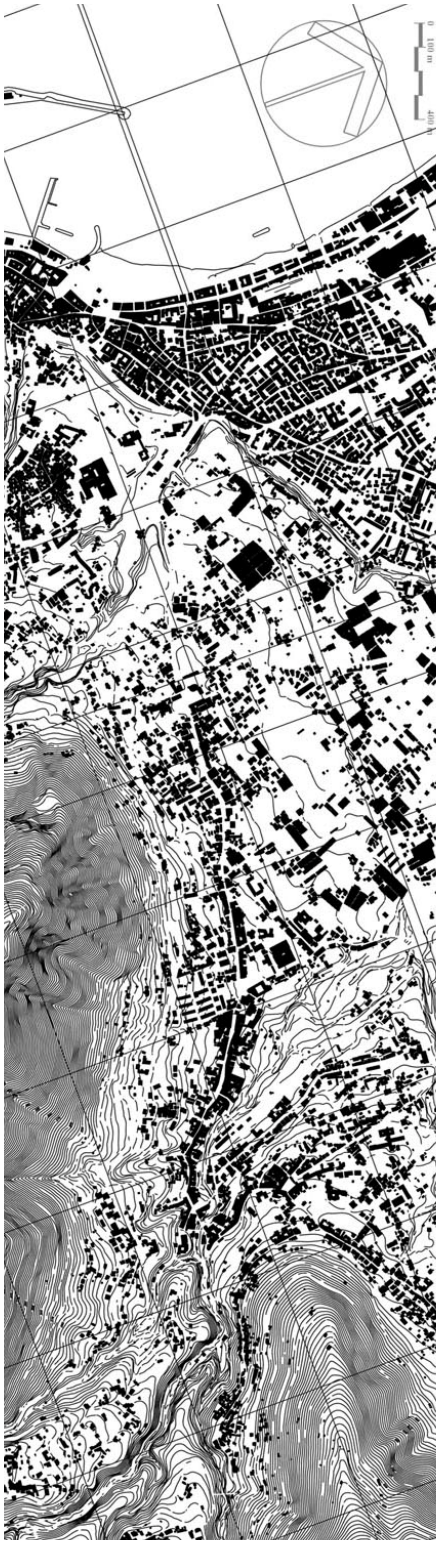

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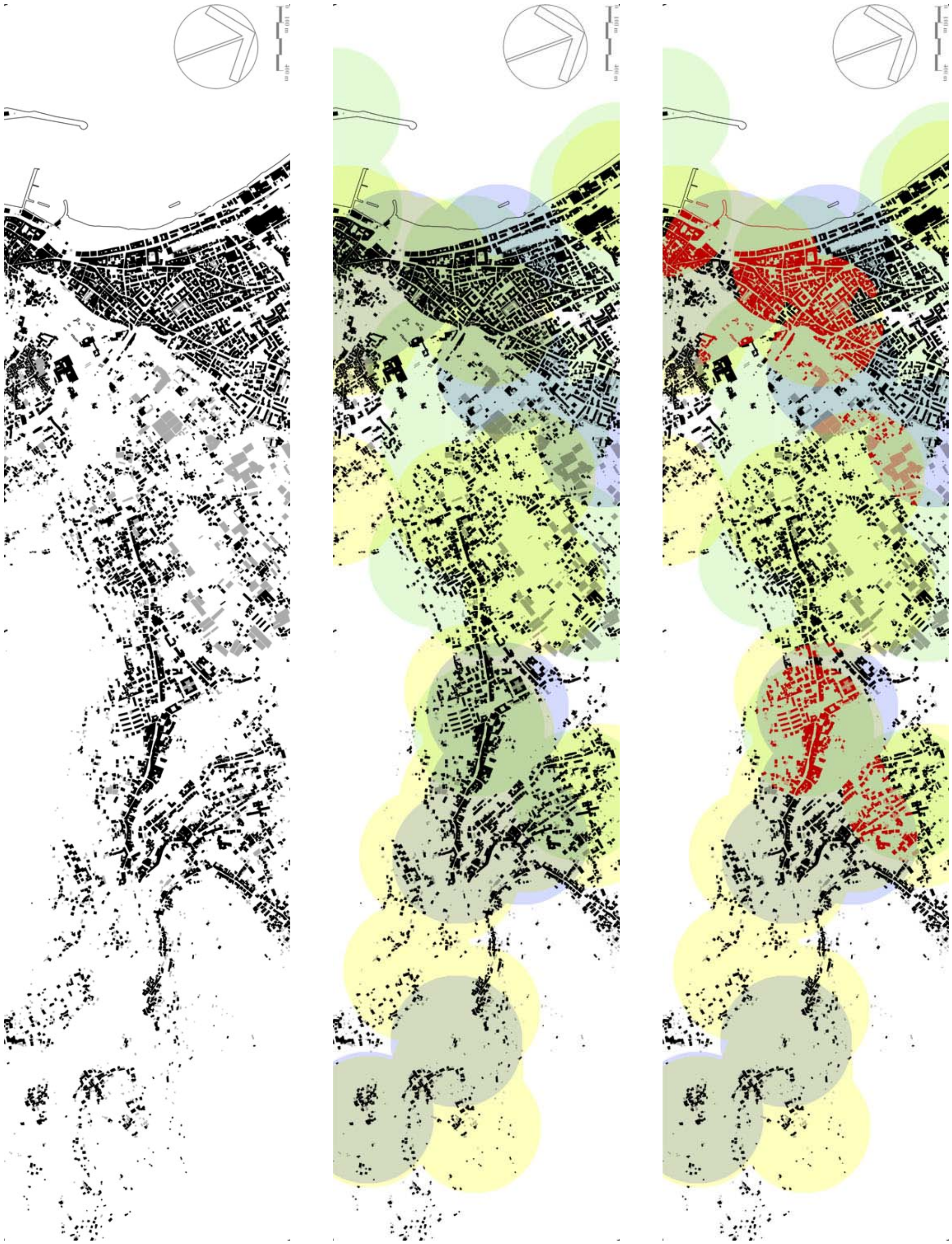

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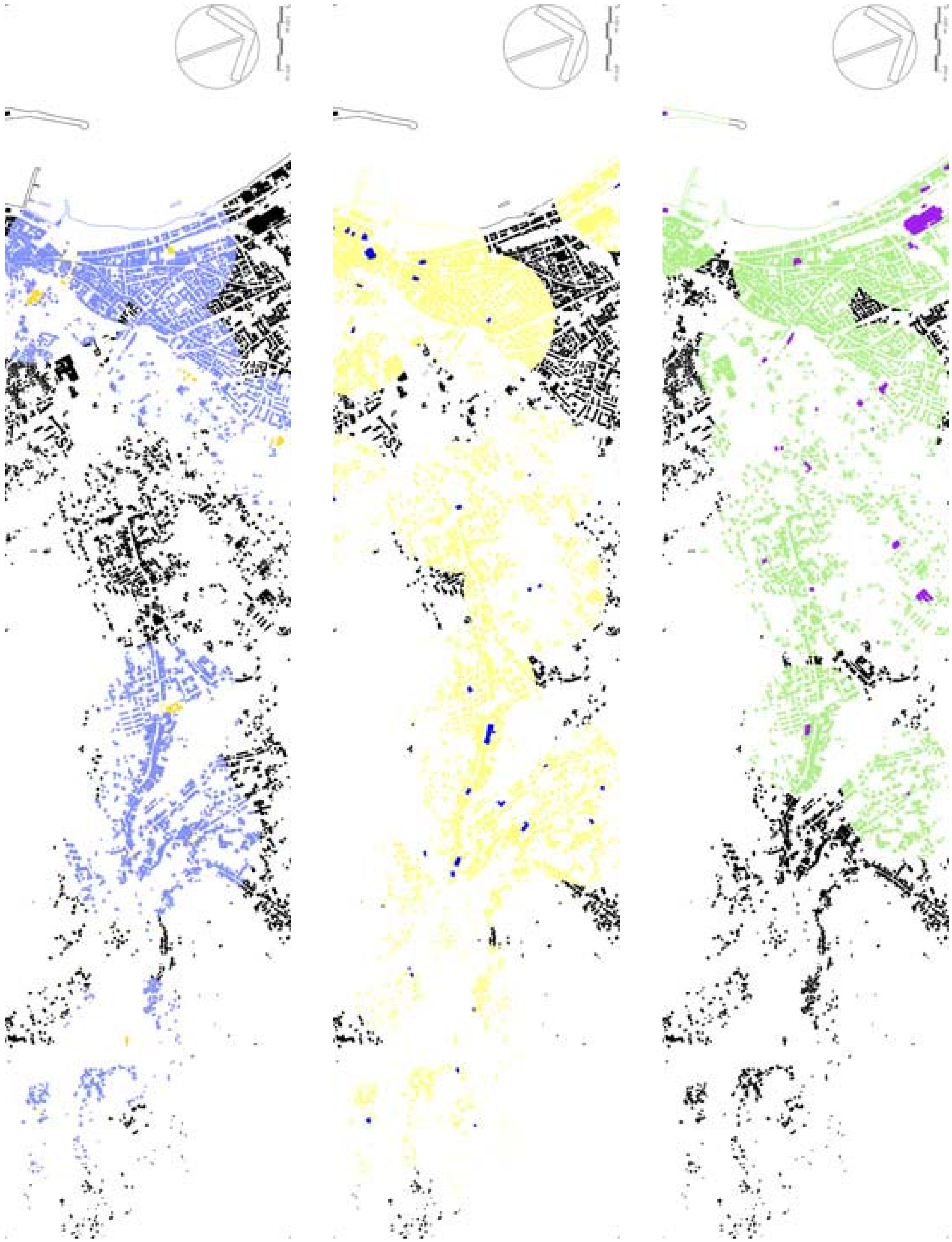

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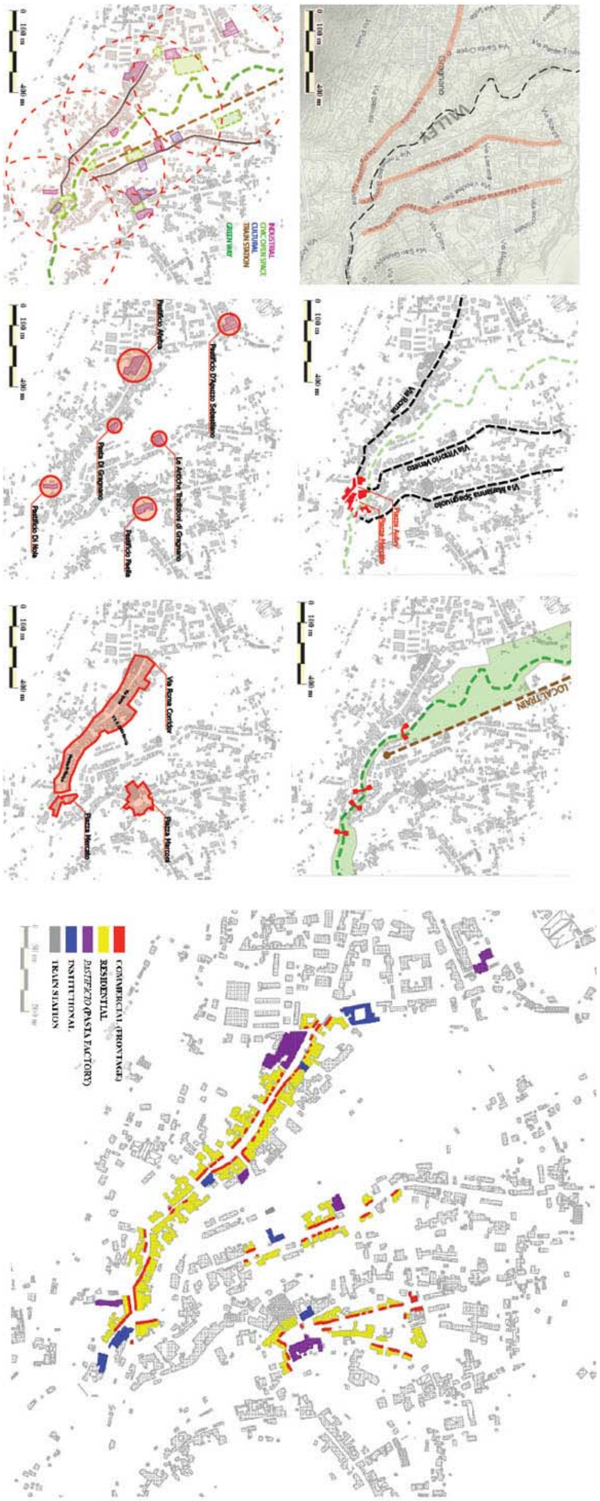

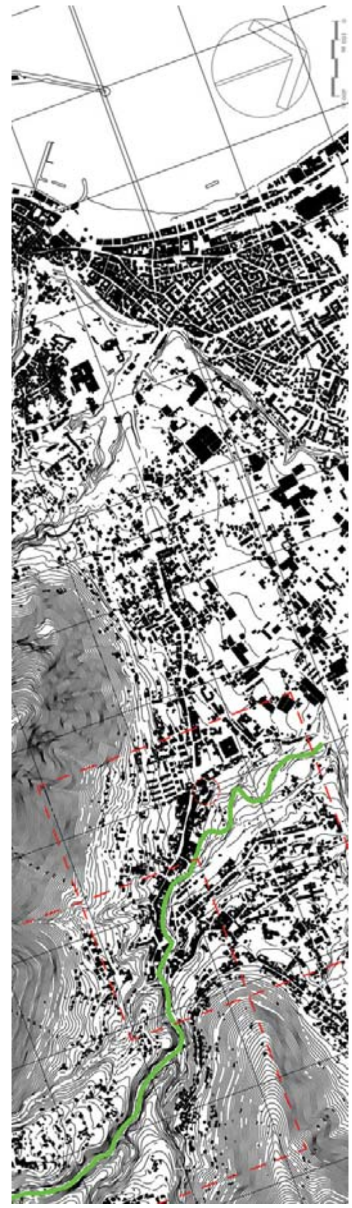

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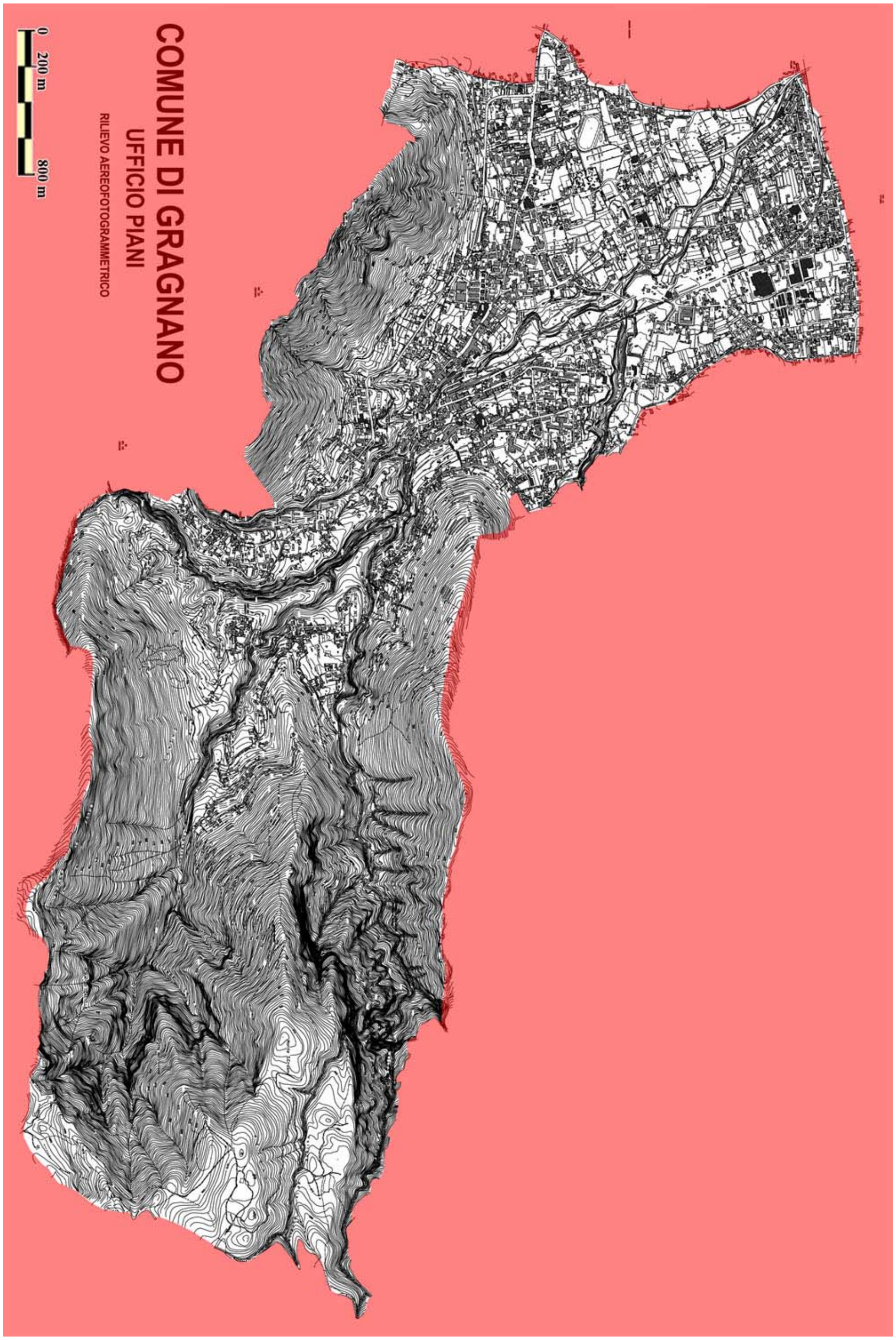

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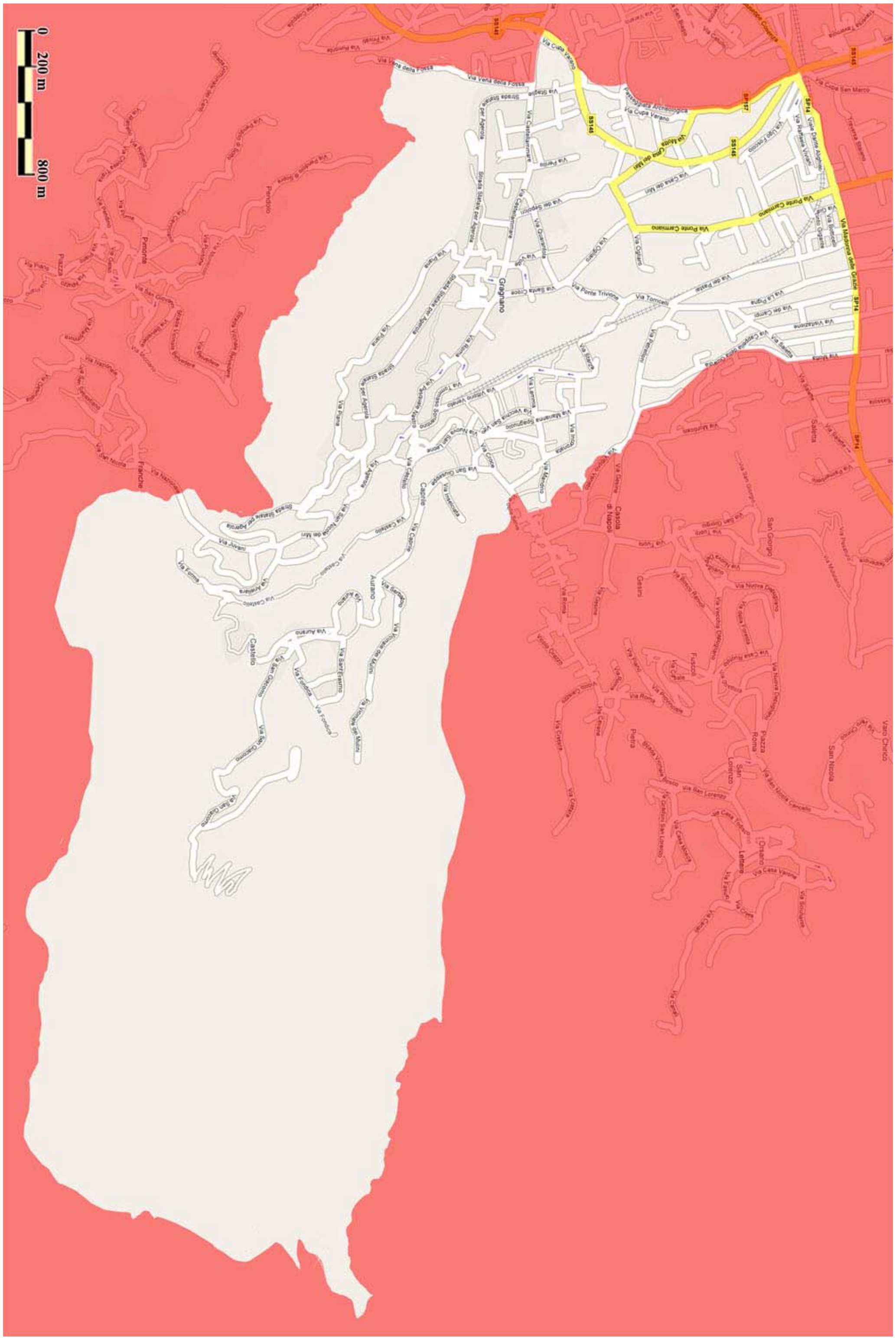

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Chapter 3: Regional Tourism

Section 1: The Benefits of Italy

Italy is a nexus for art, culture, and history. It is also a wonderland of romance, excitement, and imagination. By far, Italy is one of the most desired countries in the world for travelers from all over.

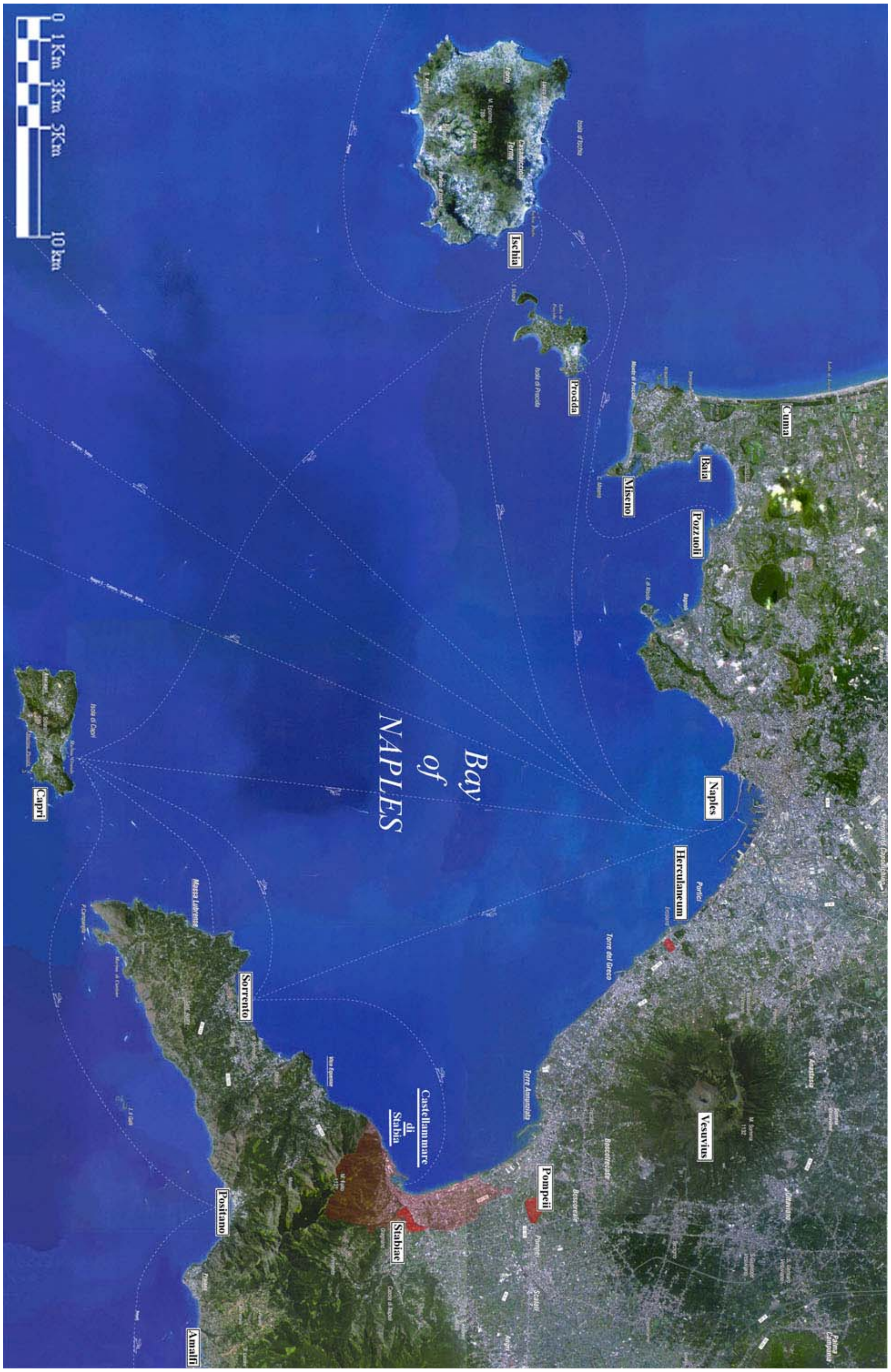
Tourism is naturally advantageous for Italy. From Alpines Mountains in the north to the sandy beaches of the south, magnificent landscapes are all across Italy. These fine destinations are available by land, air, and sea. National railroads vein throughout continental Italy, connecting small towns and metropolitan areas alike. Regional international airports are in every major city, including Naples, plus intercontinental hubs in Milan and Rome. More dramatic are the domestic and international ferries that are able to conveniently access the many Italian ports on the mainland and islands that have existed since the Romans.

Section 2: The Amalfi Peninsula

Gragnano's location in Italy is especially special for tourism. Gragnano is on the Amalfi Peninsula, in between infamous tourist icons Naples, Pompeii, and Sorrento. What surround the birthplace of Italian pasta are real Neapolitan culture of Naples, ancient Roman archaeology, and the glamorous Mediterranean lifestyle. To complement the art of dry pasta in Gragnano is the art of pizzas in Naples, which is the birthplace of Italian pizzerias. It would also be criminal to neglect the culinary art of Italian seafood, local to the Amalfi Coast and the Bay of Naples.

From Naples to Sorrento, a local train line, Circumvesuviana, connects all the attractions in between. The rail can cover thirty miles in less than one hour, while hitting over twenty stops including all major tourist destinations. Significantly, the Central Station in Naples is a hub for both the Italian national railways and the local train line, and it is readily connected to the international airport via public transit. Hence, affordable public access to Gragnano and the region greatly enhances tourist opportunities.

Furthermore, everything is accessible on the Amalfi Coast by car. The terrain and mountains of the Amalfi are tenuous and difficult to navigate by bus. The narrow and windy roads coastal roads do not readily accommodate the bulk of mass transit. Cars, in turn, are the safest and most effective means of transportation on the Amalfi and the Campania Region.



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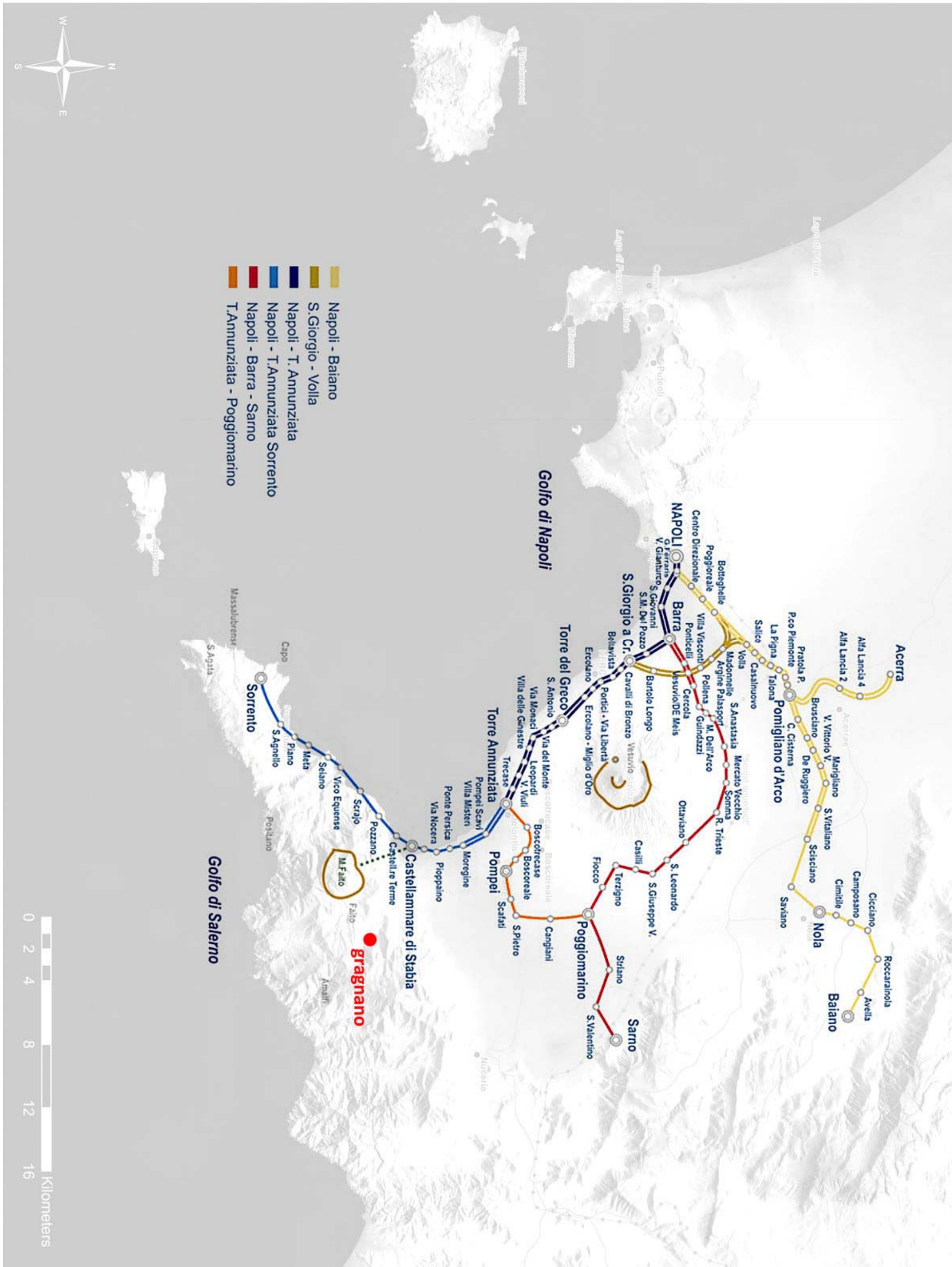

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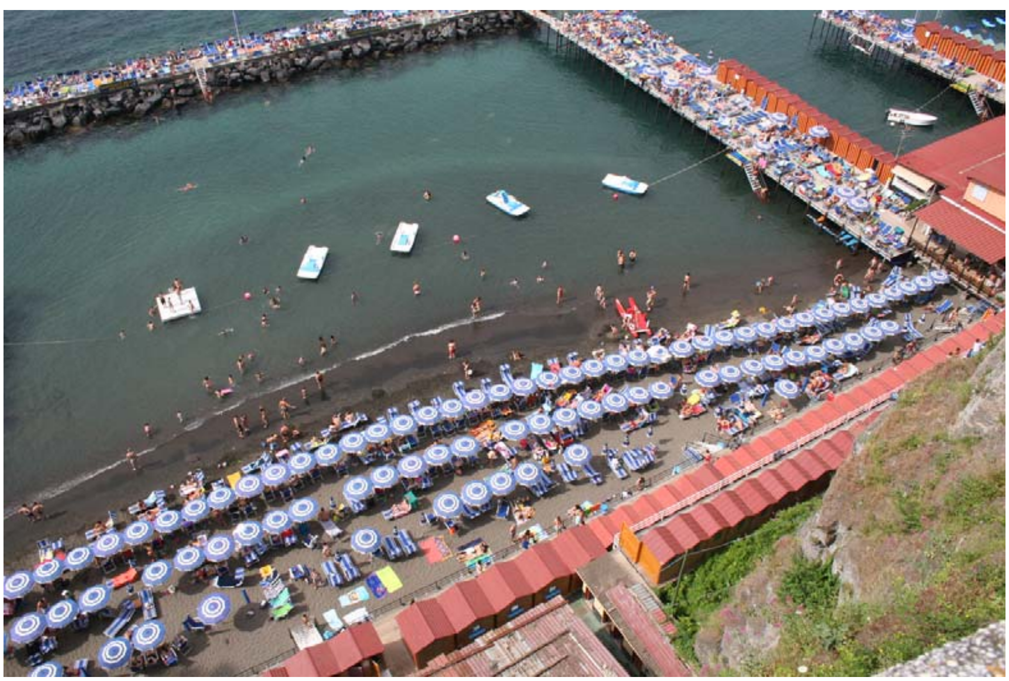

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Chapter 4: The Role of the Car

Section 1: Automotive Identity

Automobiles have become apart of their users' daily routine, necessity, and—most significantly—identity. In architectural design there is a typical stigma against cars. However, it the fact is that people own cars. Cars are part of peoples' lives, and it should not be overlooked nor ignored.

Automobiles have become a necessary component of people's lives. Comparable with the clothes worn and the meals consumed, cars also identify the personalities, status, and priorities of their owners. In fact, automobiles are constant reminders of how we live our lives and how we (alternatively) could live our lives. Automobiles have become a persistent component of international lifestyles and culture.

In fact, real estate development revolves around the way people use and park their cars. The feasibility of multifamily, retail and office real estate all depend upon the frequency of automotive traffic and the availability of parking accommodations. Cars and parking have become a fundamental component of life and business.

Section 2: Vehicular Utility

Man has destinations to reach. Methods of effective transportation have always been in demand. Methods have continued to evolve throughout history accompanying technological progress. In fact, transportation methods and technological progress have been mutually beneficial driving forces.

Over millennia, man has walked, ran, and ridden. Only over the past century has the act of driving become a significant aspect of life, identity, and economics. The car has quickly taken over man's way of life. It drives methods of business, urban economics, and regional and national development. Undeniably, the car has changed the landscape of human living.

Consequently, as cars have become a necessity, so have the need for the facilities that upkeep and store them. Mechanic shops, parking garages and parking lots have become common place in global real estate and modern urban landscape—supply and demand. Of these facilities, structured parking (or garage) has become particularly common in urban environments to address the demand for automotive parking. These vertical storage facilities have become pertinent in the development of modern cities and they have become acceptable uses in cities' zoning plans. Structured parking may not be the highest and best use for urban sites, but they are low-risk, low-maintenance, and profitable.

It is critical to understand that cars—as we know it—is but a phase in the evolutionary timeline of man's utility for transportation. Cars used to be carriages and cars will evolve to become something more efficient, faster, and more universally accessible. As the definition for vehicles changes, so will the needs for vehicles' storage. Horses had barns; carriages had carriage houses; and cars have garages. In lieu of a competitive real estate market, smart growth, and continuing demand for habitable space, it is critical to capitalize on the sustainable potential of newer and more adaptable parking solutions.

Chapter 5: Parking

Section 1: Parking Methodology

Structured parking is the most economically and physically effective method to address urban parking demands. As any method of storage where horizontal surface is scarce, the strategy is to go vertical. Hence, structured parking has taken the form of modern day parking garages as commonplace massive concrete manifestations above and underground. They are examples of form-after-function and on a minimal budget.

Structured parking is financially viable only in dense urban environments where the demand for parking is high and the fees justify the development. In any metropolitan area the cost of construction is relatively constant per unit area, while the variable is in the location and site conditions. For any structured parking project to be independently financially feasible, the gains from customer fees must outweigh the cost of development. Hence, like any business, the goal is to minimize costs and expenses enable to maximize profit. So for areas in a given metropolis where parking demand is not high, structured parking's development costs require government subsidies to be feasible.

Affordability is a significant factor that contributes to the outcome of structured parking in its design, form, and aesthetics. To meet the very basic requirements of parking functionality, minimal design considerations are requirements beyond building code and fire safety considerations. Enhanced design instead translates to additional materials and constructions costs, which increases risk of project failure. Hence, for any structured parking project to be holistically viable, substantial amount of income must be available in the operations process of the total development to negate the cost of construction.

As true with any storage strategy, parking is most efficient when cars can be packed tightly. The goal is to park as many cars in a given amount of cubic space as possible. The math becomes improving the ratio of vehicle-to-volume, which is a numbers game. Certain practical considerations in automotive operations however prevent 100% efficiency in space use. In fact, 100% efficiency may not be possible due to industrial design of automobiles' exterior forms. In conventional structured parking, driving lanes, clearances, and human circulation considerations all contribute to spatial inefficiency. The most ideal and efficient parking system would in turn negate the inefficiencies in conventional garages.

Section 2: Parking in Real Estate Development & Economics

Structured parking can be a driver for future development and a necessary accessory to existing development. Multifamily and commercial projects depend on users and their means of access. When users rely on private transportation to market their identity, accessibility often directly translates to automobiles and parking spaces. Parking for profitable developments in turn becomes a necessity for feasibility, which is a critical component in a real estate development due diligence process. Most significantly, in real development processes, effective parking solutions make projects happen.

<u>Section 3: History of Parking</u>

Where to park the car? Parking is a common act. It is not a consideration of “how” but a simple and thoughtless act of doing. For most of the global population, parking is a necessary act of utility, not dissimilar with the act of finding a bathroom. Parking is driven by utility and the necessary development and construction of parking spaces to satisfy both utilitarian and legal demands. To date, parking facilities have been developed primarily to be cost effective alone.

But seriously, where to park the car? When automobiles were first introduced, they competed with an existing transportation mode of horse carriages. Cars were only available to the wealthy, and they were often stored inside converted barns and carriage houses hidden from the elements. Once automobiles have become more affordable in the U.S., more creative means of storage were developed for vehicle storage. Mechanical parking facilities were the first of structured garages in the United States. These mechanized facilities were adapted from building shells, and man-operated mechanisms assisted in the lifting and orientation of the parking process. It is important to understand these initial mechanized facilities were not fully automated, so cars still need to be driven when moving on horizontal surfaces.

In time, via marketing, conventional parking garages with driving ramps replaced the early mechanized facilities as the predominant method of structured parking. By this point, automobiles were widely available to public in developing countries, and cars were on the streets en mass. Beam, column, and ramp became standard kit of parts for structured parking. These conventional structures became the most common and cost effective means of storing parked vehicles. These garages are the parking facilities that populate contemporary urban environments in developing and developed countries.

In terms of project feasibility, ramped garages make great sense. They are the least inexpensive method to vertical storage of automobiles. For paved lots, the cost of construction is around $7,000. For conventional ramped garages, the cost of construction around $15,000 per space for above ground structures and around $45,000 for underground facilities. Although the cost of construction doubles with vertical construction, the quantity of cars accommodated multiplies exponentially and saves significant amount of land area. Building concrete structure vertically has so far made great economic sense. However, in the advent of new parking technologies developed in Asia and Europe, parking solutions have become more compact, more effective, and more sustainable.

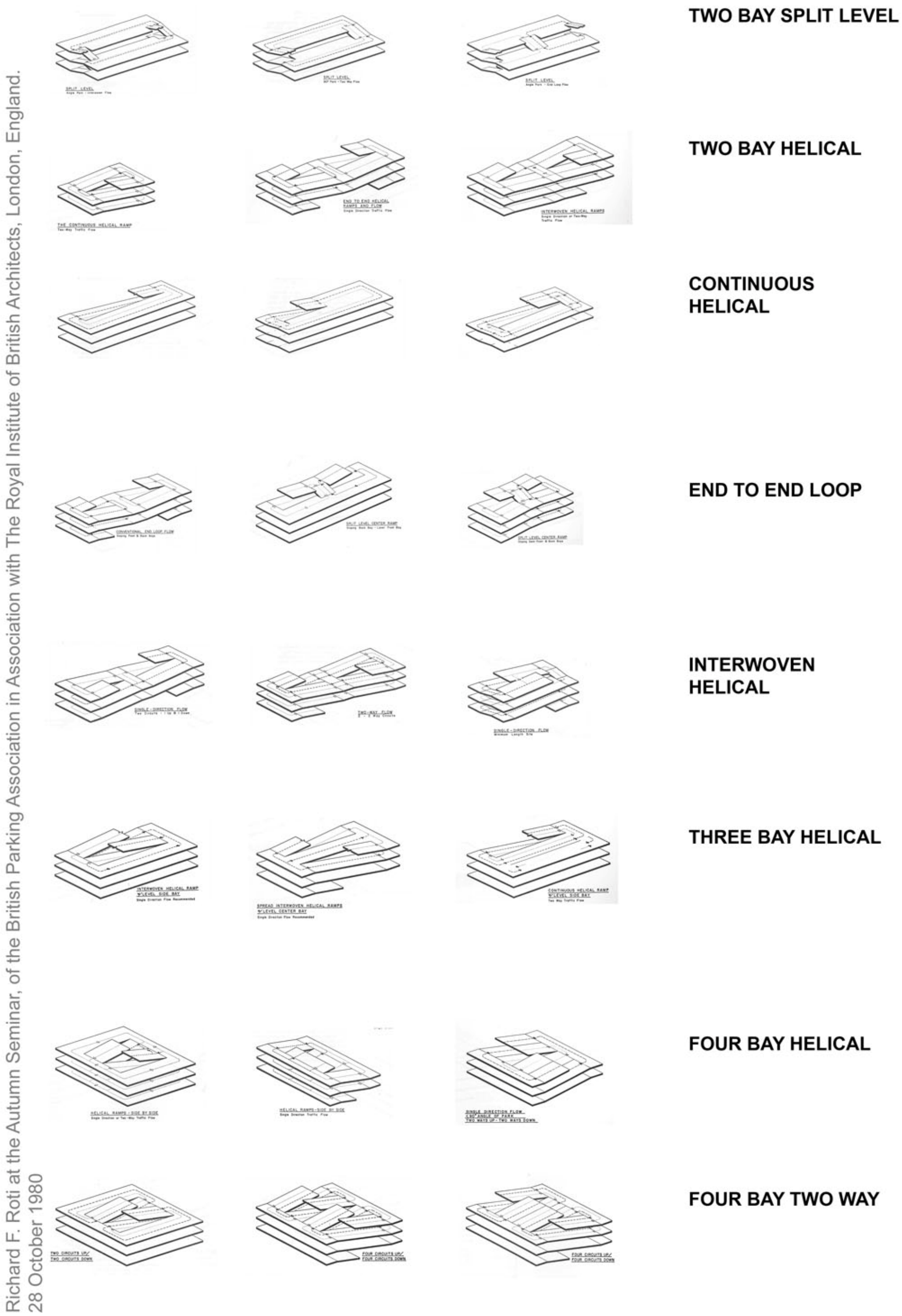


Figure 5-3-1. Traditional ramped parking typologies

Section 4: Automated Parking

Subsection 1: What is Automated Parking?

Automated parking is a new automated mechanized technology in its real estate infancy in the United States. Equivalent technology and associated companies have, however, utilized automated parking in Asian, European, Middle Eastern, and South American markets for many years. In older and denser cities of the world, the compact and automated engineering of automated parking has had a lot of success. In 2010, fire safety codes have finalized identified automated parking has a separate construction compared to conventional ramped structured parking, facilitating the future development of this technology within the United States.

Automated parking is a mechanized storage system for temporary and long-term automotive shelving. Once the driver leaves the vehicle at the entry of an automated parking facility, the entire process becomes fully automated. The analogy is leaving the car for valet parking, except without a human in the driver's seat. The ignition is turned off of and the automobile becomes an inanimate object ready to be stored.

What is the same with all automated parking systems is the efficient use of time, real estate and safety. Vehicles are dropped off for the automated valet at the garage's entrance. Via electronic means each vehicle that is stored is assigned an ID for future retrieval. Users may later recall vehicles using the ID via the garage's graphic interface or a mobile device (i.e. phone). Sophisticated computer software can in fact organize and reshuffle vehicles in the automated facility to optimize retrieval time based on users' projected time for retrieval. In such a case, long-term parking can be shelved farther away, and short-term parking can be placed closer to the entrance for access.

Automobiles are set onto scaffolding and shelves of pre-defined dimensions. Like any vertical shelving system (bookshelves, cubbies, or vending machines), the steel scaffold system is designed to accommodate most if not all automobiles without sacrificing spatial efficiency. For any space, it would be ideal to accommodate a small compact vehicle or a large sports utility vehicle. Dimensional benchmarks for spaces can be determined from existing automotive data, and each automated parking manufacturer may utilize different sets of standards for dimensions based on differences in technology and design.

Subsection 2: Measured Benefits of Automated Parking

Automated parking is the most innovative and sustainable strategy for automobile storage to date. Most significantly, automated parking systems are impermanent and they can house more automobiles in the same cubic volume than any other structured parking method. Impermanent parking structures are absolutely advantageous in real estate development. The parking system becomes a temporary occupant for any site and the highest and best use for the site never becomes permanently affected. By contract, conventional ramped garages would require the demolition and excavation of the entire structure so a site may be re-used, which is highly unsustainable.

In addition, automated parking promotes vehicle fuel efficiency and a safer environment for car parking by eliminating the need to operate the vehicle inside the garage. An automated parking garage utilizes computer software to control the transferring and lifting of vehicles from one location to another. The human driver component is limited to only bringing the user's car to the garage's entrance. In minimizing vehicle operations, the car's ignition is turned off at the entry, eliminating any further emission. More significantly, the freedom for a user to not operate the vehicle also eliminates potential human safety concerns that are associated with conventional ramped garages, especially at night. The lack of human occupancy is a marketable component for user safety and simplified way-finding.

Automated parking systems also mean sustainable energy use and reduced financial needs for upkeep. With zero human occupancy inside of an automated garage, lighting becomes a minimal necessity only designed for maintenance technicians. With no human occupancy and no vehicle emissions, the garage no longer needs to be natural or mechanically ventilated. Being fully automated, management and software updates can be controlled remote offsite. Although there is energy use associated with an automated system's operations, the anticipated energy use is to be much lower than the alternative safety lighting, elevators, signage and ventilation associated with ramped garages. Reduced energy use and minimal on-site management directly translate to minimized operating costs.

Furthermore, of the benefits that are applicable for management and ownership many of these benefits can also be passed onto the user. Of these features is the elimination of vehicular damage and associated insurance costs. An automated parking system will not incur the risk of fender benders, keying, or typical bad driving in a conventional ramped garage. Without a running engine, and cars being shelved separately, the possibility of vehicle fire is also minimized. In the event a vehicle fire does occur, instances are isolated within the shelving racks system in addition to sprinklers and other fire safety measures that are already in place. Conclusively, automated parking offers to most safe experience in parking for owners, users and automobiles.

Chapter 6: Derelict Fabric, the "Where"

<u>Section 1: Via Roma</u>

Downtown Gragnano is the site for this thesis investigation. Historic prominence in Italian pasta manufacturing, strategic geographic location, and present efforts for urban renewal and infrastructure development make Gragnano an ideal urban candidate to explore the undiscovered potential of automated parking. In Gragnano, automated parking has the potential to catalyze the urban redevelopment through necessary accommodation for parking and rehabilitation.

Downtown Gragnano is supported by its historic main street, Via Roma. Via Roma is the historic center in Gragnano where pasta was hung to be dried by the prevailing winds of Bay of Naples. Given its age, this artery also befell victim to the 1980 earthquake. The urban fabric in downtown Gragnano was effectively torn by multiple buildings' collapse. What remains of a tightly knit industrious Italian hillside town is a derelict fabric that is waiting to recuperate by overcoming modern infrastructural challenges.

On Via Roma display much of Gragnano's historic relevance and modern woes. The streetscape of Via Roma is adorned by facades of historic pasta factories, but these icons are also neighbored by empty lots that hold both rubble and parking. These opportune but vacant real estates along the main street possess much future development potential, built with retail and residential uses that will enliven the streetscape. A critical component to the development of these lots—in addition to historic preservation and rehabilitation—is the foresight to accommodate both current and future parking needs to support potential development.

Via Roma is the primary artery through Gragnano. It is the historic main street of this hillside town where significant vehicular and pedestrian traffic is funneled. Given the hillside topography on which the town sits, the width of street section throughout Via Roma is variably irregular. At the widest cross-sections where pasta were hung to be dried, the main street can accommodate one gas station, one pedestrian zone, one lane of diagonal parking, and two lanes of traffic. By contrast, the narrowest street section on Via Roma could only accommodate one pedestrian and one automobile. A leisure stroll through on Via Roma from Piazza Trivione (at the entry) to Via Pasquale Nastro (at the end) is no more than ten minutes; however the gently curvilinear street offers multiple instances of diversity in its street sections.

The streetscape of Via Roma expands and contracts with the designation of parking spaces and traffic barriers for pedestrians. As is, the main street is a difficult corridor to navigate for both automobiles and pedestrians. During morning, midday (siesta), and evening peak hours for traffic, Via Roma becomes a parking lot. When traffic is heavy and drivers are in a rush, pedestrian safety is sacrificed to make room for parking and vehicular mobility. Accessibility is a major concern on the historic main street of Gragnano.

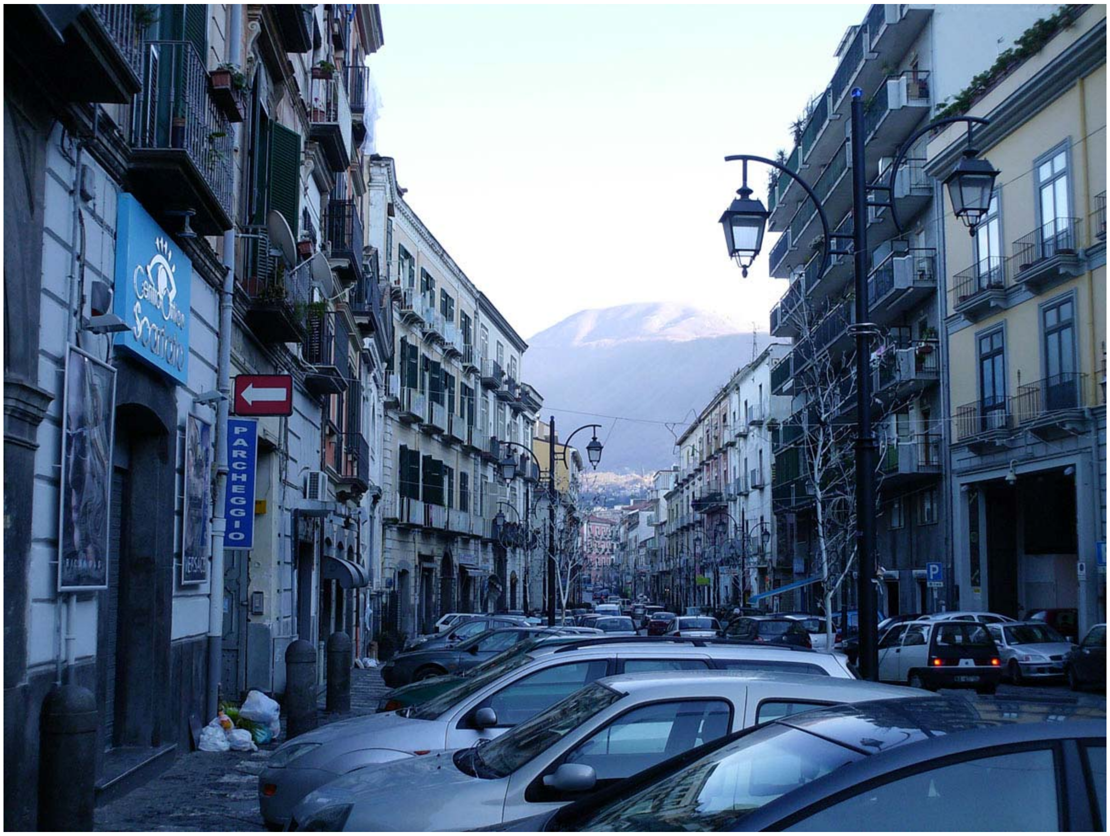


Figure 6-1-1. Parking and traffic congestion on Via Roma.

Figure 6-1-2. Parking congestion on Via Roma

<u>Section 2: The Shell</u>

One opportune site along Via Roma holds the greatest capacity for investigation. A post-earthquake building shell stands ominously amongst partially occupied historic buildings. Of this building, only its masonry shell remains. Select sections of the shell are party-walled with neighbors, while remaining rough openings that give hint of the shell's structural (in)stability. The building shell is the tallest remaining historic structure in-town; it is decisively the tallest structure if its industrious chimney stack is also included for consideration. Without proper care, the collapse of this shell will deliver substantial damage to its immediate context and further contribute to the ruined urban fabric. A historic icon in Gragnano's skyline will then disappear.

Immediately adjacent to the historic building shell is an enterprising single-level parking garage inside an expansive hollow building. The ground floor of the adjacent building has been rehabilitated using steel construction to maximize driving and turning space for parking. With even high day-time occupancy, this neighboring development serves as a necessary precedent and comparable to bring greater purpose to an endangered building shell. In fact, the existing parking within the adjacent garage can be transferred to the new automated system, allowing the neighboring building to receive a higher and better use during the redevelopment process.

Figure 6-2-1. View of historic building shell from enclosed courtyard.

Figure 6-2-2. View of enclosed courtyard perpendicular to historic building shell.

Figure 6-2-3. An enterprising parking garage adjacent to historic building shell.

Figure 6-2-4. Great spatial potential in the enterprising garage for higher use.

Figure 6-2-5. Analytical view of historic building shell’s façade.

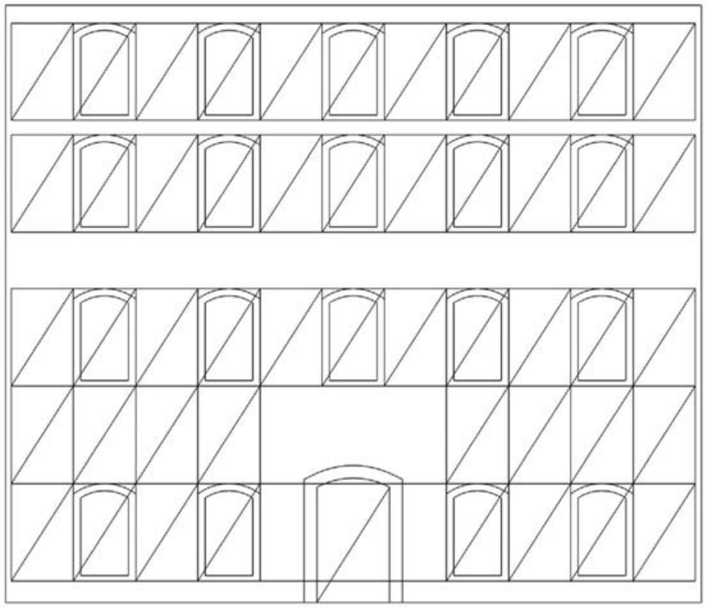


Figure 6-2-6. Façade analysis of historic building shell.

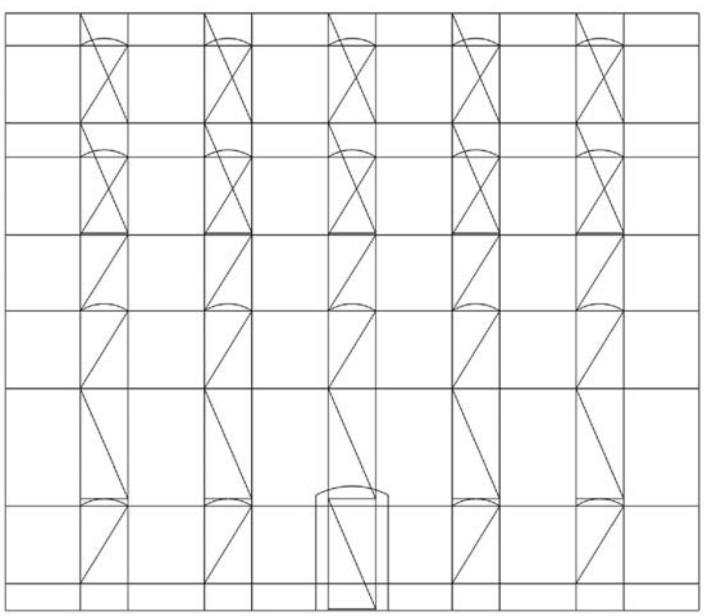


Figure 6-2-7. Proportion analysis of historic building shell's façade.

Figure 6-2-8. Interior elevation of historic building shell and the adjacency to historic smoke stack

Figure 6-2-9. Relationship between building shell and smoke stack.

Figure 6-2-10. View of smoke stack and apex of building shell from across the valley.

Figure 6-2-11. Building shell. Bird's eye view looking east.

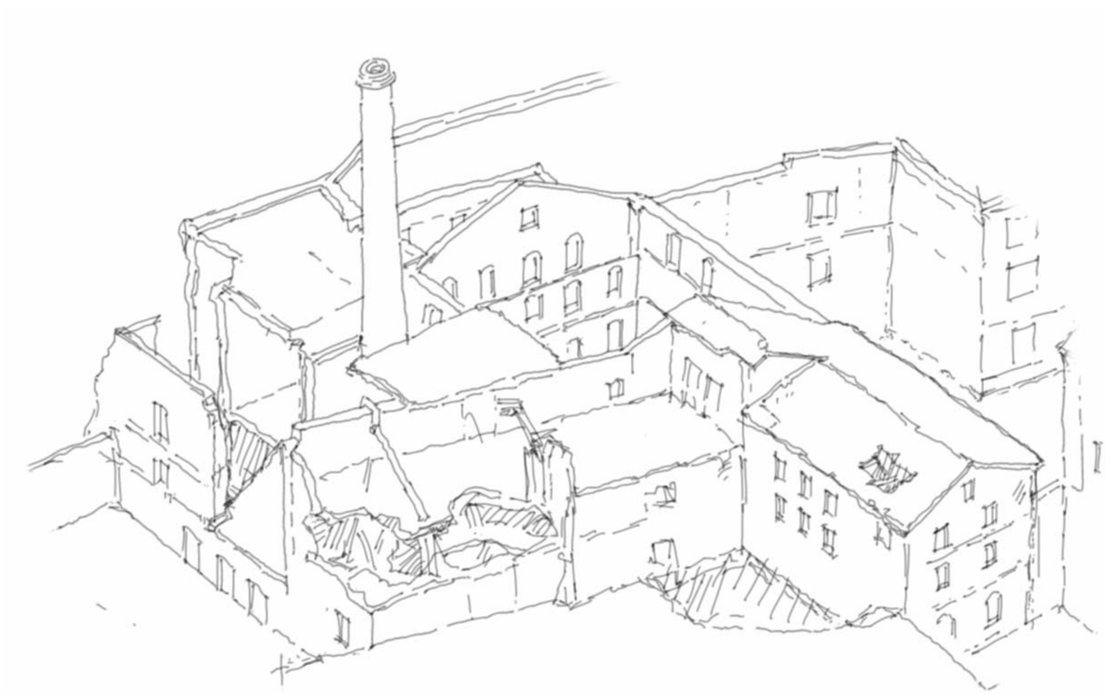


Figure 6-2-12. Building shell. Drawing analysis of bird's eye view looking east.

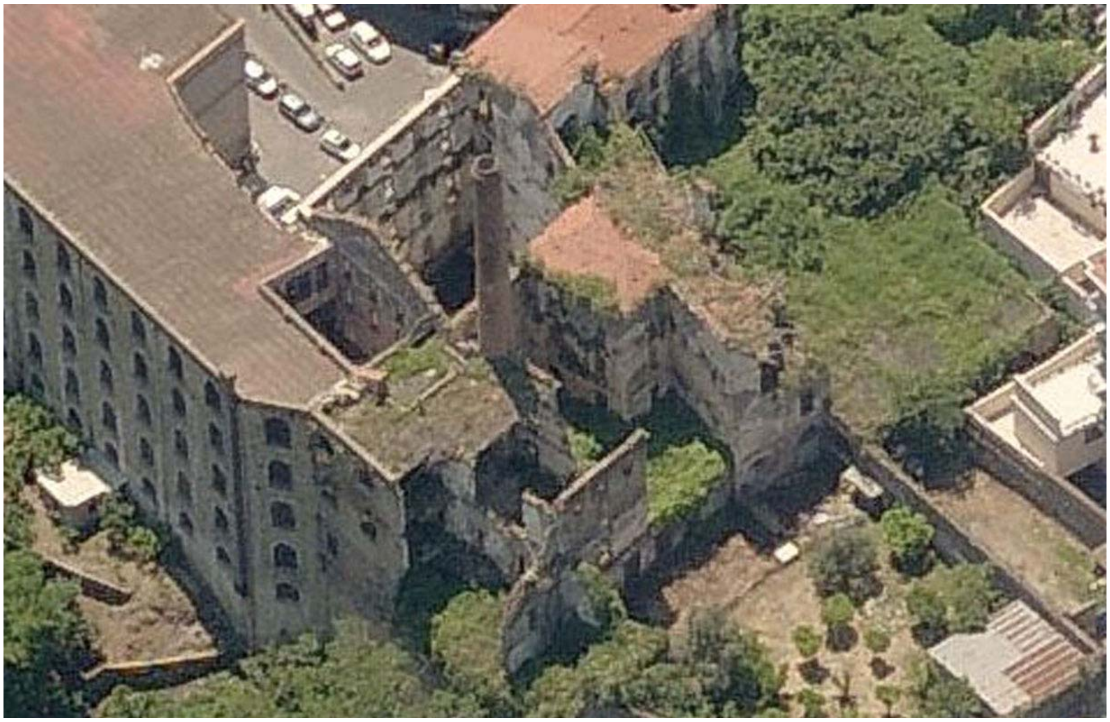


Figure 6-2-13. Building shell. Bird's eye view looking south.

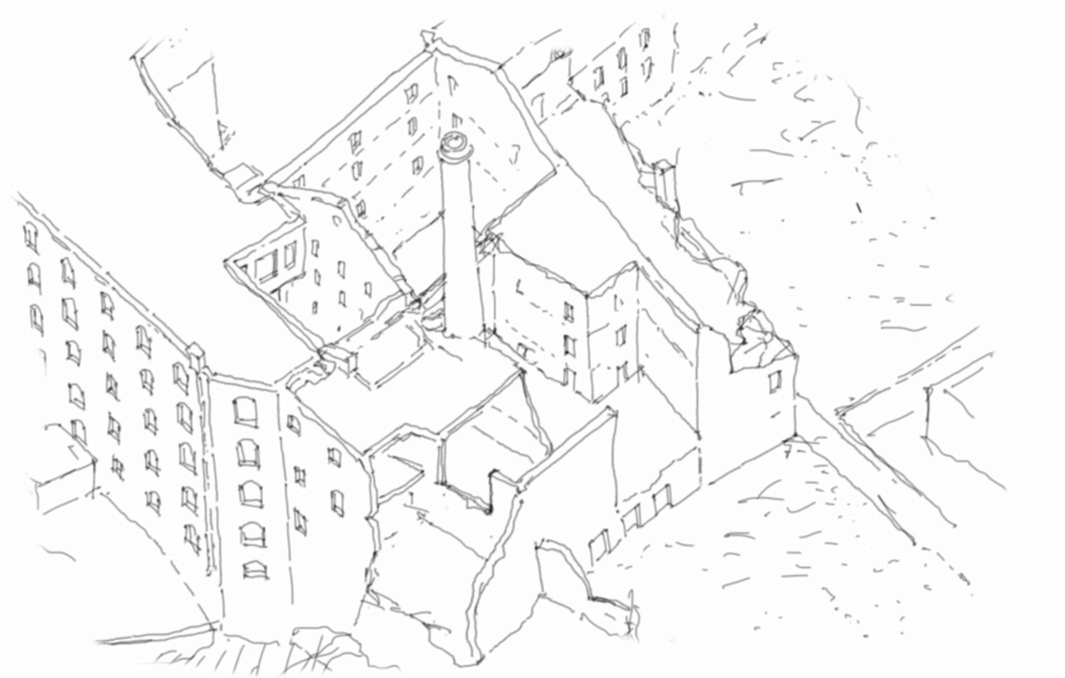


Figure 6-2-14. Building shell. Drawing analysis of bird's eye view looking south.

Figure 6-2-15. Building shell. Bird's eye view looking west.

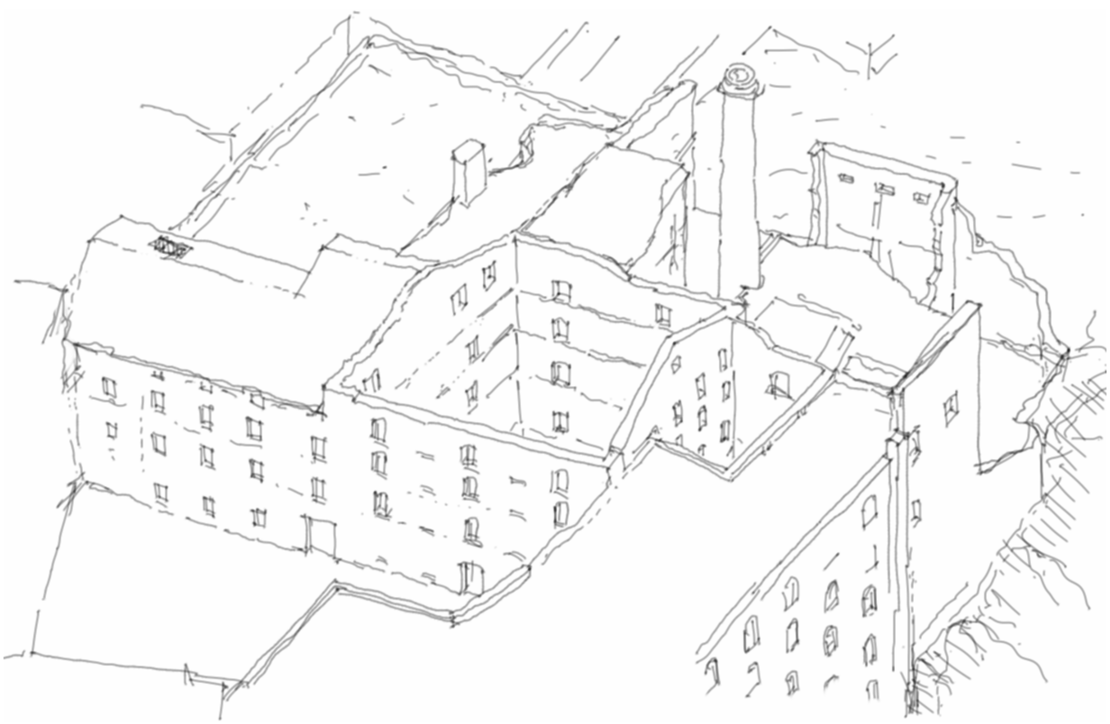


Figure 6-2-16. Building shell. Drawing analysis of bird's eye view looking west.

Figure 6-2-17. Building shell. Bird's eye view looking north.

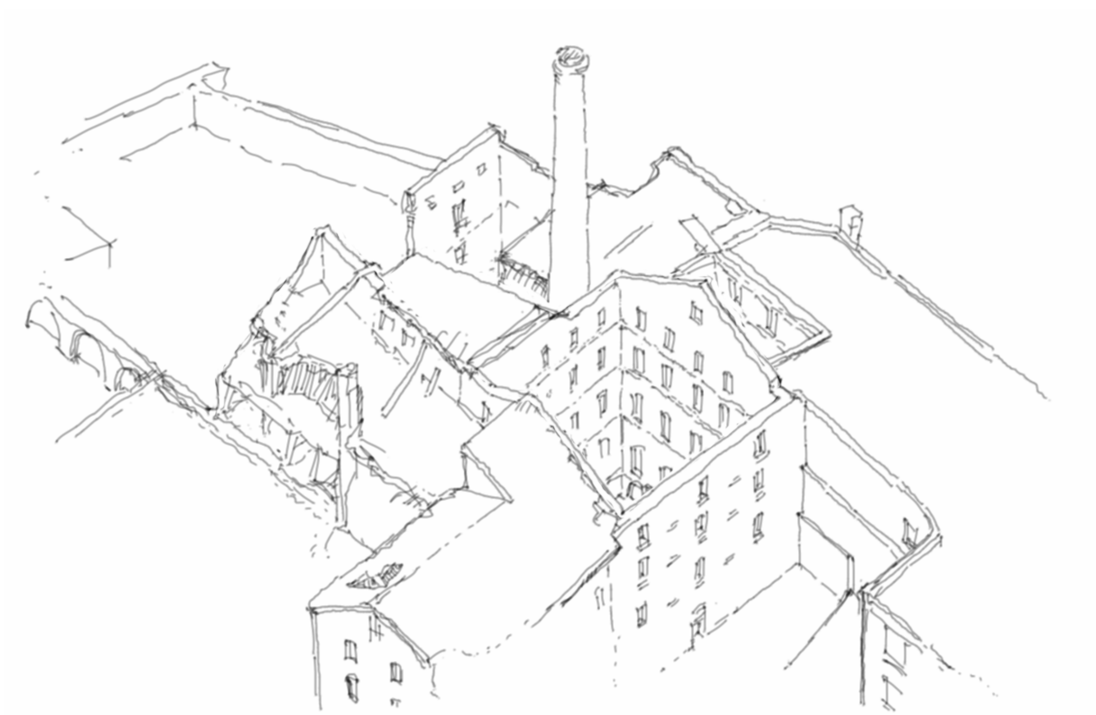


Figure 6-2-18. Building shell. Drawing analysis of bird's eye view looking north.

Figure 6-2-19. Aerial of building shell and immediate context.

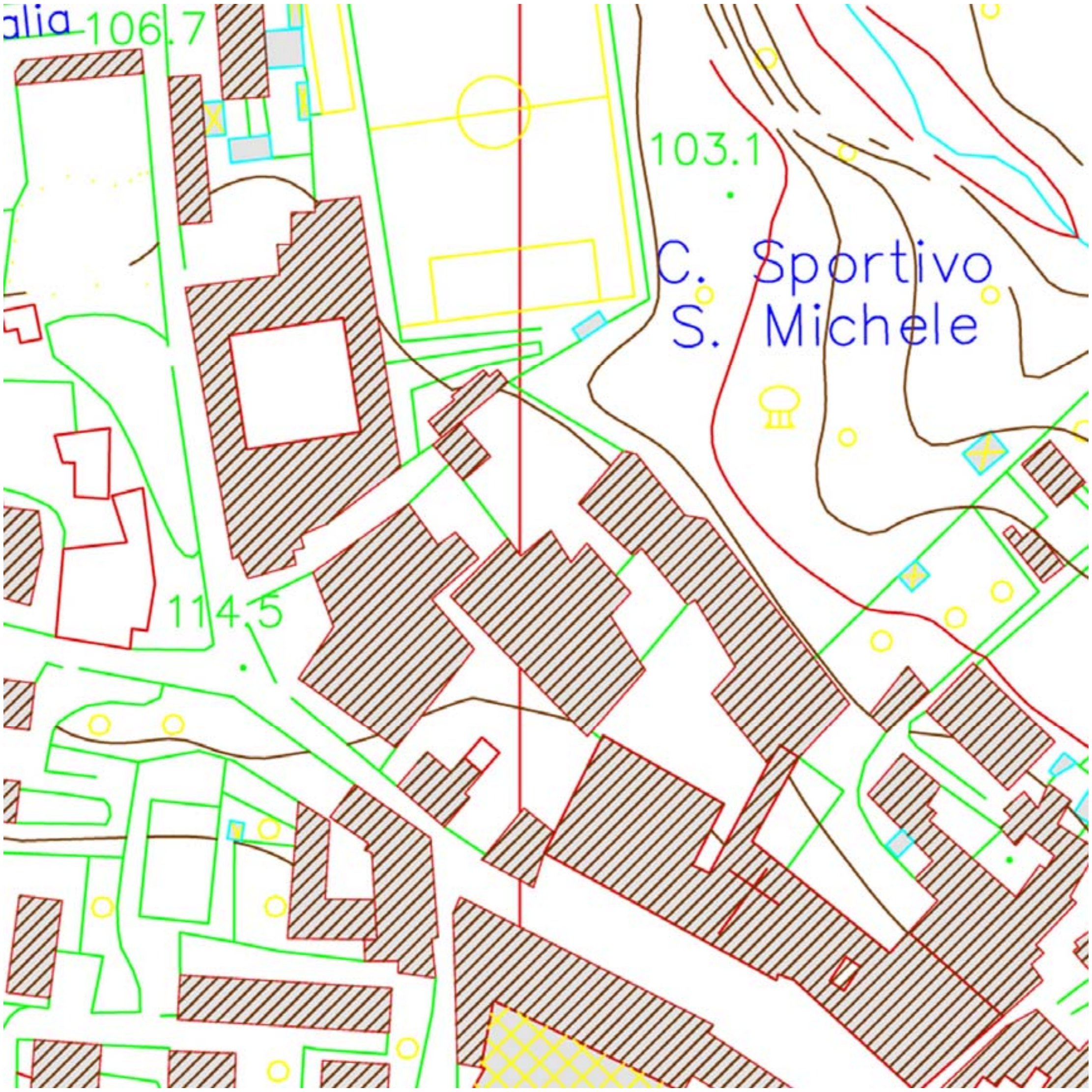


Figure 6-2-20. Solid and void relations surround the building shell.

Section 3: Access

Gragnano is a town that was built on steep topography. Hence, it is commonplace for access to be bottle-necked at multiple locations. In fact, given the nature of road engineering on the hillside, there is only one road to access multiple destinations, and very little hierarchy exist along the thoroughfare. Strategically it is of utmost importance to eliminate on-street parking to maximize street width of traffic flow and to promote pedestrian safety—there is very little room on the historic streets of Italian hillside towns.

Alternative means of access are available to Gragnano, but such methods are ineffective if the destination is downtown. The most attractive means of downtown access is the local train line that connects to downtown Castellammare di Stabia, 3 miles towards the bay. The train line was once used for pasta transportation from Gragnano to regional distribution centers, such as Naples. However, current user capacity for the train is minimal as its original design was for commercial use only. The final stop is in fact in downtown Gragnano on Via Tommaso Torrentino, along Via Roma. However, after reaching Via Roma, alternative transportation methods would be necessary to continue.

Buses are popular means of public transportation in the region. However, given the varying widths of Via Roma, not even compact buses can access the main street. From Castellammare di Stabia, buses take an alternative route up the mountain enable to bypass downtown Gragnano to reach destinations beyond. A walk from the nearest bus stop to Via Roma is estimated to be fifteen minutes at a reasonable pace, not fit for the casual tourist or visitor. With streets unfit for public transportation, downtown Gragnano must rely automobiles and motorbikes as primary means of efficient transportation.

Downtown Gragnano has significant potential for economic revival. However, issues in infrastructure, preservation, and redevelopment must be effectively and simultaneously tackled first. It is the intent of this architectural thesis to use a singular development strategy to address these issues. A single site in downtown Gragnano in fact has the capacity for such complex exploration, and it will be used to meet challenges in historic preservation, parking accommodating, and urban redevelopment so to promote economic stimulus in Gragnano and the region.

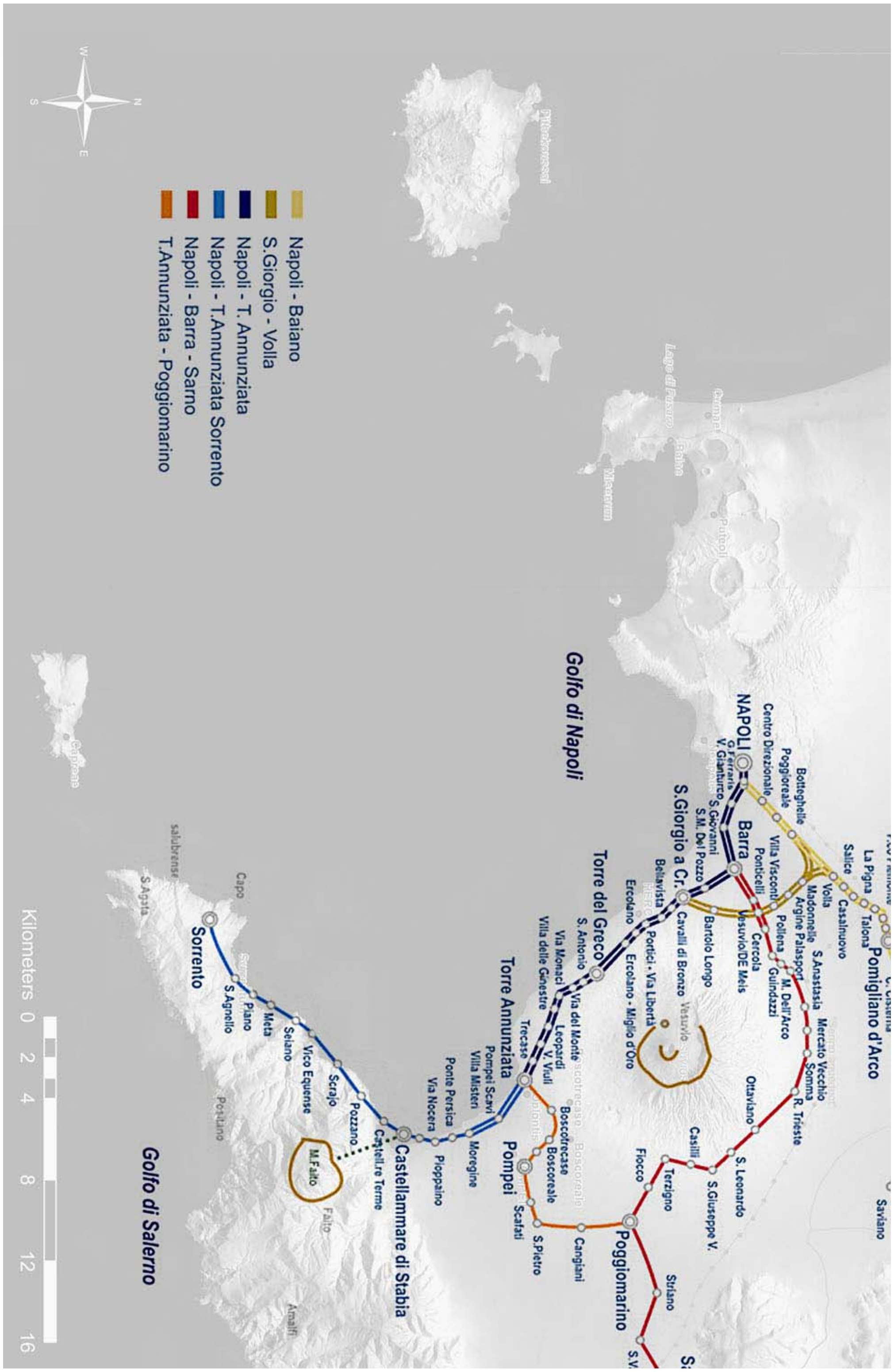


Figure 6-3-1. Regional access of Circumvesuviana commuter train.

Figure 6-3-2. At Piazza Trivione, entry to Via Roma, looking north.

Figure 6-3-3.At Piazza Trivione, entry to Via Roma, looking northwest.

Figure 6-3-4.At Piazza Trivione, entry to Via Roma, looking southeast.

Figure 6-3-5.Looking southeast at the choke to Via Roma.

Figure 6-3-6. On Via Roma looking northwest, back towards the choke.

Figure 6-3-7. On Via Roma, looking northwest, back towards the choke.

Chapter 7: Urban Scaffold, the "What"

The intervention site to catalyze urban renewal is adjacent to downtown Gragnano's primary access. The building shell that remains standing since the 1980 earthquake necessitates immediate stabilization. The irregular parallelogram and the four walls of the shell provide a simple, geometric foundation for structural stabilization. Not only are the regularized rough openings structural vacancies, they also contribute to the weakest points on the remaining masonry construction. Opportune extensions from the engineered modular skeleton of an automated parking system would be ideal to serve as the scaffolding to stabilize this shell.

The insertion of automated parking serves two primary purposes. Immediately, the skeletal structure of automated parking can stabilize the damaged building shell. Simultaneously, the versatile, impermanent, and modular conception of automated parking systems can offer adaptable, phased strategies to address issues in parking and catalyze redevelopment. In Gragnano, automated parking has the innovative potential to stabilize an endangered building shell and its context, and the system will directly address challenges in parking by taking cars off of a narrow main street.

The footprint of the building shell is an irregular parallelogram, which is an ideal canvas to align the flexible modular structure of automated parking. The "habitable" footprint's perimeter dimensions (rounded down) are 18.52m, 16.71m, 16.75m, and

17.59m with diagonal lengths of 27.23m (hypotenuse of 18.52m and 16.71m) and 21.64m (hypotenuse of 16.71m and 16.75m). The flexibility and engineering criteria of automated parking systems does allow dimensions to be measured to the centimeter of precision. Structural flexibility translates to the maximized utilization of available cubic volume of space, directly contributing to spatial efficiency and optimized parking.

Without the need for driving ramps, heavy concrete structure, or over-compensating head-clearance, more cars can fit into an automated parking system than a conventional garage within the same cubic volume of space. If the footprint of the building shell was established as on-grade parking, fourteen cars can be parked in the given dimensions. If the full volume of the building shell was to be occupied by a conventional garage (up to a height of 21.92m), sixty-three cars can be fit into the facility utilizing ramps on the perimeter up against the shell. A significant number of cars can be parked in a conventional ramped typology, however at the expense of permanently attaching concrete ramps to the existing shell that should be preserved.

By contrast, in an automated system inside the building shell of above mentioned dimensions, 216 vehicles can be effectively parked. Strategically, eighteen cars can fit on any of the twelve levels. On each level, nine cars are parked on each side of the palette-moving aisle, with vehicles triple-parked in three-car rows. A surplus of 153 cars can be stored in an automated system than the conventional ramped garage within the volume of the building shell. Simultaneously, an automated system does not permanently compromise the remaining structural integrity of the shell. In fact, automated parking is an impermanent structure that will instead stabilize the shell. The construction process can be performed with zero interference by utilizing kit of parts of efficiently gauged, prefabricated steel beams, columns, cables, and connections. The entire automated system can be assembled and deconstructed in utmost efficiency.

Furthermore, the development process can capitalize on the modular, prefabricated kit of parts of automated parking. The utilization of prefabricated parts allows speedy construction and versatile modification to the system. The direct application is the adaptability of adding or reducing the allowable spaces in the system so meet projected market demand. In doing so, initial installation of the automated system can be most effectively achieved with minimal materials and construction timeline. Then per market demand, with projected growth, the system can grow by the simple addition of more modules as necessary. Space and material would never be wasteful in an automated system, establishing the opportunities for a truly multifaceted, sustainable project.

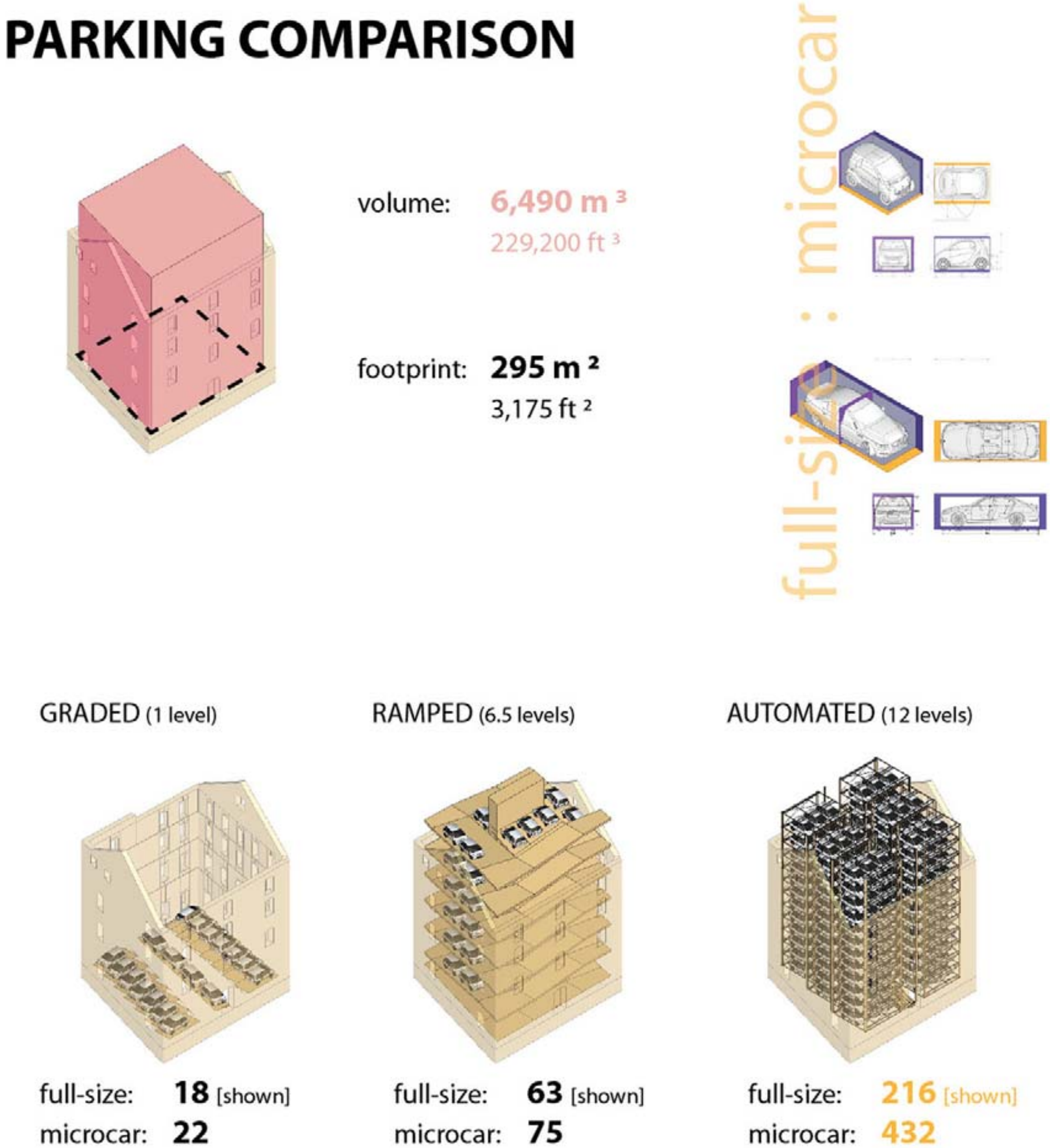


Figure 7-1-1. Comparison of parking capacity of three parking methods based on a fixed volume inside the building shell and utilizing the same vehicle dimensions.

Chapter 8: Multifaceted Sustainability

In this thesis, advanced design and engineering of automated parking pushes the technology to reach innovative solutions in simultaneous environmental and financial sustainability. Gragnano's industry in pasta manufacturing was founded based on the strategic location of the town and its access to natural springs, prevailing wind and sun. Natural elements of water, sun and wind have generated Gragnano's industry in the past, and the same elements can power Gragnano's vitality, again.

An innovative architectural intervention in Gragnano has the potential to also capitalize on the environmental opportunities of the valley. Geothermal is opportune in the Stabia region, first recognized by the Romans in their hot spas. Geothermal is opportune for heating and cooling local homes and businesses, and possibly even an automated parking facility.

By utilizing the advantageous conditions of Mediterranean sun and wind, an automated parking system has the capacity to self-sustain its energy needs via independent power generation. Given practical modular and prefabricated construction systems, contemporary technologies in solar power and wind power can easily adapt to a mechanized automated parking. Photovoltaic solar panels (PV) and wind turbines can generate the power to sustain the automated system.

In a strategic location where the automated parking system is distinguished in the skyline, the system also has the capacity to capture advantageous rights in communication and advertisement. Once the automated parking system reaches an optimal parking capacity, its height will soar over the downtown Gragnano skyline. At a uniquely elevated position, the automated parking development has the advantage to provide enhanced cellular service to Gragnano, an area otherwise has no cell tower reception. Cell towers above a soaring automated parking system can provide a necessary public service and improve the revenue generation for the project's long-term financing.

With high visibility comes with advantages in marketing, visual communication and advertisement. An automated parking system is independent of its exterior elevations, which means the building exterior can be faced and finished in anything free of the use inside. Traditional above-ground ramped facilities are challenged by the need to naturally ventilate the exhaust of running vehicles. 50% of a traditional garage's exterior must be perforated enable to meet U.S. health and safety requirement. Automated parking, by contrast, is free of the obligation to ventilate given vehicles do not operate while inside the storage facility. In turn, the exterior of an automated parking system is a blank canvas for commercialized and civic public communication, generating revenues and subsidies for the automated system's financing.

Photovoltaic solar panels, wind turbines, cell towers, and ad space all contribute to the feasibility and long-term viability of an automated parking system in Gragnano. Energy and revenue strategies help promote project vitality and assure lenders and investors of future sources of cash flow. From a real estate development and value-add perspective, the strategies is environmental and financial sustainability are also prime opportunities for marketing and branding. Automated parking becomes the only international candidate for historic preservation, urban redevelopment, and global sustainability.

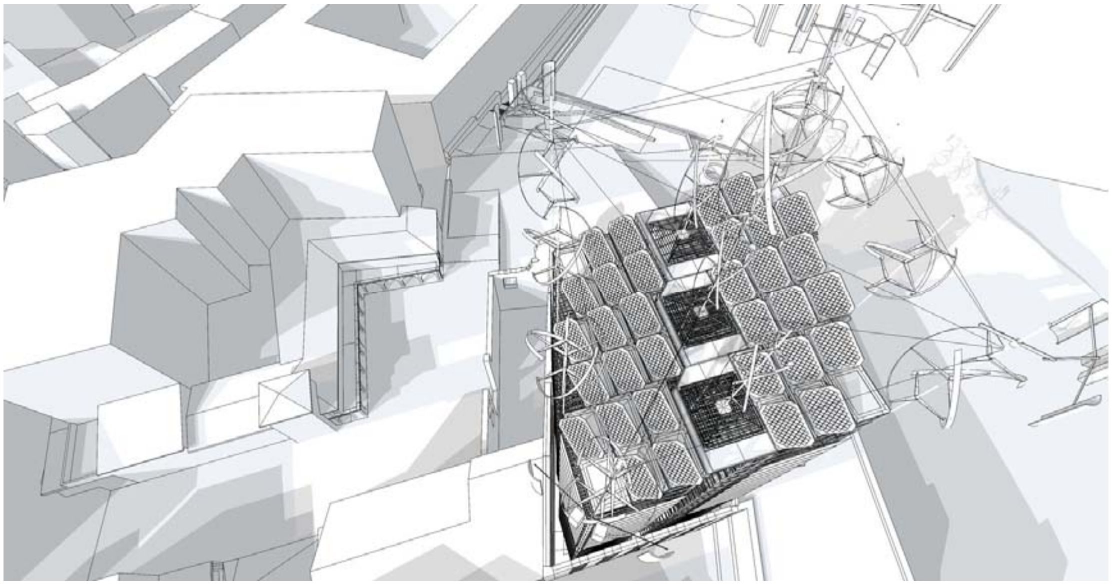


Figure 8-1-1. Multifaceted sustainable strategies on the automated parking system.

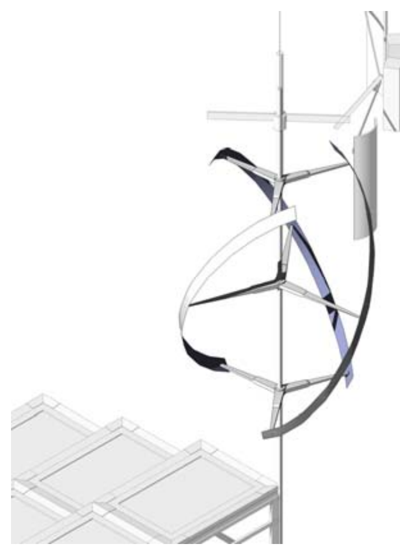


Figure 8-1-2. Cell tower improvements above wind turbines.

Figure 8-1-3. Horizontally expanded wind turbines for capturing exterior updraft.

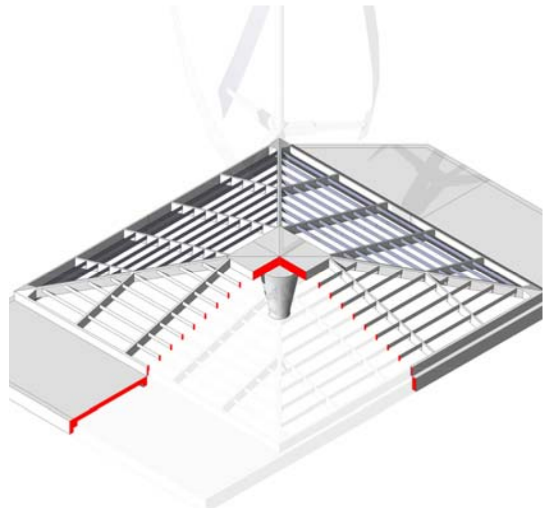
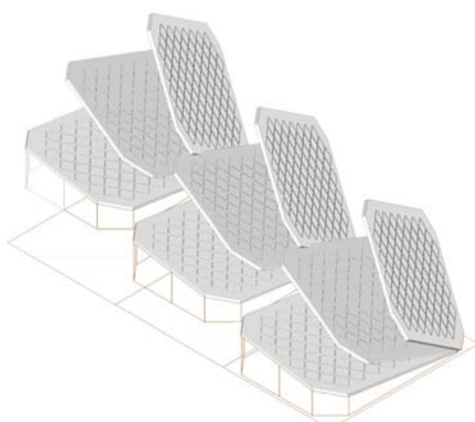


Figure 8-1-4. Vertically elongated wind turbines for capturing interior updraft.

Figure 8-1-5. Vent grille for lifting interior updraft through the entire parking tower.



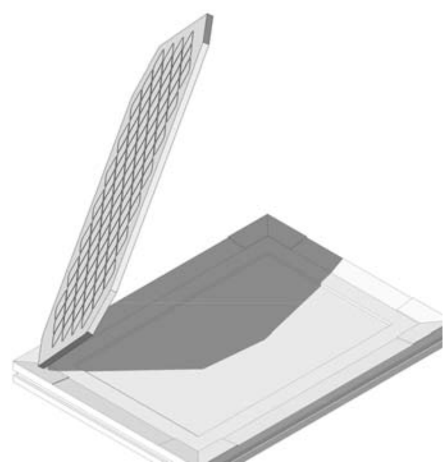


Figure 8-1-6. Tiered operable solar panel system set at optimal seasonal angles.

Figure 8-1-7. Individual solar panel is modular by design.

Figure 8-1-8. Piazza del Popolo. Opportunistic advertisement on scaffolding.

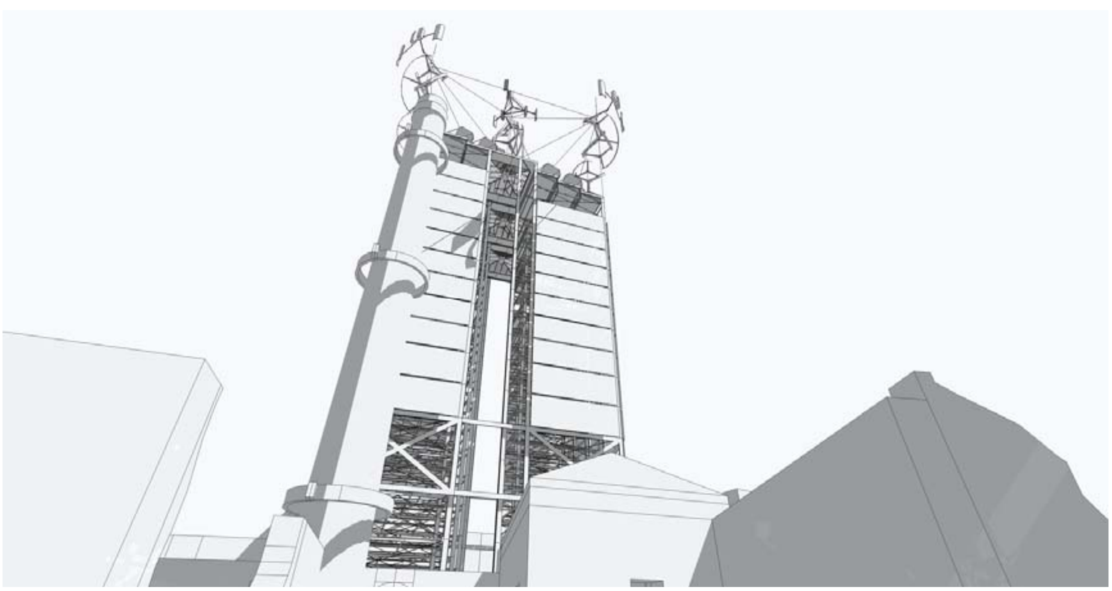


Figure 8-1-9. Pristine exterior finish is prime for advertisement and visuals.

Chapter 9: Phased Redevelopment, the "How"

Section 1: Phasing Overview

The very advantageous essence of automated parking in an ability to start the project small, and then grow. For a small Italian town such as Gragnano, the financing for capital projects is limited. Enable for urban revitalization to holistically move forward, both public and private stakeholders must be reassured of the project's long-term viability. As an innovative new approach to historic urban renewal, the project must begin small, so real data can be established to support future projections.

A small, immediate intervention can take place within the building shell along Via Roma. Carrying prefabricated structural components, small trucks can weave through the hillside town and deliver the materials to site. Prefabricated designs eliminate the complications of large machines of conventional construction sites, simultaneously avoiding potential damage to the historic masonry structure. Materials and small construction equipment can access the shell through its existing main entrance, alleviating the need for tower cranes. Instead, within the shell, a simple foundation can be rested into place and the scaffolding system for automated parking can be lifted into place via a small vehicle-based crane. Efficiently, the process of prefabrication and assembly can be completed with minimal resources in manpower and time.

<u>Section 2: Phase I</u>

The strategic goal is to take the parked cars off the roads, especially Via Roma. The initial phase of automated parking construction primarily accommodates on-street parking from Via Roma and its feeding streets. In addition, the automated parking is an efficient system; there will be availability even to accommodate neighborhood and residential parking needs.

The total height of the automated system may not exceed the total height of the building shell, only because automated parking is such an efficient system for storing cars. However, the foundation will be sized to accommodate the potential loads for the final phase of construction In the first phase, strategies in solar power and wind power technologies are not implemented, nor will strategies in revenue-generation through public communication. These strategies are not implemented for reasons in both investment and design. A heavy upfront cost in renewable energy cannot be justified until the automated parking system's cash flow stabilizes, and the first phase's construction height simply does not reach the necessary altitude above the building shell to be a viable strategy.

For the first phase, Via Roma becomes a friendlier environment for both pedestrians and the endangered historic building will be stabilized by the automated system.

Section 3: Phase II

Once the cash flow from the first phase stabilizes, the second phase can be property evaluated for development and construction. After Via Roma is free of traffic congestion and access is improved, the vacant retail spaces and lots have the potential to be re-leased and redeveloped. The addition of parking and access will attract more residential and commercial tenants, and redevelopment and automated parking can become a synergizing process.

The existing system of automated parking will be raised by adding more modular components. The same components used in the construction of the first phase will be remanufactured and added to the initial structure. The designs for the necessary components will already be completed, which translates to a savings in cost. The pre-designed and placed foundation will already be in place to receive the additional loads. In fact, for a modularized automated parking system, the process to increase maximum capacity is heavily subsidized by initial development costs during the previous phase.

The addition of parking capacity also brings the opportunity to capitalize on Phase II's new building height. In the second phase, the height of the automated system could potential exceed the height of the building shell. With stabilized cash flow from Phase I, it will be possible to project Phase II's income. In doing so, it will be financially viable to begin investing in small-scale renewal energy technologies as an addition to the automated garage. Having reached (or surpassed) the height of the building shell, solar power and wind power strategies will become effective components of the overall automated parking system.

After the second phase, the grown automated parking system could accommodate new parking demand from new retail and residential uses. In addition, a fraction of the energy-use can be offset by strategies in small-scale solar-panel and wind-turbine additions.

Section 4: Phase III

Substantial improvements are being made along Via Roma, including previously vacant lots and unoccupied tenant spaces. The streetscape should be dramatically improved, including building facades, signage, and pedestrian amenities. By this point, through strategic marketing, the renewal process for Gragnano should have hit regional and international media. The historic pasta manufacturing town in Italy is undergoing a dramatically transformation, where geographic advantages and technology are once more coming together to benefit the town's prosperity.

More visitors and tourists are coming into Gragnano. There are many more new faces in town. Much more traffic is coming in and out of downtown. The cars all have somewhere to park and the pedestrian are no longer endangered by traffic. The pasta factories and local businesses are seeing a rise in customers. There is a definite buzz in the economic rejuvenation process.

Cars need places to park and visitors need places to stay. Phase III continues the efforts in the rehabilitation of historic buildings. The existing parking garage adjacent to the automated parking system is undergoing a renovation process. The building's dimensions and its prime view over the valley make an ideal candidate for hospitality. Its entry is tucked behind a historic Italian courtyard, and next to it is a state of the art automated parking facility. Having no competition in town, this new project will be a great rehabilitated hotel development.

The vitality of the automated parking system and its neighboring hospitality use will synergize each other. In doing so, additional supporting uses will also grow from the node of new developments. Automobile rentals and cafes and restaurants are but few of the many possibilities that can grow from hospitality and automated parking services.

The automated parking system will grow taller. Its height will significantly increase in the advent of hospitality next-door and the prospects of car rental dealership sharing its available spaces. With its new height comfortably above the building shell, public communication strategies in community announcements and advertisements can become new revenue streams to support the urban renewal process. Renewal energy strategies will also proportionally grow with the rise of the automated system.

Section 5: Phase IV

Substantial development and construction projects should have been underway and near completion. With new businesses and industries in town, employment rate is higher, and economic vitality grows. When population grows, capital improvement projects and local businesses will also grow to support new residents and their lifestyles. The earthquake ruins around downtown Gragnano will be the first sites for new multifamily and mixed use development projects.

The first automated parking system may or may not continue to grow during this process. There are now new opportunities for more sites for automated parking interventions, especially in conjunction with new multifamily and commercial and mixed use projects.

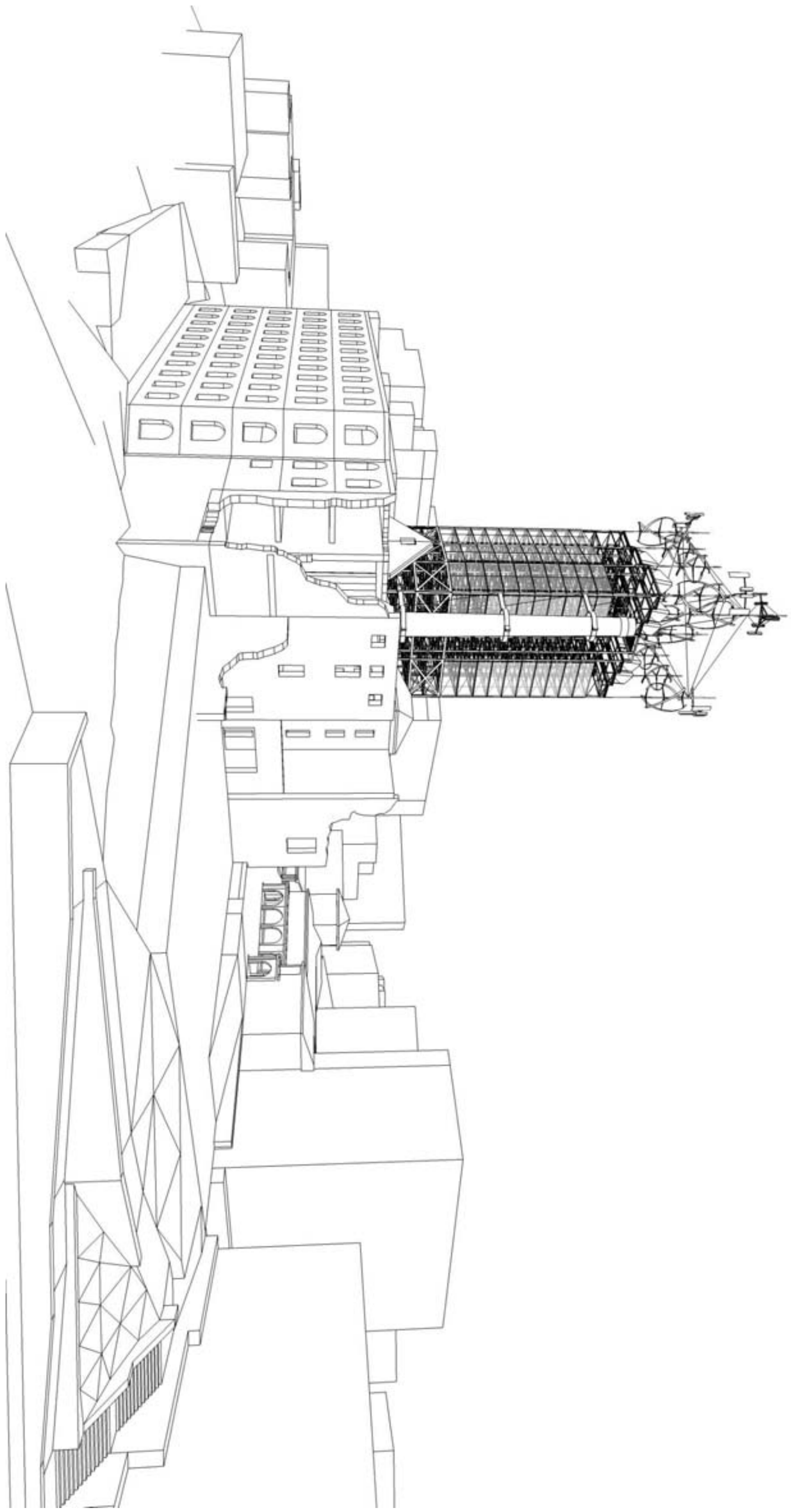


Figure 9-5-1. Final phase of automated parking erection in Gragnano.

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Figure 9-5-2. Final phase of automated parking view from soccer field.

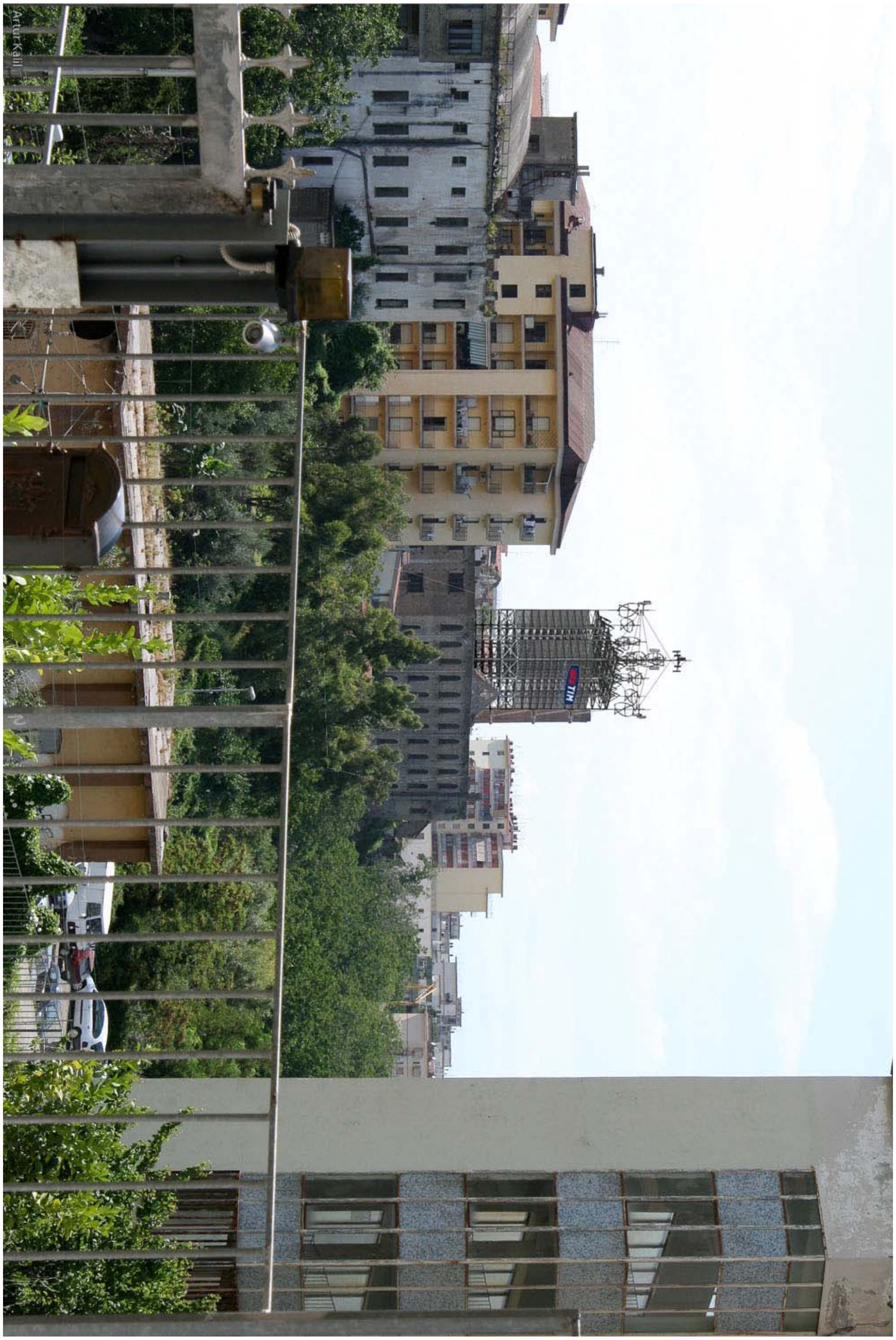


Figure 9-5-3. Final phase of automated parking view from across the valley.

Figure 9-5-4. Final phase of automated parking view from the entry courtyard.

Figure 9-5-5. Final phase of automated parking view from renovated adjacent lot.

Section 6: Final Phase

The final phase of the redevelopment process signals the recovery of Gragnano's urban fabric. The first automated parking system has greatly served to stabilize the endangered building and shells and in turn catalyzed urban redevelopment around Gragnano. In turn, automated parking has served its purpose. The highest advantage of an automated parking system is its ability to be disassembled without damaging the existing building shell that has been stabilized. The automated parking system moves out of the building shell and is transferred to another location. Meanwhile, a higher and better use moves into the building shell, continuing to support the existing context.

Cars as we know it will not remain the same way over time. It is utmost important for automobile parking facilities to foresee potential changes in the industry and utilize innovative technology that will be able to adapt to both seen and unforeseeable changes.

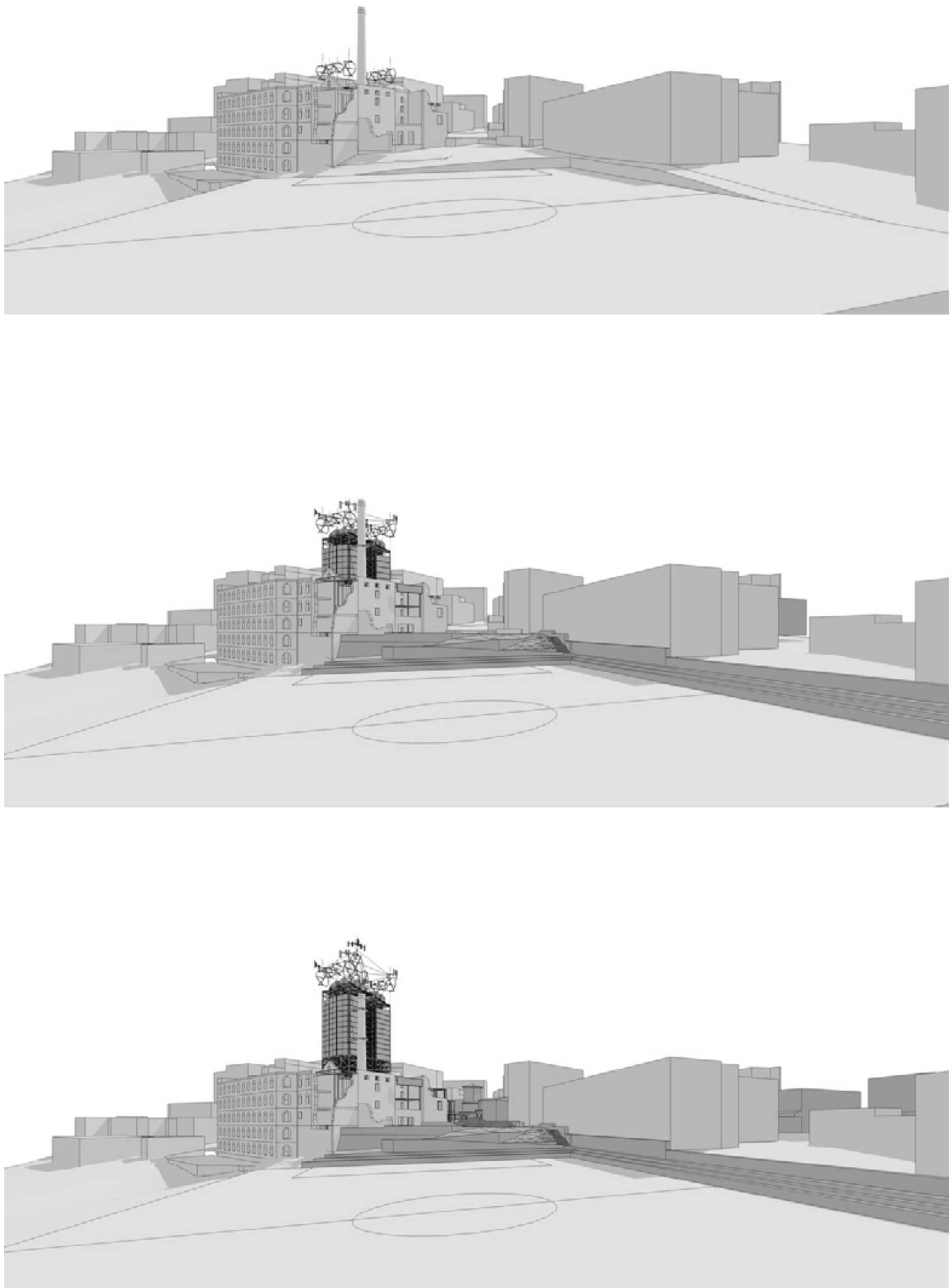


Figure 9-6-1. Tower's growth as an indication of urban renewal's success (1).

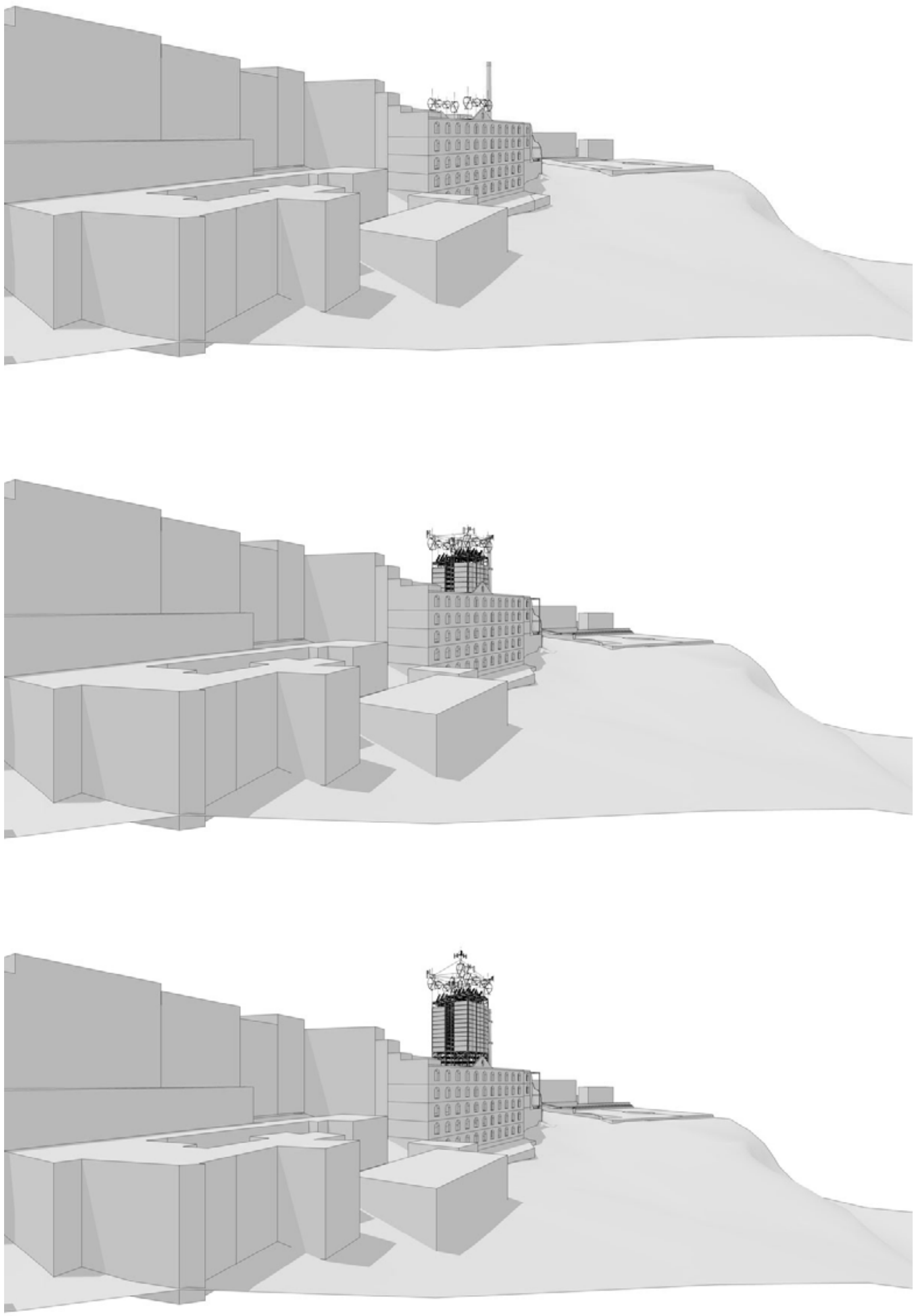


Figure 9-6-2. Tower's growth as an indication of urban renewal's success (2).

Figure 9-6-3. Downtown Gragnano existing uses around building shell. (Yellow – residential; red – commercial and retail frontagel; blue – civic)

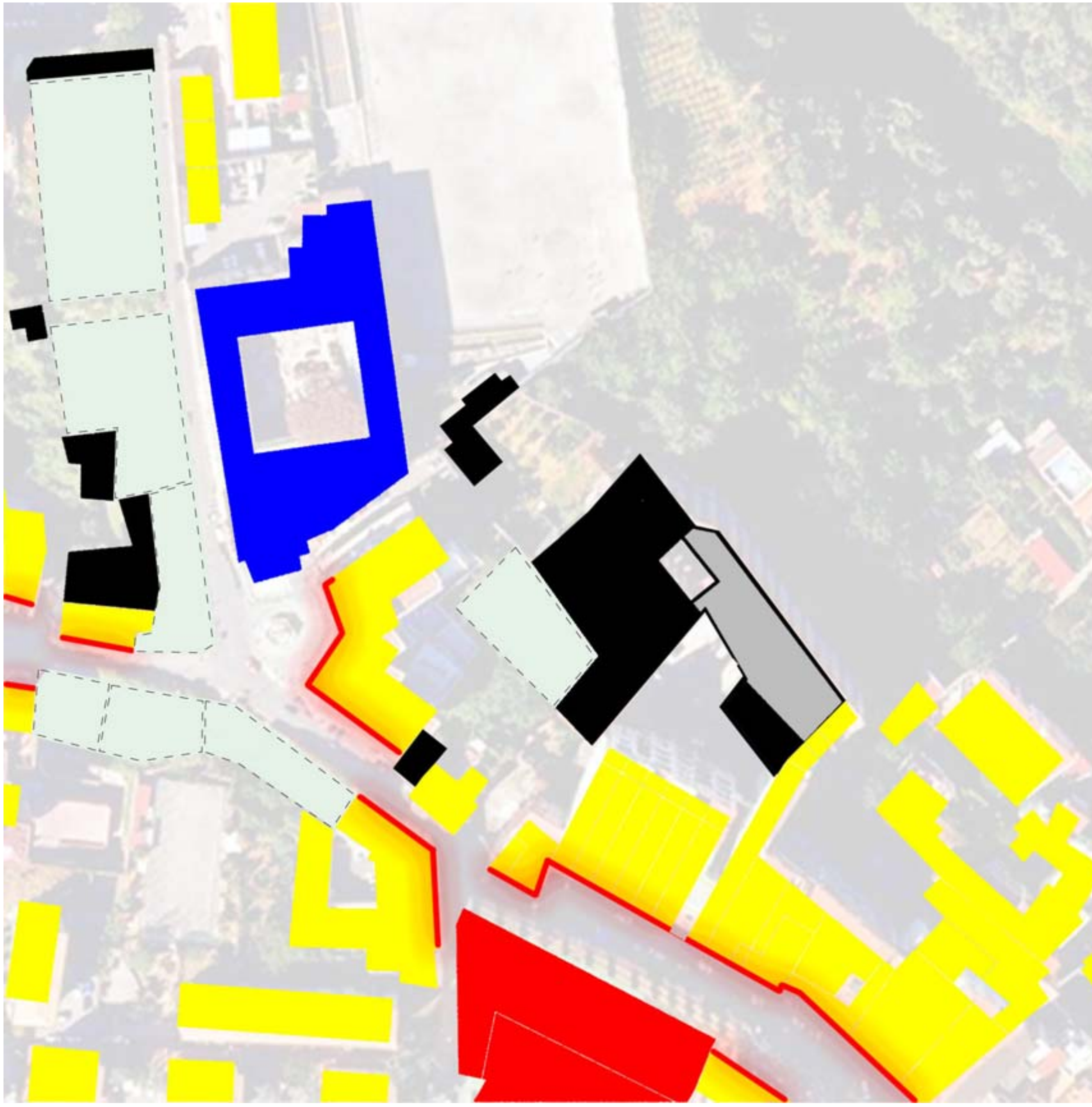


Figure 9-6-4. Downtown Gragnano existing ruins (black) and vacant lots (dashed boundaries) around the building shell.

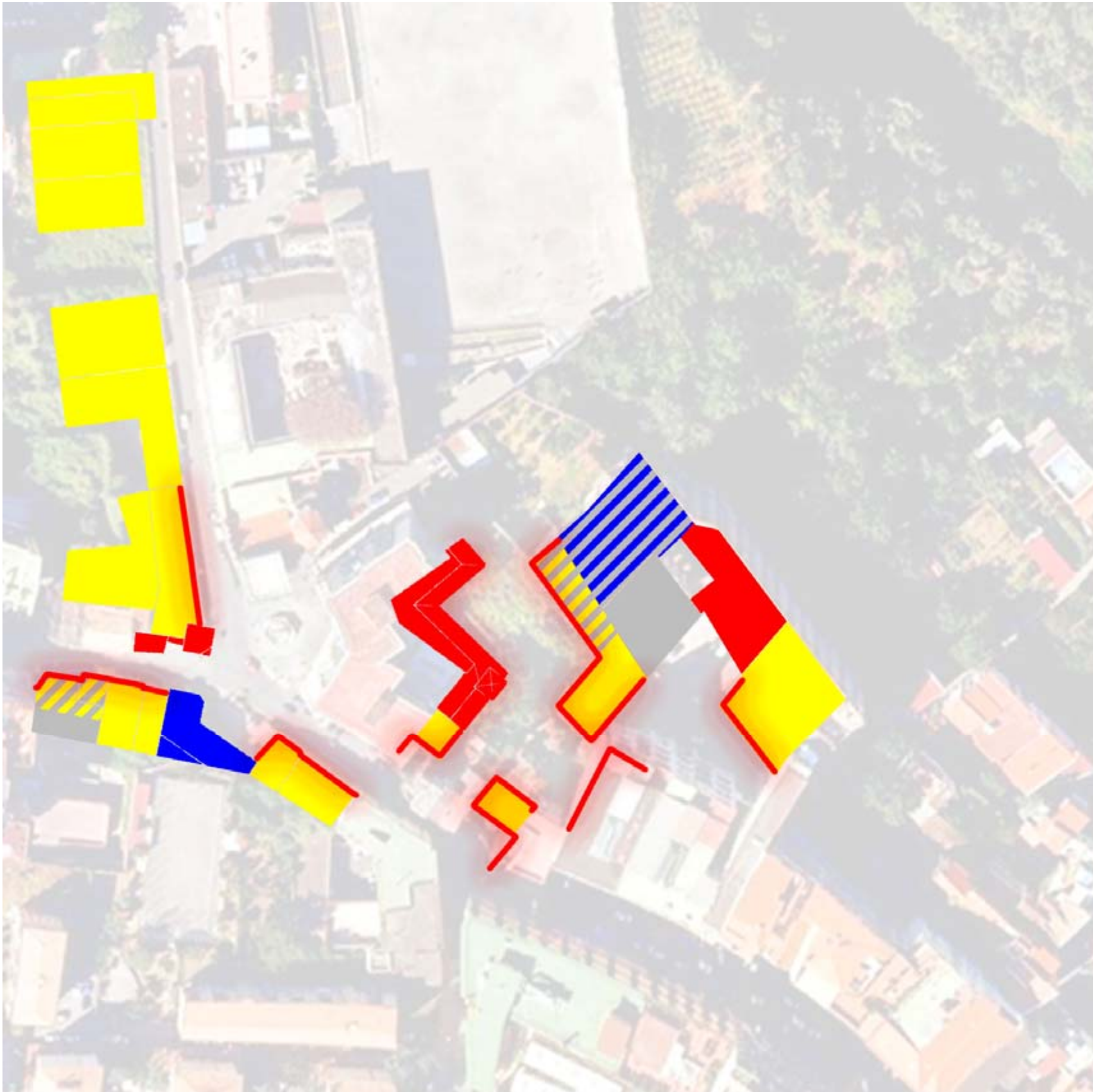


Figure 9-6-5. Downtown Gragnano proposed new uses. (Mixed use indicated by stripes. Yellow – residential; red – commercial and retail frontage; blue – civic; gray – parking)

Figure 9-6-5. Downtown Gragnano proposed uses with existing uses. (Mixed use indicated by stripes. Yellow – residential; red – commercial and retail frontage; blue – civic; gray – parking)

EXISTING

EXISTING

Use	Building (m^2)	Plate	Floors	Total	ft^2
Residential	End	660	3	1980	21305
		390	3	1170	12589
	Hi-Rise	975	5	4875	52455
	Low	178	3	534	5746
	Courtyard	1100	4	4400	47344
		300	5	1500	16140
		60	1	60	646
		140	1	140	1506
	Total			**14659**	157731
Commercial	End	660	1	660	7102
	Hi-Rise	1185	1	1185	12751
	Low	975	1	975	10491
	Courtyard	1100	1	1100	11836
	Pasta	1950	2	3900	41964
		1410	1	1410	15172
	Total			**9230**	99315
Civic	Museum	2385	3	7155	76988
	Total			**7155**	76988
Parking	Abandon	760	1	760	8178
	Total			**760**	8178

Total Existing (sqft) 342,211

PROPOSED

INFILL

Building (m^2)	Plate	Floors	Total	ft^2
Low	130	1	130	1399
Circle	285	2	570	6133
	250	2	500	5380
	165	4	660	7102
Tower	410	2	820	8823
	470	2	940	10114
	415	2	830	8931
	225	2	450	4842
Face-Muse	480	3	1440	15494
	340	3	1020	10975
	340	3	1020	10975
			8380	90169
Low	130	1	130	1399
Inn/Dine	480	2	960	10330
Circle	285	1	285	3067
	250	1	250	2690
	165	1	165	1775
Tower	45	2	90	968
	390	1	390	4196
	470	1	470	5057
			2270	24425
Circle	255	3	765	8231
			765	8231
	105	11	1155	12428
			1155	12428

135,253

ADAPTATION

Building (m^2)	Plate	Floors	Total	ft^2
Courtyard	215	2	430	4627
	415	4	1660	17862
Gable	280	3	840	9038
			2930	31527
Parking	710	1	710	7640
Gable	280	1	280	3013
Hotel	430	5	2150	23134
	415	1	415	4465
Courtyard	215	1	215	2313
			3770	40565
Parking	710	3	2130	22919
	135	5	675	7263
			2130	22919
	375	17	6375	68595
			6375	68595

163,606

Total Proposed (sqft) **298,859**

Table 9-6-1. Estimated total occupancy between existing and proposed uses.

Chapter 10: Technical Specifications

Section 1: Specifications

The strength of automated parking is in its highly efficient use of space measured in cubic volume. Modular parking stalls utilize fixed dimensions, and any stall must accommodate incoming vehicles regardless of the automobile's dimensions. The stall must be big enough to fit all anticipated vehicles.

In this thesis, the dimensions of individual stalls are optimized to accommodate two distinguish vehicle dimensions to optimize volumetric efficiency. Instead of one global stall dimension, this thesis utilizes two complimenting stall dimensions. The first dimension accommodates most of the sedans and compact cars in Italy, where the lengths, widths, and heights are optimized to fit those dimensions. The second dimension accommodates the over-sized vehicles such as SUV's and jeeps.

Statistically, smaller vehicles are more common in Italy, so the smaller stalls are much more available in the automated parking system to optimize overall space use. Whereas the larger stalls are scarcer by comparison, they are intended to accommodate the lesser likelihood of over-sizes cars while still able to store more compact ones. The sum is a total saving in volumetric space, so efficiency is maximized.

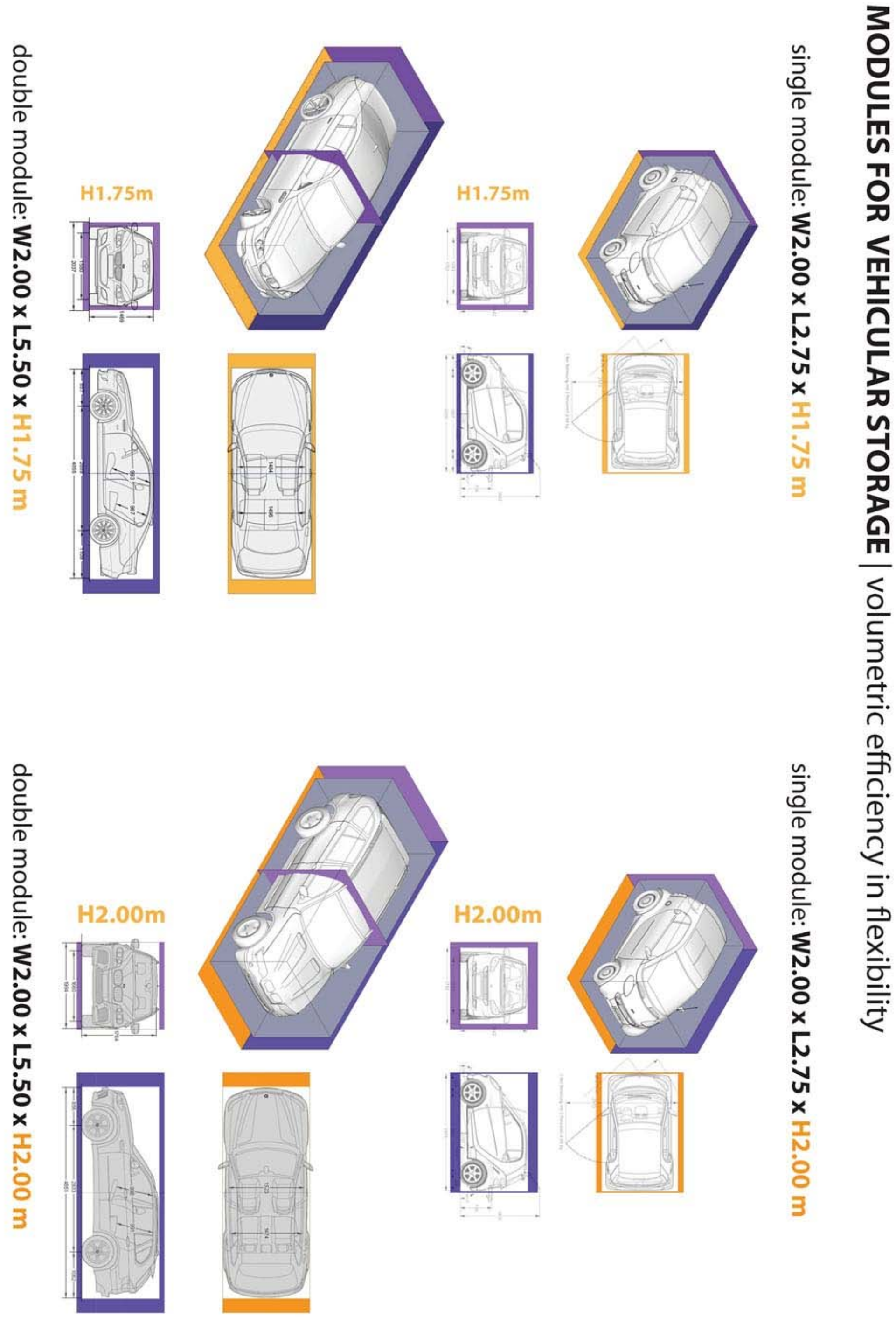


Figure 10-1-1. Specifications of two modular dimensions utilized in the built system.

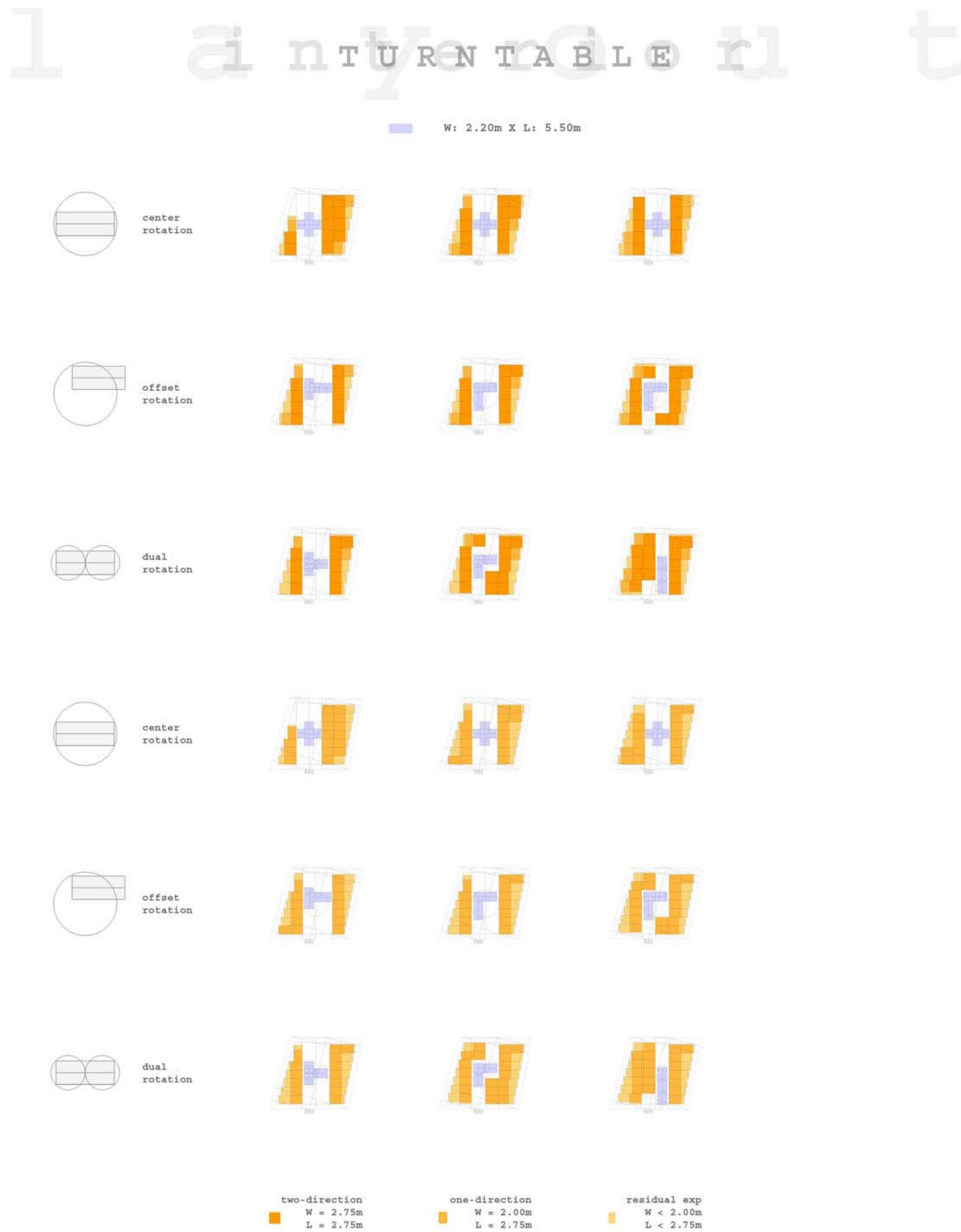


Figure 10-1-2. Versioning of horizontal layout of garage and turntable positioning.

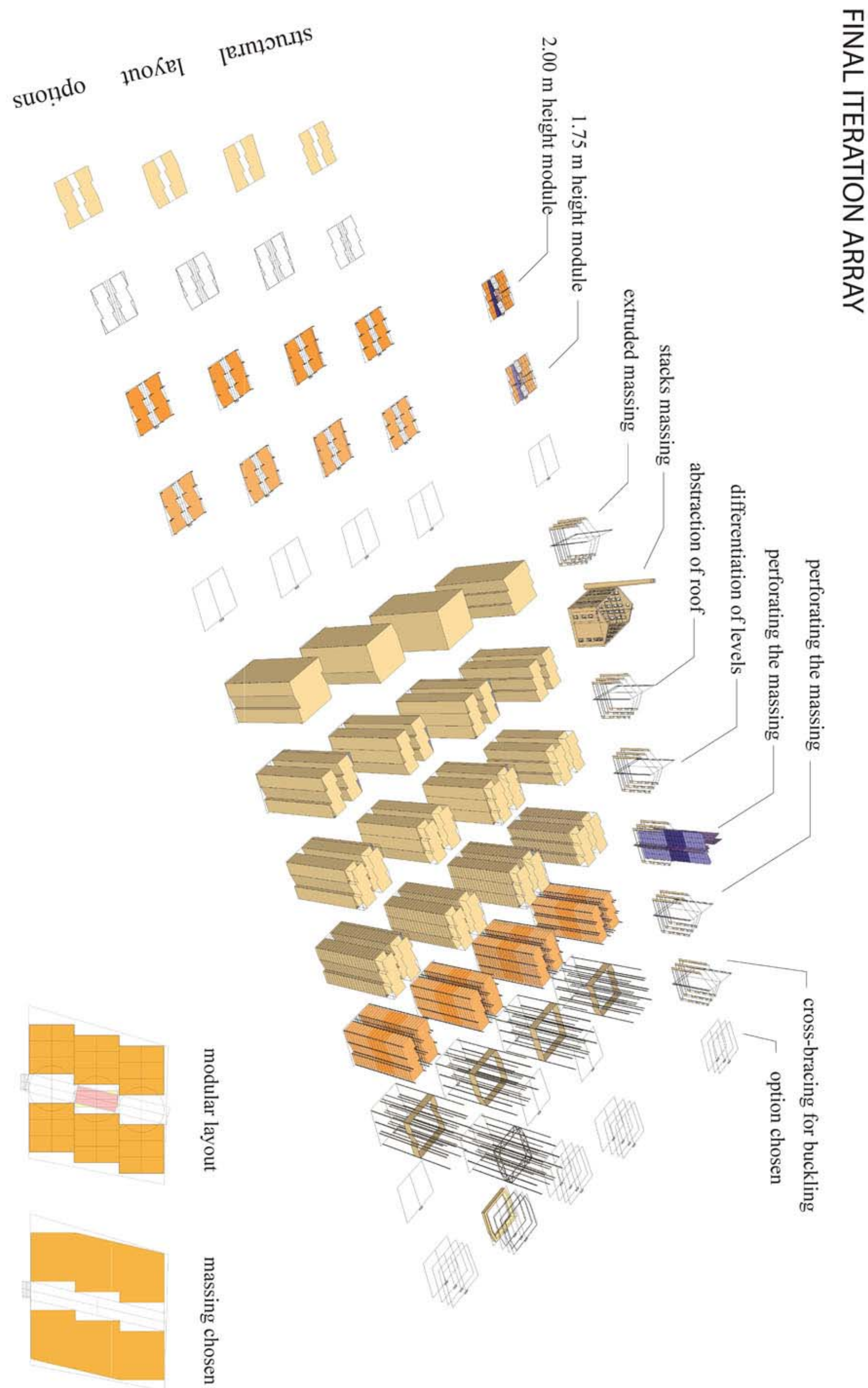


Figure 10-1-3. Versioning of modular layout and horizontal massing of tower.

Section 2: Construction

Structurally, automated parking systems are very similar to traditional scaffolding systems. They are a combination of primary and secondary members that support primary live and dead loads while resisting against lateral loads. However, the system is simple but precise. Prefabrication is a necessary strategy to ensure all parts of the automated system are precise so misalignment and errors are minimized during the assembly process. Very precisely, the racks in an automated system are thinly gauged steel beams, columns and diagonal bracing members.

For the building shell in Gragnano, in this thesis, all the construction components can be moved into the interior of the shell via a small truck. The design of the automated system in this thesis refined the construction process to minimize disruption to the historic masonry structure that requires stabilization. The foundation and bottom level of racks are laid into place first, including the mechanized turntable for movement. Then, with a small truck-based crane, additional racks can be lifted into place by docking the crane onto the mechanized palette. In essence, utilizing a small crane that sits on the turntable, the automated parking garage borrows the concept of a kangaroo crane via self-construction.

Once the automated system has reached a maximum height beyond the building shell, a belt-frame lateral bracing system will be placed around the structure just above the shell. This strategy will help stabilize the overall system from the foundation to the height of the belt-frame, while allowing slight lateral movement above similar to move skyscrapers built to withstand lateral loads.

Very minimal and fundamental modifications are made to existing automated systems' structures enable to optimize adaptation as a supporting scaffold system. The historic building shell is stabilized via small extensions from the automated system's main structural frame. Clamps are attached to the existing rough openings to provide lateral support from multiple directions. The clamps and other point-based supporting members are used with minimal contact with the masonry structure so to preserve the shell's integrity.

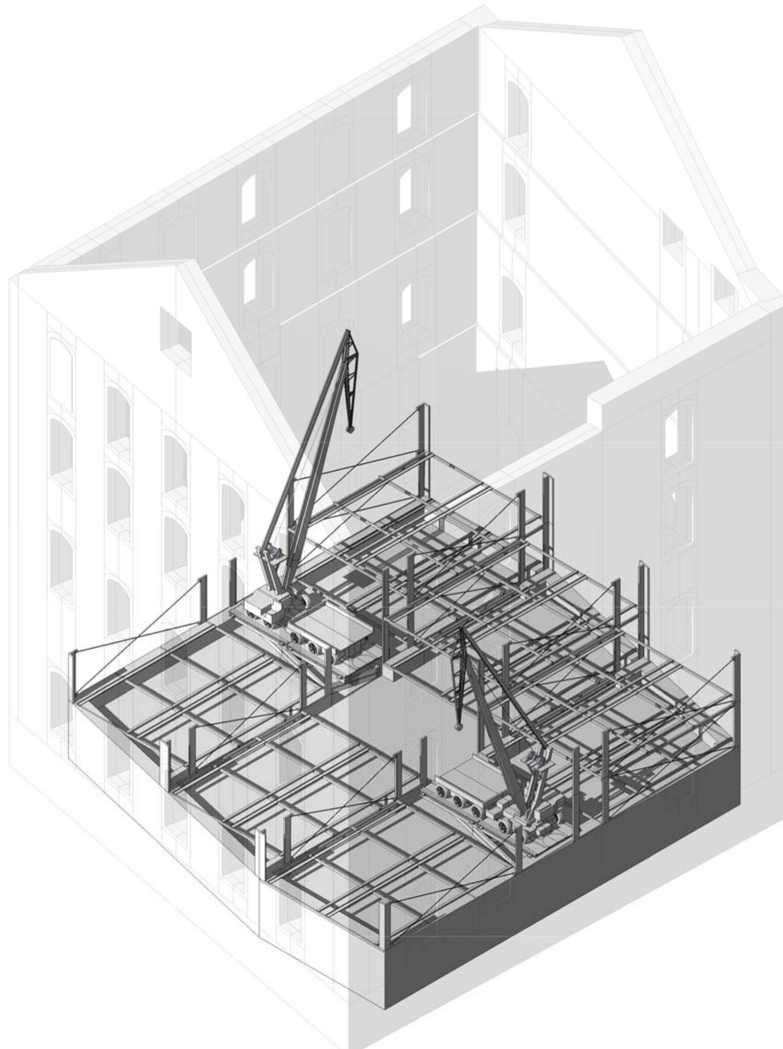


Figure 10-2-1. Construction of foundation. Small cranes utilize the turntable to move horizontally. Turntable raises after the completion of each level of stacks.

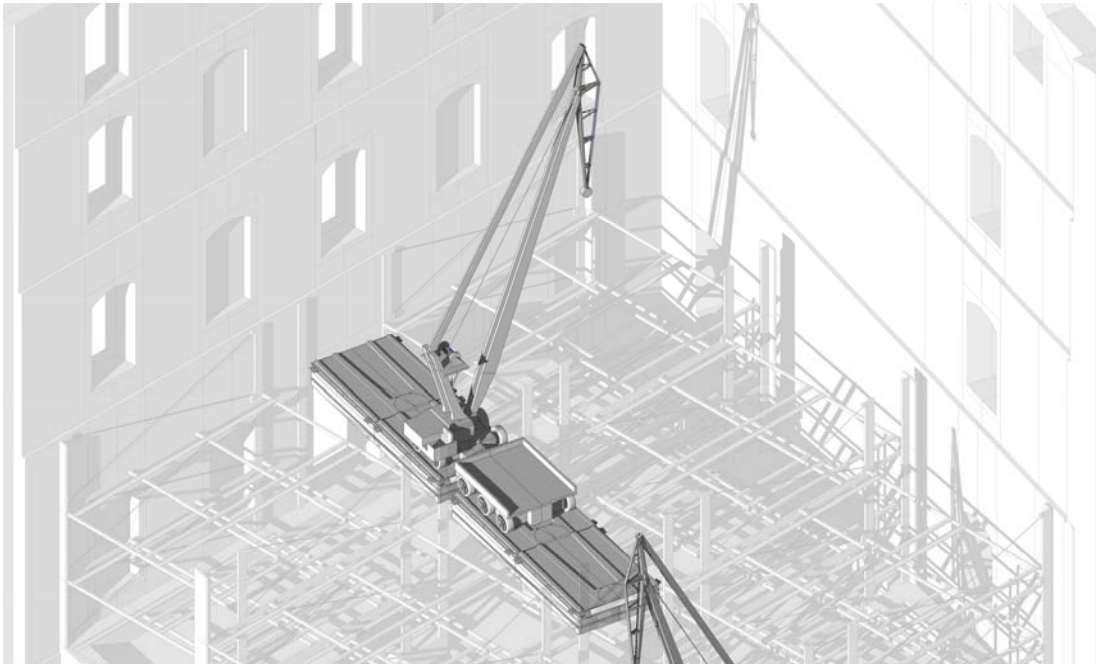


Figure 10-2-2. Construction of scaffolding (primary and secondary structures). The small crane can be moved from turntable to turntable to maximize utility.

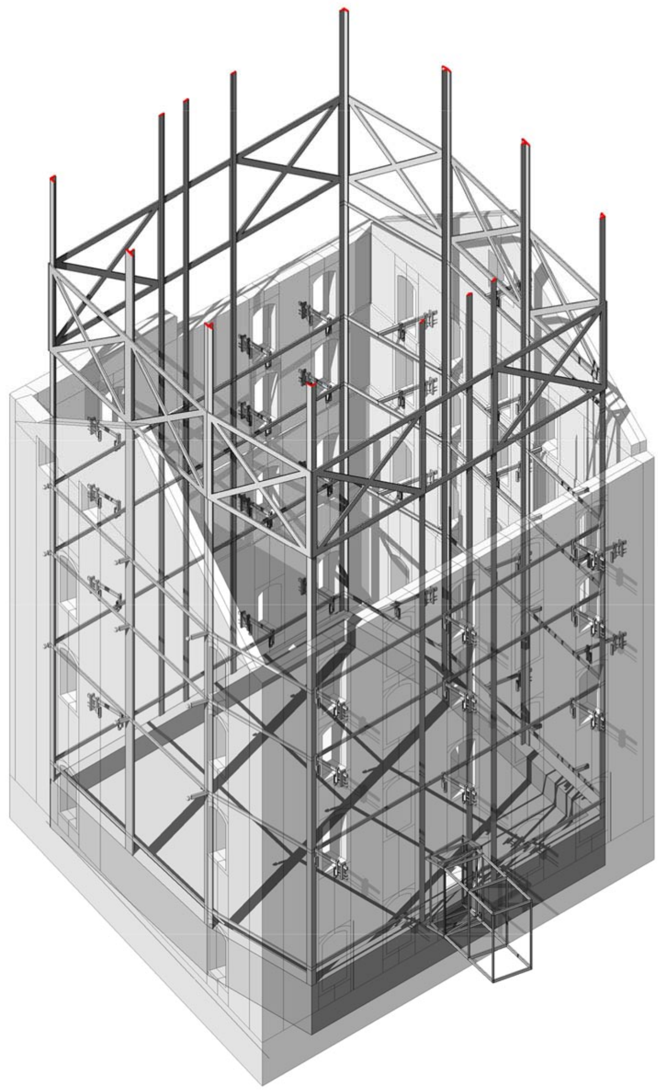


Figure 10-2-3. Primary scaffolding utilizes a belt frame. Extensions from the main structure stabilize the building shell at strategic point on the walls.

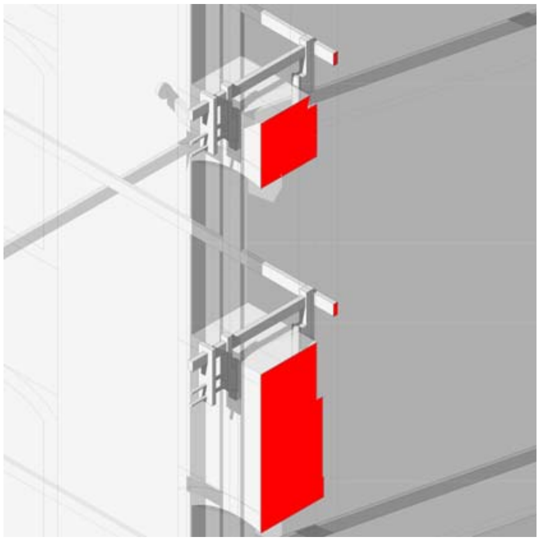
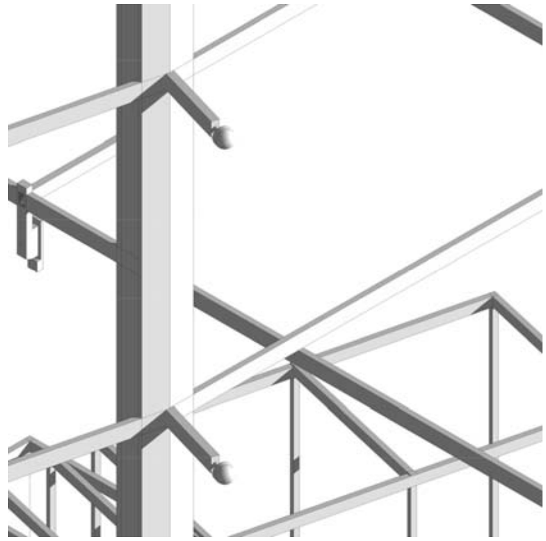



Figure 10-2-4. Detail of stabilizing clamps. Clamps attach through the rough opening in the walls to stabilize the structure in both directions.

Figure 10-2-5. Detail of stabilizing tips. Extensions loaded with shocks extend from primary structural frame to reach out and gently stabilize the building shell.

Section 3: Computerization

The storage of vehicles is completed automated. The automated system is able to detect the dimensions of an incoming vehicle and property store it in the appropriate stall. When operated with user input for expected retrieval times, the automated parking system can calculate, sort, and organize the arrangement of parked cars so the potential wait-time will be minimized upon vehicle retrieval by user. For example, long-term parked vehicles can be sorted farther away than short-term vehicles, and the system can automatically resort its catalog of vehicles as anticipated retrieval times approach.

Maintenance for automated parking garages can be performed remotely 95% of the time. Given modern information systems technology, an automated / computerized storage system can be operated and maintained from a remote location. On-site service is seldom necessary with the exception of regular quality assurance and maintenance services for the physical equipment. All customer services are also provided remotely.

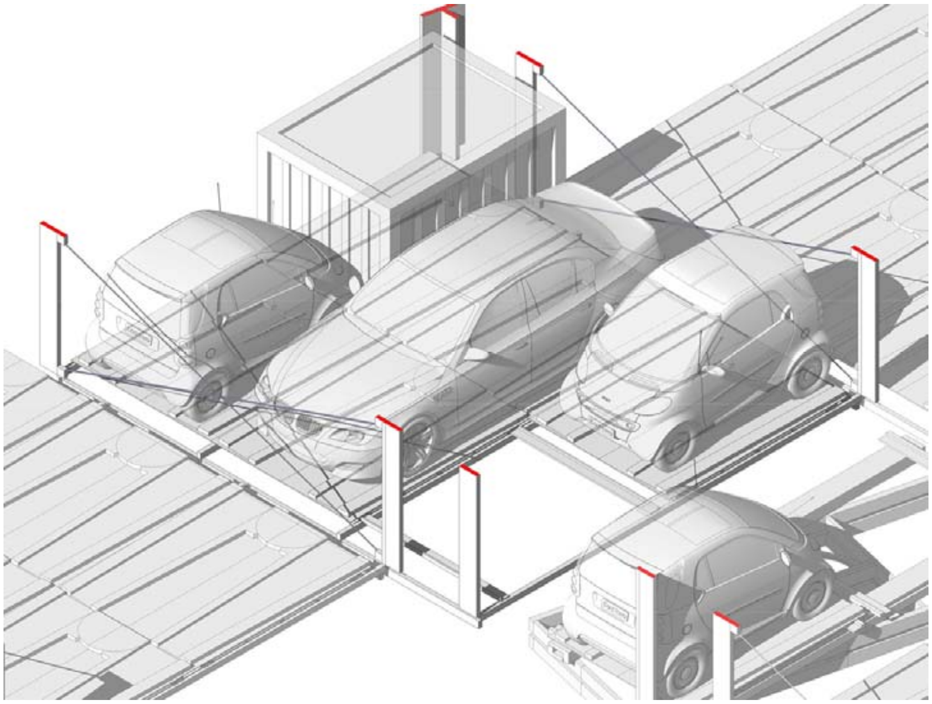


Figure 10-2-6. Modular car "storage" spaces highly versatile in use. Spatial utility is maximized when retailers can also utilize the automated facility for storage.

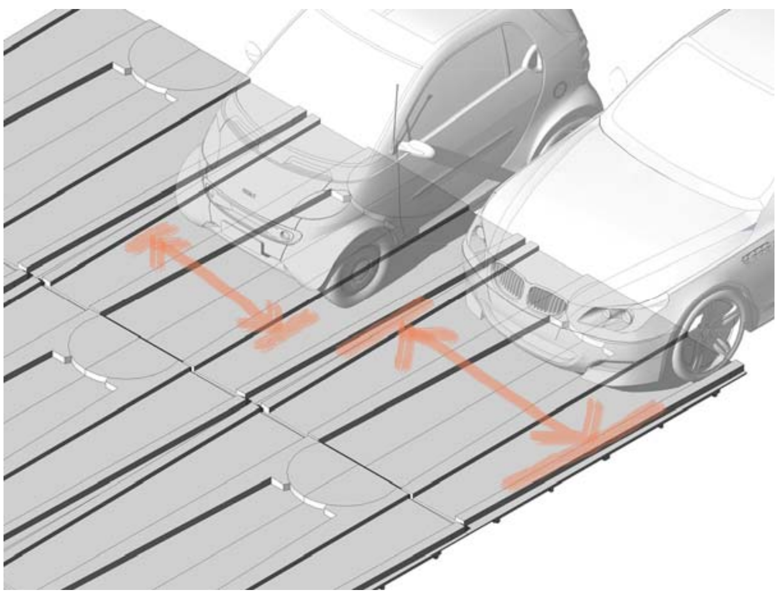


Figure 10-2-7. Detail of palette. An adaptable palette is designed to house vehicles of different tire-to-tire dimensions.

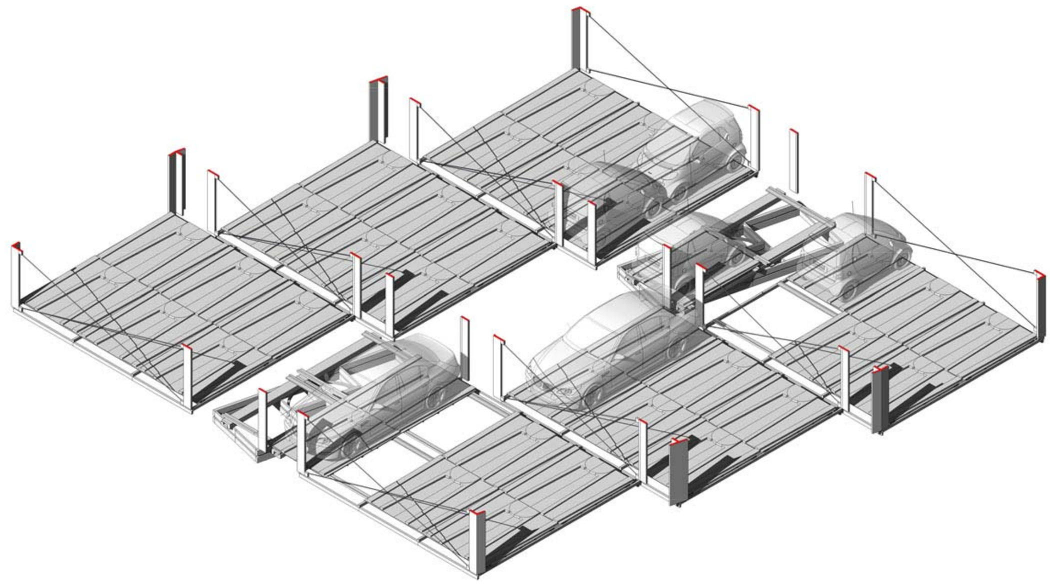


Figure 10-2-8. A typical level in the automated garage. Each stall can park up to two micro cars or one full size sedan or SUV (based on height of the level).

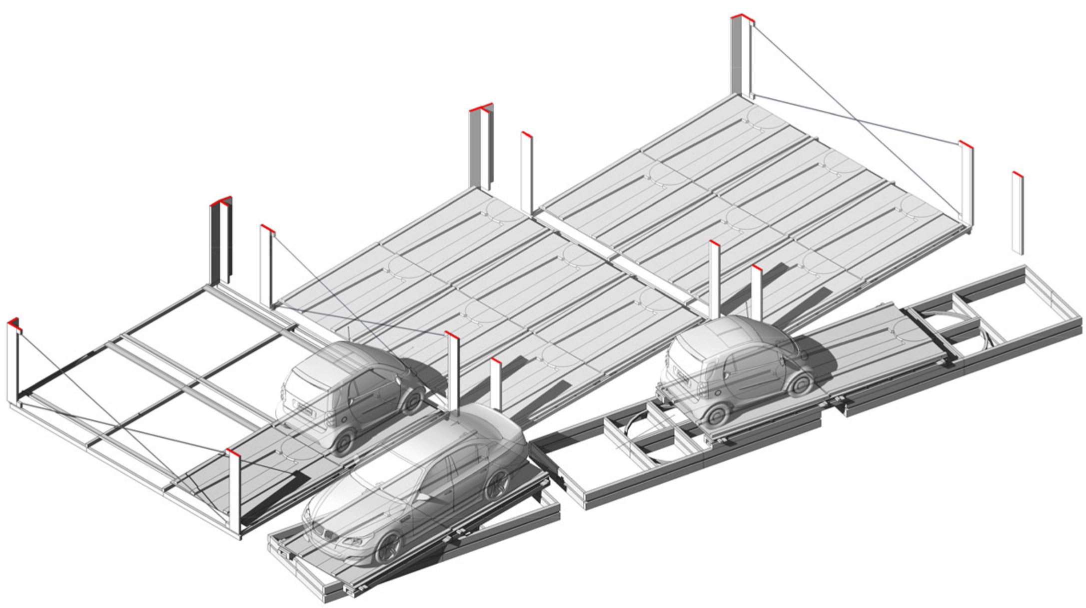


Figure 10-2-9. The turntables can work together to shuffle and re-arrange vehicles in and out of parking stalls to maximize retrieval time efficiency.

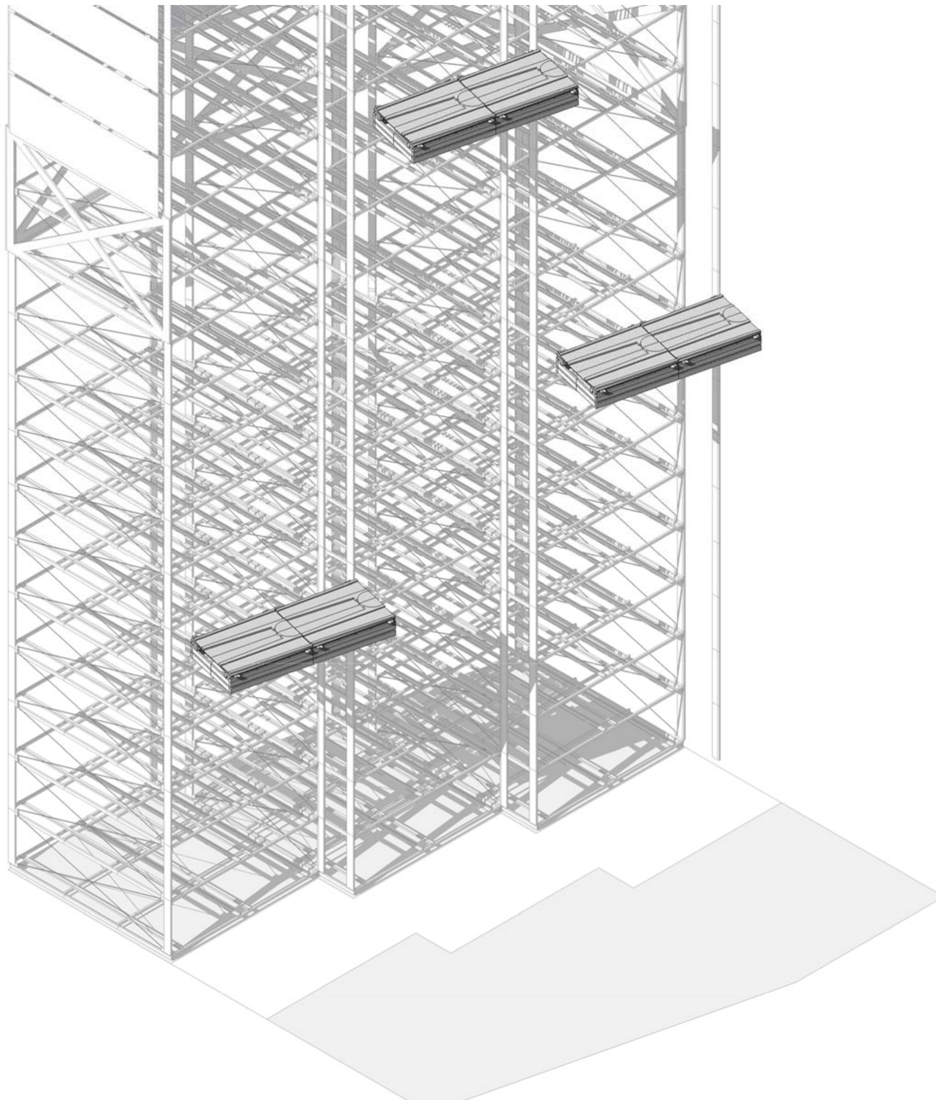


Figure 10-2-10. Three turntables are in the automated system to maximize utility and minimize retrieval wait time.

Chapter 11: Project Summation

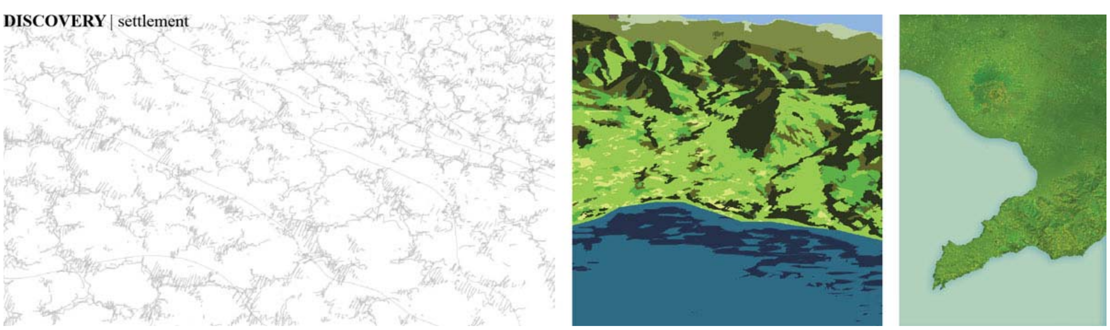
This thesis utilizes strategize innovations in automated parking to provide solutions to multifaceted issues in urban renewal and economical revitalization. Architectural design processes discover simultaneous opportunities to meet multifaceted challenges that affect the urban environment. The solutions in Gragnano are very much opportunistic in one automated parking facility's potential to address concurrent issues in historic preservation, parking, urban design and real estate development. In Gragnano, economic revitalization very much depends on the feasibility of urban renewal.

Appendices

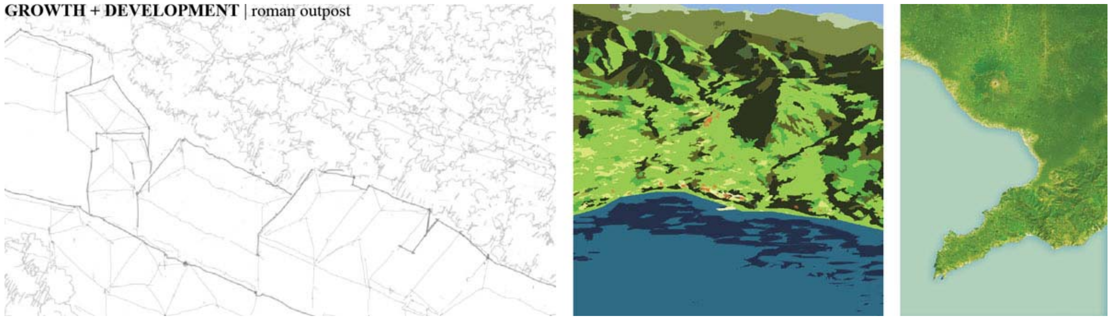
Appendix A: Gragnano Storyline

This thesis postulates the timeline of urban development in Gragnano an its regional context based on historically significant events in the Bay of Naples region. The understanding of cyclic trends in urban development helps to build the argument for urban revitalization. Most importantly, this helps to tell the story of Gragnano.

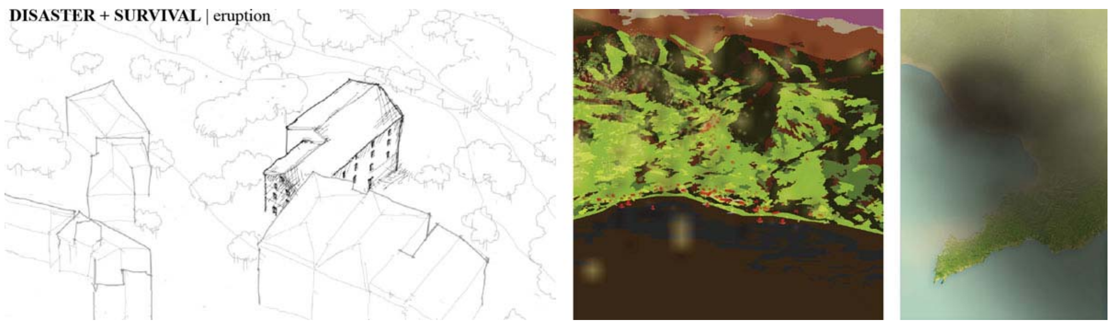
Existing conditions of Gragnano from micro to macro. A hollow building shell sits amidst urban ruins.



The natural environment of Castellammare di Stabia attracted initial settlers.

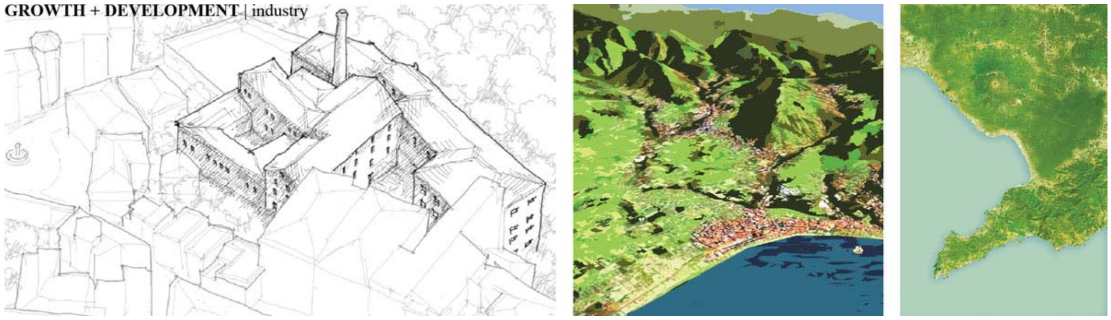


The Romans also discover the Campania region. The coast of Castellammare di Stabia once was the vacation designation for Roman elite—like Miami.



Mount Vesuvius erupts in 79 A.D. This follows a tremendous earthquake in the region. Pompeii, Stabia and surround Roman towns are devastated by the eruption

Millennium later, the region is re-settled. The coast line of Stabia recedes giving new opportunities along the water, and agriculture blooms in the aftermath of Vesuvius.



After the Middle Ages, pasta industry in Gragnano flourishes with the support of regional advantages in springs, wind and sun, and its access to regional economies.

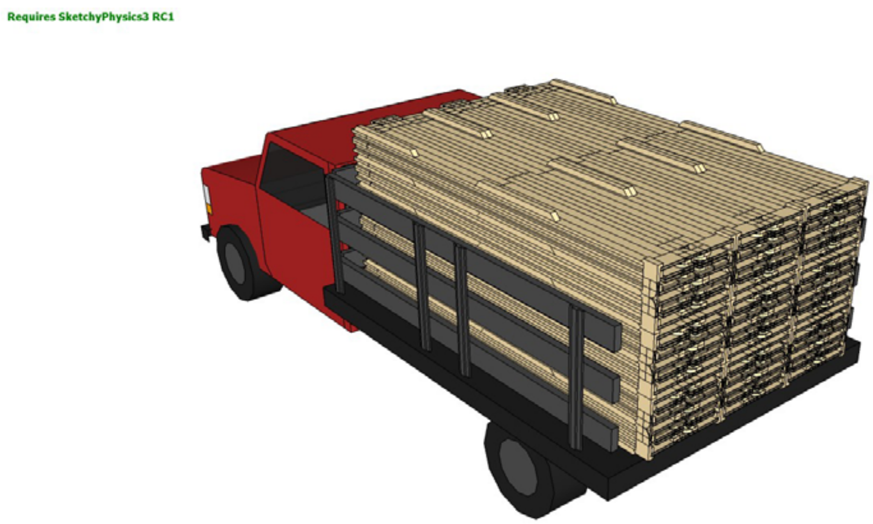
Economy in Gragnano declines after the World Wars, losing to competing Italian pasta industries in the North. Earthquake then hits the Campania region in 1980. Urban fabric is devastated, and lack of competitive industry prevents recovery.

Reconstruction and revitalization efforts take place in the near future. An automated parking system alleviates issues in infrastructure and brings demand for new residential and commercial uses. Urban fabric of Gragnano recovers.


Once the economy of Gragnano rejuvenates, the need for automated parking in the history building shell may no longer be necessary. A higher and better use may instead replace the automated parking system given its impermanent design, and the building shell may become adapted for a new occupancy.

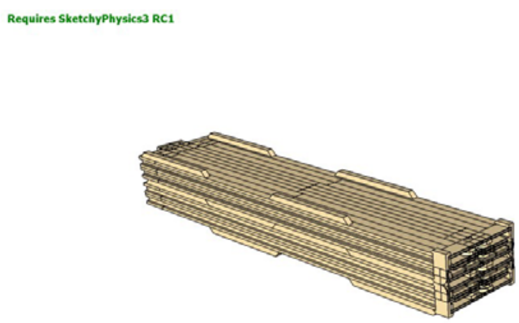
Appendix B: Kit of Parts

A primary and initial consideration for construction in Gragnano is the accessibility of materials and gentile construction methods in support of historic preservation. This section demonstrates a carefully engineered set of ideas for the prefabrication, transportation, and systematic “construction” of modulated kit of parts. Although the concept may not be most effective in financial feasibility, it explores the high capacity in engineering and prefabrication for automated parking systems and the efficient and sensitive erection methods.

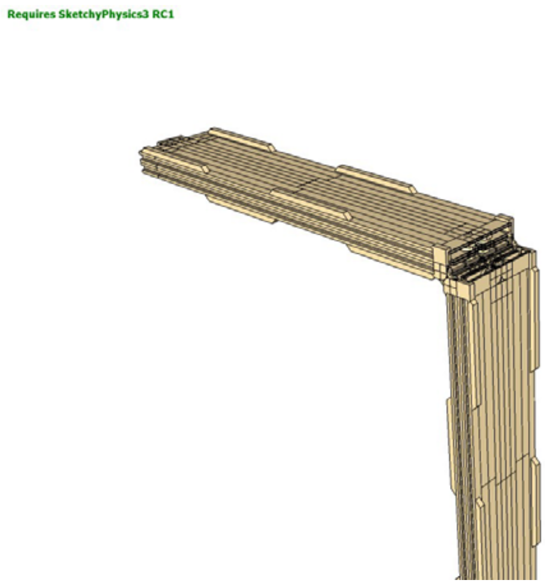


Transportation of prefabricated components to site. Small trucks are much easier to maneuver in historic Italian towns.

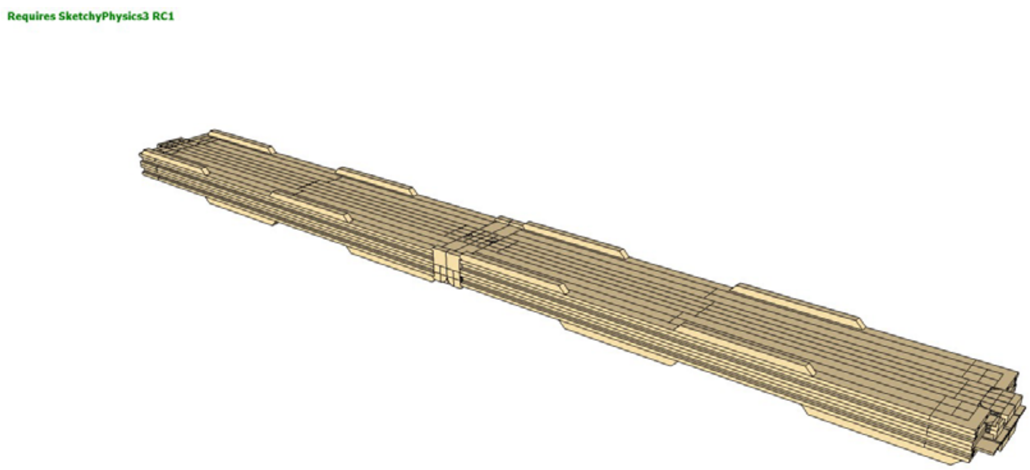
A conservative load of prefabricated components.



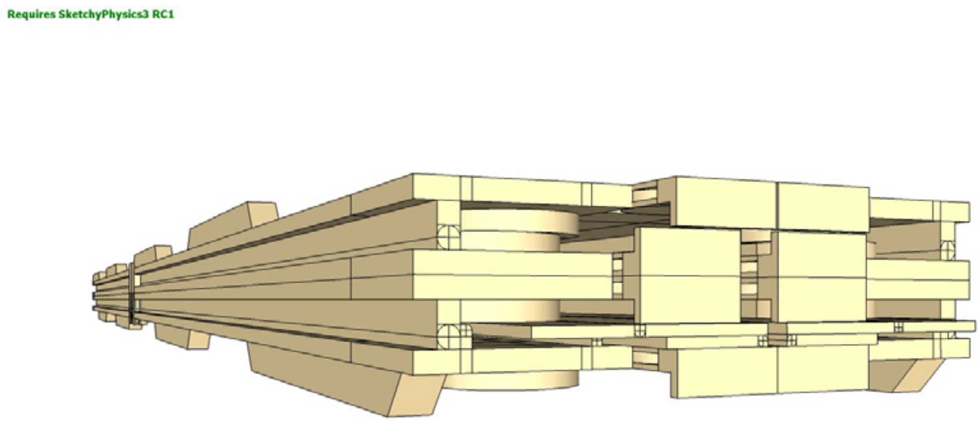
An individual component as pre-assembled kit of parts ready of assembly.



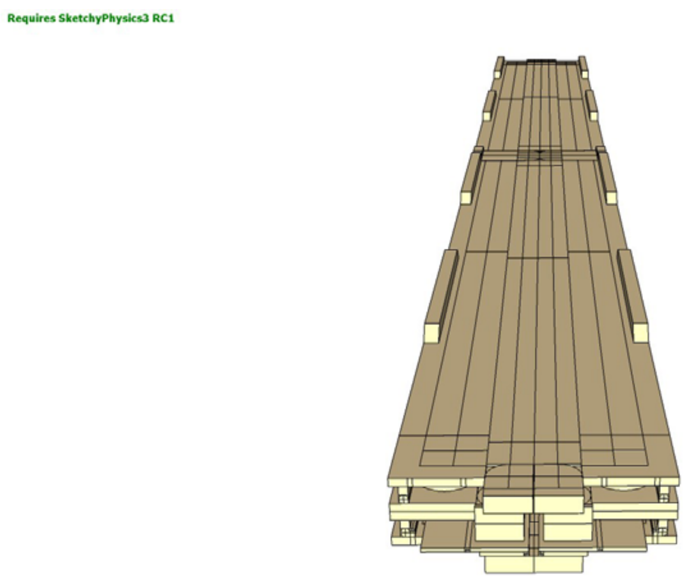
Unfolding out an individual component.



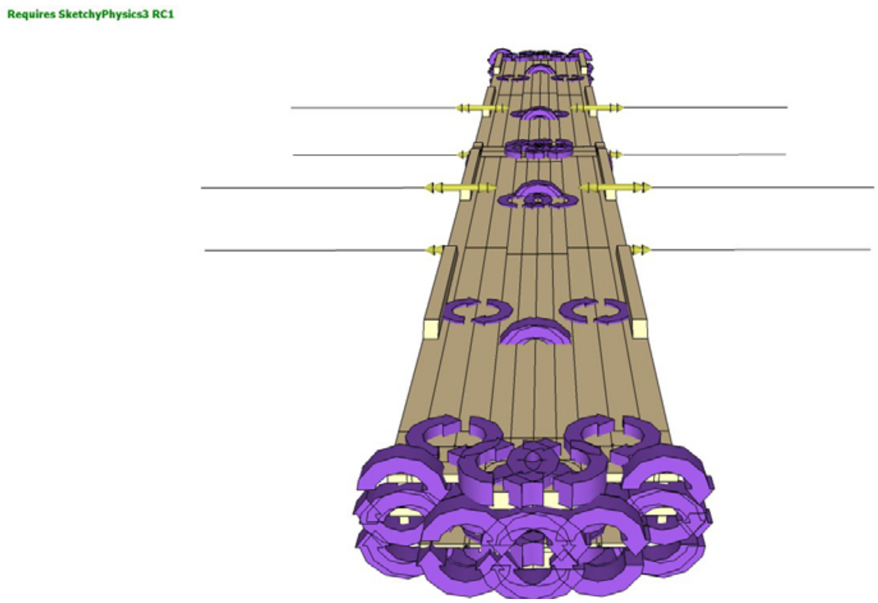
Stretching a component to be taut after unfolding.



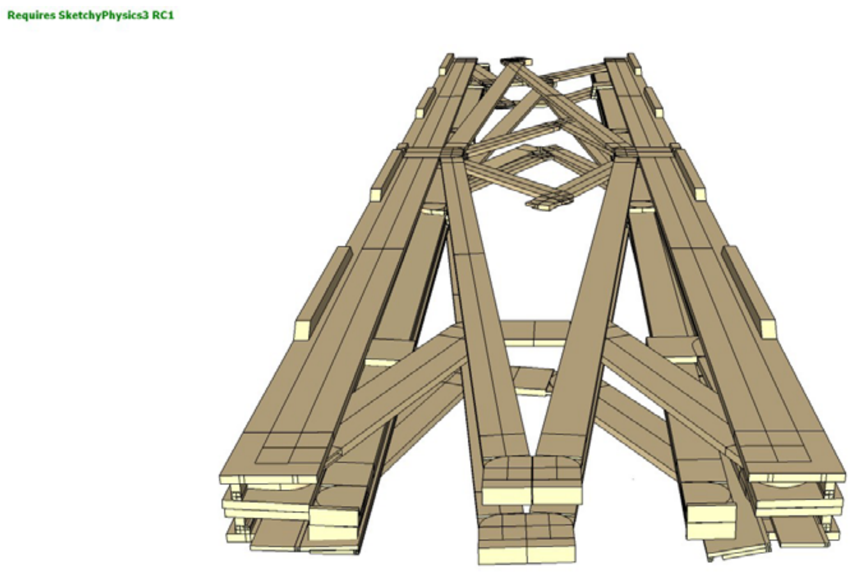
Close-up of the engineered detail of the folded members of one component.



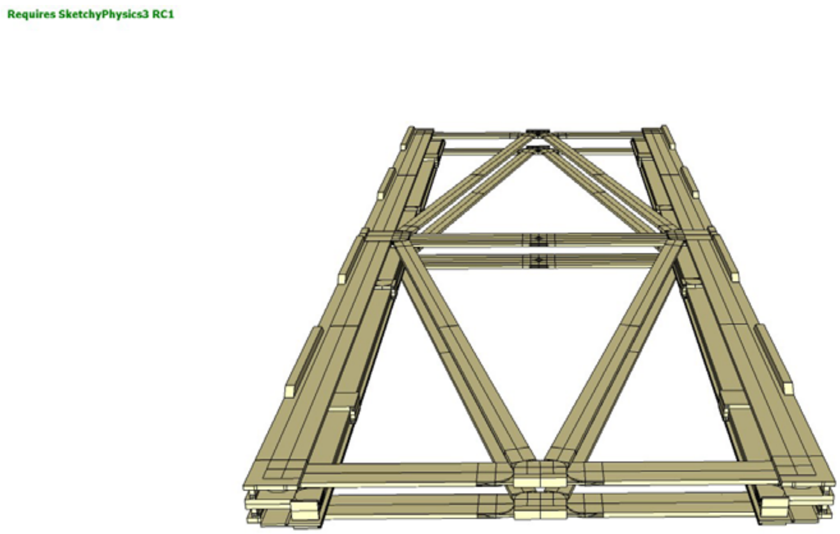
Stretched component ready to be expanded.



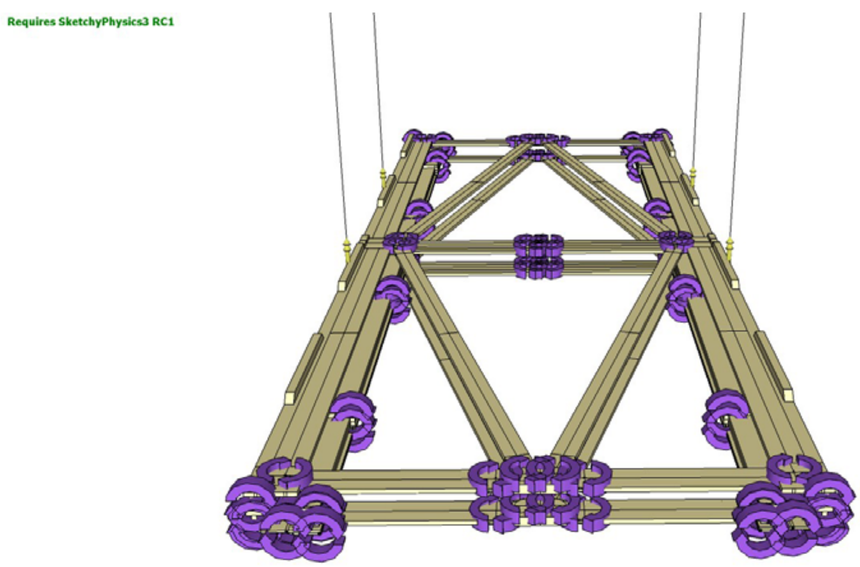
Indication of the direction of initial expansion and involved hinges and rotating members necessary for this process.



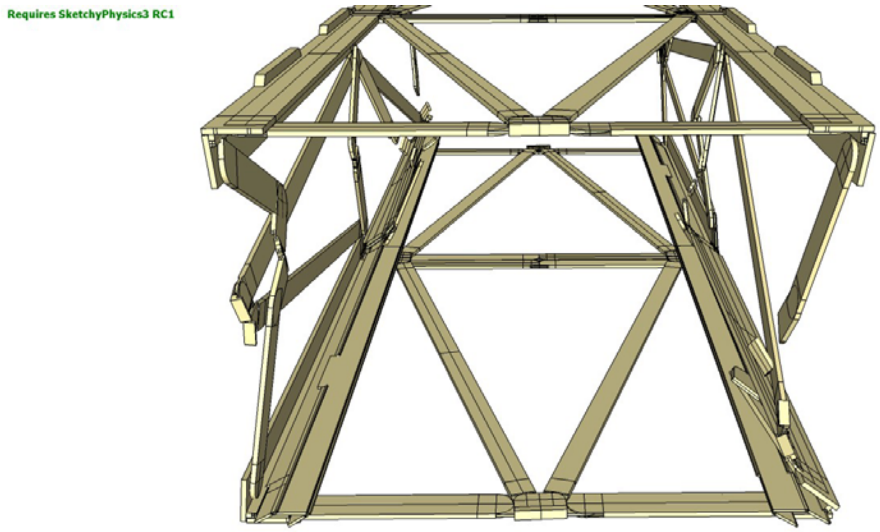
Horizontal expansion process. The members of one component are revealed.



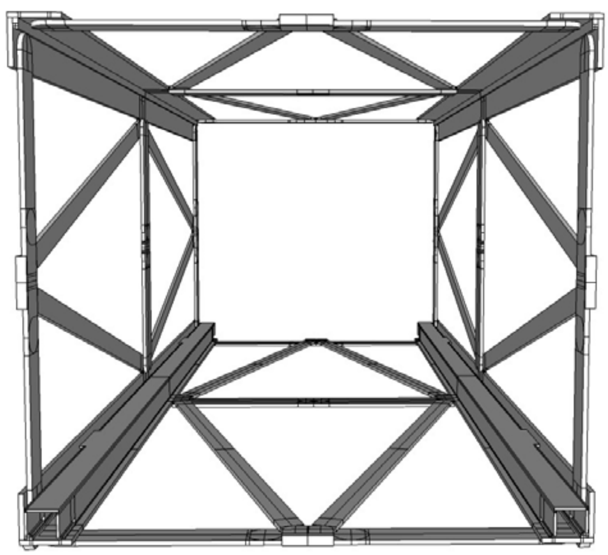
Component is fully stretched in the horizontal orientation and ready for vertical expansion.



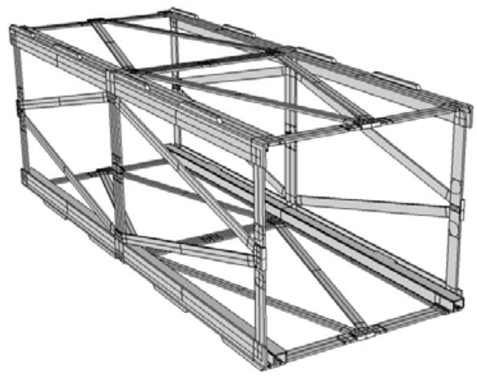
Indication of hinges and rotation points for vertical expansion of the component.



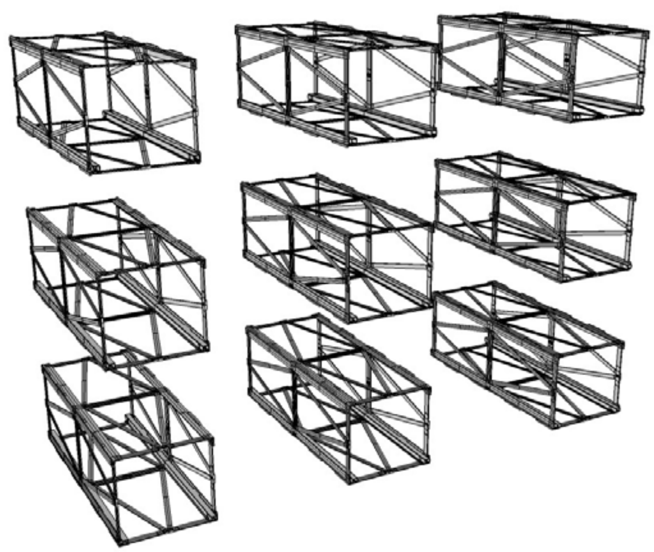
Digital model does not accurately represent the vertical expansion process. As a free physics engine was used in this process. There should be no lateral movement during the vertical expansion process.



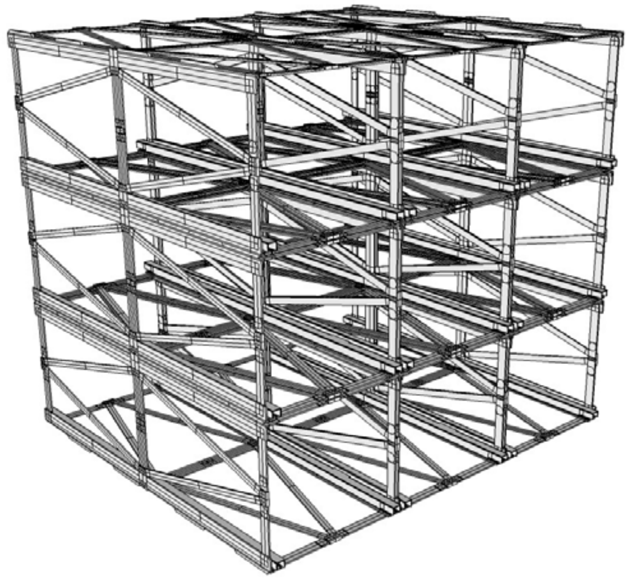
A component is fully expanded to become a single stall for car storage. It comes complete with guide rails for palette access.



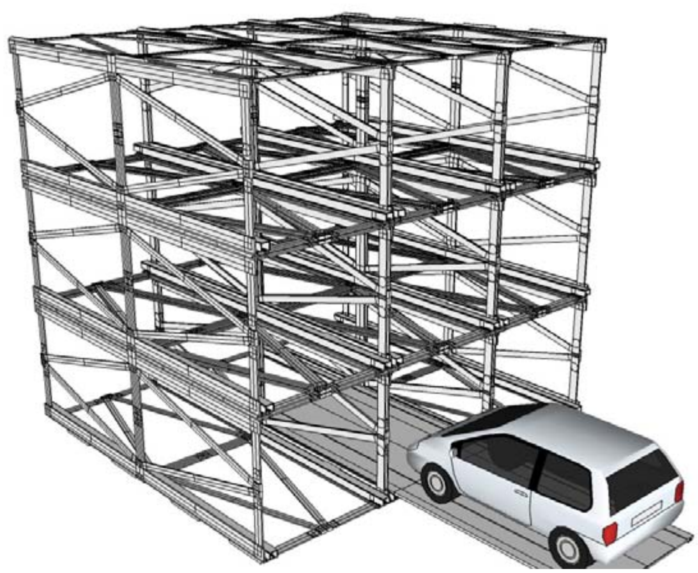
Each prefabricated stall is an independent component of an overall automated system.



The advantage of prefabrication is duplication and versatility in application.



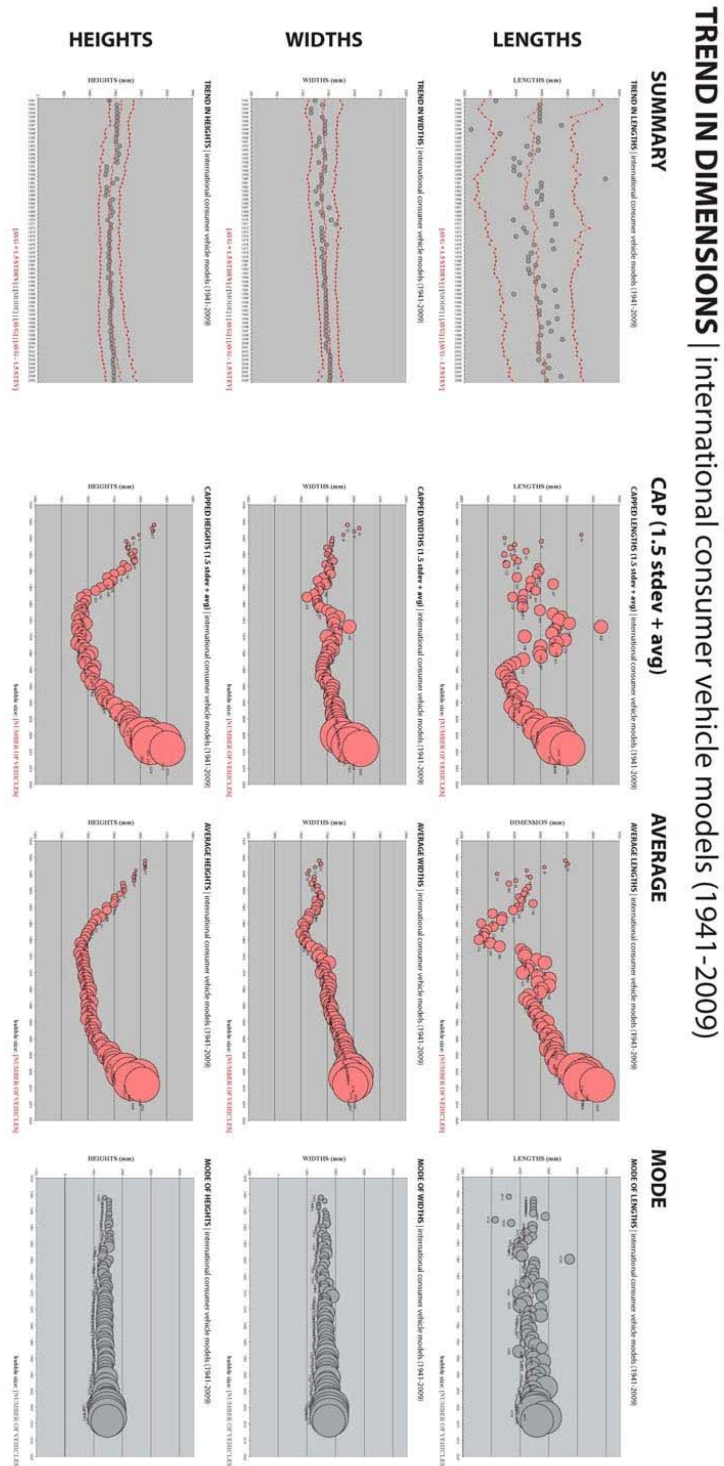
A set of stalls are assembled and attached to become an independent rack system.



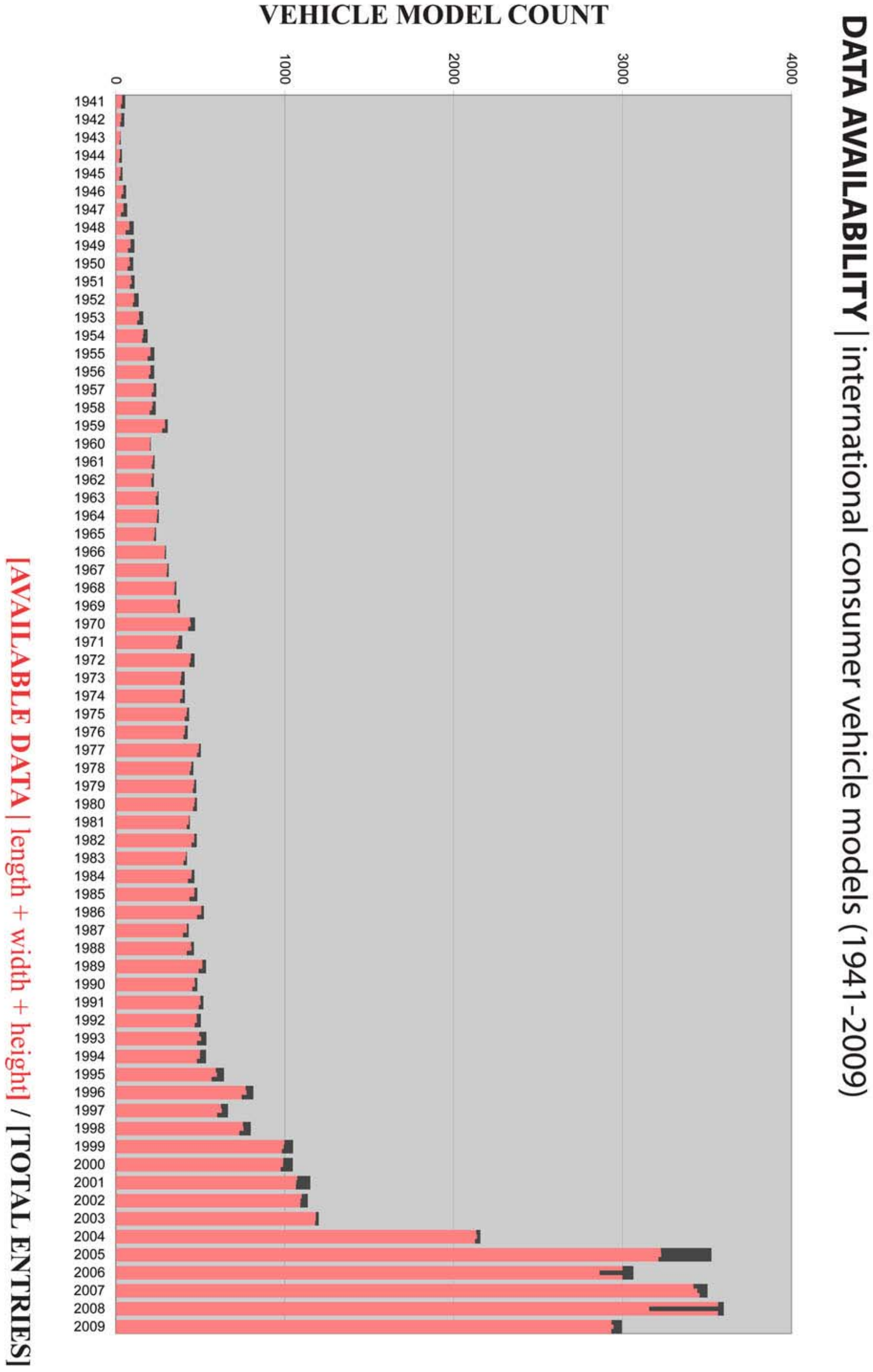
Vehicles are stored via a tray / palette.

The end result is the highly efficient use of space and effectively engineered assemblage process.

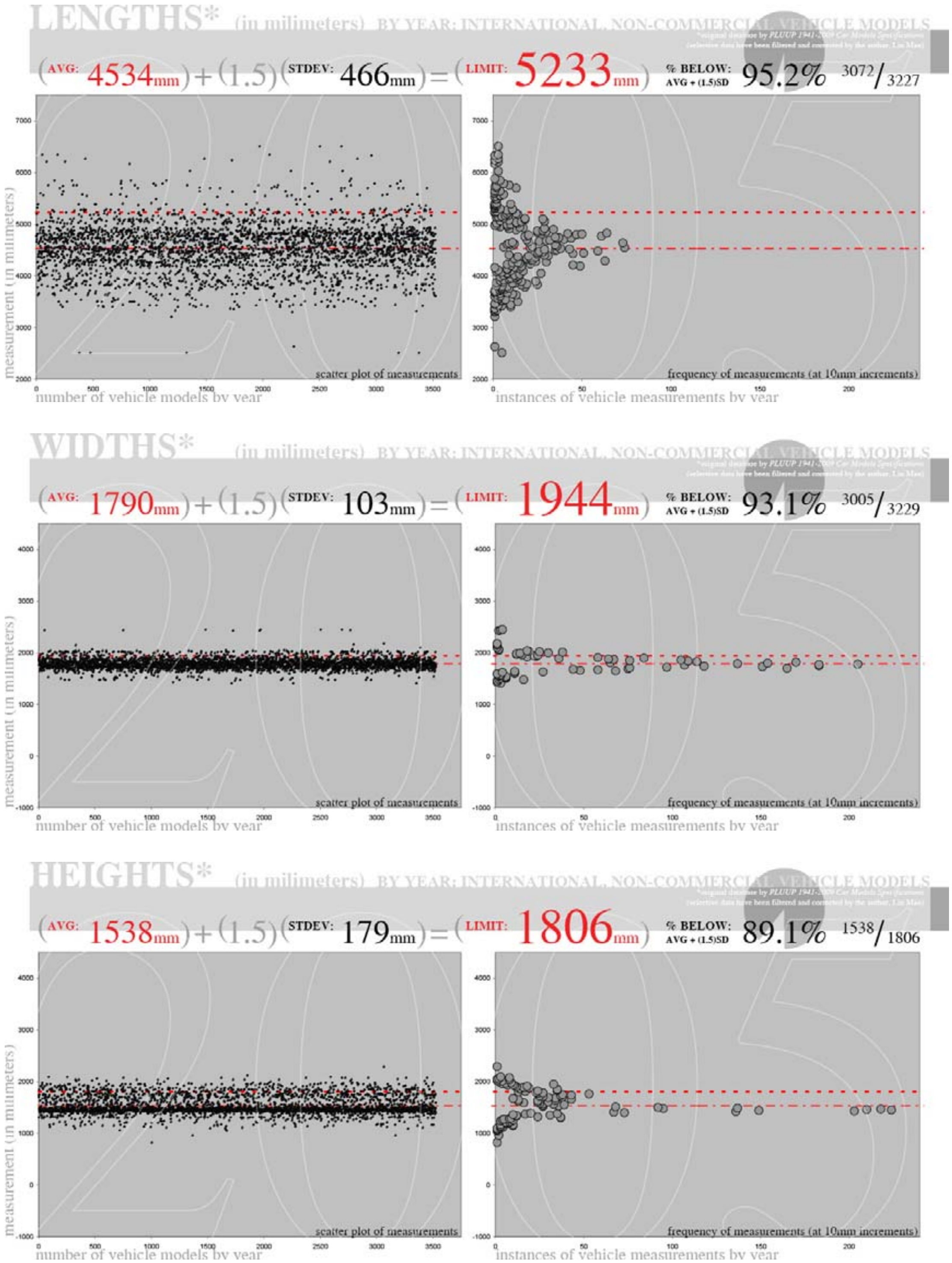
Appendix C: Consumer Vehicle Data Analysis (1941-2009)



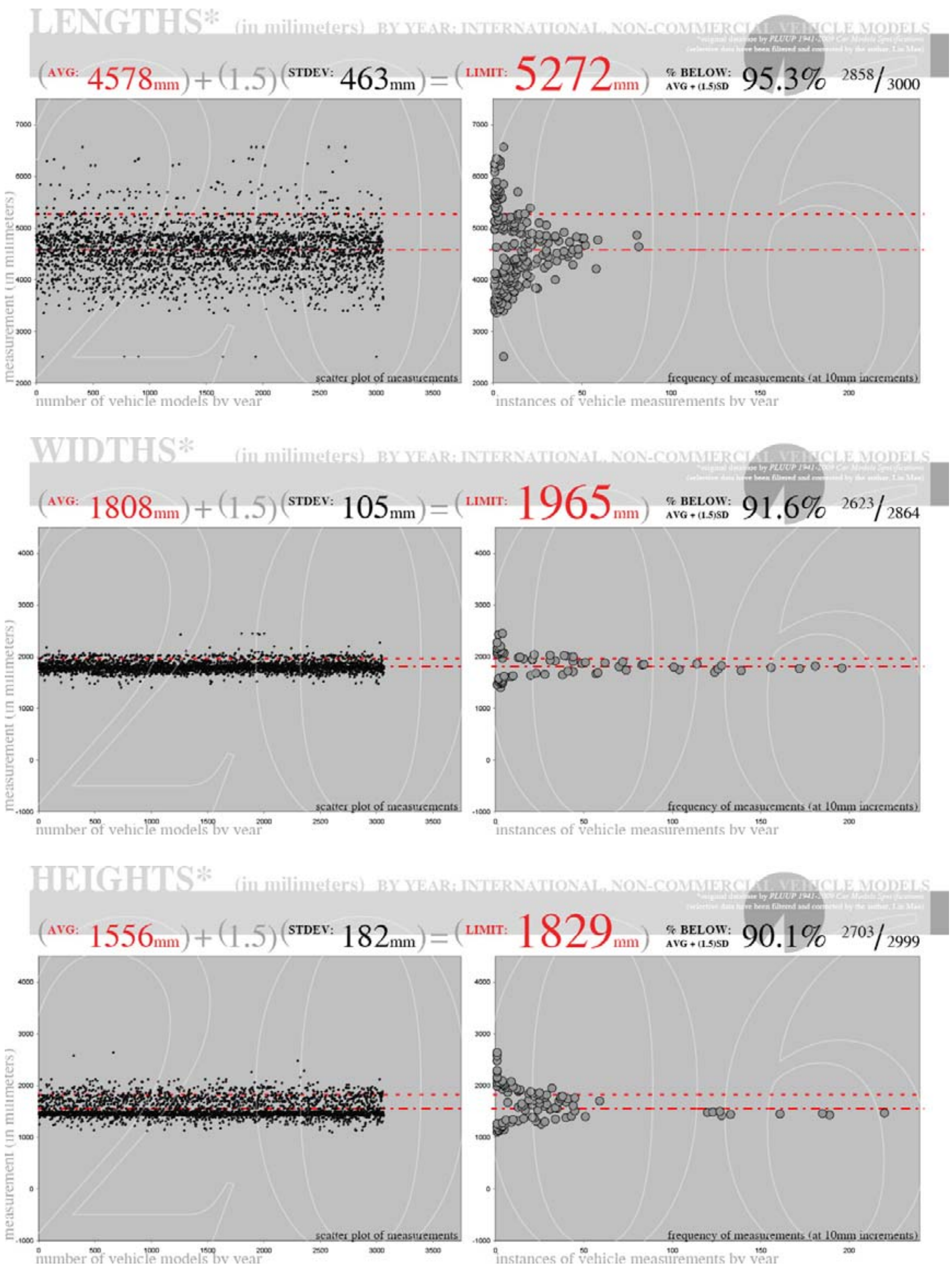
Trend of cars getting bigger over time based on annual manufactured models.



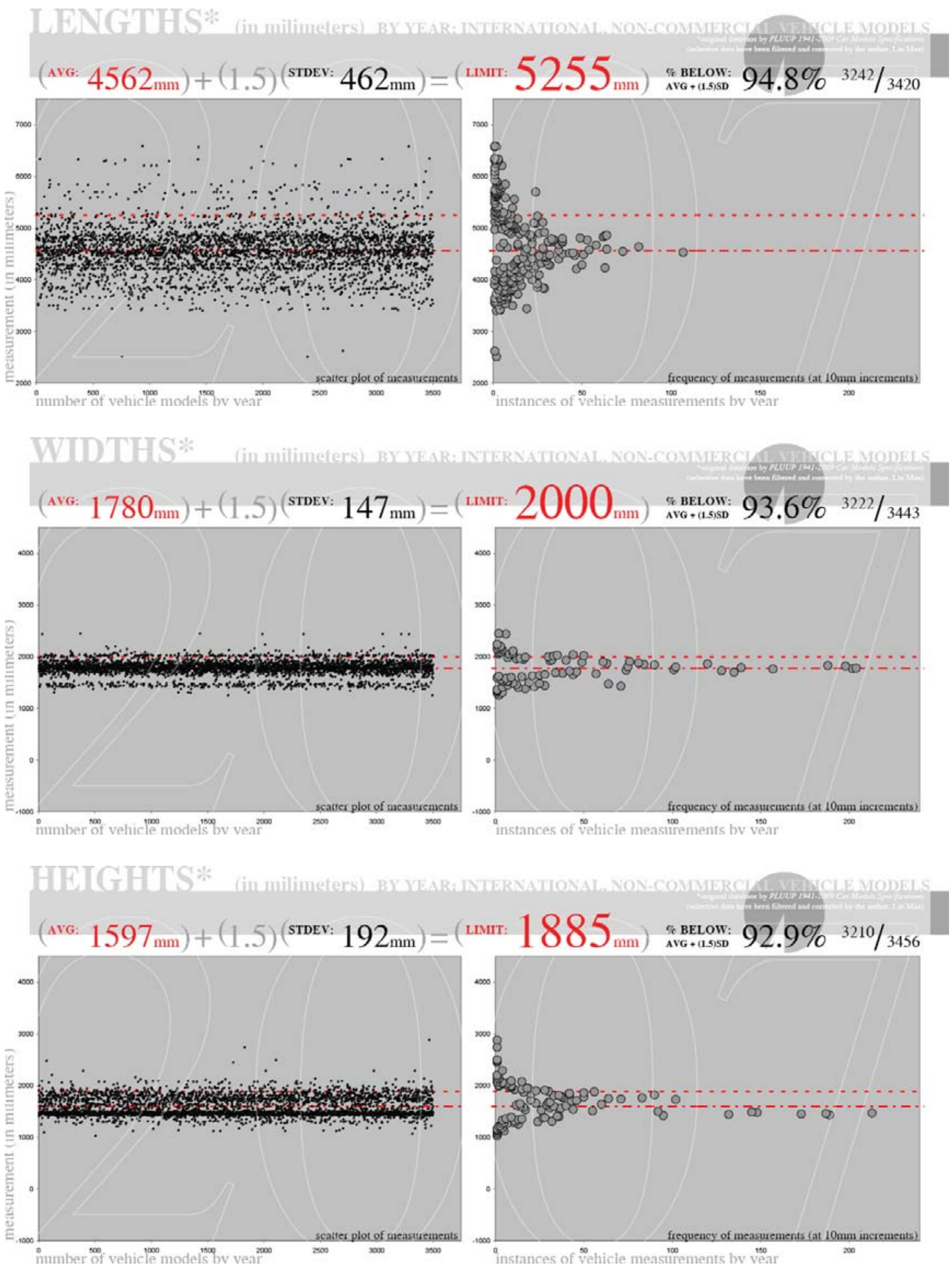
Trend of more car models become available on the market over time



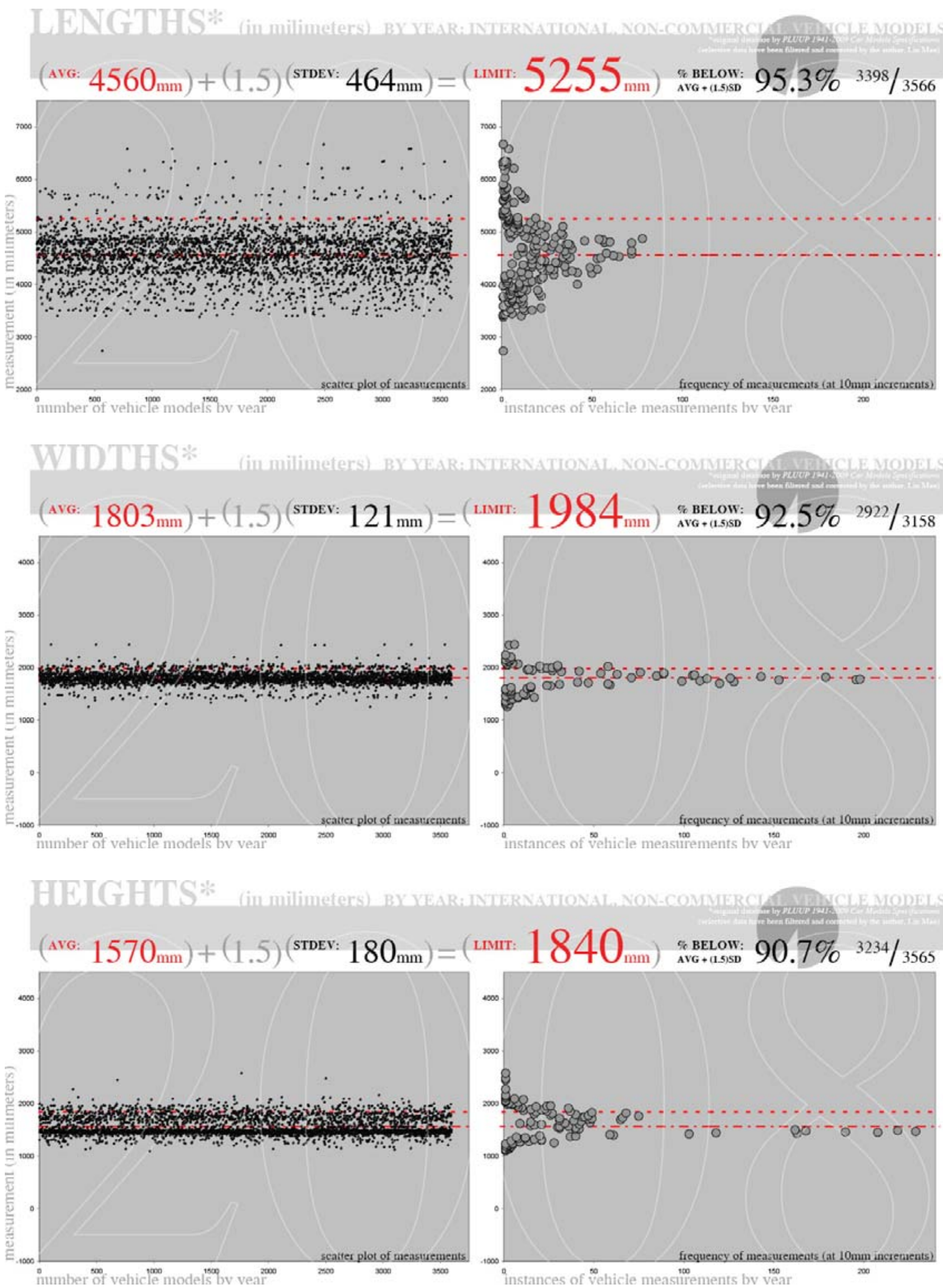
Visual data representation of the optimal dimensions to accommodate majority of vehicles based on all manufactured models' lengths, widths and heights for 2005.



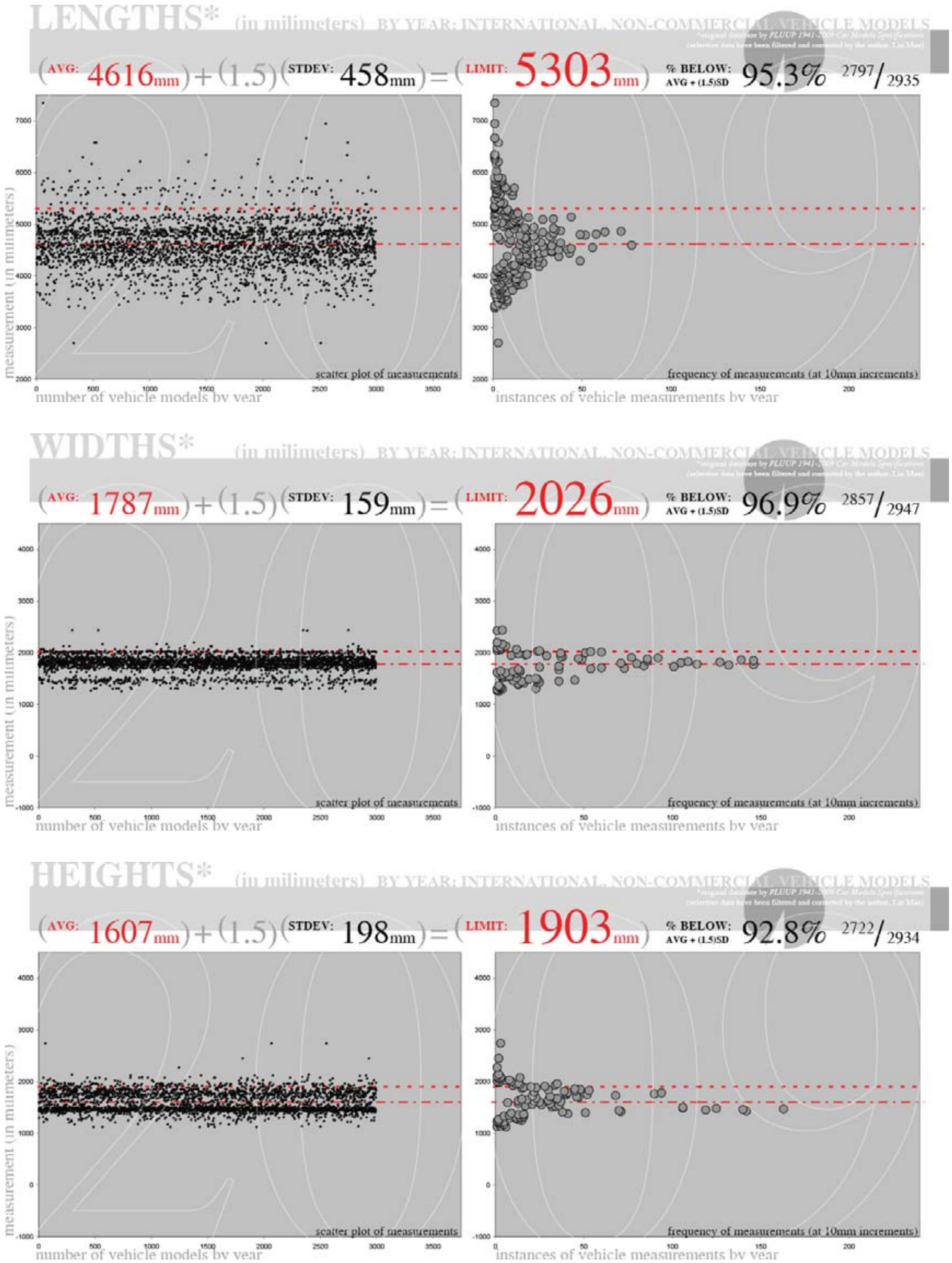
Visual data representation of the optimal dimensions to accommodate majority of vehicles based on all manufactured models' lengths, widths and heights for 2006.



Visual data representation of the optimal dimensions to accommodate majority of vehicles based on all manufactured models' lengths, widths and heights for 2007.



Visual data representation of the optimal dimensions to accommodate majority of vehicles based on all manufactured models' lengths, widths and heights for 2008.



Visual data representation of the optimal dimensions to accommodate majority of vehicles based on all manufactured models' lengths, widths and heights for 2009.

Consumer Vehicle Models Data Abstract (1941-2009)

Year	Cars					Lengths					
		Entries	No Entries	< 1.5SD	%	Mode	ModeCnt	Avg Mean	Stdev	Avg-1.5SD	Avg+1.5SD
1941	55	38	17	35	92.1%	3610	2	4495.0	741.4	3383.0	5607.0
1942	50	33	17	29	87.9%	4460	3	4504.2	775.6	3340.9	5667.6
1943	29	28	1	25	89.3%	4460	3	4415.0	764.4	3268.5	5561.5
1944	36	26	10	24	92.3%	4460	3	4347.7	672.2	3339.5	5355.9
1945	39	29	10	28	96.6%	4460	3	4234.5	552.5	3405.8	5063.2
1946	61	44	17	41	93.2%	4460	4	4361.1	561.7	3518.6	5203.7
1947	67	45	22	43	95.6%	4880	5	4306.0	530.6	3510.0	5102.0
1948	106	80	26	75	93.8%	3130	3	4279.9	537.1	3474.3	5085.5
1949	110	87	23	83	95.4%	3690	4	4353.7	527.6	3562.3	5145.0
1950	103	81	22	76	93.8%	4430	7	4341.6	480.6	3620.8	5062.4
1951	111	90	21	82	91.1%	4430	6	4337.6	508.5	3574.8	5100.4
1952	135	108	27	99	91.7%	4210	6	4317.6	531.5	3520.4	5114.8
1953	162	137	25	125	91.2%	4430	5	4328.6	494.5	3586.9	5070.3
1954	188	164	24	148	90.2%	4280	6	4371.8	546.2	3552.5	5191.2
1955	228	205	23	186	90.7%	3960	7	4317.9	585.7	3439.3	5196.4
1956	227	205	22	190	92.7%	4070	9	4296.0	593.5	3405.7	5186.2
1957	239	224	15	207	92.4%	3960	10	4217.3	595.5	3324.1	5110.5
1958	236	219	17	203	92.7%	3960	11	4254.9	605.3	3347.0	5162.8
1959	307	291	16	267	91.8%	4070	10	4252.4	664.0	3256.4	5248.5
1960	207	205	2	189	92.2%	5730	7	4174.6	657.3	3188.6	5160.5
1961	229	222	7	204	91.9%	4490	9	4221.1	640.1	3261.0	5181.3
1962	225	218	7	201	92.2%	4490	9	4196.3	625.4	3258.2	5134.3
1963	253	247	6	229	92.7%	4410	7	4184.9	606.1	3275.7	5094.0
1964	254	248	6	230	92.7%	4500	6	4185.0	630.9	3238.7	5131.3
1965	238	232	6	215	92.7%	4490	7	4165.5	643.8	3199.8	5131.2
1966	297	293	4	272	92.8%	4410	7	4208.7	615.3	3285.8	5131.7
1967	313	306	7	281	91.8%	4190	10	4244.6	635.1	3292.0	5197.2
1968	358	350	8	323	92.3%	4700	16	4326.8	613.7	3406.3	5247.3
1969	379	369	10	339	91.9%	4700	14	4342.5	625.7	3404.0	5281.1
1970	469	440	29	404	91.8%	3950	11	4340.6	619.2	3411.9	5269.3
1971	393	372	21	345	92.7%	4770	10	4385.8	616.1	3461.5	5310.0
1972	466	445	21	408	91.7%	4150	12	4417.0	675.6	3403.7	5430.4
1973	407	389	18	362	93.1%	4200	12	4353.7	600.6	3452.9	5254.5
1974	409	395	14	365	92.4%	4000	14	4349.3	596.4	3454.7	5243.9
1975	434	422	12	396	93.8%	4700	12	4332.2	538.5	3524.5	5140.0
1976	425	410	15	375	91.5%	4350	12	4389.0	603.3	3484.1	5294.0
1977	503	493	10	452	91.7%	4730	13	4432.9	551.7	3605.3	5260.4
1978	459	448	11	408	91.1%	4300	16	4389.6	541.1	3578.0	5201.2
1979	476	465	11	423	91.0%	4240	12	4432.3	550.6	3606.4	5258.2
1980	480	468	12	427	91.2%	4240	11	4403.7	528.5	3611.0	5196.5
1981	438	434	4	401	92.4%	4380	10	4398.4	535.6	3595.1	5201.8
1982	479	465	14	430	92.5%	4240	14	4356.0	518.2	3578.7	5133.4
1983	421	417	4	381	91.4%	4270	12	4341.7	506.6	3581.8	5101.6
1984	465	450	15	422	93.8%	4430	13	4357.8	481.8	3635.2	5080.5
1985	482	466	16	439	94.2%	4380	12	4373.6	462.7	3679.5	5067.8
1986	521	506	15	479	94.7%	4540	14	4383.5	448.3	3711.1	5055.9
1987	431	420	11	400	95.2%	4760	9	4375.8	463.1	3681.2	5070.5
1988	462	445	17	424	95.3%	3960	11	4386.9	464.9	3689.6	5084.3
1989	534	512	22	492	96.1%	4400	12	4406.6	449.0	3733.1	5080.2
1990	482	467	15	449	96.1%	4470	15	4425.9	446.9	3755.5	5096.2
1991	518	500	18	475	95.0%	4800	17	4396.6	463.2	3701.7	5091.4
1992	503	479	24	456	95.2%	4450	16	4410.7	476.7	3695.7	5125.7
1993	536	494	42	468	94.7%	4450	13	4435.9	443.0	3771.4	5100.4
1994	534	499	35	468	93.8%	4800	16	4423.8	462.7	3729.7	5117.9
1995	640	592	48	559	94.4%	4630	18	4456.2	428.9	3812.9	5099.5
1996	814	769	45	721	93.8%	4490	21	4448.5	430.6	3802.6	5094.4
1997	664	622	42	594	95.5%	4680	18	4460.8	455.4	3777.6	5143.9
1998	799	752	47	711	94.5%	4480	24	4429.3	455.3	3746.4	5112.3
1999	1049	998	51	941	94.3%	4900	40	4451.7	456.1	3767.6	5135.8
2000	1047	991	56	948	95.7%	4440	29	4458.2	486.5	3728.4	5187.9
2001	1151	1074	77	1027	95.6%	4440	24	4456.9	474.6	3745.0	5168.8
2002	1136	1101	35	1062	96.5%	4440	41	4476.5	474.4	3764.9	5188.1
2003	1201	1184	17	1130	95.4%	4640	49	4470.0	469.7	3765.4	5174.6
2004	2158	2134	24	2018	94.6%	4440	49	4557.0	475.1	3844.3	5269.7
2005	3526	3227	299	3072	95.2%	4550	74	4534.2	465.9	3835.5	5233.0
2006	3064	3000	64	2858	95.3%	4640	82	4577.5	462.7	3883.5	5271.5
2007	3503	3420	83	3242	94.8%	4530	107	4561.6	462.3	3868.2	5255.0
2008	3599	3566	33	3398	95.3%	4870	78	4559.6	463.9	3863.8	5255.5
2009	2996	2935	61	2797	95.3%	4590	78	4616.1	458.1	3928.9	5303.3
MIN					87.9%	3130.0		4165.5	428.9	3188.6	5055.9
AVG					93.3%	4409.3		4373.9	543.8	3558.1	5189.6
MAX					96.6%	5730.0		4616.1	775.6	3928.9	5667.6
STDEV					1.8%	348.5		102.5	85.0	197.1	121.1

Lengths data for consumer car models for 1941 – 2009.

Consumer Vehicle Models Data Abstract (1941-2009)

Year	Cars					Widths					
		Total	No Entries	< 1.5SD	%	Mode	ModeCnt	Avg Mean	Stdev	Avg-1.5SD	Avg+1.5SD
1941	55	37	18	35	94.6%	1490	4	1670.0	204.2	1363.8	1976.2
1942	50	32	18	30	93.8%	1630	3	1676.6	229.9	1331.7	2021.4
1943	29	27	2	25	92.6%	1410	3	1654.1	232.1	1306.0	2002.2
1944	36	25	11	24	96.0%	1410	3	1631.2	219.2	1302.3	1960.1
1945	39	28	11	26	92.9%	1630	3	1624.3	196.8	1329.1	1919.5
1946	61	45	16	43	95.6%	1680	5	1650.9	177.5	1384.6	1917.1
1947	67	46	21	44	95.7%	1680	6	1649.1	178.1	1382.0	1916.3
1948	106	81	25	74	91.4%	1680	7	1641.4	170.7	1385.3	1897.4
1949	110	88	22	83	94.3%	1680	9	1662.6	162.6	1418.8	1906.4
1950	103	84	19	76	90.5%	1570	6	1663.1	157.8	1426.4	1899.8
1951	111	94	17	85	90.4%	1570	7	1673.5	161.5	1431.2	1915.8
1952	135	109	26	99	90.8%	1510	7	1677.8	164.6	1430.9	1924.7
1953	162	139	23	124	89.2%	1660	10	1656.4	158.6	1418.5	1894.3
1954	188	162	26	146	90.1%	1680	11	1669.0	159.3	1430.0	1907.9
1955	228	206	22	186	90.3%	1680	12	1657.7	165.4	1409.6	1905.7
1956	227	206	21	185	89.8%	1560	15	1657.0	170.8	1400.8	1913.3
1957	239	224	15	204	91.1%	1680	16	1633.5	167.4	1382.3	1884.6
1958	236	214	22	197	92.1%	1680	18	1629.7	156.4	1395.1	1864.2
1959	307	292	15	266	91.1%	1610	13	1624.3	180.3	1353.9	1894.8
1960	207	203	4	187	92.1%	1620	10	1606.0	178.4	1338.3	1873.7
1961	229	219	10	199	90.9%	1620	15	1614.7	169.1	1361.0	1868.4
1962	225	210	15	194	92.4%	1560	12	1611.2	159.3	1372.3	1850.1
1963	253	236	17	224	94.9%	1500	12	1599.2	149.4	1375.1	1823.2
1964	254	244	10	225	92.2%	1620	11	1615.5	164.6	1368.6	1862.5
1965	238	230	8	213	92.6%	1620	13	1610.8	168.0	1358.8	1862.7
1966	297	290	7	261	90.0%	1530	15	1624.8	164.6	1377.9	1871.7
1967	313	304	9	279	91.8%	1760	13	1639.1	174.0	1378.0	1900.2
1968	358	348	10	316	90.8%	1610	17	1662.1	169.6	1407.8	1916.5
1969	379	364	15	330	90.7%	1640	20	1676.0	178.6	1408.1	1943.8
1970	469	443	26	397	89.6%	1800	24	1669.3	169.3	1415.5	1923.2
1971	393	367	26	337	91.8%	1890	24	1681.6	162.5	1437.9	1925.4
1972	466	442	24	401	90.7%	1620	21	1705.1	185.4	1427.0	1983.3
1973	407	386	21	357	92.5%	1620	23	1684.4	165.2	1436.6	1932.3
1974	409	395	14	357	90.4%	1620	31	1687.0	163.9	1441.2	1932.9
1975	434	419	15	388	92.6%	1630	27	1679.5	145.8	1460.8	1898.2
1976	425	408	17	373	91.4%	1710	30	1697.5	156.4	1462.9	1932.1
1977	503	491	12	453	92.3%	1620	30	1705.7	140.2	1495.4	1916.0
1978	459	445	14	404	90.8%	1660	33	1698.8	138.8	1490.6	1906.9
1979	476	462	14	418	90.5%	1620	30	1708.4	140.9	1497.1	1919.7
1980	480	465	15	429	92.3%	1660	27	1705.7	131.2	1508.8	1902.5
1981	438	432	6	398	92.1%	1660	38	1703.3	131.9	1505.5	1901.2
1982	479	464	15	428	92.2%	1660	33	1698.8	128.8	1505.7	1892.0
1983	421	413	8	378	91.5%	1660	34	1699.3	123.9	1513.4	1885.2
1984	465	448	17	414	92.4%	1690	32	1703.6	119.3	1524.6	1882.6
1985	482	465	17	437	94.0%	1670	34	1711.1	114.7	1539.0	1883.1
1986	521	506	15	473	93.5%	1650	37	1714.2	113.8	1543.5	1884.9
1987	431	421	10	392	93.1%	1700	43	1711.0	112.1	1542.9	1879.2
1988	462	448	14	422	94.2%	1700	41	1716.6	117.1	1540.9	1892.3
1989	534	512	22	480	93.8%	1700	74	1725.7	117.0	1550.1	1901.3
1990	482	469	13	430	91.7%	1700	56	1737.0	123.0	1552.5	1921.6
1991	518	502	16	465	92.6%	1700	56	1740.2	118.0	1563.2	1917.2
1992	503	480	23	443	92.3%	1700	72	1738.1	118.2	1560.8	1915.3
1993	536	505	31	469	92.9%	1700	59	1744.9	112.3	1576.5	1913.3
1994	534	498	36	465	93.4%	1700	57	1746.8	114.7	1574.8	1918.8
1995	640	599	41	561	93.7%	1700	61	1757.2	107.7	1595.6	1918.8
1996	814	774	40	715	92.4%	1700	97	1762.6	112.4	1594.0	1931.2
1997	664	628	36	582	92.7%	1700	58	1767.4	113.1	1597.7	1937.1
1998	799	756	43	704	93.1%	1700	82	1759.5	111.5	1592.2	1926.7
1999	1049	994	55	915	92.1%	1740	78	1768.3	109.3	1604.4	1932.2
2000	1047	990	57	908	91.7%	1700	82	1773.5	109.8	1608.8	1938.2
2001	1151	1068	83	993	93.0%	1700	80	1775.7	109.2	1612.0	1939.5
2002	1136	1094	42	1036	94.7%	1750	77	1779.0	110.4	1613.4	1944.6
2003	1201	1184	17	1103	93.2%	1780	87	1779.9	107.3	1618.9	1940.9
2004	2158	2139	19	1955	91.4%	1780	149	1796.8	102.0	1643.9	1949.8
2005	3526	3229	297	3005	93.1%	1780	205	1789.8	102.9	1635.4	1944.2
2006	3064	2864	200	2623	91.6%	1780	196	1807.7	104.5	1650.9	1964.5
2007	3503	3443	60	3222	93.6%	1780	204	1779.8	147.0	1559.3	2000.2
2008	3599	3158	441	2922	92.5%	1780	198	1803.0	120.7	1621.9	1984.1
2009	2996	2947	49	2857	96.9%	1770	146	1787.1	159.3	1548.2	2026.0
MIN					89.2%	1410.0		1599.2	102.0	1302.3	1823.2
AVG					92.3%	1663.0		1696.6	147.5	1475.2	1917.9
MAX					1.0	1890.0		1807.7	232.1	1650.9	2026.0
STDEV					1.6%	85.9		56.5	32.1	97.7	38.3

Widths data for consumer car models for 1941 – 2009.

Consumer Vehicle Models Data Abstract (1941-2009)

Year	Cars					Heights					
		Total	No Entries	< 1.5SD	%	Mode	ModeCnt	Avg Mean	Stdev	Avg-1.5SD	Avg+1.5SD
1941	55	30	25	29	96.7%	1380	3	1618.7	155.9	1384.9	1852.5
1942	50	26	24	25	96.2%	1530	5	1616.5	151.8	1388.8	1844.3
1943	29	23	6	22	95.7%	1530	4	1618.3	152.4	1389.6	1846.9
1944	36	20	16	17	85.0%	1530	4	1583.0	141.4	1370.9	1795.1
1945	39	21	18	18	85.7%	1530	4	1577.6	130.5	1381.9	1773.4
1946	61	33	28	29	87.9%	1530	6	1574.2	114.0	1403.2	1745.3
1947	67	31	36	29	93.5%	1510	4	1576.1	118.9	1397.8	1754.5
1948	106	58	48	54	93.1%	1530	8	1533.4	146.5	1313.7	1753.2
1949	110	72	38	69	95.8%	1530	11	1536.4	160.9	1295.0	1777.8
1950	103	70	33	67	95.7%	1510	6	1537.9	151.7	1310.3	1765.4
1951	111	83	28	80	96.4%	1510	7	1521.6	169.0	1268.0	1775.1
1952	135	101	34	97	96.0%	1580	7	1502.0	183.7	1226.4	1777.6
1953	162	127	35	121	95.3%	1530	8	1502.7	156.0	1268.7	1736.7
1954	188	156	32	150	96.2%	1570	10	1499.9	167.0	1249.3	1750.4
1955	228	188	40	181	96.3%	1530	14	1470.9	170.4	1215.3	1726.5
1956	227	196	31	188	95.9%	1530	18	1473.2	150.4	1247.6	1698.8
1957	239	213	26	206	96.7%	1330	11	1433.0	160.9	1191.6	1674.3
1958	236	201	35	192	95.5%	1330	11	1451.1	162.3	1207.7	1694.6
1959	307	274	33	258	94.2%	1310	15	1431.2	163.9	1185.4	1677.0
1960	207	203	4	193	95.1%	1530	12	1417.8	153.7	1187.3	1648.4
1961	229	213	16	203	95.3%	1450	13	1411.2	145.0	1193.7	1628.7
1962	225	211	14	199	94.3%	1330	17	1401.6	128.1	1209.5	1593.6
1963	253	237	16	225	94.9%	1330	20	1394.5	120.8	1213.3	1575.7
1964	254	242	12	227	93.8%	1310	16	1391.4	135.0	1188.9	1593.8
1965	238	226	12	214	94.7%	1450	14	1384.8	133.6	1184.4	1585.2
1966	297	289	8	278	96.2%	1390	17	1370.7	132.5	1172.0	1569.4
1967	313	301	12	290	96.3%	1410	22	1377.8	132.8	1178.7	1577.0
1968	358	346	12	334	96.5%	1450	23	1376.8	135.9	1173.0	1580.5
1969	379	368	11	354	96.2%	1410	24	1368.5	129.4	1174.5	1562.5
1970	469	429	40	414	96.5%	1350	29	1377.5	131.5	1180.2	1574.7
1971	393	359	34	345	96.1%	1410	26	1383.7	139.3	1174.7	1592.6
1972	466	436	30	418	95.9%	1410	37	1381.3	121.5	1199.0	1563.5
1973	407	381	26	366	96.1%	1380	31	1383.7	119.6	1204.3	1563.1
1974	409	381	28	363	95.3%	1380	36	1386.0	126.2	1196.6	1575.3
1975	434	408	26	386	94.6%	1390	37	1391.6	131.1	1194.9	1588.3
1976	425	400	25	381	95.3%	1370	39	1386.0	120.7	1204.9	1567.1
1977	503	481	22	463	96.3%	1390	44	1392.7	113.2	1222.8	1562.6
1978	459	437	22	415	95.0%	1370	43	1396.9	120.6	1216.0	1577.8
1979	476	456	20	431	94.5%	1370	41	1398.3	128.3	1205.9	1590.7
1980	480	457	23	425	93.0%	1390	43	1406.9	137.2	1201.1	1612.8
1981	438	420	18	391	93.1%	1370	39	1406.0	129.8	1211.3	1600.7
1982	479	448	31	418	93.3%	1370	46	1395.8	126.6	1205.9	1585.7
1983	421	400	21	375	93.8%	1420	35	1399.4	127.6	1208.0	1590.7
1984	465	427	38	390	91.3%	1360	35	1412.6	141.3	1200.8	1624.5
1985	482	436	46	404	92.7%	1410	42	1398.7	141.8	1186.0	1611.4
1986	521	481	40	446	92.7%	1400	48	1406.6	141.7	1194.1	1619.1
1987	431	397	34	370	93.2%	1390	34	1399.4	131.6	1201.9	1596.8
1988	462	420	42	383	91.2%	1400	34	1408.9	140.5	1198.1	1619.7
1989	534	490	44	451	92.0%	1430	45	1399.7	143.7	1184.2	1615.1
1990	482	453	29	414	91.4%	1430	32	1416.6	158.6	1178.7	1654.5
1991	518	491	27	442	90.0%	1430	48	1423.3	166.1	1174.2	1672.4
1992	503	467	36	426	91.2%	1400	38	1414.3	159.0	1175.8	1652.8
1993	536	481	55	438	91.1%	1400	40	1419.6	158.8	1181.5	1657.7
1994	534	480	54	434	90.4%	1400	41	1428.6	156.0	1194.7	1662.6
1995	640	567	73	510	89.9%	1400	47	1430.9	169.6	1176.6	1685.3
1996	814	745	69	650	87.2%	1430	81	1445.0	172.8	1185.7	1704.3
1997	664	600	64	531	88.5%	1400	47	1457.6	192.7	1168.5	1746.6
1998	799	731	68	652	89.2%	1420	83	1453.5	175.2	1190.7	1716.4
1999	1049	983	66	881	89.6%	1420	69	1484.1	184.8	1206.9	1761.3
2000	1047	976	71	879	90.1%	1430	109	1473.6	184.4	1196.9	1750.2
2001	1151	1066	85	959	90.0%	1430	75	1496.2	178.5	1228.5	1764.0
2002	1136	1092	44	994	91.0%	1460	83	1498.3	175.6	1235.0	1761.7
2003	1201	1180	21	1067	90.4%	1470	116	1502.2	174.1	1241.1	1763.3
2004	2158	2127	31	1925	90.5%	1450	152	1539.5	193.2	1249.7	1829.4
2005	3526	3213	313	2863	89.1%	1450	224	1537.8	178.5	1270.1	1805.6
2006	3064	2999	65	2703	90.1%	1470	220	1556.1	182.0	1283.0	1829.1
2007	3503	3456	47	3210	92.9%	1470	213	1597.2	191.8	1309.5	1884.8
2008	3599	3565	34	3234	90.7%	1470	229	1570.0	179.8	1300.3	1839.7
2009	2996	2934	62	2722	92.8%	1470	163	1606.8	197.6	1310.5	1903.2
MIN					85.0%	1310.0		1368.5	113.2	1168.5	1562.5
AVG					93.2%	1432.6		1458.2	150.7	1232.2	1684.2
MAX					1.0	1580.0		1618.7	197.6	1403.2	1903.2
STDEV					2.9%	66.9		75.1	22.5	65.2	96.6

Heights data for consumer car models for 1941 – 2009.

Glossary

Palette (noun): The palette is a tray for carrying an automobile once it enters the automated parking facility. The automobile sits on the palette at all times, like a dish on a waitress's tray via delivery. The palette is not available in all automated parking systems, which vary based on manufacturer.

Turntable (noun): The mobile platform in an automated parking system where automobiles are loaded and transported to pre-designated stalls. The turntable is able to rotate on the horizontal orientation, so cars can turn at a stationary position. The turntable may also include the function for vertical movement like an elevator lift. Likewise, it may or may not also support a palette tray for carrying the vehicle, which differentiates based on specific automated parking manufacturer.

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