People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
Kasdi Merbah University - Ouargla
Faculty of Applied Sciences
Department of Mechanical Engineering

Order number: …………
Serial number: …………

A dissertation submitted in fulfillment of the requirements for the degree of Master

Domain: Science and Technology
Field: Mechanical Engineering
Specialty: Mechanical Manufacturing and Production

Title :

STUDY AND DESIGN OF AN AUTOMATED PARKING: THE STRUCTURE

Presented by:
Laid BENFRIHA
Yakoub BOUAICHA

Publically defended on: June, 11 2018

Before the jury:

President	Mr Brahim ISSASFA	Assistant Professor A	UKM Ouargla
Supervisor	Mr Mehdi KHALFI	Assistant Professor A	UKM Ouargla
Examiner	Mr Mohamed Salah BENNOUNA	Assistant Professor A	UKM Ouargla

Academic year: 2017/2018

Acknowledgment

We would first like to thank our thesis advisor **Mr. M. Khalfi** of the mechanical engineering department at Ouargla University. The door to **Mr. Khalfi** office was always open whenever we ran into a trouble spot or had a question about our research or writing. He consistently allowed this thesis to be our own work, but steered us in the right direction whenever he thought we needed it

We are deeply grateful to all members of the jury for agreeing to read the manuscript and to participate in the promotion of this thesis.

We extend our sincere thanks to all members of the Department of Mechanical Engineering, and all those who contributed directly or indirectly to this work.

And finally, last but by no means least, we must express our very profound gratitude to our parents and families for providing us with unfailing support and continuous encouragement throughout our years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Authors

Laid BENFRIHA / Yakoub BOUAICHA

Contents

Chapter III Preliminary design

Chapter IV 3D Structure Modeling

List of figures

List of tables

Abbreviations

AGV: Automated Guided Vehicle.

APF: Automated parking facility.

APS: Automated parking system.

AVSRS: Automated vehicle storage and retrieval system.

RGC: Rail Guided Cart.

UNFPA: United Nations Population Fund.

Introduction

The world is undergoing the largest wave of urban growth in history. According to the United Nations Population Fund (UNFPA) in 2014; 54% of the world's population lives in towns and cities, a proportion that is expected to increase to 68% by 2050 [1].

As more and more parts of the developing world improve their standard of living, they adapt a lifestyle of mobility as has been known in the developed world for the last decades. So more and more people are living in highly urbanized regions and have the desire and the means to drive automobiles. This leads to parking places becoming more and more a scarce commodity, and make finding a parking place a real challenge in densely populated cities.

Nowadays, Parking structures are found all over the world. They serve office buildings, shopping centers, banks, universities, airports, train stations, bus stations, and hospitals, in both urban and suburban settings [2]. The need for such facilities is that a car is usually kept parked somewhere for 22.5 hours because a driver spends about 90 minutes a day in the car at an average.

A parking lot needs fairly large space, around 25 m^2 per parking spot. This means that lots usually need more land area than for corresponding buildings, offices or shops if most employees and visitors arrive by car. This means covering large areas with asphalt.

This problem is reduced in multi-story parking garage, but there is always the need of larger surface per parking spot because of the allowance needed to be made for driving the car into the parking space or for the opening of car doors (for drivers and passengers), there is also a need of driving lanes or ramps to drive the car to/from the entrance/exit to a parking space.

This is why, as long as there have been automobiles, people have been thinking about technical installations making it possible to park more vehicles in a given volume. This became possible by the development of *Automated (car) Parking Systems* (APS).

APS are also generically known by a variety of other names, including: *Automated Parking Facility* (APF), *Automated Vehicle Storage and Retrieval System* (AVSRS), *Car Parking System*, *Robotic Parking Garage*, and *Mechanical Parking Systems*.

The essence of these mechanical parking systems is that a mechanical conveyor system takes care of at least a part of the transportation of the vehicle from the entrance of the parking facility to the parking place and back. The transport can be done fully-automatic or semi-automatic. Fully-automatic means that no people are inside the vehicle or controlling the system during the transport. The installation operates computer controlled, unmanned and completely automatic. In semi-automatic parking facilities the user drives the car in the parking garage to a platform where he parks his car. When parked the users can leave the car and operate the system so that through the lifting and/or sliding of platforms more parking places become available.

Over the years, a greater global interest in Automated Parking has been created. An important number of manufacturers and marketers have begun to market their systems include such names as FATA, Rothary, TREVI, Klaus, Krups, Wohr, Robotic, APS, HK Systems, Stokes, Auto Space, Sky Parking America and others.

Advantages of automated parking systems are that it reduced parking search traffic and thus saves time that would be consumed in searching for parking space. It also reduces the chances of theft or damage. The automated parking also shows environmental friendliness since engine is turned off. It also offers advantages for municipalities in terms of space efficiency, increased visual impact and public safety, less litter, fights and accidents because there are no people inside, no need for installing signs, lighting, pedestrian areas etc. Cars inside are moved automatically, which means no need for an expensive ventilation system. No need to employ staff (except for occasional maintenance) [3].

In Algeria, According to the national statistics office; the number of registered vehicles was over 5.8 million vehicles in 2016, 62% are touristic cars, representing one car for every seven citizens [4]. Moreover 44 % of these touristic vehicles are registered in only 5 among 48 provinces namely: Algiers, Blida, Oran, Constantine and Tizi-Ouzou, what explains the important traffic jam in these provinces and also the difficulty finding a place to park.

But although this huge number of cars, unfortunately, to the best of our knowledge, there are only few multi-story parking garage in the whole Algerian territory installed in the last years in addition to the conventional parking surfaces, no automated parking were installed till now even with their notable advantages.

By this memory, we want to contribute to the resolution of these problems by a study and conception of an automated parking. This study includes as a bibliographic part; a full overview on APSs, including historical background, their importance, examples of APSs all around the world as well as technical and structural aspects. Then as a practical chapter; we designed a full structure of an Automated Parking System using SolidWorks, all related conditions and parameters had been studied and reported.

Chapter I
Overview on Automated Parking Systems

I.1 Introduction

A car is usually kept parked somewhere for 22.5 hours because a driver spends about 90 minutes a day in the car at an average. But finding a parking place in big cities popular destinations is becoming a challenge.

Planners, developers, architects and engineers are all looking for viable solutions. A parking facility should meet the functional/operational design requirement, which can supply safe and efficient passage of vehicles. Parking is sometimes provided in the form of a parking lot without human, aesthetic or integrative considerations. This has given parking a poor public perception and has frequently disrupted existing urban fabric [5].

I.2 Definitions

Parking: Is the act of stopping and disengaging a vehicle and leaving it unoccupied. Parking on one or both sides of a road is often permitted, though sometimes with restrictions. Some buildings have parking facilities for use of the buildings' users. Countries and local governments have rules for design and use of parking spaces.

A parking space: is a location that is designated for parking. It can be in a parking garage, in a parking lot or on a city street. The space may be delineated by road surface markings. The automobile fits inside the space, either by parallel parking, perpendicular parking or angled parking.

A parking lot: also known as a car lot, is a cleared area that is intended for parking vehicles. Usually, the term refers to a dedicated area that has been provided with a durable or semi-durable surface. In most countries where cars are the dominant mode of transportation, parking lots are a feature of every city and suburban area. Shopping malls, sports stadiums and similar venues often feature parking lots of immense area.

Parking lots needs large space, average 25 m^2 per parking spot. This means that lots usually need more land area than for corresponding buildings for offices or shops if most employees and visitors arrive by car.

Parking lots tend to be sources of water pollution because of their extensive impervious surfaces. Most existing lots have limited or no facilities to control runoff. Many areas today also require minimum landscaping in parking lots to provide shade and help mitigate the extent of which their paved surfaces contribute to heat islands. Many municipalities require a minimum number of parking spaces, depending on the floor area in a store or the number of bedrooms in an apartment complex.

I.3 Conventional parking systems

Conventional car parks have been in vogue since the invention of cars, most homes and offices make provisions for parking cars, this increases organization and reduces traffic problems.

A good car park must ensure easy entry and exit, this is not the case for most car parks, some parks have limited space, so you have to figure out vacant lots before you park your car. There is less demand in terms of energy, conventional car parks are static, the only energy requirement found in most parks, is the lighting, this require minimal energy.

Figure I-1: *A conventional car parking*

Cities now offer several car parking facilities such as single level, multi level and underground. Multi-level, as the name suggests, has parking spaces at multiple floors. It also has ramps or lifts to move between levels. This offers the advantage of optimal space using.

Figure I-2: *Multi-level car parking*

The parks are operational round the clock, as long as it is not situated in restricted areas. Conventional car parks can be simplistic or complex, this depends on the location and purpose, when the car park is aimed at beautifying the environment, or situated in high rise buildings, the price of construction is usually high [6].

Conventional or traditional car parking systems are found everywhere but this system is full of problems such as:

- We can see in many shopping malls, hospitals huge traffic jam in front of the parking. The parking guard stops the entire vehicle and gives a payment slip, this creates traffic jam.
- It is difficult and time consuming to find out the parking slot which costs extra fuel and wastes time.
- Security problem is another problem in manual car parking, people can enter in parking slot and there snatching, robbery can happen.
- In manual parking system, some guards needs to be appointed for the whole job, it is costly enough.

I.4 Automatic parking systems

Automatic parking systems are very space efficient. An automated parking system is a mechanical system that moves cars from the entry to an available parking space. It uses multiple levels and stacks cars vertically to use as less land as possible to park as many cars as possible.

The system doesn't need as much space to park as a human does. There’s no need for ramps, pedestrian areas etc. They commonly use a system of pallets, lifts, and signaling devices. They insure space availability and can better deal with traffic flow.

These systems are fast, efficient and environmentally sound. The technology has been refined over the last 100 years however; the principle has remained the same: parking, simple and automatic.

Figure I-3 : *An Automated Parking System*

I.4.1 History

Automated parking systems first appeared in 1905 in Europe; Paris - France at the Garage Rue de Ponthieu, and during 1920’s in North America. A ‘Paternoster system’ was built to park cars, around 1920; it was structured like a Ferris wheel that could adjust eight cars in the space of two cars. The structure became popular as it was easy to operate and occupied lesser space. It could also be incorporated into a building. Concurrently, an APS with the ability to park more than a thousand cars was being installed by Kent Automatic Garages.

The need to introduce automated parking systems was to maximize the value of available land by condensing parking. The 1950’s the industry was at its peak in North America with a number of high profile systems built but demand for the systems fell off shortly after that time.

Although demand in other parts of the world, notably Japan, Korea and parts of Europe, continued to increase for automated parking systems, since the turn of the century there have been around 15 systems installed in North America and the rate of installation is increasing.

Figure I-4 : *Paternoster system car parking*

I.4.2 Advantages of Automated Parking Systems

Automated parking systems have a number of sustainability benefits over conventional parking. The precise benefits vary with system type and project site but the general potential benefits include:

- Up to 50% less volume of the parking structure to handle the same number of vehicles compared to conventional ramped parking facilities, this feature adds to the competitiveness of automated parking systems as land prices in large cities are very high.
- Reduction in operational energy consumption because no internal lighting is required (except for maintenance), simple ventilation as only two air changes per hour are required and no requirement for other energy consuming assets including passenger lifts, amenities and barrier control systems.
- Reduced vehicles emissions (CO_2, NO_x, …) as engines are switched off during parking process.

- Smaller building footprint reduces the need for excavation and ground works, reducing the amount of construction waste sent to landfill.
- High levels of recycled content through the use of steel in equipment.
- Nontoxic materials are used in construction (e.g. volatile organic compounds in paints).
- Highest safety standards guaranteed for persons and vehicles. The transfer stations for entering and retrieving vehicles are located in well-lit, safe areas and are monitored by security cameras.
- Increased personal security and safety especially at night.
- Reduced risk of accidents for pedestrians, and exposure to vehicle exhaust in waiting lines is also avoided.
- The vehicles, once enter APS, are safe from damage, dents, theft and vandalism.
- Preferred parking for car sharing and low emission vehicles.
- Less construction or building maintenance cost.
- High quality of aesthetics to the environment by its design integration.
- Reduced acoustic noise.
- Electric vehicle charging facilities.
- Spaces accessible to all users, e.g. disabled or parents with children [7].

In addition to all this benefits, computer controlled parking garages enable and facilitate the integration of services, such as parking space reservation systems, traffic control, carwash stations for parked vehicles and many more innovative customer services and support systems.

There is also this unaesthetic and unfavorable existence of ramped parking structures in urban surroundings. Automated parking systems are constructed with a closed facade, thus giving city planners and architects considerable freedom of design regarding the shape and appearance of the parking facility.

Finally, automated parking systems represent profitable investment opportunities for municipal authorities, parking corporations, property and business owners as well as other investors. The investment in automated parking garages enables high returns due to the high level of space efficiency and utilization.

I.4.3 APS types

Generally, the process of parking a vehicle for drivers in automated parking systems remains the same regardless of the technology used: it’s just the methodology of moving the vehicles to and from the parking module that differs.

I.4.3.1 Classification by operation mode

Automated parking systems can be either semi-automated or fully-automated. The choice between fully and semi-automated APS is often a matter of space and cost, however large capacity (over 100 cars) tend to be fully automated.

a) Semi-Automated Parking Systems

A Semi-Automated Parking System uses a mechanical system to move cars to their parking space, only it needs a human action to work, either by the driver or an attendant. This action can be as simple as pushing a button.

b) Fully-Automated Parking Systems

A Fully-Automated Parking System does not require any staff, it’s entirely automatic. From a driver’s perspective they simply park their vehicles in a parking module are guided to the correct parking position by sensors via a display sign. The drivers switch off their engines and the parking module door is closed to secure the module. Once the module is secured the vehicle is removed from the parking module and stored. When drivers return and request their vehicles, their vehicles are returned to a parking module, usually facing the correct direction, ready to be driven away. Since there is no requirement for ramps, driveways and personnel access to the parking areas, automated parking can typically park twice the number of vehicles in the same volume as conventional parking.

I.4.3.2 Classification by technology

The types of technology used in automated parking systems can be divided into 07 main categories: AGV systems, Tower systems, Crane systems, RGC systems, Silo systems, Puzzle systems and Shuttle systems.

Each technology has both advantages and disadvantages over another, and the selection of one technology over another largely depends on the project site, building codes and the client’s requirements in terms of budget, throughput, density and redundancy [8].

a) AGV Systems

More recently Automated Guided Vehicle (AGV) technology is being used in automated parking and although AGVs have been used in automated warehousing for decades, they remain unproven in automated parking systems. Vehicles are parked on pallets in the parking modules which are collected from the parking modules by the AGVs driving beneath the vehicle pallet, lifting it, and then moving it out of the parking module into the system.

Typically AGV systems operate on solid, finished concrete floors and can move in both lengthways and sideways directions (X and Y planes) along fixed paths and are also able to rotate on the spot. This potentially allows for the vehicle pallets to be collected by an AGV from any direction, and with several AGVs operating on a floor, it also allows for multiple, simultaneous parking and retrieval movements along multiple paths. Vehicle elevators are used within the system to move the vehicle pallets with or without an AGV.

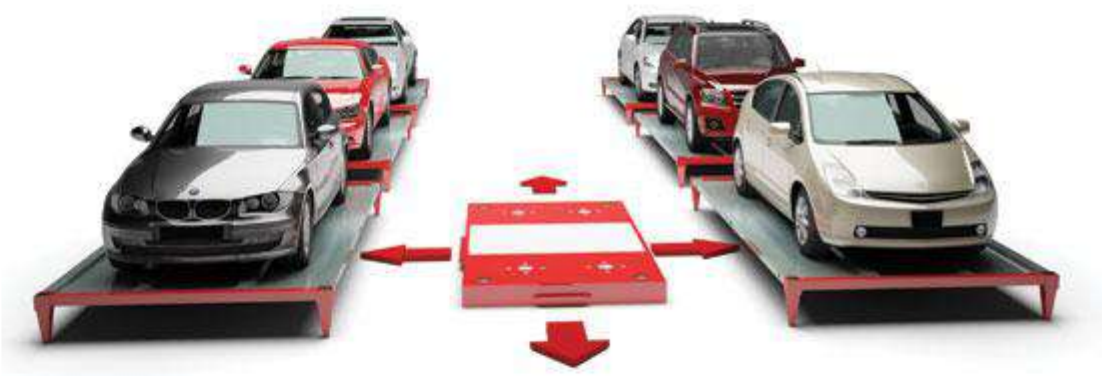


Figure I-5: *AVG Systems*

b) Tower Systems

Tower systems typically consist of a vehicle elevator with a parking space either side of the elevator shaft. This configuration is repeated over a number of levels to complete the parking tower. Typically there is a parking module located on the ground floor, where the vehicle is turned, and the vehicle elevator simple raises to one of the parking levels of the tower and deposits the vehicle sideways into a parking space. This process is reversed to retrieve a vehicle.

As there is a single mechanism to park and retrieve vehicles system redundancy is an issue with tower systems.

Figure I-6 : *Tower Systems*

c) Crane Systems

Crane parking systems utilize a single mechanism to simultaneously perform the horizontal and vertical movements of the vehicle to be parked or retrieved in the parking system. The simultaneous horizontal and vertical movements allow the vehicle platform to move to and from one parking spot to another very quickly. The crane mechanism moves horizontally on rails, typically located on the floor and ceiling of the parking system, and has a vertical elevator platform fitted where vehicles to be parked and retrieved are placed. This means that a floor-to-ceiling opening in the center of the system is required for the crane(s) to operate.

The crane mechanism can move in line with the normal direction of a vehicle (a longitudinal system) or orthogonal to it, i.e. sideways (a transverse system) depending on the site constraints. If higher throughput or redundancy is required, crane systems can also have two cranes running parallel to one another should the site constraints allow it. As there is typically only one mechanism for the parking and retrieval of vehicles the system redundancy is potentially low but back-up motors, switches, etc. can be installed to increase the system's redundancy.

Figure I-7: *Crane Systems*

d) RGC Systems

Nowadays Rail Guided Cart (RGC) technology is being used in automated parking. The RGCs operate in a similar ways to Automated Guided Vehicles (AGVs) except the RGCs are less complex and more robust than AGVs and therefore more cost effective and more reliable.

Vehicles are parked on pallets in the parking modules which are collected from the parking modules by the RGCs driving beneath the vehicle pallet, lifting it, and then moving it out of the parking module into the system. The number of RGCs in the system is flexible and can be based around the client's throughput and budgetary requirements.

Figure I-8: *RGC Systems*

e) Silo Systems

Silo systems are cylindrical systems typically with a single, centrally positioned mechanism used to park and retrieve vehicles. The central mechanism moves vertically and rotates simultaneously allowing the vehicle platform to move to and from one parking spot to another very quickly. Typically silo systems are installed underground, and are most suitable where soil conditions are particularly unfavorable, but can also be installed above ground.

Single or multiple parking modules are possible with silo systems but typically only one vehicle can be parked or retrieved at one time. As there is only one mechanism for parking and retrieving vehicles, and little possibility of adding another, system redundancy can be an issue.

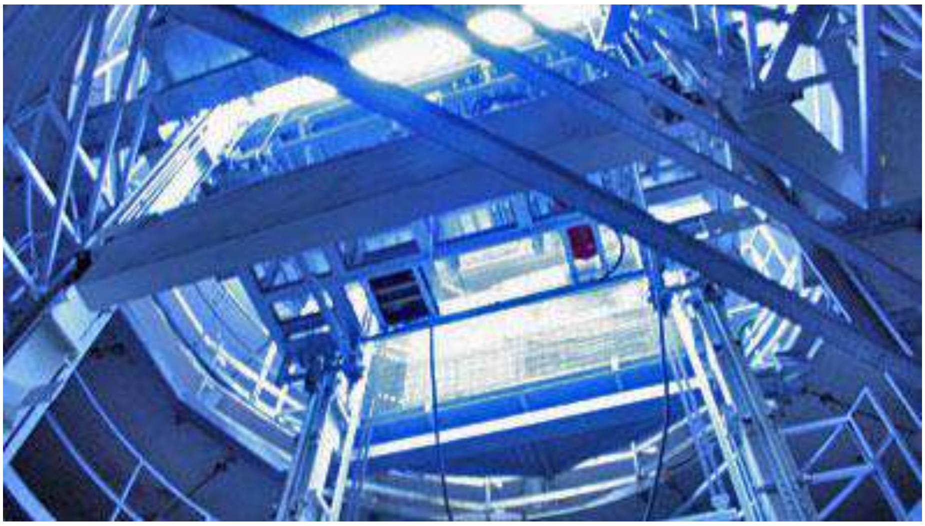


Figure I-9: *Silo Systems*

f) Puzzle Systems

Puzzle systems offer the densest form of automated parking, typically utilizing around 95% of the floor area, and are often used in smaller systems. In a horizontal puzzle system a grid of pallets covers a solid floor, or steel frame, and each pallet is supported by a set of rollers and belts that are driven by motors fitted to the support frames underneath each pallet location. The rollers and belts maneuver the pallets until the pallet with the required vehicle on is maneuvered to the desired location, e.g. parking module, elevator, etc. The pallet support frames are installed in all possible parking positions and typically there are two fewer pallets than support frames per floor which provides the necessary free spaces to maneuver the pallets.

Puzzle systems also provide flexible layout options as the system configuration is highly adaptable as a pallet can be maneuvered from one support frame to an adjacent on in any direction. This means the system shape can vary greatly, instead of being rectangular or square, puzzle systems can also be “T” shaped, “U” shaped, “L” shaped, “H” shaped, etc. as long as there is a route for pallets to get from their current location to their destination location via an adjacent support frame. This also makes maneuvering around structural members possible that may not otherwise be possible with other system types.

Scissor lifts are typically used in puzzle systems as they allow the pallets to move on and off the lift platforms in all directions. Electrical cantilevered lifts can also be used but the pallet movements on and off the lift platform are more restricted.

Turning the vehicles can be done in the parking module, on an elevator, or within the parking system.

Figure I-10: *Puzzle Systems*

g) Shuttle Systems

Shuttle systems utilize autonomous shuttles and elevators to park and retrieve vehicles. The number of shuttles in the system is typically flexible and is based around the client's throughput and budgetary requirements. The shuttles move horizontally in a shuttle lane, which is either a recess in a solid floor or a set of rails in a steel or concrete structure, to a designated location. A robot, or pallet exchanger, or conveyor belts, located on the shuttle then park or retrieve a vehicle at the designated location by moving the vehicle from or to the shuttle and the parking space.

Typically there is a single row of vehicles either side of the shuttle lane but for increased parking density a second row of vehicles can be added. The retrieval process for the second row of vehicles is slower than for the first row as the robot has a longer distance to travel to retrieve the vehicle and there may be a vehicle parked in the front of the vehicle to be retrieved, which has to be removed before the vehicle in the second row can be retrieved. A third row of cars can be added but the retrieval process is very slow.

When a vehicle is required to be moved from one level of the system to another there are two options for achieving this, one with vehicle elevators and the other with shuttle elevators.

When vehicle elevators are used a shuttle moves adjacent to a vehicle elevator and deposits the vehicle on the vehicle elevator platform. The vehicle elevator then moves the vehicle to the designated parking level and another shuttle collects the vehicle from the vehicle elevator. In this option shuttles remain on their assigned levels, therefore at least one shuttle is required per parking level which can make redundancy an issue if only one shuttle is used per level. The system throughput can be very high when vehicle elevators are used in this configuration.

When shuttle elevators are used the shuttle moves with the vehicle on to a shuttle elevator located at either end of the shuttle lane. The shuttle elevator moves to the designated level whereupon the shuttle with the vehicle moves off the shuttle elevator to a designated location. In this option the shuttles are free to go to and from any level in the system allowing for fewer shuttles than parking levels and greater redundancy. However the shuttle elevators are often the system bottlenecks and throughput is much lower than with vehicle elevators.

Figure I-11: *Shuttle Systems*

I.4.4 Costs

a) Construction Costs

The direct comparison of costs between an APS and a multi-story parking garage can be complicated by many variables such as capacity, land costs, area shape, number and location of entrances and exits, land usage, local codes and regulations, parking fees, location, and aesthetic and environmental requirements.

The following table from *International Parking Institute* indicates construction cost comparisons for a conventional garage versus an automated garage in three different configurations:

Table I-1 : *Comparison of building costs for generic APS and multi-story parking garages*

Application	Type	Parking Spaces	m² per Space	Building Cost	Cost per Space
Freestanding Above Grade	Parking Garage	200	30	373,831,776.00 DZD	1,86 9,158.88 DZD
	APS	200	20.9	610,397,196.75 DZD	3,051,985.98 DZD
Below Building Above Grade	Parking Garage	200	42	788,551,402.50 DZD	3,942,757.01 DZD
	APS	200	20.9	715,537,383.75 DZD	3,577,686.92 DZD
Below Building Below Grade	Parking Garage	200	42	1,103,971,963.50 DZD	5,519,859.82 DZD
	APS	200	20.9	820,677,570.75 DZD	4,103,387.85 DZD

Prices are converted from US Dollar to Algerian Dinars based on the average exchange rates for April 2018.

Therefore, the conventional above grade garage is less costly than the automated garage, unless the site is very small that results in a very poorly efficient conventional garage. Automated garage saves floor area at the high unit cost that counterbalances the cost of the automated machinery.

b) Operating Costs

Compared to the conventional parking, computerized parking facilities require more electrical power still the management and maintenance of these parking facilities is much less labor-intensive.

To determine operating expenses for parking facilities, one must first define what is included. The following categories are included in operating expenses:

- Labor Costs (wages and benefits)
- Management Fees/Costs
- Security Costs
- Utilities
- Insurance
- Supplies
- Routine Maintenance
- Structural Maintenance
- Snow Removal
- Elevator/Parking Equipment Maintenance

The size and age of a structure make a difference, but clearly, hours of operation and type of use have the greatest impact on the total cost; a facility with the primary purpose of providing parking for retail/dining/entertainment uses requires more cashiers than a general parking facility serving daytime commerce in a downtown. Security costs can be a huge variable. Utility costs, due to location and type of lighting, as well as type of structure, also make a significant impact on the total picture.

Taxes, whether sales, property, parking, or some other type, should be included here keeping in mind the wide range of taxes among facilities. A municipally-owned structure for instance, would likely pay no property tax, while a privately-owned structure could have a substantial property tax bill [2].

I.5 Parking facilities in Algeria

According to the Algerian Press Service, five new car parks were received in 2015 in Algiers, pending the launch of 10 other parks.

These five car parks, with a capacity of 550 to 800 places are located in El Biar, Kouba, Hydra, Sidi M'hamed and El Madania. The upper floor of each of these parking areas will be reserved for commercial premises, according to the same source.

El Biar Park, which will house 730 vehicles, has a bus station with 11 platforms and a restaurant on the upper floor. The Kouba Park, with a capacity of 800 vehicles, has been equipped with a bus station with 12 platforms and a restaurant as well. Hydra Park has 784 parking spaces.

Among the parks under construction, El Madania located at Avenue des Bouadou. It is composed of 8 floors and can accommodate 612 places including 30 reserved for the disabled. Located on an area of 1600m, this car park also has commercial premises and a café.

The *Wilaya of Algiers* has also signed with *Cosider* an agreement for the realization of 10 other parks with floors from 700 to 1500 Places, added the same source. Three have a minimum capacity of 1,500 Places, while 7 parking spaces will be built by private operators.

Another multi-storey car park, which can accommodate 532 light vehicles, was opened near the Constantine railway station. After eleven years of work, marked by several reassessments that brought the cost of 250 million to some 650 million dinars, this infrastructure will help alleviate parking difficulties [9].

I.6 Examples of APSs around the world

There are a number of examples from different countries that have replaced conventional parking with automated parking and hence achieved a number of benefits. Some examples are listed below:

I.6.1 Automated underground car park Donnersbergerstraße

The 4 levels automated underground car park Donnersbergerstraße with 284 parking spaces for residents is in operation since 2006 in Munich, Germany. The parking system has 4 driving-through transfer cabins.

- System length: 121 m
- System width: 12 m
- Storage height: 8,70m
- Area of the parking system: 1452 m²
- Volume of the parking system: 12633 m^3
- Volume per parking space: 45 m^3
- Max. Vehicle dimensions: Length 5,25 m / Width 2,20 m / Height 1,70 m (212 parking places) / 2,00 m (72 parking places) / Weight 2,50 t

Figure I-12 : *View into one of the two parking shelve systems*

I.6.2 St Joseph Parking

Located in the Sigefroi street, in Luxemburg, St Joseph Parking is a Parksafe type parking: everything is automated thanks to sensors in the vertical conveyor.

Here are the maximum dimensions allowed for this car park and other specifications:

- Year of construction: 2007
- Number of parking places: 46
- Parking levels: 4
- System length: 12,20 m
- System width: 16,60 m
- Storage height: 9,20 m
- Area of the parking system: 203 m^2
- Volume of the parking system: 1920 m^3
- Volume per parking space: 42 m^3
- Max. Vehicle dimensions: Length 5,25 m / Width 2,20 m / Height 1,60 m (30 parking places) / 2,00 m (16 parking places) / Weight 2,50 t

Figure I-13 : *Parking of Sigefroi street*

I.6.3 Madrid Multiparker 710

In this automatic Multi-parker system from WÖHR, an occupied pallet is exchanged with an empty one at the same time, this exchange method speeds up the system time. Two SRU's move along the same aisle to serve 155 car parking places in a fast and efficient way.

- Year of construction: 2009
- Parking Levels: 5
- System Length: 31,36 m
- System Width: 22,60 m

- Storage Height: 13,27 m
- Area of the parking system: 709 m²
- Volume of the parking system: 9.440 m^3
- Volume per parking space 60,9 m^3
- Max. vehicle dimensions: Length 5,25 m, Width 2,10 m, Height 1,90 m and Weight 2,5t.

Figure I-14 : *Madrid Multiparker 710*

I.6.4 Parksafe 580, Budapest

Four towers with 200 public parking places built within a space of 300 m² on the off-street side of a landmarked building. Cameras record an image of the license plate so that the car can be easily found and retrieved from one of the four towers even if the ticket is lost.

- Year of construction 2007
- Number of parking places 200
- Parking Levels 13
- System Length 24,93 m
- System Width 12,08 m
- Storage Height 26,65 m (aboveground) 4.91 m (underground) 31.56 m (in total)
- Area of the parking system 301 m²
- Volume of the parking system 9.590 m^3
- Volume per parking space 48 m^3
- Max. vehicle dimensions: Length 5,25 m, Width 2,20 m, Height 2.00 m and Weight 2,5 t.

Figure I-15 : *Parksafe 580*

I.6.5 Parksafe 583, Liverpool

The free-standing steel parking tower of ten levels braces the facade. A total of 84 parking places are hidden behind the facade of the Albany building creating an impressive number of parking places between buildings in a niche approximately 10m wide by 18m long.

- Year of construction: 2006
- Storage height: 21,00 m
- Area of the parking system: 177 m²
- Volume of the parking system: 3717 m^3
- Volume per parking space: 45 m^3
- Max. Vehicle dimensions: Length 5, 25 m / Width 2, 20 m / Height 1,60m (63 parking places) / 2,00m (21 parking places) / Weight 2,50 t

Figure I-16 : *Parksafe 583*

Chapter II
Structural steel framing

II.1 Introduction

As seen on the previous chapter, structural steel is largely used in automated parking systems building because of a long list of benefits such as high resistance and faster construction times; this is why we have concerned this chapter to show and define the mechanical characteristics of the materials and rolled products used to make a metal structure.

II.2 Structural steel framing

Structural steel framing, describes the creation of a steel skeleton made up of vertical columns and horizontal beams. This skeleton provides the support for the roof, floors and walls of the structure [10].

Vertical charges are transferred as concentrated loads. The individual elements are often hot rolled steel profiles with an important section. They are typical IPE column and beam. Other I-shaped profiles or hollow sections such as box or tube profiles can also be used. Connecting two or more elements is done by either bolting or welding.

Figure II-1 : *Construction of Steel Frame Structure*

II.2.1 Types of structural steel framing

There are three main types of structural steel framing systems [11].

II.2.1.1 Conventional Steel Fabrication

Is when members of steel are cut to the correct lengths, and then welded together to make the final structure. This can be done entirely at the construction site, which is labour-intensive, or partially in a workshop, to provide better working conditions and reduce time.

II.2.1.2 Bolted Steel Construction

Occurs when finished and painted steel components are produced then shipped to the site and simply bolted in place. This is the preferred method of steel construction, as the bulk of the fabrication can be done in workshops, with the right machinery, lighting, and work conditions. The size of the components are governed by the size of the truck or trailer they are shipped in, usually with a maximum length of 6m for normal trucks or 12m for long trailers. Since the only work to be done at site is lifting the steel members into place and bolting, the work at site is tremendously fast.

II.2.1.3 Light Gauge Steel Construction

Is a type of construction that is common for residential and small buildings in North America and parts of Europe. This is similar to wood framed construction, except that light gauge steel members are used in place of wood. Light gauge steel is steel that is in the form of thin (1-3mm) sheets of steel that have been bent into shape to form C-sections or Z-sections.

Choosing which type of steel frame to use for a given project requires the consideration of a number of factors, including building width, height, location, roofing type, and building use.

II.2.2 Advantages and disadvantages of steel structures

Steel structures have the following advantages:

- They are super-quick to build at site, as a lot of work can be pre-fabbed at the factory.
- They are flexible, which makes them very good at resisting dynamic (changing) forces such as wind or earthquake forces.
- A wide range of ready-made structural sections are available, such as I, C, and angle sections
- They can be made to take any kind of shape, and clad with any type of material

- A wide range of joining methods is available, such as bolting, welding, and riveting

Steel structures have the following disadvantages:

- They lose strength at high temperatures, and are susceptible to fire.
- They are prone to corrosion in humid or marine environments.

II.3 Structural steel

A good knowledge of the materials used in metal construction is essential for the realization of a structure, as well for its design as its dimensioning. It is also necessary to define the resistance of the different structural elements which will be studied in the next two chapters.

Structural steel has been for a long time used in construction and we can find a large number of references about this in literature. In the next sections, we will only “transcribe” some fundamentals on structural steel already available universally, from only one reference as resource of information with minor modifications.

II.3.1 Families of products

II.3.1.1 Hot rolled products

Once the refining phases of the steel are completed, the molten metal is poured into ingot molds. But steel can not usually be used in ingots by processing industries or direct users. These ingots are heated and then processed by hot rolling. Laminating consists in crushing the metal, preheated, between two cylinders whose directions of rotation are opposite. A first phase of roughing is carried out in a special mill called blooming-slabbing, depending on whether the product must have a square (bloom) or rectangular (slab) section (Fig. II.1). For the finishing, the material used varies according to the shape of the finished products: grooved rolls are used for the sections and smooth rolls for the sheets [12].

A more recent process than conventional casting through ingots is continuous casting. In the process, the steel is no longer poured into several molds, but is poured into a water-cooled copper bottomless mold. It solidifies during its passage and comes out continuously as a square or rectangular bar according to the section of the mold. The steel rod outgoing continuous casting machine is cut to the desired length by a torch. This method has the advantage of eliminating the ingots stage for which intermediate heating is necessary and to reduce the manufacturing time of the profiles.

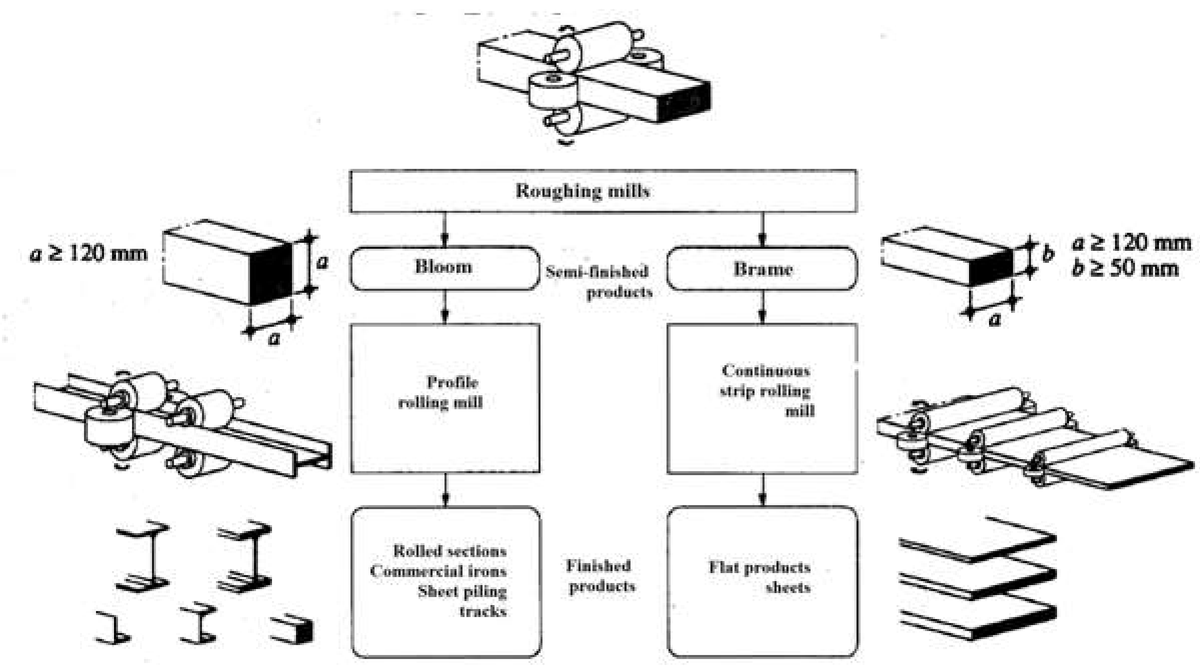


Figure II-2: *Main phases of hot rolling.*

II.3.1.2 Double tee profiles

The profiles can be divided into two groups:

- Double-tailed profiles with narrow wings, whose moment of inertia I_z is small vis-à-vis the moment of inertia I_y. The weight per running meter (unit weight) of these profiles is relatively low; they are used mainly as bent elements. We distinguish the light series IPE, whose wings are of constant thickness, and the series INP, slightly heavier, with the inner faces of the inclined wings.
- Wide-winged double-tee profiles, which have a higher moment of inertia than narrow-wing profiles. They find multiple applications elements biased in flexion, in flexion left or subjected to a normal effort. There are three types of sections HEA, HEB, HEM. For a distance between the two wings HEA is the lightest and the HEM is the heaviest. For equal inertia, the HEA is again the lightest, but its dimensions will be greater than those of an HEB and much higher than those of a HEM. Note that the distance between the inner faces of the wings is identical for HEA, HEB and HEM profiles of the same number: this feature may be of interest for the design of certain assemblies.

In the last few years, there has been a new series of profiles on the market: HHD profiles specially created for building columns. There are also profiles called W, M or S which are the profiles in North American double tee. Their dimensions are noticeably different from those of European profiles, but the complete series can be compared to the European double series.

II.3.1.3 U profiles

U profiles are often used as secondary elements. In Europe, the **UNP** series are distinguished with the internal faces of the inclined wings and **UAP** with constant wing thickness.

II.3.1.4 Flat products

Among the flat products, one distinguishes between wide-plates and sheets. Flats are hot-rolled steel sheets on all four sides. Given the rolling in the direction of length, these large dishes have a preferential sense (better resistance in length than across). Their dimensions vary within the following limits: width 160 to 600 mm, thickness 5 to 50 mm.

The sheets are hot-rolled only on the large faces. Their edges are rough rolling or cut with shears or torch they are subdivided according to the standards into three categories:

- Heavy plates, thickness $t \geq 5$ mm,
- Medium plates, 5 mm> $t \geq 3$ mm,
- Thin sheets, $t < 3$ mm.

Thin sheets have limited use in metal construction because of their flexibility and low thickness (danger of corrosion)

II.3.1.5 Tubular profiles

In the series of tubular sections, there are square tubes, rectangular tubes and round tubes. They are divided into two categories: seamless tubes and welded tubes. Seamless tubes are obtained from ingots or hot-rolled round irons. The latter are manufactured flat product drawn cold, and then rolled cold in a series of rollers (continuous forming) or using presses. The sheets are then welded by automatic methods. The weld describes a helical curve around the axis of the cylinder or follows a generator. Tubular profiles are increasingly used in metal construction and more particularly in the realization of lattices. They are more expensive than the usual profiles but have the advantage, compared to buckling, of having identical inertia along the two axes. In addition, they are often preferred for aesthetic reasons.

II.3.1.6 Commercial irons

Market irons include:

- Angles with equal or unequal wings, used mainly in making lattices,

- High T-Shaped T-bars (**TPH**) and wide-base T-irons (**TPB**), used as secondary elements (not to be confused with the half-profiles **IPET**, **HEAT** and **HEBT** which are double-tee profiles whose cutting longitudinal is usually performed by the firm),
- The irons z, essentially used as secondary elements,
- Flat irons used, for example, for producing welded composite beams of small dimensions or for stiffening plates (maximum width 150 mm).
- Round irons and square irons used as lattice or bracing bars.

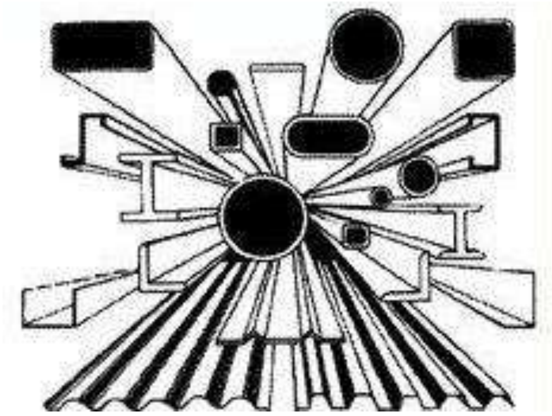


Figure II-3: *Examples of merchant bars.*

II.3.2 Characteristics of structural steels

II.3.2.1 Chemical composition

The structural steels contain from 0.1 to 1% of carbon depending on the desired properties, and, depending on the case, addition elements such as manganese, nickel, chromium, molybdenum, titanium, tungsten (increase in mechanical characteristics) , copper (against corrosion), silicon (deoxidation), aluminum (grain refining) ...

They also contain a small proportion of residual nitrogen, sulfur and phosphorus (residual impurities unfavorable to mechanical characteristics and weld ability).

Depending on its components during the shading and heat treatment of alloys during their development, steel will have varying mechanical and technological properties.

In general, it can be said that by increasing the carbon content or the content of alloying elements, the strength characteristics of the steels are increased, but their weld ability is impaired (by more or less active quenching effect). (Depending on the products)!

II.3.2.2 Process of making steel

Carbon steels are distinguished from "stainless" steels (steels made passive, that is to say insensitive to corrosion in the mass by adding significant percentages of chromium, nickel and molybdenum). Carbon steel is manufactured by one of two major production sectors that are:

- The "smelting and steelmaking with oxygen" sector,
- The "scrap and electric furnace" sector.

In both cases, the steel is refined in a refining station.

Stainless steel (not considered in these notes) is, for its part, produced solely from the electrical industry.

Effervescent steel is no longer accepted, and in the case of deoxidation, certain grades require the steel to be completely "calmed down" by the addition of deoxidation elements such as silicon and manganese.

II.3.2.3 States of delivery of steels

We distinguish:

- Steel in the raw state of rolling (AR);
- Normalized steel (N), which has undergone, after rolling and return to ambient temperature, a complete normalization heat treatment, or which has undergone a normalizing rolling procedure. Normalization consists of heating to the austenitic domain and cooling in the open air (which is slower than the product is thick) in order to obtain a steel with a finer "ferrito-pearlitic" structure. Grain refining increases the weld ability of steels. Normalizing rolling is a hot rolling procedure in which the variation in temperature and strain over time is controlled. The final deformation is carried out in a temperature range such that the austenite is recrystallized completely, leading during cooling to a "fine perlite" structure material (a condition equivalent to that obtained after normalization);
- Thermo mechanical steel (M), which has undergone a rolling and cooling procedure at specified temperatures and conditions. The final deformation is carried out in a temperature range which allows a refining of the austenite grains (before transformation) by hardening and re-crystallization. The rolling is followed, according to the thickness and the shape of the products, of cooling with calm air, of an accelerated cooling or of a superficial tempering followed by a self-income, whose transformations structural

properties lead to a "fine ferrite-pearlite". The properties of thermo mechanical steel can not be obtained or preserved by heat treatment alone.

- Steel in the quenched and tempered state (Q) which, after rolling and return to ambient temperature, has been heated to a temperature slightly above the normalization temperature, and then has undergone a complete quenching treatment and income, or which, after a suitable rolling, has been tempered directly followed by an income. High strength steels are thus obtained.

These different manufacturing processes do not involve the same curing mechanisms (which give the steel its resistance performance) and, therefore, do not exploit the presence of carbon and alloying elements with the same efficiency. Thus, with identical mechanical performances, the **N** steels are the richest in carbon, the **Q** steels are the poorest in carbon and the **M** steels have, in general, intermediate carbon contents.

For a given analysis, the **M** steels have higher mechanical characteristics than the **N** steels as well as a less loaded chemical composition (fewer alloying elements) with given mechanical characteristics.

M steels, unlike materials **N**, are not suitable for subsequent heat treatments (except stripping) or hot deformations (1100 °). The high temperature treatment of the steels **M** leads to a lowering of their resistance.

II.3.2.4 Normative References

The following reference standards, general and structural steels, apply:

- **EN 1090** Execution of steel structures;
- **EN ISO 12944** Anticorrosion of steel structures by paint systems;
- **EN 1461** Hot-dip galvanized coatings on ferrous finished products;
- **EN 10025** Hot-rolled products of structural steel (unalloyed, weld able fine-grained, corrosion-resistant, tempered-tempered (high yield strength);
- **EN 10164** Structural steels with improved deformation characteristics in the direction perpendicular to the surface of the product;
- **EN 10210** Hollow profiles for hot-finished construction;
- **EN 10219** Cold-formed hollow sections for construction.

II.3.3 Mechanical properties of structural steels

Whatever their chemical compositions and production methods, the vast majority of structural steels can use the following conventional values:

$$E = 210.000\ N/mm^2;\ G = 80.770\ N/mm^2;\ \nu = 0.3;\ \alpha = 12\times10^{-6}/°C;\ \gamma = 78.5\ KN/m^3$$

II.3.3.1 Elastic limit and tensile strength

The nominal values of the elastic limit f_y and the tensile strength f_u (corresponding to the maximum resistance R_m), change according to the type of steel.

Table II-1 : *Yield and tensile strength for most common steel grades*

	Yield strength (N/mm²)				Tensile strength (N/mm²)	
Grade	**t ≤ 16**	**16 < t ≤ 40**	**40 < t ≤ 63**	**63 < t ≤ 80**	**3 < t ≤ 100**	**100 < t ≤ 150**
S275	275	265	255	245	410	400
S355	355	345	335	325	470	450
t is nominal thickness (expressed in mm)						

II.3.3.2 Ductility

For structural steels, minimum ductility expressed in terms of limits is required as follows:

- The ratio f_u / f_y (minimum tensile strength specified f_u to the specified minimum yield strength f_y): ≥ 1.10;
- The elongation at break over a calibrated length of the test piece of 5.65 $\sqrt{A_0}$ (where A_0 is the initial cross-sectional area): greater than or equal to 15%;
- The ultimate deformation ε_u (corresponds to the tensile strength fu): ≥ 15ε_y, where ε_y is the elastic deformation = f_y / E).

II.3.3.3 Tenacity

Tenacity can be defined as the measurement of the resistance of steel to the sudden propagation of a crack called brittle fracture. This type of rupture occurs without (or after a very weak) plastic deformation. The brittle fracture can be the consequence of either a cold crack of welding in a structure subjected to static loads, or of a fatigue crack, that is to say a pre-existing micro or macro-crack which spreads under a solicitation of fatigue.

II.3.3.4 Fatigue resistance

The mechanical behavior of steel can be affected by stresses lower than its limit of elasticity but applied a very large number of times in more or less cyclic form. This can lead to a rupture called "fatigue". To estimate the fatigue strength of a steel, it determines, in the absence of residual stresses, its endurance limit σ_D which, for a given type of stress and for a mean stress σ_m fixed, is the limit value towards which tends the stress amplitude σ_a when the number of cycles at break becomes very large (for steels often 2×10^8 cycles).

Practically we can estimate that these are the conditions (type of stress, σ_m, σ_a) below which the risk of fatigue failure disappears. But this limit of endurance ($\sigma_D = \sigma_m + \sigma_a$) depends on many factors: the geometry of the piece through the effect of scale and especially the influence of the notch effects, the surface condition and the superficial defects, the mode of stress (type and frequency), the residual stresses, the environment (temperature and corrosion), ...

In steel framing, it is the welded joints that generally condition the resistance to fatigue of the construction. This is due to the geometry of the welded joint (stress concentration) and is due to the notch effect associated with the bead.

II.3.3.5 Influence of temperature

With the exception of the decreasing resilience, the strength characteristics of the steels (elastic limit and modulus of elasticity in particular) increase slightly when the temperature falls below the ambient temperature.

On the other hand, above the ambient temperature, the plasticity increases and the resistance characteristics decrease!

There is a significant threshold of about 500 °C, below which the variations remain low, and above which the steel begins to lose substantially its resistance properties (at 400 °C for example, the elastic limit decreases by 38% and the modulus of elasticity of 13%). In case of fire in particular, it will be necessary to limit the heating of the steel load-bearing elements to temperatures lower than 500 °C, for example by protecting them with insulating materials.

II.3.4 Technological features

II.3.4.1 Weld ability

The weld ability of steels, i.e. weld joint ability, is influenced by the chemical composition and metallographic structure of the steel. By increasing the content of the alloying elements, the weld ability is reduced.

On the other hand, an improvement of the weld ability is obtained by the refining of the grain. Construction steels are generally weld able. The weld ability is judged on the basis of the risk of ruin by cracking and breaking from defects. The most dangerous ones may be geometrical (these defects are in the design and practice of welding) and metallurgical (hot cracks, lamellar tear cracks and cold cracks).

II.3.4.2 Formability and cutting

Hot forming usually starts with a high temperature heating which causes a structural transformation and thus fundamentally modifies the mechanical properties of the steel. If the temperature is too high, it can also cause a magnification of the grain harmful to the resistance to brittle fracture. Such an operation must be followed by a normalization heat treatment which makes it possible to restore the steel to its original mechanical properties. Such an operation is only possible with steels of the standards EN 10025-2 and EN 10025-3.

Steel construction steels can be cut by: shearing, nibbling, punching, and cutting. These processes cause surface irregularities and localized work hardening of the edges. Often, if these defects are problematic, the sections are finished by grinding (or bore for the punched holes). These steels can also undergo thermal cutting (oxycutting, plasma torch or laser beam).

II.3.4.3 Corrosion resistance

In order to meet the durability and durability requirements of the structures mentioned in EN1990, common structural steels can be protected against the attack of atmospheric corrosion by coatings of various types and adapted to the conditions of use. We find:

- Metallic coatings by galvanizing (zinc) or aluminizing (aluminum) with dipping or continuous (sheets).
- Paintings (several layers including "primaries" with inhibiting power).
- Thin sheets coated and plasticized (after prior galvanizing).

There are also structural steels with improved resistance to atmospheric corrosion. These are carbon steels with added alloys such as **Cu**, **Cr**, **Ni**, **P** called "self-patinable"; they do not require any protection because they develop a clean protective layer after exposure to the weather.

II.3.5 Structure steel designation

Designation of structural steels consists of a succession of letters and numbers which always begin with the letter S, followed by a number equal to the specified minimum value of the yield strength for the lowest thickness range. This set can be followed by additional symbols that can be successively:

- A letter defining the state of delivery of the steel: **N** for normalized or normalizing rolling, **M** for thermo mechanical rolling, **Q** for quenching and tempering;
- Two letters or a letter and a number specifying the requirements for the transition temperature of the resilience (**J** for 27 Joules, **K** for 40 **J**, **L** for 60 **J**, R for 20 °, **0** for 0 ° and 2 to 6 for -20 to -60 °). The latter are simplified for fine grain steels: **L** for 27 **J** at a minimum T ° of -50 ° for **N** and **M** steels; **L** for 27 J at a minimum T ° of -40 ° and L1 for 27 J at -60 ° for Q steels;
- Possibly the letter G followed by a number: G2 for calmed steel, G3 for normalization annealing, G4 for free delivery condition, ...
- Possibly an indication for a supplementary specification: D for galvanic aptitude, W for improved resistance to atmospheric corrosion, H for tubes, Z15, 25 or 35 for lamellar tear resistance, C for cold work hardening, CR for hot rolling and cold working, ...

II.3.5.1 Hot rolled products of non-alloy structural steel

The requirements and grades of steel for non-alloy steel flat hot rolled products are specified in EN 10025-2. These elements are used for conventional welded, bolted or riveted structures subjected to service at ambient temperature. These steels are designated by:

- The letter S;
- The minimum value of the elastic limit (for a thickness ≤ 16 mm) in N/mm²: 235, 275, 355, 450;
- The quality with respect to the weld ability and the resistance to brittle fracture, by a symbol designating the minimum breaking energy: JR (27 Joules at 20 °), J0 (27 Joules at 0 °), J2 (27 Joules at -20 °), K2 (40 Joules at -20 °);
- Optionally: C, for a steel capable of cold forming; Z, for improved properties perpendicular to the surface.

Examples of designation: S235JR, S275J0, S355K2 …

II.3.5.2 Hot-rolled fine-grained weld able structural steel products

The requirements and grades of steel for long-grain hot-rolled products in fine-grained weldable steel are specified in EN 10025-3. These elements are used for highly stressed welded structures such as bridges, lock gates, tanks ... subjected in service at room temperature or low temperature.

The steels of these elements have a chemical composition assuring them very good weld ability, are completely calmed down and have a fine grain structure. They are obtained by standardization heat treatment or normalizing (N), or by thermo mechanical rolling (M).

These steels are designated by:

- The letter S;
- The minimum value of the elastic limit (for a thickness ≤ 16 mm) in N/mm²: 275, 355, 420, 460;
- The delivery status symbol: N or M;
- The letter L for the specified minimum energy quality of the breaking energy at temperatures not lower than -50 °, otherwise, this relates to temperatures above -20 °;
- Optionally: Z, for improved properties perpendicular to the surface.

Examples of designation: S275N, S355NL, S420NL, S460ML, S275M …

II.3.5.3 Hot rolled structural steel with improved resistance to atmospheric corrosion

The requirements and grades of steel for hot-rolled long and flat products of steel with improved resistance to atmospheric corrosion are specified in EN 10025-5. These elements are used for conventional welded, bolted or riveted structures subjected to ambient temperature service where atmospheric corrosion resistance is required. These elements can not undergo heat treatment.

These steels are designated by:

- The letter S;
- The minimum value of the elastic limit (for a thickness ≤ 16 mm) in N/mm²: 235, 275, 355;
- The quality, as to the weld ability and the resistance to brittle fracture, by a symbol: OJ, J2, K2;
- The symbol W designating the resistance to atmospheric corrosion;
- Optionally: P, for a higher phosphorus content (for S355 only); Z, for improved properties perpendicular to the surface.

Examples of designation: S235J0W, S355J2WP, S355K2W …

II.3.5.4 Hot rolled steel products with high yield strength

The requirements and grades of steel for high-strength steel flat products are specified in EN 10025-6. The steels of these elements have elastic limits ranging from 460 to 960 N/mm^2. It is hardened and tempered steel.

These steels are designated by:

- The letter S;
- The minimum value of the elastic limit (for a thickness ≤ 50mm) in N/mm^2: 460, 500, 550, 620, 690, 890, 960;
- The symbol Q designating the delivery condition "hardened and tempered";
- Possibly the letter L (or L1) for the specified minimum value of impact bending fracture energy at temperatures not lower than -40 ° (or -60 °), otherwise, this relates to temperatures greater than -20 °;
- Optionally: Z, for improved properties perpendicular to the surface.

Examples of designation: S500QL, S620QL1, S890Q …

Chapter III
Preliminary design

III.1 Introduction

New product design may seem like a relatively easy process to many, but there are several steps and processes that need to be taken in order to have a successful design. We can count seven steps in this process.

The first one is assessing the problem; the problem is identified and then ideas and solutions are coming up to rectify this problem. These ideas could stem from a gap in the market, or a product that doesn't function as well as it should. This is what we have done is the introduction of this paper.

Research comes in second place; this involves researching in depth to see if there are other similar products on the market, this ensures that no product is replicated and also means that we can identify problems with current products that are similar and work to improve them. Contents of chapter I refer to this step of our product design.

In this chapter we will explore the two next steps which are:

- Thinking of ideas and concepts to come up with a solution and picking sketches that may well work; then,
- Creating prototypes of these sketches, these should be to show the basic form of the product (are not necessarily fully functioning).

At the end of this chapter, we will gather all what we need to complete the 3D modeling of the final design that incorporates all the functions necessary to the success of our Automated Parking System design. This step will be done on the next chapter.

Testing and manufacturing are the last steps and, unfortunately, they are out of our reach.

III.2 Main ideas

After the research done in the previous chapters, it is quite sure that structural steel framing is most accommodate for automated parking systems, so the main idea of our conception is a multi-story construction in structural framing with no ramps, driveways or personnel access.

At the entrance should be a reception zone where the driver parks his car on a pallet, a control of dimensions and weight should be done before permitting the driver to leave his car in this zone; if the car does not respect the condition of parking, the drive should be guided to the exit.

If the weight and dimensions of the car are tolerated, the drive will be invited to leave his car and lock it, and then the reception zone should be secured before moving the vehicle to the lift area, in this area, the pallet with the vehicle is guided to one of the levels according to the availability of parking spaces on each level. Another lifting area should exist to return the vehicle from the parking space to an expedition area when its owner requests it.

On each level, should be three rows where we can find cells on the two sides of the central row where cars will be stored, on the central row, a server will be able to move along the row and guide the pallet with the vehicle on transversely to one of the two sides.

The number of parking spaces on each level may vary according to the client's needs and the available surface, the number of levels can not exceed five including ground level, if there is need to add more levels, columns resistance must be recheck.

Normally, car will be stored in the lowest level (ground level if the construction is above guard) if there are available spaces in this level, else it will be lifted to the next level, and this is to reduce lift use frequency, but, a study should be done to better decide on what level the vehicle should be stored depending on his weight.

To make the building ecological, the structure can be covered by photovoltaic panels, the produced energy can be used to operate the parking.

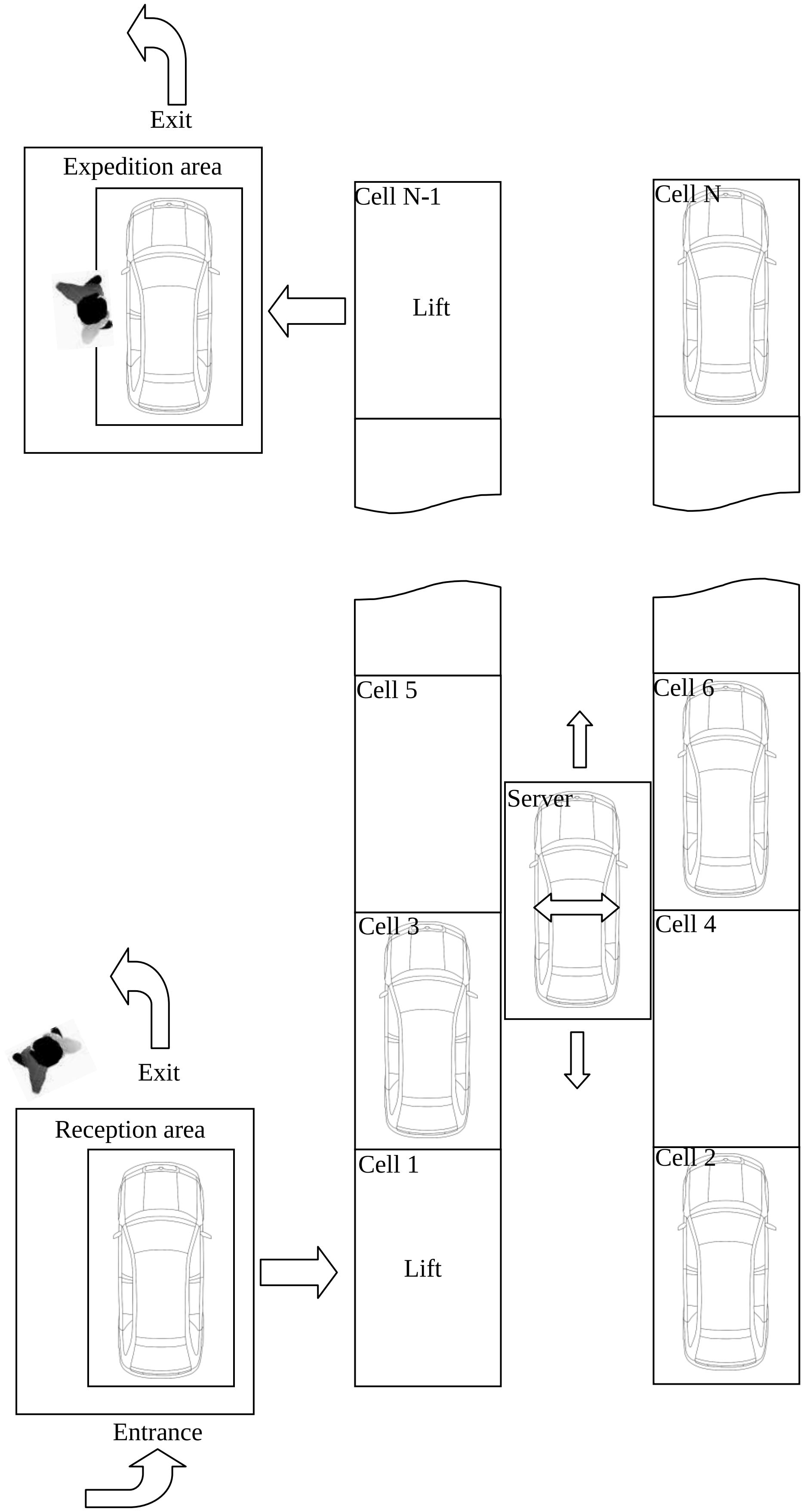


Figure III-1: *Main idea of our APS conception*

III.3 Cell configuration

Based on statistics on the most used cars in Algeria (over 150 models, see Appendix A), we have determine the minimum dimensions of the cell, in addition to length, width and height, weight is also considered.

In order not to oversize the structure, the maximum dimensions given in the appendix are not taken into consideration, dimensions smaller than these were considered limiting the access to the parking for some car models, only few models which are of a very low percentage are forbidden. Maximum dimensions are shown in figure III-2.

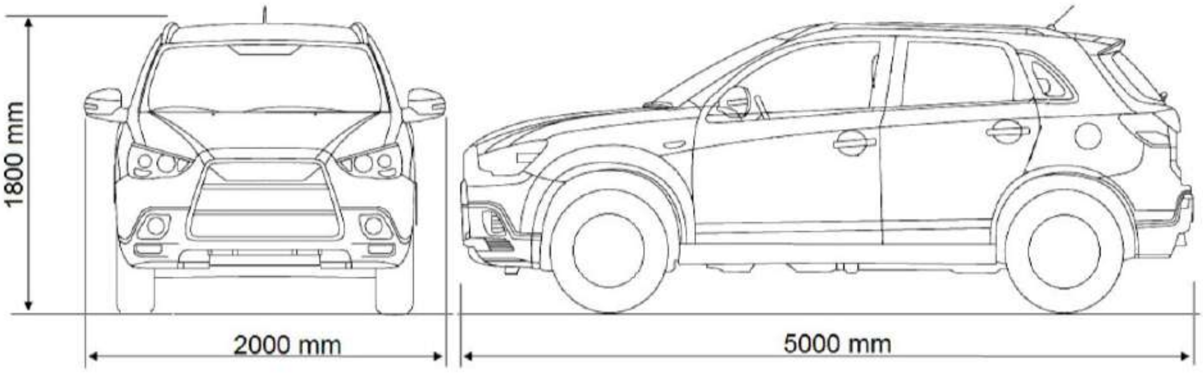


Figure III-2 : *Maximum dimensions considered*

We have considered a maximum length of five meters, the maximum width is two meters and maximum height is 1.8 m, the maximum weight is limited to 2500 kg; these values are increased by a margin of safety, the final dimensions are reported in Table III-1.

Table III-1 : *Cell size*

	The car	Safety margin	The cell
Length (L)	5000	+1000	6000
Width (W)	2000	+200	2200
Height (H)	1800	+200	2000
Weight (We)	2500 Kg	+500	-

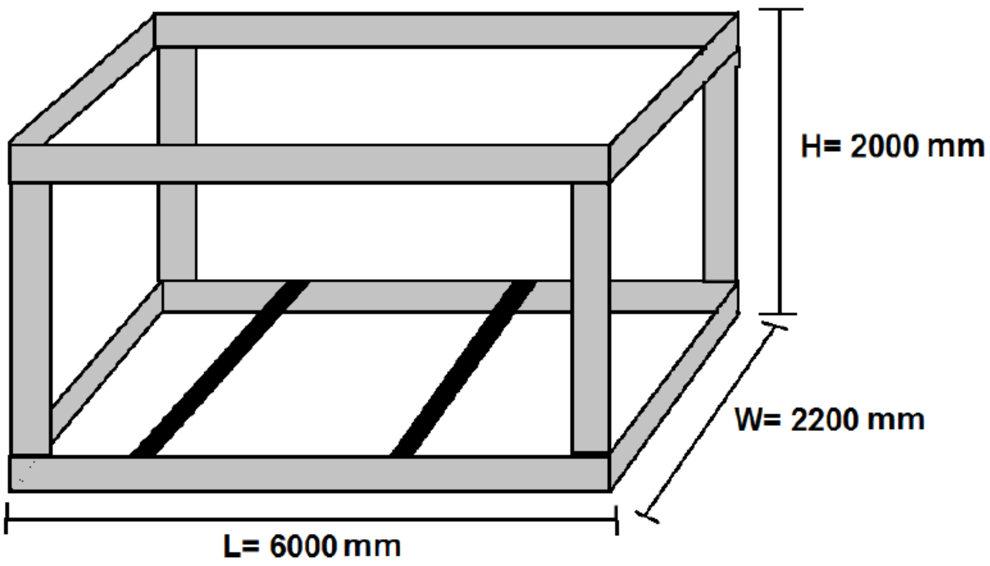


Figure III-3 : *Cell prototype*

Figure III-3 shows the design of the cell with the dimensions obtained previously.

III.4 Pallet design

The pallet is where the car stops, then the system guided it to parking space (cell), it represents the definition of the place of the car in the parking lot. When the vehicle owner wants to pick up his car, the system retrieves the pallet to the expedition area with the car on it.

A steel frame with a 3 mm thickness diamond plate (checker plate) on it will ensure this operation. By adding 4 wheels to the frame, moving the pallet transversally into the cell will be much easier. A preliminary prototype in shown in figure III-4.

Figure III-4 : *Preliminary prototype of the pallet*

III.5 Server design

As we have see in section III.2, the server must be able to move longitudinally along central row and, able to move the pallet transversally to one of the two sides. To ensure these two functions, we propose a steel frame with 4 wheels driven by a steel cable.

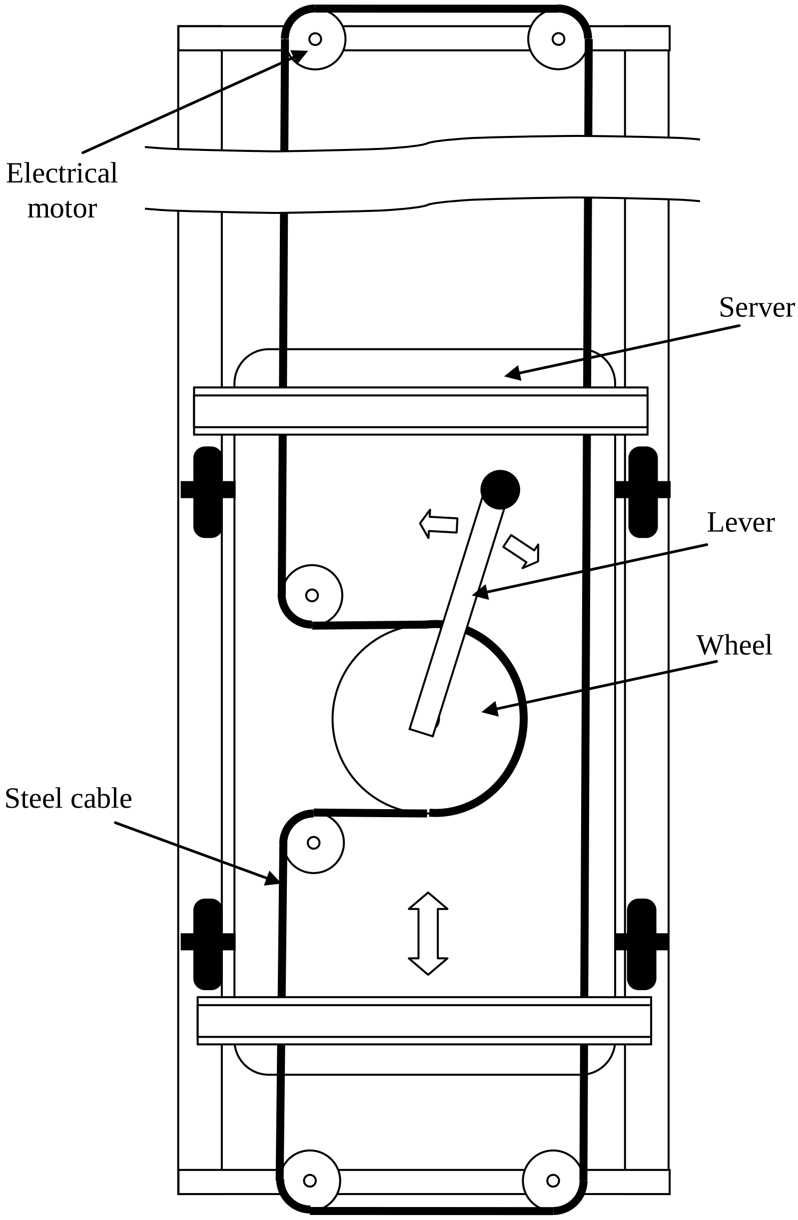


Figure III-5: *Sever prototype*

A fixed lever on a wheel (whose cable passes over it) makes it possible to move the pallet transversely when the wheel is free to rotate relative to the frame; in this case the frame must be blocked. In the opposite case, i.e. the wheel blocked with respect to the frame, the server assembly moves on the action of the steel cable. In the two cases, it is the same electrical motor that ensures movement by means of the steel cable.

Chapter IV
3D Structure Modeling

IV.1 Introduction

In this chapter we will establish 3D models of the deferent parts of the Automated Parking System considering preliminary, describe the prototype of this project that we propose, Based on the definition of basic components, with the definition of the program used in the design and study of this model.

IV.2 Used software

For 3D modeling we have use **SolidWorks** software which is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes; an European software company headquartered in France that develops 3D design, 3D digital mock-up, and product lifecycle management (PLM) software.

SolidWorks was created in 1993 by the eponymous American publisher, and acquired on June 24, 1997 by Dassault Systèmes. According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013.

Among the largest organizations using SolidWorks, we can mention Franckie, Packaging Equipment MMC, AREVA, Patek Philippe, Mega Bloks, Axiom , ME2C, SACMO, Le Boulch, Robert Renaud, Lorenz Baumer, the Paris Opera , Jtekt, GTT and the French Ministry of Education.

IV.2.1 Version

Dassault Systèmes currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product. For us we will accomplish our 3D models with a SolidWorks Premium 2010 version which was released on December 9, 2009.

IV.2.2 Modeling technology

Building a model in SolidWorks usually starts with a 2D or 3D sketch of shapes. The sketch consists of geometry such as points, lines, arcs and splines. Dimensions are added to the sketch to define the size and location of the geometry. This sketch is then extruded or cut to add or remove material from the part.

SolidWorks is a solid modeler, and utilizes a parametric feature-based approach. This parametric nature means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed.

IV.2.3 File format

SolidWorks files use the Microsoft Structured Storage file format. This means that there are various files embedded within each SLDDRW (drawing files), SLDPRT (part files), SLDASM (assembly files) file, including preview bitmaps and metadata sub-files.

IV.3 Elements 3D modeling

The design we propose is based on four essential elements: an element consisting of four welded columns with a transverse beam, longitudinal beams, pallets and finally servers.

Figure IV-1 shows what the structure looks like for only six cells (to keep the figure clear and representative).

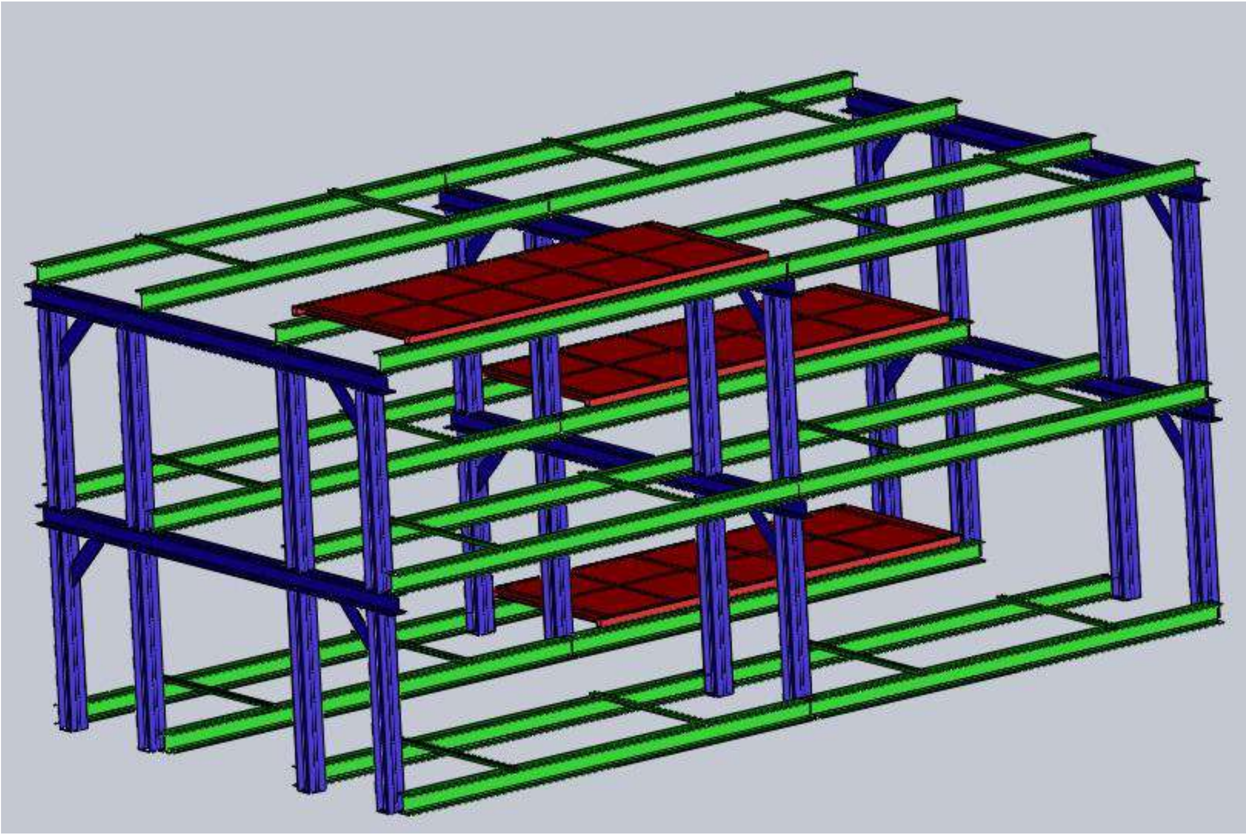


Figure IV-1 : *6 cells assembly with: Pallets (red), Beams (green) and Welded columns assemblies (blue)*

IV.3.1 Pallet

The first component we will model is the pallet that the car holds on it; it consists of simple parts: a steel frame formed by rectangular tubes of 100 × 80mm section and different lengths, covered with checker plate and able to move transversally by means of four wheels fixed on the bottom with shafts. The figure IV-2 shows an exploded view of the pallet with all its components.

Drawing components of the pallet was easy, simple features were used. For the beams, a 2D sketch is draw and then extruded at different length.

For the steel frame, we first chose a 40 × 40mm steel angle (see figure IV-3, the sketch on the left), but when the simulation was done, we found that the tension was high and the displacement was important in the center reaching 14 mm. It was essential to replace the steel angle with a rectangular tube. 80 × 50mm section was enough to ensure an acceptable displacement (2.7 mm) compared to the first result.

On the other hand, we found a problem when fitting in the wheels; there was interference between the pallet and the UPN-beam serving as rail for the wheels. To solve this problem, we decided to increase the dimensions of the rectangular tube to 100 × 80mm. This selection was appropriate in view of all the results.

The length and width of the pallet are respectively 5300mm by 2200mm

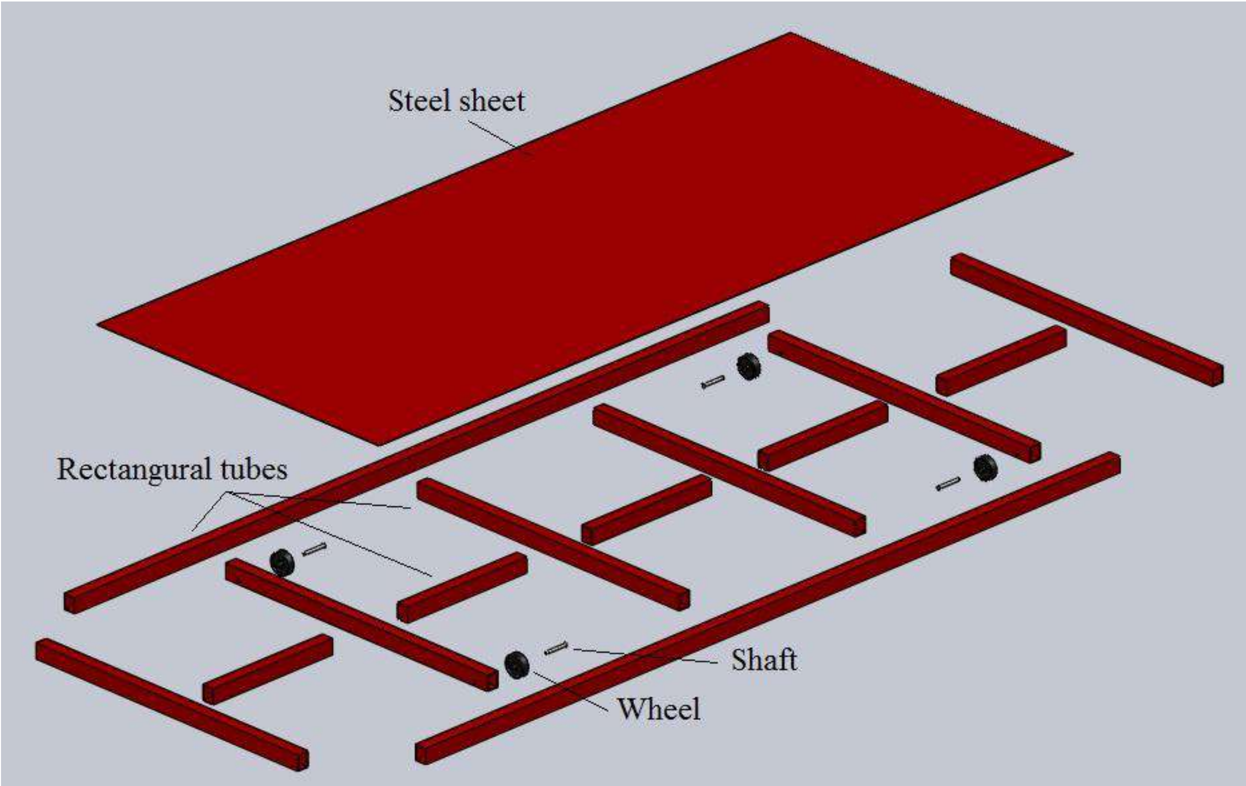


Figure IV-2 : *An exploded view of the pallet*

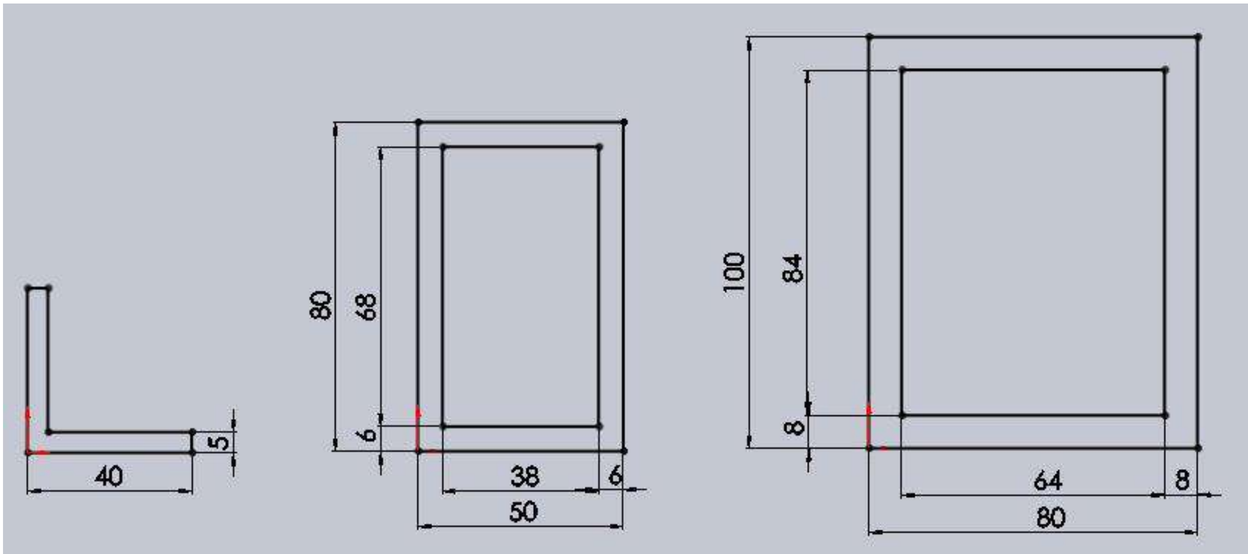


Figure IV-3 *: Frame beam sketching*

The wheel and the shaft were molded by revolution; results are shown in figure IV-4.

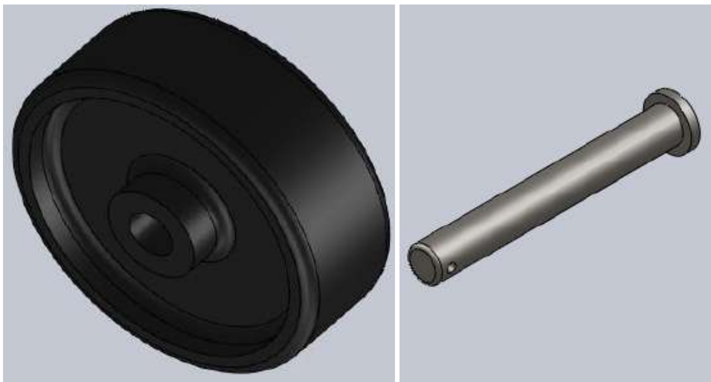


Figure IV-4 : *Wheel and shaft*

IV.3.2 Beams

The beams (shown in green on figure IV-1) must ensure several functions:

- They must support the pallets with the cars on top,
- Ensure the rigidity of the automated parking structure and,
- Serve as rails for the servers on central rows.

To be able to ensure these functions, we have chosen HEA wide-winged double-tee profile as solution. Two of HEA240-beams welded with two other UPN80-beams forming a host for pallets. The HEA240-beams are perforated at their ends to assemble them with the other parts of the structure (the columns).

Based on the two sketches shown in figure IV-5, beams are modeled by extrusion and then assembled to gather to form one of the two main elements forming the structure (see figure IV-6).

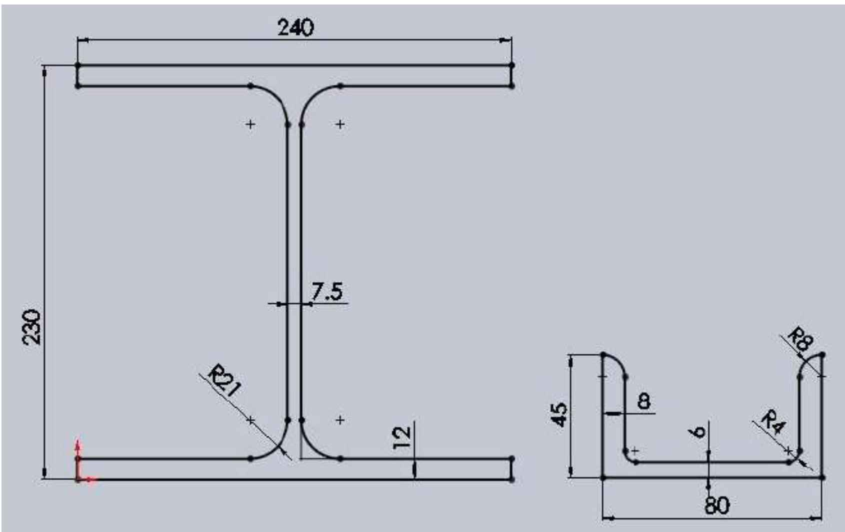


Figure IV-5 : *HEA and UPN beams sketching*

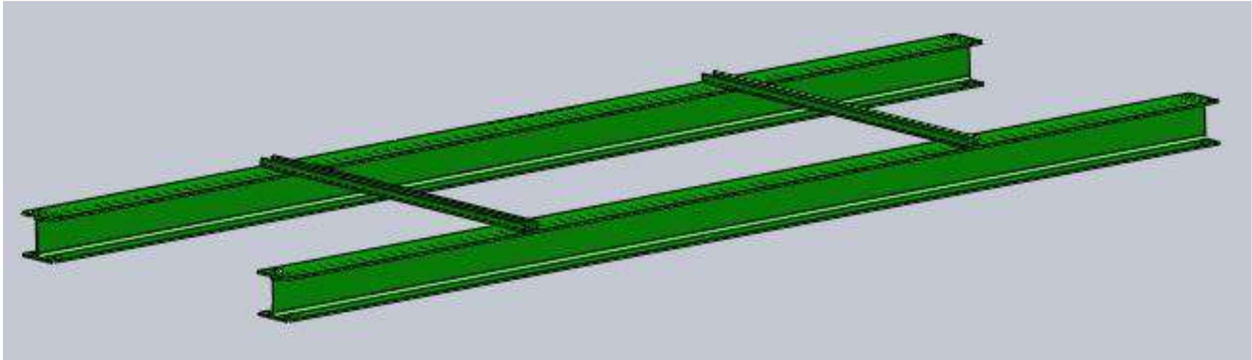


Figure IV-6 : *Welded beams assembly*

When the pallet is inserted in the cell, the two (pallet and beams) looks like shown in figure IV-6.

Figure IV-7 : *Beams with the pallet on top*

IV.3.3 Welded columns assembly

For the second principal element of the structure we have choose to use the same wide-winged double-tee profile HEA240 for both beam and columns.

Four vertical columns of 2400 mm height are welded to a horizontal beam of 6700 mm length (equivalent to three rows) to form the element shown in figure IV-8.

This element is assembled with the second one by bolts. In this way, the structure can be easily constructed by fabricating these two main elements at the workshops and then transported to the site to be bolted together on site.

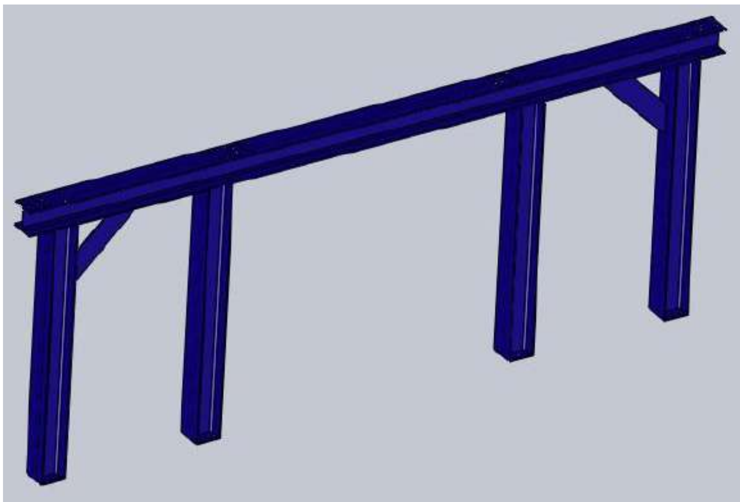


Figure IV-8 : *Welded columns assembly*

IV.3.4 Server

In the first place, the server was not taken into consideration, because, as the title indicates, this work was devoted to the study of the structure only. It was planned to study the servers and the lifters in a separate work, but as a technical requirement for the proper functioning of our design, we have designed the server too.

Like the pallet, the server is formed of a steel frame with four wheels making it able move along the central row. Frame is formed with rectangular tube of 100 × 80mm section, same used on pallet.

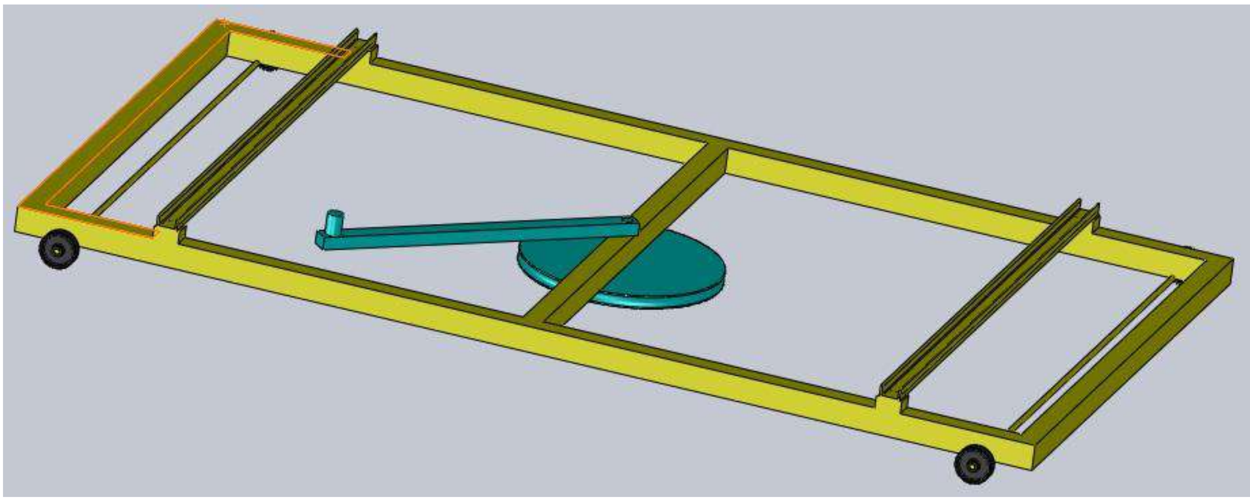


Figure IV-9 : *Server – the assembly*

Figure IV-10 shows the server when placed on the beams.

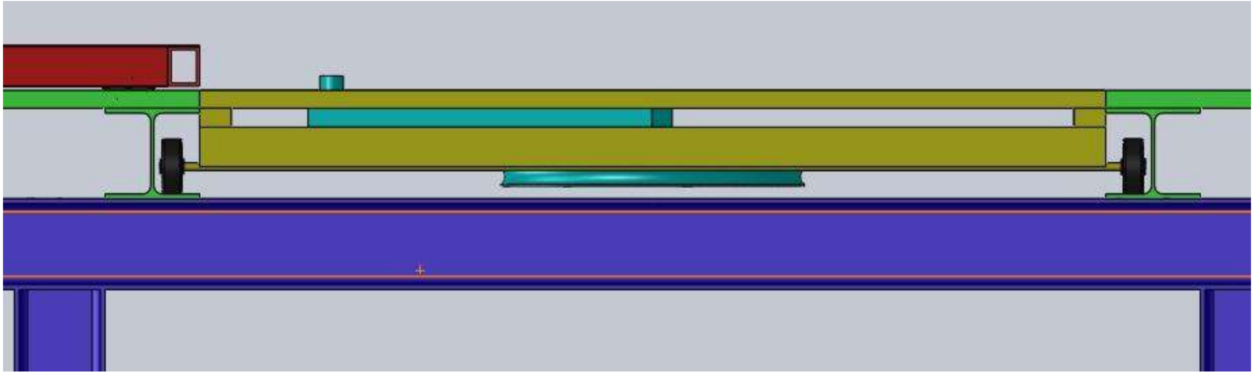


Figure IV-10 : *Server position relative to other elements of the structure*

IV.4 Parts resistance analysis

Three common structural steel grades used in all manner of construction projects across many countries are S235, S275 and S355. When analyzing the parts, we have assigned the S275N steel as chosen material. Its mechanical properties are shown in the Material selection window (see figure IV-11).

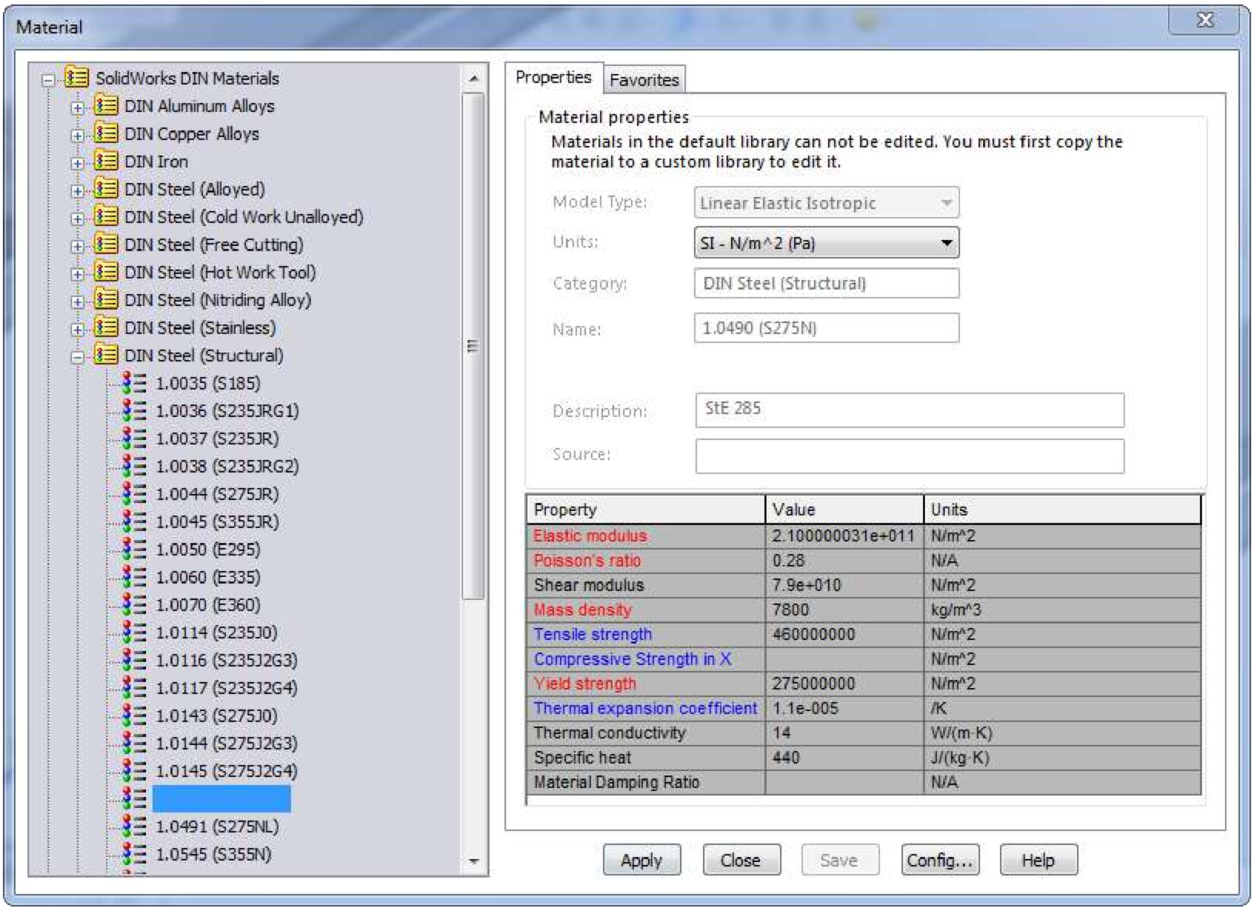


Figure IV-11 : *Material selection windows showing S275N steel properties*

IV.4.1 Pallet

As said on section IV.3.1, simulation has led as to change from 40 × 40mm steel angle (chosen at first time for the frame), by a rectangular tube 80 × 50mm. Another technical problem leads us to choose 100 × 80mm rectangular tube to ensure proper operation of the pallet.

Knowing that the maximum load is up to 3000 kg, this load will be supported by two longitudinal beams of rectangular tubes. Each one of these two beams will support half of the charge, thus, the beams will be fixed at two points corresponding to the wheels locations, and then a load of 15000N is applied on the top face.

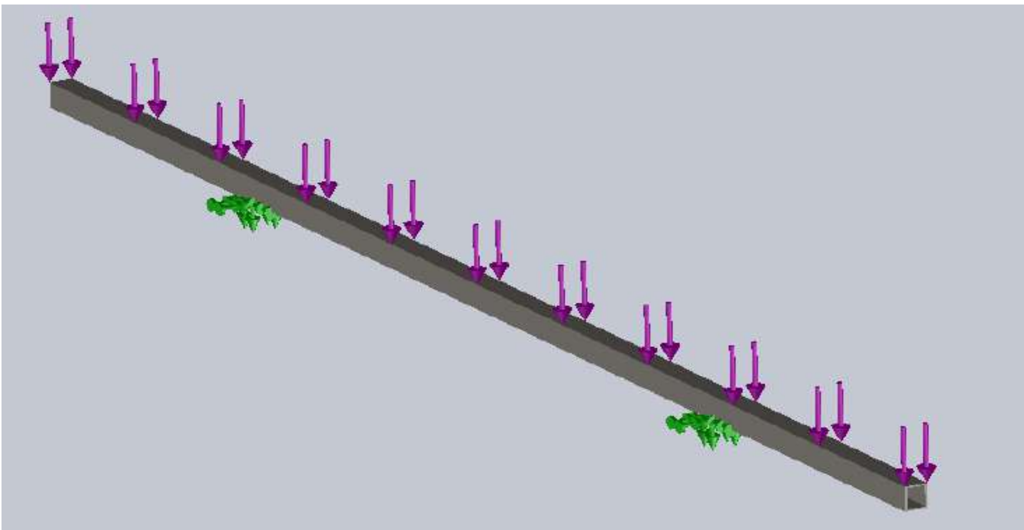


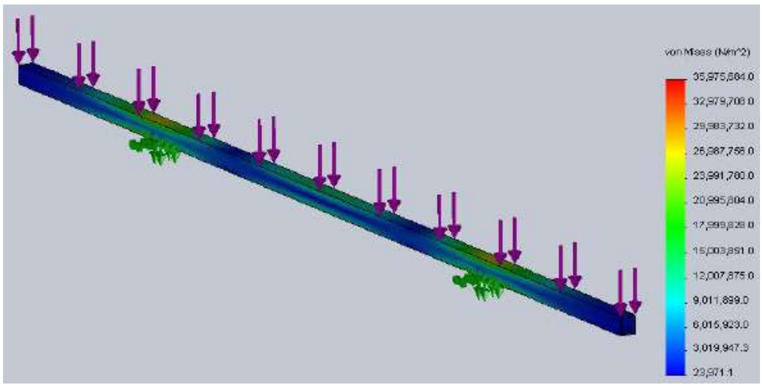
Figure IV-12: *Rectangular tubes fixed and loaded*

Table IV-1 is a summary of the analysis results. Stress, strain and displacement are presented on figure IV-13.

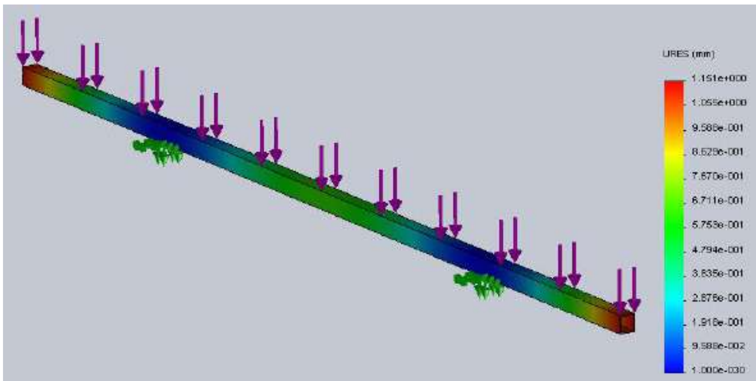
Table IV-1 : *Results of rectangular tubes analysis*

Type	Min	Location (mm)	Max	Location (mm)
Stress (N/m²)	3971.100	(29, 51,0)	3.597×10^{7}	(105.66,71.49,4118.18)
Displacement (mm)	0	(105,71,1200)	1.150	(65,27,0)
Strain	3.880×10^{-8}	(103,62,9)	1.49178×10^{-4}	(97,69,189)

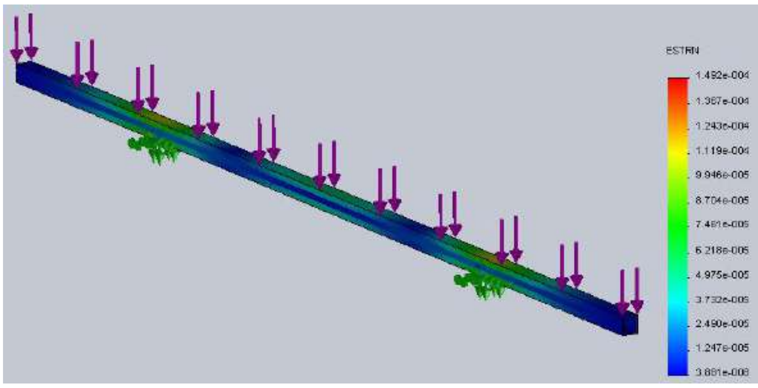
It is clear that the maximum value of the internal stress and equivalent to 3.6×10^{7}; this value is very less than 275×10^{6}. It means that the pallet will withstand the applied forces. In addition, the maximum displacement is about 1.2 mm; it is very small and will not have any problem when moving the pallet.



Stress



Displacement



Strain

Figure IV-13 : *Results of rectangular tubes analysis*

IV.4.2 Beams

Similar to the beams of the pallet, the HEA 240 beams are subjected to bending forces, they are supported at their ends by the columns welded assemblies, and receive loads representing the weight of the pallet in addition to the weight of the vehicle, all concentrated in four places representing the points of contact between the wheels of the pallet and the UPN80 beam.

According to the characteristics of the pallet assembly, the weight of this one is about 954kg added to 3000kg, the weight of the vehicle. To simulate this bending force, a load of 40000 N is applied on UPN80 beams as shown in figure VI-14.

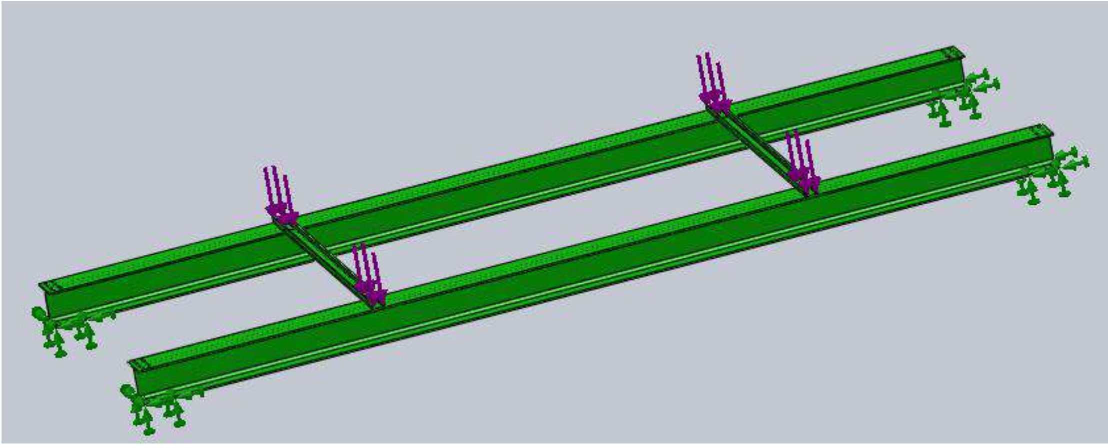
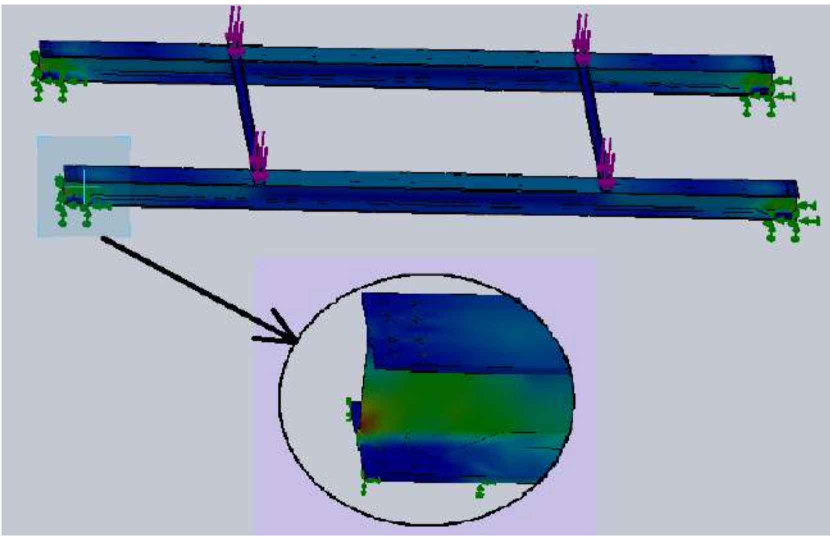


Figure IV-14: *Beams fixed and loaded*

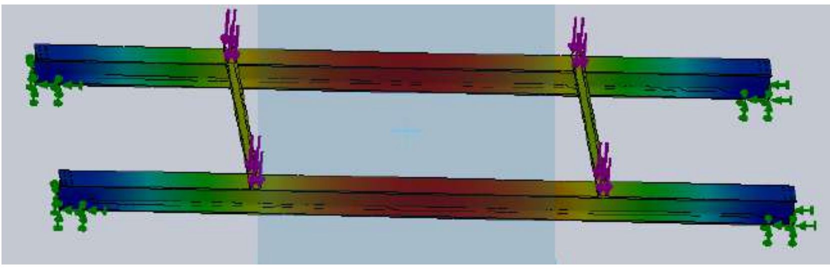
Table IV-2 : *Results of beams analysis*

Type	Min	Location (mm)	Max	Location (mm)
Stress (N/m²)	4846.41	(0,1,33)	7.37×10^{7}	(1843,33,0)
Displacement (mm)	0	(0,0,200)	1.26	(190,10,3000)
Strain	1.52×10^{-8}	(231,8,48)	0.0002	(1839,62,5989)

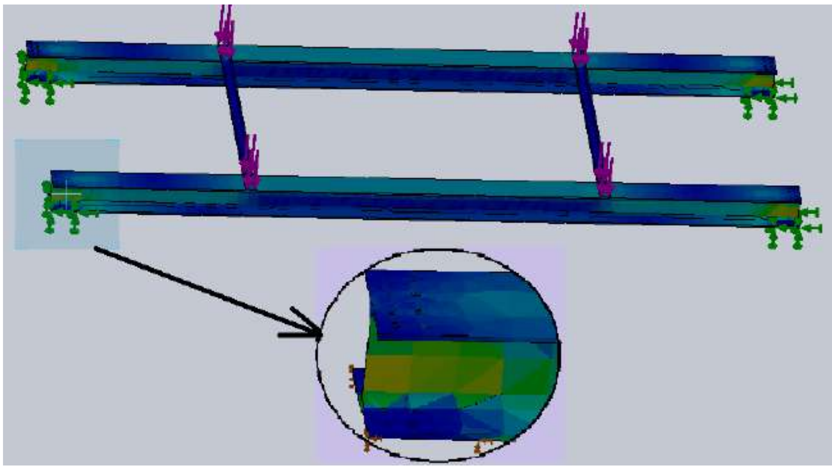
Results in this table shows that maximum stress is very less than the elastic limit, only 73.7 MPa comparing to 275 MPa steel's elastic limit. A maximum displacement is recorded at middle of the beams and does not exceed 1.26 mm which is acceptable considering to the beam length.



Stress



Displacement



Strain

Figure IV-15 : *Results of beams analysis*

IV.4.3 Welded columns assembly

For the resistance analysis of the welded columns, these are recessed at the base. The forces exerted on these elements are of the compression type. The lowest element, i.e. on the ground level, must support the load equivalent to four levels including the weight of the structure that adds to the weight of the vehicles stored.

Knowing that the weights of the different parts of the conception structure are:

- 954kg for the pallet.
- 762kg for the beams.
- 1026kg for the columns.

A vertical load of 41 tons is concentrated in 4 places (over 10 tons on each point), those are the points of contact between the beams and the welded columns assembly.

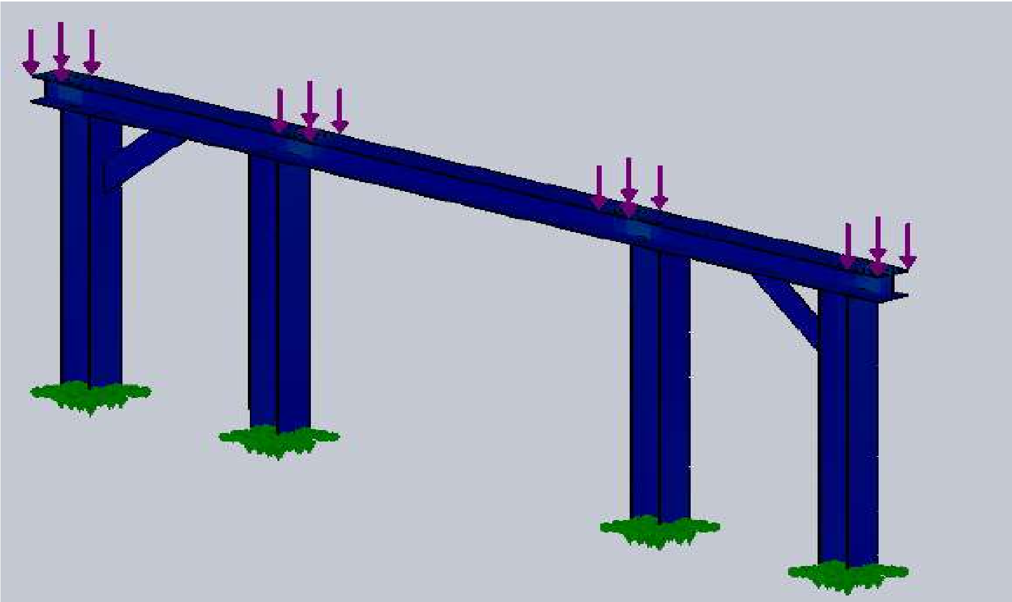


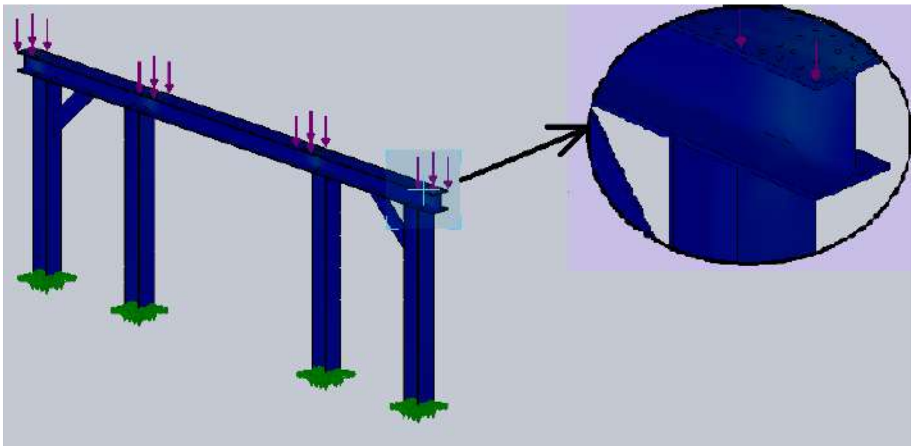
Figure IV-16 : *Columns fixed and loaded*

A recap of the results of the analysis is shown in the following table:

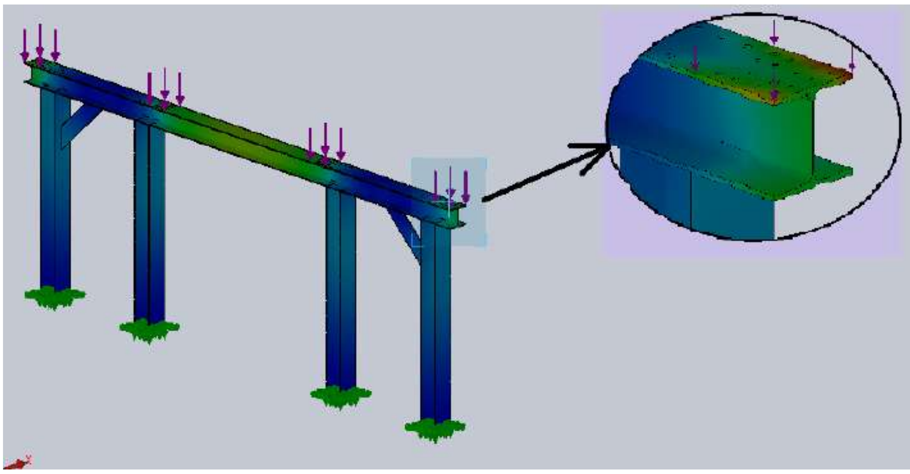
Table IV-3 : *Results of columns analysis*

Type	Min	Location	Max	Location
Stress (N/m²)	4021.64	(56,2635,4882)	19.6×10^{7}	(87,0,208)
Displacement (mm)	0	(50,2640,6420)	0.93	(240,0,0)
Strain	1.4×10^{-8}	(32,2635,1816)	0.003	(141,0,6521)

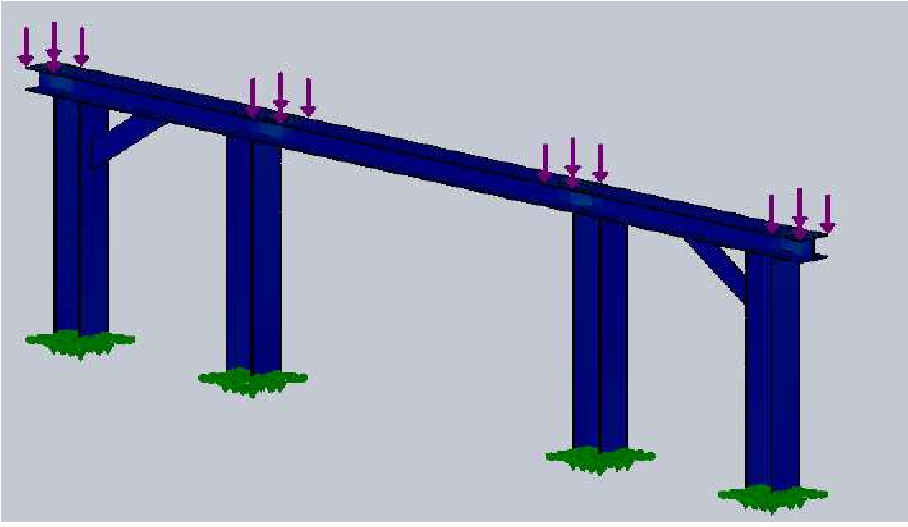
We can see that the maximum stress has not reached the rupture limit, in addition, the maximum displacement recorded is of a very small value; so; we can say that the structure is rigid and will support the weight of the structure as well as the load of the vehicles stored.



Strain



Strain



Strain

Figure IV-17: *Results of columns analysis*

Conclusion

More and more people are living in highly urbanized regions and have the desire and the means to improve their standard of living; they adapt a lifestyle of mobility and always want to drive automobiles. This leads to parking places becoming more and more a scarce commodity, and make finding a parking place a real challenge in densely populated cities.

Nowadays, Parking structures are found all over the world. The need for such facilities is that a car is usually kept parked somewhere for 22.5 hours because a driver spends about 90 minutes a day in the car at an average.

A parking lot needs fairly large space, around 25 m² per parking spot. This means that lots usually need more land area, a problem than have been reduced by adapting multi-story parking, but there is always the need of larger surface per parking spot because of the allowance needed to be made for driving the car into the parking, driving lanes and ramps.

After multi-story parking, making it possible to park more vehicles in a given volume is became possible by the development of Automated Parking Systems where a mechanical conveyor system takes care of the transportation of the vehicle from the entrance of the parking facility to the parking place and back.

Advantages of automated parking systems are that it reduced parking search traffic and thus saves time that would be consumed in searching for parking space. It also reduces the chances of theft or damage. The automated parking also shows environmental friendliness since engine is turned off.

In Algeria, According to the national statistics office; the number of registered vehicles was over 5.8 million vehicles in 2016, 62% are touristic cars. Moreover 44 % of these touristic vehicles are registered in only 5 among 48 provinces what explains the important traffic jam in these provinces and also the difficulty finding a place to park.

Unfortunately, there are only few multi-story parking garage in the whole Algerian territory installed in the last years in addition to the conventional parking surfaces, no automated parking were installed till now even with their notable advantages.

By this work, we wanted to contribute to the resolution of these problems by a study and conception of an automated parking. Our conception is based on structural steel construction formed mainly from two parts: vertical element of four columns welded to a transversal beam and, horizontal beams to support the vehicles weight.

These two main parts of the structure fabricated at workshops and then transported to the site of the construction to be bolted together; by this way, the structure will be easily constructed.

By this configuration, the park dimensions and capacity can change according to the available land, we have imposed only one limitation; the number of level can not exceed five. This car park is able to take in any vehicle having dimensions less than the maximum ones authorized, namely: 5 m long, 2 m high and 2 m wide. As for weight, it must not exceed 3 tons.

To benefit from the services of this automated parking, a driver will park his car on a pallet in a reception area and then leave it and let the rest to automation. The system will take the car (the pallet) to a lifter to be guided to one of five levels including ground level (according to spaces availability), then a server will transport the car from lifting area to one of the empty cells in the reached level. This server is able to move in a central row between two rows of parking spaces.

When the owner wants to retrieve his car, the server will take the car to another lifter from where it will be guided back to an expedition area.

We would like to say that this study allowed us to see the interest of parametric design; we have made several changes in our first design before arriving at this final design and that by spending time only.

It was planned to study the structure only at the beginning of this work, but it had turned out that the server design was necessary to ensure the proper functioning of the parking. In addition to structure study, the design of elevators and retrieving system from the reception zone and to the expedition area, as well as the study of the control system with all its sensors and actuators, are necessary to finish this park study.

This is why we recommend other works to get involved in all this sections to have at the end a full study of an APS project, including an economic study and a feasibility study.

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Appendix

A. Dimensions and weight of some of the most existing car models in Algeria

Vehicle mark	Type of car	length (m)	Width (m)	Height (m)	Unloaded weight (kg)
Hyundai	Accent	4,2	1,67	1,405	1 105
	Atos	3,565	1,525	1,57	884
	i10	3,665	1,66	1,5	933
	Trajet	4,695	1,84	1,76	1 857
	Tucson	4,475	1,85	1,65	1 540
	Grand i10	3,765	1,66	1,505	855
	Accent RB	4,37	1,7	1,45	1165
	Creta	4,27	1,78	1,665	1165
	H-1	5,125	1,92	1,925	1 974
Toyota	Yaris	3,945	1,695	1,51	1 045
	RAV 4	4,57	1,845	1,66	1 605
	Corolla Verso	4,37	1,177	1,625	1 535
	Hi Lux Pick-Up	5,255	1,76	1,795	1 710
	Land Cruiser SW	4,95	1,97	1,91	2 510
	Corolla Break	4,41	1,71	1,5	1 330
	Auris 90	4,33	1,76	1,46	1 200
	Avensis SW	4,78	1,81	1,48	1 520
Peugeot	206+	3,872	1,664	1,446	933
	407	4,691	1,811	1,447	1 441
	207	4,045	1,72	1,47	1 204
	Partner	4,38	1,81	1,801	1 310
	307	4,218	1,757	1,51	1 158
	306	4,03	1,69	1,37	680
	406	4,598	1,765	1,412	1 310
	308	4,25	1,86	1,46	1 080
	205	3,71	1,57	1,38	830
	208	3,962	1,829	1,46	1 050
Renault	Mégane	4,235	2,037	1,471	1 215
	Espace	4,656	1,86	1,728	1 901
	Kangoo	4,282	1,829	1,839	1 320
	Clio Campus	3,818	1,94	1,417	920
	Captur	4,122	1,778	1,566	1 190
	Kadjar	4,449	1,836	1,598	1 536
	Express Fourgon	4,006	1,6	1,77	1 060
Dacia	Logan	4,346	1,733	1,447	998
	Sandero	4,057	1,733	1,523	941
	Duster	4,316	1,822	1,63	1 205
	Sandero Société	4,02	1,746	1,534	1 105
	Dokker	4,363	1,751	1,814	1 205

Vehicle mark	Type of car	length (m)	Width (m)	Height (m)	Unloaded weight (kg)
Kia	Picanto	3,595	1,595	1,48	855
	Sportage	4,44	1,855	1,635	1 415
	Venga	4,068	1,765	1,6	1 270
	Pride	3,565	1,605	1,46	
	Sportage EX	4,48	1,855	1,645	1794
	Carnival	4,81	1,985	1,76	2 093
Volkswagen	Tiguan	4,426	1,809	1,703	1 501
	Cross Polo	3,972	1,682	1,462	975
	Golf	4,276	1,799	1,436	1 401
	Scirocco	4,26	1,81	1,41	1 205
	Touareg	4,801	1,94	1,709	2 185
	Caddy	4,408	1,793	1,822	1 654
	Golf Sportsvan	4,34	1,81	1,58	1 319
	Passat	4,769	1,82	1,47	1 532
	Amarok D/Cabine	5,254	1,954	1,834	1 951
Nissan	Patrol	4,475	1,94	1,84	2 220
	Micra Visia	3,78	1,665	1,525	900
	Pixo	3,565	1,6	1,47	855
	Navara	5,296	1,85	1,795	1 960
Citroen	Evasion	4,454	1,818	1,714	1 595
	Nemo	3,864	1,716	1,721	1 090
	C-Elysée	4,42	1,74	1,46	980
	C5	4,779	1,86	1,458	1 506
	C15	3,995	1,636	1,8	945
	C8	4,727	1,854	1,752	1 770
Ford	Ranger D/Cabine	5,359	1,85	1,821	2 205
	Edge	4,808	1,928	1,692	2 038
	B-Max	4,077	1,751	1,604	1 275
	Scorpio	4,847	1,875	1,402	1 639
	C-Max	4,38	1,858	1,626	1 390
	Fiesta	3,969	1,722	1,495	1 051
	Focus	4,36	1,858	1,469	1 338
Suzuki	Alto	3,5	1,6	1,47	855
	Swift	3,85	1,695	1,51	945
	Celerio	3,6	1,6	1,54	805
	Baleno	4	1,75	1,47	905
	Splash	3,72	1,68	1,59	975
	Jimny	3,695	1,6	1,705	1 060
Land Rover	Evoque	4,365	1,9	1,635	1 640
	Evoque coupe	4,37	1,98	1,61	1 825
	Range Rover Sport	4,85	1,983	1,78	2 184
	Discovery	4,97	2	1,848	2 230

Vehicle mark	Type of car	length (m)	Width (m)	Height (m)	Unloaded weight (kg)
Mercedes	Classe M	4,804	1,926	1,796	2 130
	Classe CLK Coupé	4,638	1,74	1,413	1 660
	Classe SLK SLK 200K	4,103	1,777	1,296	1 390
	Classe GLC	4,656	1,89	1,644	1 735
	Classe CL CL 500	5,065	1,871	1,418	2 045
	Classe R	5,157	1,922	1,674	2 380
BMW	X1	4,439	1,821	1,598	1 425
	Série 7	5,039	1,902	1,491	1 900
	Série 1	4,227	1,751	1,43	1 310
	Série 5	4,907	1,86	1,464	1 880
	M3	4,671	1,877	1,424	1 520
	X5	4,886	1,938	1,762	2 040
Audi	Q5	4,629	1,898	1,655	1 755
	A1	3,973	1,74	1,416	1 090
	S1	3,975	1,74	1,417	1 315
	RSQ3	4,41	1,841	1,58	1 730
	Q3	4,388	1,831	1,608	1 605
	A6 Allroad Quattro	4,94	1,898	1,452	1 855
	Q7	5,052	1,968	1,741	1 995
Mazda	BT-50	5,075	1,805	1,745	1 725
	3	4,465	1,795	1,45	1 220
	Tribute	4,395	1,8	1,765	1 510
Honda	FR-V	4,285	1,81	1,61	1 573
	Civic	4,14	1,7	1,44	1 122
	Accord	4,75	1,84	1,44	1 432
	Logo	3,78	1,64	1,52	938
Mitsubishi	Carisma	4,475	1,71	1,405	1 280
	Pajero Long	4,9	1,875	1,87	2 310
	Outlander	4,655	1,8	1,68	1 385
Mini	Mini	3,723	1,683	1,407	1 090
	Countryman	4,1	1,79	1,56	1 340
Opel	Sintra	4,67	1,83	1,757	1 766
	Zafira	4,47	1,8	1,65	1 525
	Corsa	4,02	1,74	1,48	1 163
	Karl	3,675	1,595	1,485	939
	Omega	4,898	1,776	1,455	1 595
	Signum	4,651	2,036	1,466	1 530
Seat	Leon	4,263	1,816	1,459	1 213
	Exeo	4,66	1,77	1,43	1 410
	Toledo	4,48	1,71	1,46	1 175
	Ateca	4,363	1,841	1,601	1 359
	Ibiza	4,061	1,693	1,445	1 049
	Arona	4,138	1,78	1,543	1 187

Vehicle mark	Type of car	length (m)	Width (m)	Height (m)	Unloaded weight (kg)
Skoda	Fabia	3,992	1,732	1,467	1 055
	Octavia	4,67	1,814	1,461	1 225
	Superb	4,83	1,82	1,46	1 392
	Yeti	4,22	1,79	1,69	1 265
	Rapid	4,48	1,71	1,46	1 135
	Superb	4,833	1,817	1,462	1 392
Chevrolet	Malibu	4,87	1,86	1,47	1 595
	Cruze	4,6	1,8	1,48	1 300
	Aveo	3,92	1,68	1,51	1 030
	Trax	4,25	1,77	1,67	1 379
	Spark	3,64	1,6	1,52	939
	Epica	4,81	1,81	1,45	1 615
Subaru	Legacy	4,73	1,78	1,51	1 537
	Forester	4,6	1,8	1,74	1 540
	Outback	4,79	1,82	1,61	1 571
	B9 Tribeca	4,87	1,88	1,72	1 941
Daewoo	Lanos	4,07	1,68	1,43	1 005
	Evanda	4,77	1,82	1,44	1 445
	Matiz	3,5	1,5	1,49	776
	Kalos	3,88	1,67	1,5	960
Ssangyong	Kyron	4,66	1,88	1,76	1 965
	Tivoli Xlv	4,44	1,8	1,61	1 405
	Tivoli	4,2	1,8	1,6	1 497
	Rodius	5,13	1,92	1,85	2 115
MG	ZT	4,79	1,78	1,41	2 010
Lexus	RX	4,89	1,9	1,69	2 100
	GS	4,88	1,84	1,46	1 735
maximum		**5,35**	**2,037**	**1,925**	**2510**

B. Distribution of the national automobile park as of December 31, 2016

WILAYATE	SOURCE D'ENERGIE				TOTAL
	ESSENCE	%	GAZOIL	%	
Adrar	17 852	54,96	14 632	45,04	32 484
Chlef	75 485	58,68	53 157	41,32	128 642
Laghouat	17 721	59,33	12 150	40,67	29 871
Oum El Bouaghi	32 508	61,71	20 167	38,29	52 675
Batna	85 293	53,41	74 399	46,59	159 692
Bejaia	104 831	55,59	83 745	44,41	188 576
Biskra	48 954	60,20	32 367	39,80	81 321
Bechar	16 374	66,56	8 225	33,44	24 599
Blida	246 091	76,42	75 935	23,58	322 026
Bouira	71 225	73,03	26 298	26,97	97 523
Tamanrasset	12 720	59,72	8 580	40,28	21 300
Tebessa	52 249	65,02	28 113	34,98	80 362
Tlemcen	91 960	63,72	52 369	36,28	144 329
Tiaret	46 701	67,70	22 279	32,30	68 980
Tizi Ouzou	100 595	50,68	97 897	49,32	198 492
Alger	1 086 549	71,33	436 690	28,67	1 523 239
Djelfa	43 647	61,87	26 904	38,13	70 551
Jijel	50 892	66,33	25 830	33,67	76 722
Setif	90 347	59,55	61 372	40,45	151 719
Saida	35 103	68,45	16 182	31,55	51 285
Skikda	81 184	69,02	36 436	30,98	117 620
Sidi Bel Abbes	53 812	65,10	28 847	34,90	82 659
Annaba	142 857	76,63	43 571	23,37	186 428
Guelma	35 856	69,06	16 065	30,94	51 921
Contantine	153 995	70,60	64 121	29,40	218 116
Médéa	64 881	64,67	35 441	35,33	100 322
Mostaganem	68 704	65,93	35 496	34,07	104 200
M'sila	47 809	49,38	49 016	50,62	96 825
Mascara	56 494	65,60	29 626	34,40	86 120
Ouargla	47 065	54,93	38 618	45,07	85 683
Oran	189 132	62,82	111 926	37,18	301 058
El Bayadh	12 068	51,64	11 303	48,36	23 371
Illizi	3 313	41,42	4 686	58,58	7 999
Bordj Bou Arrerridj	58 085	60,57	37 815	39,43	95 900
Boumerdes	101 492	63,27	58 909	36,73	160 401
El Tarf	32 409	63,36	18 738	36,64	51 147
Tindouf	2 096	52,15	1 923	47,85	4 019
Tissemesilt	19 216	66,93	9 494	33,07	28 710
El Oued	35 626	72,16	13 742	27,84	49 368
Khenchela	25 932	63,86	14 677	36,14	40 609
Souk Ahras	18 478	62,25	11 205	37,75	29 683
Tipaza	96 859	73,16	35 532	26,84	132 391
Mila	48 038	66,03	24 710	33,97	72 748
Ain Defla	40 661	70,19	17 267	29,81	57 928
Naama	9 014	51,55	8 471	48,45	17 485
Ain Temouchent	29 975	67,86	14 194	32,14	44 169
Ghardaia	22 379	54,54	18 655	45,46	41 034
Relizane	28 861	62,38	17 405	37,62	46 266
TOTAL	3 853 388	66,00	1 985 180	34,00	5 838 568

Abstract

Nowadays, we find parking structures all over the world, the need for such facilities is that a car is usually kept parked for 22.5 hours because his owner spends about 90 minutes a day in his car at average.

In Automated Parking Systems, mechanical conveyor transports the vehicle from the entrance of the parking to the parking place and back, this helps to solve many problems. APS are ecologic since engine is turned off; they also reduce theft or damage probability as well as parking search traffic, and thus save time.

In our country, over 5.8 million vehicles was registered in 2016, 44 % of theme are registered in only 5 among 48 provinces resulting an important traffic jam in these provinces and also the difficulty finding a place to park. Even with their notable advantages no automated parking were installed till now to solve such problems, this is why we have choose to study and concept an automated parking system.

Our conception is based on structural steel construction formed mainly from two parts that we have analyzed for résistance. These two parts can be fabricated at workshops and then transported to the site of construction to be bolted together making the construction so easy. The park dimensions and capacity can change according to the available surface.

Key words: *Parking, Automation, Conception, 3D modeling.*

ملخص

في وقتنا الحاضر، نجد مواقف السيارات في جميع أنحاء العالم، والحاجة لمثل هذه المرافق تنبع من كون السيارة عادة ما يتم ركنها لمدة 22.5 ساعة لأن مالكها غالبا ما يمضي فيها حوالي 90 دقيقة فقط في اليوم.

في حالة مواقف السيارات الآلية، يتكفل ناقل ميكانيكي بنقل السيارة من مدخل الموقف إلى مكان ركنها وكذلك إعادتها، ومن المؤكد أن هذا يساعد على حل العديد من المشاكل. هذه المواقف صديقة للبيئة باعتبار أنه يتم إيقاف المحرك خلال عملية الركن؛ كما أنها تقلل من احتمال السرقة أو إصابة السيارات بأضرار بالإضافة إلى تقليل حركة المرور الناجمة عن عملية البحث المستمر عن أماكن لركن السيارات، وهو ما يعني توفيرا للوقت كذلك.

في بلدنا تم إحصاء أكثر من 5.8 مليون سيارة في عام 2016، 44% منها مسجلة في 5 ولايات من أصل 48 مما أدى إلى ازدحام مروري كبير في هذه الولايات، وبالتالي صعوبة في إيجاد أماكن لركن السيارة. حتى مع مزاياها المتعددة، لم يتم حتى الآن إنشاء أية مواقف سيارات آلية لحل مثل هذه المشاكل، وهذا هو السبب في كوننا أقدمنا على دراسة وتصميم نظام وقوف آلي للسيارات.

يعتمد تصميمنا على هيكل فولاذي يدخل في تركيبه بشكل أساسي فقط قطعتان قمنا بتصميمهما ودراسة مقاومتها للإجهادات. يمكن تصنيع هاتين القطعتين في ورش العمل ثم نقلهما إلى موقع البناء ليتم ربطهما معاً مما يجعل عملية البناء سهلة للغاية. أضف إلى ذلك أن أبعاد الموقف وقدرة استيعابه يمكن أن تتغير وفقًا للمساحة المتاحة للبناء.

الكلمات المفتاحية: موقف سيارات، نظم آلية، تصميم، نماذج ثلاثية الأبعاد.

Résumé

De nos jours, nous trouvons des structures de stationnement partout dans le monde, le besoin de telles installations est qu'une voiture est généralement garée pendant 22,5 heures parce que son propriétaire passe environ 90 minutes par jour dans sa voiture en moyenne.

Dans les systèmes de stationnement automatisés, un convoyeur mécanique transporte le véhicule de l'entrée du parking à l'espace de stationnement et vice versa, ce qui aide à résoudre de nombreux problèmes. Les APS sont écologiques puisque le moteur est éteint; ils réduisent également le vol ou la probabilité de dommages ainsi que le trafic de recherche de stationnement, et ainsi gagner du temps.

En 2016, notre pays a compté plus de 5,8 millions de véhicules, 44% d'eux sont immatriculés dans seulement 5 wilayas parmi 48, entraînant un embouteillage important dans ces wilayas ainsi qu'une difficulté pour trouver un endroit de stationnement. Même avec leurs avantages notables, aucun parking automatisé n'a été installé jusqu'à présent pour résoudre ces problèmes, c'est pourquoi nous avons choisi d'étudier et de concevoir un parking automatisé.

Notre conception est basée sur une construction métallique formée principalement de deux pièces que nous avons analysées à la résistance. Ces deux pièces peuvent être fabriquées dans des ateliers puis transportées sur le site de construction pour être boulonnées ensemble, ce qui rend la construction si facile. Les dimensions et la capacité du parc peuvent changer en fonction de la surface disponible.

Mots clés: *Parking, Automatisation, Conception, Modélisation 3D.*