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A Design Study of an Innovative Barrier System for Personal Parking Lots

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Abstract

The increase in the number of cars made it necessary to protect the parking areas. This research includes a literature review about commercially available barriers, which are arm barriers, rising bollards, chain barriers, automatic and manual private barriers from the point of common and side-by-side parking lots. Their advantages and disadvantages are evaluated. After the literature review work, a design requirements list for a car park protector, which includes important and strong properties of existing systems, are developed. The requirements list can provide a base for the design or the development of a new car parking protector.

1. INTRODUCTION

Temporarily parking areas usually called "parking lots" can be closed, open, shared or private types. It is necessary to protect parking lots in the heavy traffic locations with excessive number of vehicles. Many obstructive systems have been designed to protect these areas. They are called “barriers” and each different barrier has different properties. For example; according to the conditions of fast operation, high safety or only deterrence can come to the forefront. These properties can be further derived. Barrier grades can be made according to such properties or the areas of use. There are also personal or common parking area protecting barriers rather than check point barriers. Currently motorized personal barriers are not preferred in side by side parking lots. They are replaced by barriers designed for common areas. On the other hand, in the private parking lots, common area barriers and existing private barriers are considered. The design goal of common area barriers and existing private barriers and user expectations are among the topics of ineterest in the current work.

In authors home country, Turkey, vehicles are parked on road sides as well as barrier controlled parks like private or public parking areas. The barriers discussed in this study are systems developed for the areas requiring control, rather than the roadside parks. Controlled passage areas can be an enclosed car park, paid only highways, or a street closed to traffic in certain hours. On the other hand common parking areas are a public parking area for residents, community or institutions (Figure 1). In the later, the surroundings are generally closed, the entrance and exit is under control and it is suitable for parking of multiple vehicles. If parking entry is protected by a barrier or sign, this is called "restricted public parking area". Vehicles entering this parking lot must have the right to make entrance. Here the barrier prevents foreigners or other vehicles from entering the public parking area. Vehicles that pass through the barrier can be parked in a suitable area or private areas reserved for them. If the parking area is not reserved, this area is open for public use. Private parking spaces can also be found here.

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Figure 1. *An example public parking area and general layout.*

Some places within the residential and institutional parking area can be reserved for specific persons. These areas are called private or private parking areas. This area can be within a common parking space protected by a common park barrier. Also it can be on a street entrance without a barrier. Street-side parking spaces (side by side) of apartment buildings can be the example and they can be frequently occupied. On the other hand, private parking areas in a site car park can be protected by marking the car owners' apartment numbers. This protection is done only with visual stimuli and is open to occupation. If such parking areas are not protected by a barrier, those who are unaware of the rules or who do not see the signs can park their vehicles there.

All possible types of parking barriers for side by side parking lots, known as private parking lots, and the reasons of preference are examined. A literature survey was conducted and existing barrier products were examined. Thus, product characteristics of a system that best meets the needs have been determined. A great design specification of a barrier has been prepared considering the customer expectations. Excellent designs can be made based on the requirements and constraints contained in this specification. All the advantages and disadvantages are determined for each barrier types used in side by side parking lots. These findings are then used for "designing a new personal parking space barrier".

2.2. Parking stabilizer diversity

The first automatic barrier, Electric Transition Gate, was patented and started to be used by H. Gilette in 1880 (Fig. 2) [1]. In this period when motor vehicles have not yet become widespread, the purpose of the invention is to regulate the passage of pedestrian and horse carts at intersections of railways. At that time, the rarely seen motor vehicles increased rapidly with the development of the assembly line in 1913 by Henry Ford, and over time they replaced the horse carts. Increasing number of motor vehicles in the increasingly crowded cities, parking problems have emerged a century after the invention of the first barrier. These systems have been used to protect traffic from foreign vehicles and to regulate traffic, prevent the passage of horse carriages and pedestrians on the train route, although needs and conditions change over time.

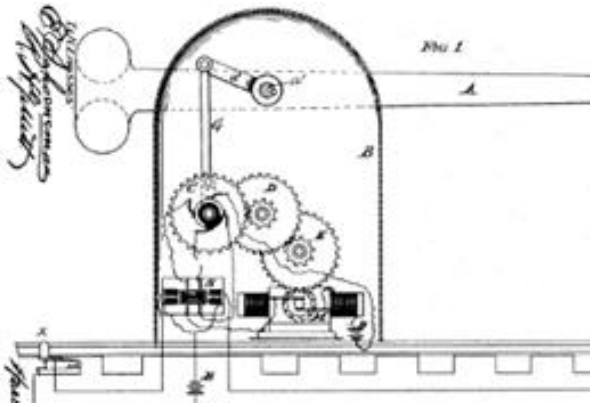

Figure 2. *The first patented barrier [1].*

Parking spaces may be allocated for use by a community or a person. Residential or working place car parks belong to a certain community. However, private parking may also be available in these common areas or in other private areas. In addition to an institution's main entry barrier, there may also be different barriers for special areas within this park area. That is, there are private parking spaces reserved for the managers and barriers to protect them. There are also many different types of barrier designs for different access control points and parking spaces. These designs to be discussed below are grouped under six headings and dicussed below.

2.1. Arm barrier

Arm barriers have a fast operation time with quite economical use. It is preferred in the site and institution enterances, parking spaces where the fast operation is required or economic solution is expected. The barrier arms are usually made of aluminum. An impact of a car crush or strangers can easily damage the aluminum arm and the drive mechanism connected to that arm. It is unprotected in this regard. It has more deterrent effect than the protective. People or animals can pass under the barrier arm (Figure 3).

Figure 3. *Automatic arm barrier [2].*

2.2. Rising bollards

Hydraulic, pneumatic and mechanical rising bollards are separated in three types. They are generally cylindrical shape (Figure 4) and used where high strength is needed. rising bollards have the ability to stop vehicles moving at high speeds. Some rising bollards have the strength and stability to continue their function even after the crash. Because they do not obstruct pedestrian access, it is preferred to use rising bollards in streets and streets that are closed by municipalities during busy hours. Installation is difficult. In addition, their costs are also high.

Figure 4. *Rising bollard [3].*

2.3. Chain barrier

It is a design developed to close wide open parking areas (Figure 5). It operates on the principle of closing the parking area by stretching a chain or a steel rope with a length of 30 meters by a motor at one end. Cost is high. It is preferred in wide parking lots parked side by side. If any vehicle parked on the chain line, the barrier will not close and the entire parking space will remain open. In this respect, it is important that the

vehicles enter the parking lot completely. For this reason, it is not used in park areas that are wide but half entered. It allows pedestrian and animal crossing. It has no serious protection. This chain breaks off when you drive over the chain. If the chain does not break, it removes the barrier from the ground where it is bound. Crossing over the chain can also be intentionally wrecking. For this reason, chain barriers are able to deteriorate quickly.

Figure 5. *Chain barrier [4].*

2.4. Automatic personal barrier

It is applied to the large parking lots infront of the apartments or private areas reserved for the individuals. There are two kinds of barriers. The first is electrically powered motorized barrier. The second is manual barrier that work with human power. The latter is relatively cheap. There is no burden on the electrical installation. Mechanical installation is also easy because it can be completed with a few bolts. Mostly they have a structure that can be assembled in places. On the other hand, when a vehicle approaches it is difficult to see. They have little resistance against the bracing or have the ability to come into open position to avoid damage to themselves and the car in case of impact. They are easily damaged by accidental or malicious crashing of vehicles. At the same time, there is little resistance to crushing or people to stand on barriers. When the vehicle is parked on the obstacle, if the obstacle avoidance operation starts, it may damage the parts under the vehicle (Fig. 6).

Figure 6. *Automatic personal barrier [5].*

2.5. Manual personal barrier

It is the cheapest model among all of the barrier types applied to private car parks. They do not have any electronic or electromechanical components. They are manufactured from bended and welded simple metal profiles (Figure 7). There is a mechanical lock on it. The owner, stop the vehicle, unlocks and push down the barrier than parks over the barrier. After exiting the car park, the owner brings the barrier to the locked position by hand. Because it is economical, it is the most preferred model among all other barrier types.

Figure 7. *Manuel personal barrier [6].*

3. DISCUSSIONS: EVALUATION OF CARPARK BARRIER TYPES

3.1. Automatic personal barriers

Such barriers are designed for private car parks and are used often. Motorized (automatic) parking barriers consist of; motor, gearbox and electronic control unit. It is controlled by a remote control device. It is powered by electricity and usually obtain its energy from sun panels on it. The barrier is not tall enough. The difficulty in recognizing from inside of the vehicle could cause accidents. It stays under the car so does not narrow the parking lot. If they are mounted in sequence, vehicles can be parked between the two barriers. These gaps are filled with fixed iron or plastic separators. These barriers stay under the vehicle in the open (unprotected) position. Parking is not possible till the barriers reache to the open position. The barrier height is ≤ 120 mm. This height allows to park without rubbing the lower part of a normal vehicle. However, it is imperative that the floor is completely flat and leveled with the road. If the parking lot floor is higher than the road level, the height of 120 mm may hit under the vehicle. This can result in frequent vehicle sump / exhaust and bumper damage. Again, involuntary work of automatic personal barriers in a similar manner may also cause some accidents. The barriers that are under the vehicle can operate accidentally or after a fault. So both the vehicle and the barrier can be damaged. According to the requirements and conditions, the manual and automatic parking blockers meet the same need with different methods and cost.

3.2. Manual personal barriers

Such inhibitors generally do not contain electronic / electromechanical components. Steel profiles and joints are combined into various shapes and transformed into moving mechanisms. The remote control is opened and closed manually. Locking is done with padlocks. When enterance needed to the parking place, the owner parks the car to a temporary place, get out and opens the lock on the barrier, brings the barrier to the horizontal position and parks the car on it. When leaving the parking space, the vehicle is removed from the parking space to a temporary place and locks the obstacle in the vertical position. Their use in crowded and heavy traffic street entrances can cause traffic accidents. They do not narrow the parking area. If used side by side, the gap between them should be filled with a fixed barrier (Fig. 8). They are 70 mm tall and can be parked on flat ground without rubbing under the vehicle. If the mounting floor is not aligned with the road, there may be accidents such as rubbing of the vehicle and bumpers. In the first accident the car can be damaged and also the barrier destroyed. For this reason, the level of the floor is very important for comfortable use.

Figure 8. *Fixed barrier types used between manual personal barriers.*

3.3. Chain barriers

Chain barriers are often used in side by side parks as they are suitable for covering large areas. The system consists of a motorized unit and a passive counterpart. The part where the motor is located has electronic components and gearbox. When the remote control signal reaches, the motor starts and the chain / steel rope in the tensioned state connected to the gear box loosens on the ground. Vehicles that pass through the chain enter the parking lot. After entering the parking lot and leaving the safety sensor line, the barrier motor runs in the reverse direction and stretches the chain to re-protect the parking lots. Parking width and vehicle length are quite important in installation of a chain barrier system. When the chain is spread on the ground, it is expected that whole of the vehicle on it to enter the parking lot to come back to the tensioned (closed) position again. When the vehicle is on the chain, the photocell safety system prevents the chain from being stretched therefore damaging itself and vehicle. The chain does not move to the tensioned position as long as the vehicle is between the safety sensor line. The entire parking lot remains unprotected while the chain is laid on the floor. So their use can cause problems in a narrow car park areas also with long vehicles. The system can be applied to the narrow car parks, but the entire chain barrier system will be ineffective with the first vehicle stays on the photocell line. These are limited to the perception distance of sensors. The required chain lifting force can be obtained by choosing suitable motor and gear combination for desired distance. Tensioned chain or steel rope accidentally break off (depending on impact strength and chain strength); barrier can be disassembled, serious vehicle damage can occur, and broken chain / steel rope can also harm people walking on the sidewalk. Some commercial chain barrier systems can cover 16 m [4]. In the case of special production this value can be up to 50 m (maximum photocell distance). Because of the large montage area, it causes a loss in park space.

3.4. Arm barriers

Arm barriers electric motor-driven systems operated by automatic switching systems (Figure 9) like remote control and so on. The incoming signal is transmitted to the electronic control board. This card activates the motor, the gear moves, the barrier arm goes up and the parking lot is opened. The weight of the barrier arms is balanced by a counter spring. The spring give opportunity to use the long aluminum arms and to close the wide areas. The standard model and the economic barriers are 6 m long, but can be applied up to 9 m wide areas in special conditions. The longer barrier arm causes an increase in operation time. The parking area ise narrowed by the wide barrier cabinet. In possible accidents, because the aluminum arm is weak, serious damage doesn not occure in the barrier or the vehicle. However, the leaning and bending barrier arms can be dangerous for the pedestrians. The accident costs for these vehicles or barriersa are given in Table 3. Arm barriers are operated automatically. When the remote control is used, the barrier arm goes up and vehicle enters / exits the car parking lot. They also have a photocell safety system. The car has not yet entered the car park entirely, the safety photocell prevents the arm from crashing. If it is too long or it can not be parked in the parking lot due to the shortness of the area and it is still in the photocell line, the barrier does not go down. Side-by-side parking shortness or parked vehicle lengths (vehicles not fitting in the park) are problematic for chain, arm barrier and rising bollard systems. These barriers should not be used in parking lots with this problem.

Figure 9. *A private parking place with an automatic arm barrier instead of a personal barrier.*

3.5. Rising Bollards

They are often used to prevent terrorist attacks, In military, consulates or other important institutional entrances which needs high sequrity. They have a blocking strength of a fast approaching truck loaded with bomb. The body is round shaped. The body above the ground is 50-100 cm. There is also an anchor embedded under the ground. The barrier is open (ie unprotected) and enters in the anchor completely, rises up again in the protection position. In the market; hydraulic, pneumatic and electromechanical rising bollards are available. They can also be used in side by side parking areas. They fully satisfy the expectations, because they are unbeatable, robust and long lasting. But their use in side by side parking lots could create some problems. All rising bollars use a common photocell security system. So if a vehicle parks between the photocell line, it restricts the operation of other bollards because this line is common. These barriers do not close and the car park becomes unprotected. The second problem is that bollards need anchors buried underground. If there is a cellar, a closed car park or a basement under the installation floor, the rising bollard can not be applied to those areas. Their costs are too high as well as transportation and installation. The number of pistons that a hydraulic system with a fixed piston can lift is limited. After this limit, either a second hydraulic system must be installed for each additional piston, or the engine or other associated pump capacity must be increased. These improvements increase the piston unit price. In a hydraulic system, the cost is inversely proportional to the number of pistons until the maximum number of pistons is reached. The unit cost decreases as the number of pistons increases. Unit price is fixed in electromechanical systems. The cost is directly proportional to the number of rising bollards and this is taken into account in the installation. Unit costs for electromechanical and hydraulic bollards are given in [7]. Besides quality, the product should be economical as well. The economy here includes not only the price of installation, but also the duration of service and the ability to meet the needs of properly. The waiting time in the side-by-side parking lots is also very important. When entering the parks affected by heavy traffic, if the barrier does not open for a reasonable period of time (3 - 4 sec), this can cause trouble. Possible traffic accidents may occur during this time.

3.6. General evaluation of parking barriers

A general evaluation and comaprison of the parking barriers is given in Table 3. While examining the current 7 trademark products; cost, duration of operation, light and heavy accident damage for vehicle / barrier, maximum length / per vehicle ratio, cost per vehicle are all considered. As a result, it has been understood that the cheapest product would be the "personal barrier without motor - brand 3" and the most expensive is "hydraulic barrier - brand 7". The operation period was seen to be "professional 3 and 4 m - brand 6" for the shortest (fast) barrier and "personal barriers" for the longest (slow). Because they are manual, the duration of these barriers depend on people. Depending on the vehicle speed, possible accidents lead to minor / major damage (multiplier / multiplier). The chart shows that a vehicle traveling at a speed of $\leq$ 10 km / h causes light accident and a heavy accident is caused at $\geq$ 10 km / h. A score between 0 and 10 is given according to the vehicle and barrier damage costs incurred during light incidents. Here, 0 (zero) indicates no damage and 10 (ten) indicates the highest damage. In light accidents, "personal and chain

barriers" cause the least damage to the vehicles, and rising bollards the most damage. "Chain, motorized personal and rising bollards" are not damaged at all in light accidents. In a mild accident, the chain absorbs the impact of accident by oscillating. Motorized personal barrier unlocks itself during strain. The rising bollards are not damaged because they are very sturdy. In severe accidents, they minimally damages the vehicles, personal and armless barriers (up to 4 m) with or without motor. The rising bollards are very the most dangerous in terms of damage caused to the crashing vehicle and do not suffer any damage (even during heavy casualties). All personal barriers become completely destroyed as they are weak. The maximum length is the maximum distance that a barrier can close in side by side parking lots. If a standard parking width is assumed to be 2500 mm, the maximum length of each barrier is divided by this value to obtain the length / number of vehicles ratio. The cost per unit cost is calculated by the ratio of cost / length to the number of vehicles. For example; The 16 m chain barrier can close a parking lot with 6.4 vehicles side by side parked with a width of 2500 mm. (Table 3). It is observed that the cheapest product "motorless personal barrier - brand 4", and the most expensive one is "hydraulic rising bollard - brand 7" at cost per vehicle.

4. CONCLUSIONS AND FURTHER WORK

In this paper, all barrier systems used in side by side parking lots have been examined. The goal is to design a product that best meets customer needs. Table 1 gives the advantages and disadvantages of the barriers used in parking lots. Non-motorized personal barriers are more preferred than others because they are economical. Manual work system causes difficulties in use. However, motorized barriers are used more easily. If they are 50-60 cm long, it is difficult to be recognized. Almost all personal barriers can damage the bottom of the car on sloping floors. The open space between the two barriers must be closed. Chain barriers can cover very large areas. Unit costs are reasonable. Army barriers can be applied to every floor and can lock the park exclusively. Rising bollards are safe and robust, but they are not preferred because they are expensive. They also go under the ground, they can not be installed on the floors with downstairs. The common disadvantage of chain, arm and bollard barriers is that there is only one safety sensor in the whole system. If the sensor is activated by a vehicle, the system will not operate (the barrier remains open). So, if the car does not pass the whole parking lot, barrier will stay open. For this reason, these three systems are not suitable for narrow car parks or large vehicles.

The further work aiming for a newly designed barrier should be operated with solar energy and should be used for 30 days with single charge. The cost of production should be reasonable. Therefore; installation, storage and transport should be easy and maintenance cost should be low. The number of parts should be small. It should have all the general advantages of all barriers and be free from their disadvantages. Under normal conditions, it should be able to work at least 20 times a day. Each parking lot should be independent. Neighbours should not interfere each others park areas. In the light of all these studies, a list of requirements for the most appropriate and innovative personal parking barrier design has been prepared and given in Table 2.

Table 1. *Advantages and disadvantages of the barriers used in side-by-side vehicles.*

Barrier Type	Advantages	Disadvantages
Automatic Personal	Can work with solar energy	Needs flat ground (can not be applied on bumpy ground)
	Do not narrow down the parking lot	It can be harmful if it works while under the vehicle
	Special parking area can be closed	Additional barrier between two barrier is required
	Automatic	It is difficult to notice during automatic parking
		Insufficient strength
Manual Personal	Economic	Needs flat ground (can not be applied on bumpy ground)
	Does not narrow park area	Problem to use near streets with heavy traffic
	Can close park area personally	Additional barrier between two barrier is required
		Hard to use because it is manual
		Insufficient strength
Chain	Can close wide areas	Common sensor problem
	Semi- economic	Not suitable for long vehicles or short park areas
	Automatic	Case takes up too much space.
	Can be applied to any ground	Can not close park area personally
Arm	Can close park area personally	Common sensor problem
	Can be applied to any ground	Not suitable for long vehicles or short park areas
		Case takes up too much space.
		Can not close park area personally
Rising Bollard	High strength	Common sensor problem
	Secure	Not suitable for long vehicles or short park areas
	Takes up no additional space	Costs too much
		Can not be applied areas with downstairs
		Additional barrier between two barrier is required

Table 2. *A requirements list of the newly designed personal parking blockers (design specification) – [8].*

No.	Desired features / Requirements (Desire (A) or Requests)
1	They should be able to work with renewable energy and not need 30 days of additional charge.
2	It must be reasonable and economical. The cost of production should be less than € 100.
3	Small storage volume should be (100 products / m3).
4	Weight should be low (5 kg / piece).
5	Can be installed in short time (1 hour / piece).
6	Maintenance costs must be low.
7	The estimated number of faults must be low.
8	Each parking area should be closed privately. Should not narrow the parking lot and make it unusable.
9	It must be able to be operated from the vehicle and remotely (by command).
10	Should be applied on inclined ground.
11	It must have high strength.
12	The barrier should not work randomly while the vehicle is parked, if so should not harm the vehicle or itself.
13	The area must be adequately protected and foreign entry must be prevented.
14	It must be easy to see whether the barrier is open during parking.
15	It should not be affected by impacts / accidents up to a maximum speed of 10 km / h during parking.
16	Car park with inclined ground should not damage the car during entry.
17	It should not use a common sensor for all barriers.
18	They should not be affected by the work of other barriers and should not harm their operation.
19	The system must be suitable for outdoor operation and should not be affected by weather / climate changes.
20	It must be able to operate at temperatures between -20 and +60 ° C.
21	The barrier must be open in 4 seconds maximum. It should be able to work at least 20 times a day.

4.1. The similar product designs

While determining the design specfications of the new design barrier, it is also important to look closer to the similar products. To reach a better solution, substitute products should be studied as well. In the market there a few designs exist. A world wide internet search made to find them. Most frequently available products were determined. Of course there should be more designs, but they were not reachable. The common point of how they protect the parking lot is by rising up about 50cm high from ground. When the user's vehicle arrives, they lie under the vehicle and allows the entrance (Figure 10). They have some identic features like to have a DC motor, a remote control and a fragile structure.

Figure 10. *Similar personal parking space protectors [9]*

As we discussed, there area some disadvantages. The gap from one barrier to another is usually large enough to park between them. Therefore a stationary barrier must be installed between each barriers. A small change in outer design solves the problem. Long design of the barrier closes the gap (Figure 11).

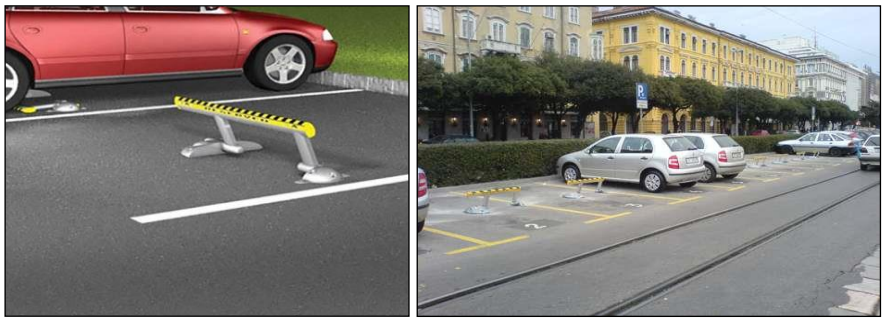

Figure 11. *Innovative large design to reduce the gap between two barriers [10]*

One other problem is the weakness of the structure. Mostly the barriers are broken at the first crush. They are weak against the vehicles. It is very important to solve that problem, too. There are more crush-resistant products. They aimed at increasing the strength of the barrier. The mechanism was redesigned by changing the movement direction from rotational to linear (Figure 12).

Figure 12. *A sample to a stronger barrier mechanism by linear movement [11]*

Table 3. *The evaluation of barrier types used in side-by-side parking spaces.*

Barrier Type	Brand	Cost	Oper.	Light	Light	Heavy	Heavy	Max.	Legth	Cost
Manual personal	4	16	<10	1	6	3	10	0,5	1	€ 16
Manual personal	3	38	<10	1	6	3	10	0,5	1	€ 38
Manual personal	2	260	4,5	1	6	3	10	0,5	1	€ 260
Manual personal	1	275	4	1	0	3	10	0,5	1	€ 275
Chain	5	2700	10	1	0	4	6	16	6,4	€ 422
Ekonomik 5 meters	6	940	8	3	4	4	5	5	2	€ 470
Orta sınıf 6 meters	5	1185	4	3	4	4	5	6	2,4	€ 494
Semi-prof. 5 meters	6	1040	4	3	4	4	5	5	2	€ 520
Semi-prof. 7 meters	6	1500	5	4	4	5	5	7	2,8	€ 536
Economic 4 meters	6	930	4	2	4	3	5	4	1,6	€ 581
Semi-prof. 5 meters	5	1200	3,5	3	4	4	5	5	2	€ 600
Semi-prof. 6 meters	6	1450	5	3	4	4	5	6	2,4	€ 604
Semi-prof. 4 meters	5	1030	4	2	4	3	5	4	1,6	€ 644
Proffessional 7 meters	5	1875	6	4	4	5	5	7	2,8	€ 670
Proffessional 9 meters	6	2575	6	4	4	5	5	9	3,6	€ 715
Semi-prof. 4 meters	6	1150	3,5	2	4	3	5	4	1,6	€ 719
Proffessional 6 meters	6	1825	3	3	4	4	5	6	2,4	€ 760
Economic 3 meters	6	920	4	2	4	3	5	3	1,2	€ 767
Proffessional 8 meters	5	2465	6	4	4	5	5	8	3,2	€ 770
Proffessional 8 meters	5	2535	6	4	4	5	5	8	3,2	€ 792
Semi-prof. 3 meters	5	1010	4	2	4	3	5	3	1,2	€ 842
Proffessional 5 meters	5	1750	3	3	4	4	5	5	2	€ 875
Semi-prof. 3 meters	6	1060	4	2	4	3	5	3	1,2	€ 883
Proffessional 4 meters	6	1700	1,5	2	4	3	5	4	1,6	€ 1.063
Proffessional 3 meters	6	1550	1,5	2	4	3	5	3	1,2	€ 1.292
Electromechanical	5	3015	9	7	0	10	0	0,6	1	€ 3.015
Hydraulic	7	3750	6	7	0	10	0	0,6	1	€ 3.750

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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