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Contents

Modelling of the Movement of Designed Vehicles on Parking Space for Designing Parking

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Abstract. Nowadays, in all cities there is an acute problem of lack of parking spaces. The vehicles are becoming more and more not only in megacities, but also in small cities of the country, and there are no more parking places - the pace of solving the problem is several times slower than the speed of transport growth among the citizens. The article is dedicated to determination of the optimum sizes parking place for designing vehicles on parking space which is an element of the roads. On example of the passenger cars and trucks are determined optimum amount parking place. The results of research on the dimensioning of parking spaces, recommendations to use of the results for the design of objects of transportation infrastructure.

Keywords: Passenger car · Truck · Auto train · Trajectory · Parking space ·
Design vehicle · Software AutoTURN · Turning radius of vehicles

1 Introduction

Trends in the size of cars in traffic flow, an acute shortage of parking space requires a more careful attitude to the design of the size of parking place and parking space [1–4]. Unfortunately, the design of parking does not take into account the composition of the traffic flow that takes shape on a specific road, transport infrastructure object (requirements are obvious here, in the USA where the size of cars is larger than in Europe, the size of parking space is larger), the duration of parking is not taken into account short-term parking near shops, banks, etc., requires more space for maneuvering upon arrival and departure from the parking space than during long-term parking) [5–9]. The most acute problem manifested itself when a ban was imposed on the transit movement of vehicles weighing more than 12 tons in the daytime along the Moscow Ring Road

(Resolution of the Mayor of Moscow dated November 15, 2012 No. 650-PP "On Amendments to Legal Acts of the Government of Moscow" [10]). According to the Moscow mayor's office, more than 150 thousand trucks with a maximum weight of more than 3.5 tons are moving through the city streets during the daytime. About 40 thousand trucks arriving daily from the regions.

At the Moscow Ring Road, large trucks make up 30% of the flow, half of which are transit and do not serve the needs of the capital [11]. At this time, there was no experience in designing parking place for cars arriving in Moscow or following in transit.

In the domestic regulatory and procedural documents, the dimensions of parking spaces for road infrastructure facilities are defined in the Methodological Recommendations of the SRC MDRS MIA [12], IRM 218.4.005-20101 и SS P 52289-20042. The dimensions in these documents were borrowed from the Handbook for Automobile Transportation and Traffic Management [13] published in the USSR in 1981, which, in turn, was a translation of the American Road Traffic Management Handbook of 1965 and the recommendations given in the third edition of the Transportation and Traffic Engineering Handbook [14].

Requirements for parking geometry in regulatory documents contain ambiguous, sometimes contradictory information that may adversely affect the level of road safety [15]. Thus, in the "Methodological recommendations on the design and equipment of highways to ensure traffic safety" [16], the turning radius of passenger cars is 8 m, and for truck is 9–12 m. When approximate calculation of the total area of coverage in parking place, including the area of maneuvering and parking, it is recommended to proceed from the average area per one passenger car of 25 m^2, on a truck –40 m^2. At the same time, in the album of typical projects "Cross-sectional profiles of highways passing through settlements" (TP503-0-47.86) 4, the average parking area for a truck should be 92.4 m^2, not 40 m^2, as stated in the methodological recommendations. The dimensions of the parking space given in the Regulations for the placement of multifunctional zones of road service on roads [17] take into account the size of modern cars, but this is not enough to develop a complete planning solution, since the parking maneuvers are not taken into account, and only the dimensions of the parking space are given. The passenger car and truck placement schemes used in the United States and the dimensions of parking spaces shown in Fig. 1 provide more complete information. The planning solution for placing parking spaces for trucks, which provides the simplest conditions for entering and leaving a parking space, recommended in the USA, is shown in Fig. 2. The sizes on the scheme presented on Fig. 3, correspond to a parking angle of 45°, while it is indicated that at angles of 30°, the width of the passages can be reduced to 6.0 m, and the width of each parking space - by 30 cm. For large trucks, the length of the longitudinal parking space must be at least 41 m, width by 5.2 m. The same values are specified in the regulations of the United Arab Emirates for large trucks on parking spaces [18].

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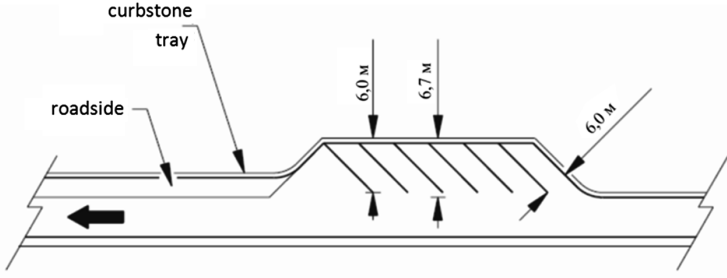
b.
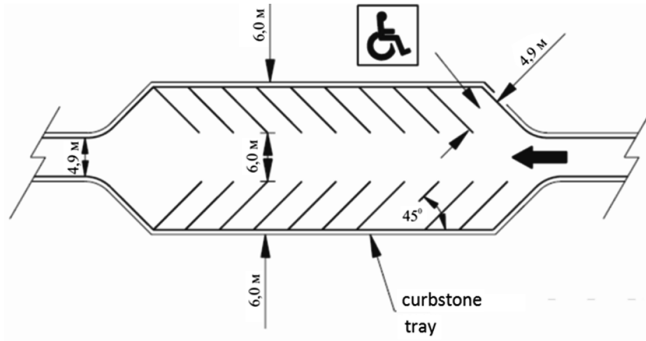
Fig. 1. Schemes of planning of parking spaces for passenger cars with one-sided (a) and two-sided (b) placement [own study]
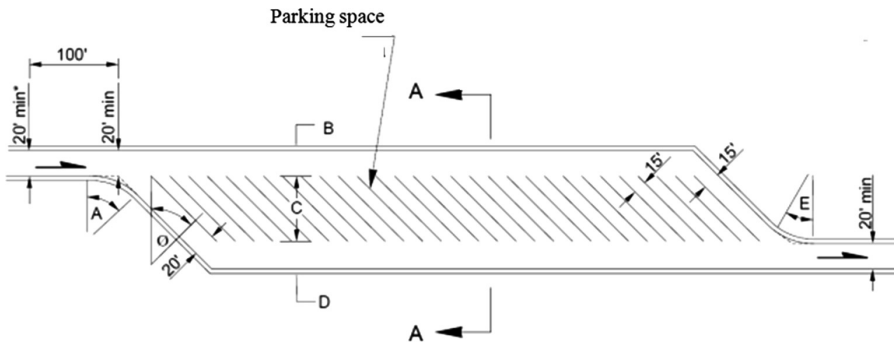
Fig. 2. The fundamental planning of the placement of parking spaces for trucks, recommended in the US: Ø [own study]

– 30–45°; A – 25,9–30,5 м; B – 9,1–13,7 м; C – 15,2–18,8 м; D – 9,1–13,7 м; E – 30,5–35,0 м.
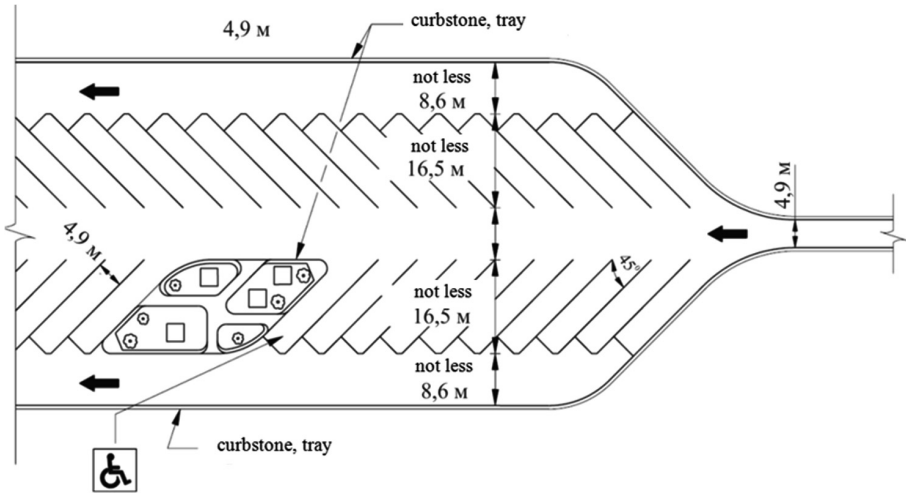
Fig. 3. Scheme of parking spaces for trucks [own study]

At the Department of Survey and design of roads MADI have been conducted research to justify the size of parking spaces for vehicles, taking into account the characteristics for modern traffic on the roads of the Russian Federation [19].

This research work included: monitoring parking maneuvers, studying the real situation when setting up parking spaces and modeling parking maneuvers of passenger cars and trucks using the AutoTURN software, which allows to simulate the movement and maneuvering of vehicles at speeds up to 60 km/h, and also to model three-dimensional movement on a 3D surface, localize modeling for various groups of vehicles; graphically represent the dynamic dimensions indicating the dynamic dimensions of the vehicles (external and internal wheels, characteristic points of the body); create vehicle reversal patterns [20].

Parking space for vehicles includes parking spaces for vehicles and a maneuvering area, designed for the entrance to parking spaces, exit and setting cars [21]. The dimensions of the parking space must ensure unhindered entry, opening the doors of the vehicles, unloading or loading luggage, and then unimpeded exit without hitting other vehicles [22].

The dimensions of the car parking space determine its type and size (length, width, turning radius of the inner rear wheel, overhang, base, gauge). To be able to bypass and open the doors of the car, the parking dimensions should be 0.5 m larger than the corresponding dimensions of the designing vehicles [23].

The "Methodological guidelines for the design and equipment of highways to ensure traffic safety" [24] indicated that parking at large recreation areas, at roadside catering establishments, motels and campgrounds should be placed between the highway and buildings with vehicle separation by types and sizes. Parking areas for trucks and passenger cars should be demarcated and provide for each type of vehicle a separate entrance to the appropriate temporary parking area [25–29].

In this case, passenger cars and buses are recommended to have on the left, and trucks on the right in the direction of travel [30].

It is recommended to place the parking of trucks parallel to the axis of movement, while parking of passenger cars mainly should be arranged according to an oblique angle at an angle of 45–60°. For long stays in the parking place, as well as in cramped conditions, when the parking place have one exit, it is recommended to install vehicles perpendicular to the direction of the axis of movement. Recommendations are given for the designation of the average area of coverage for one vehicle, taking into account the area of the exit and entry zones and the area of the parking space itself.

2   Modelling of the Movement of Designed Vehicles

To determine the width of the maneuvering of parking spaces, the authors took into account the minimum turning radius of the design vehicle and its dynamic clearance. To do this, studies have been conducted that allowed us to determine these characteristics [31, 32]. In the study, the width of the passage was determined as follows. When designing the parking space and the entrance vehicles at parking spaces, the following schemes and provisions were applied in the calculations:

1 - the road train leaves the parking space in the forward direction;
2 - auto train drives backwards in a parking space;
3 - road train drives forward;
4 - the road train leaves the parking space in reverse.

It was found that for reversing a large maneuvering lane is needed than in other variants. This maneuver is a common parking method for road train drivers. With this in mind, the width of the maneuvering strip was determined.

The design vehicle made a maneuver at the location of a parking space at an angle of 90°, 60° and 45° (see Fig. 4). After each maneuver, the parking length, maneuvering lane, and parking width were determined.

Studies have shown that for one passenger car, taking into account maneuvering, 28.7 m^2 of parking space is needed. For a road train length of 16.5 m, this value is 143.1 m^2 of area.

From Fig. 5 it follows that with more than five parking spaces, the area of parking space for one vehicle does not increase (depending on the angle). When the parking space is located at an angle of 90°, and if there are less than 5 parking spaces in the parking, the parking space is reduced by one car. At the location of parking spaces at angles of 60° and 45°, the indicator is 4 parking spaces. Similar values are obtained for cars and for trucks. Proceeding from this, it can be concluded that, when parking places at an angle of 90°, designing less than five parking spaces is ineffective for any type of car, and if placed at angles of 60° or 45°, up to four parking spaces are considered ineffective.
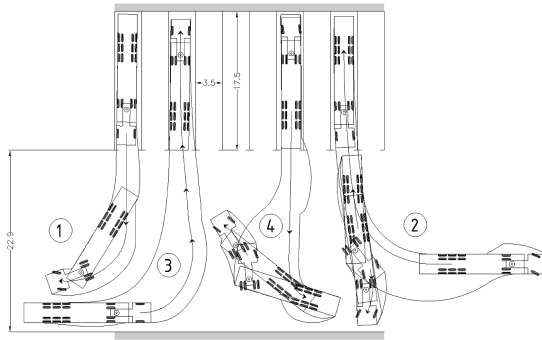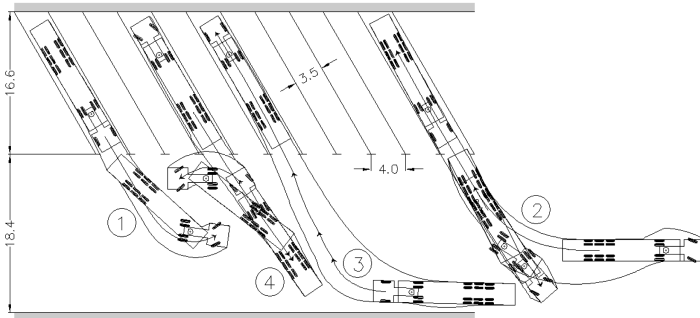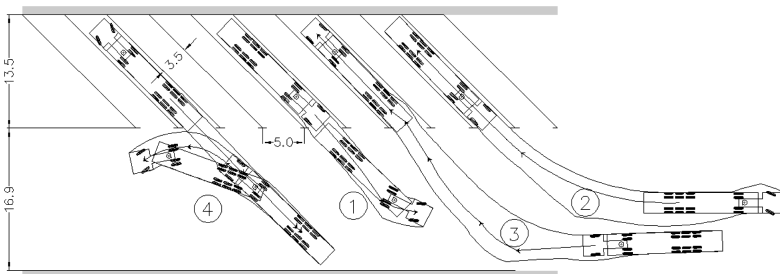
Fig. 4. Maneuvering schemes for a train (16.5 m) in a parking; (a) the location of the parking space at an angle of 90°; (b) the location of the parking space at an angle of 45°; (c) the location of the parking space at an angle of 60°; 1-way forward; 2- backing; 3- forward ride; 4 – reversing [own study]

a.

b.
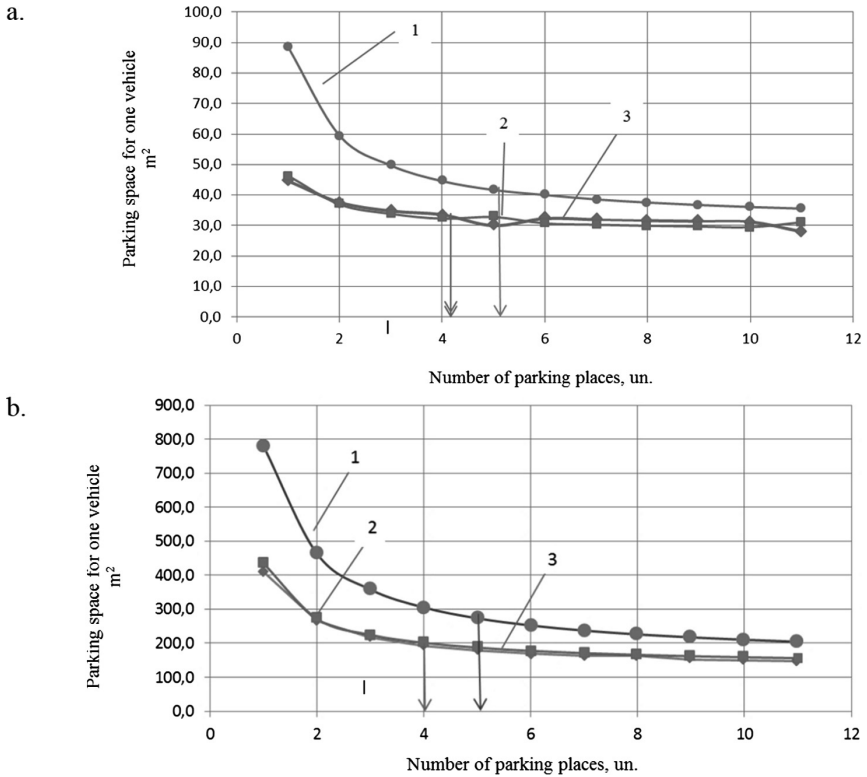
Fig. 5. The dependence of the area of parking space on the number of parking spaces for passenger cars (a) and for a train 16.5 m long (b) when set at the corners: 1 – 90°; 2 – 60°; 3 – 45° [own study]

3   Conclusion

Based on the above data, we can draw the following conclusions:

1. Less than 5 parking places at an angle of 90° is economically inefficient for any type of vehicle;
2. When located at angles of 60° or 45°, up to 4 parking places are considered to be economically inefficient.

Table 1. Recommended size of the design vehicles [own study]

Type of design vehicles	Designation		Wheelbase, m	Dimension, m			
				General		Overhang	
	RD[1)]	TR[2)]		Length	Width	Front	Rear
Passenger car	P	L	2,90	4,90	1,90	0,90	1,10
City bus	CB	M_2	6,20	12,0	2,50	2,75	3,05
Bus	B	M_3	6,90/1,30	15,0	2,50	2,60	4,20
Articulated bus	AB	M_3	5,96/6,05	18,4	2,55	2,68	3,71
Truck	T	N_3	6,80	12,0	2,50	1,50	3,70
Road train	A16	N_2+O_4	3,80/7,02	16,50	2,50	1,43	2,98
Road train	A20	N_3+O_4	6,80/4,30	19,80	2,50	1.50	0.70

Note

RD[1)] – vehicle designation adopted in the article.

TR[2)] – designation of cars in accordance with the Technical Regulations "On the safety of wheeled vehicles" (approved by the decision of the Commission of the Customs Union of 9 December 2011 No. 877)

Table 2. Minimum turning radius of the design vehicle [own study]

Type of design vehicles	Minimum turning radius, m	Minimum outer radius, m	Minimum inner radius, m
Passenger car (P)	6,55	6,85	4,42
City bus (C)	9,20	10,54	5,40
Bus (B)	10,32	11,52	6,40
Articulated bus (A)	13,12	14,21	10,10
Truck (T)	11,07	11,82	6,15
Road train (A16)	9,69	10,19	6,20
Road train (A20)	12,06	12,63	8,50

The following types of design vehicles were recommended as most frequently encountered on the roads for Russia Federation: passenger car (P); city bus (CB); bus (B); articulated bus (AB); truck (T); road train consisting of truck tractor and semi-trailer (A16); road train consisting of a truck and a trailer (A20). The main dimensions of the specified design vehicle are given in Table 1, the minimum turning radius - in Table 2. The resulting sizes of parking spaces and the scheme of their breakdown are
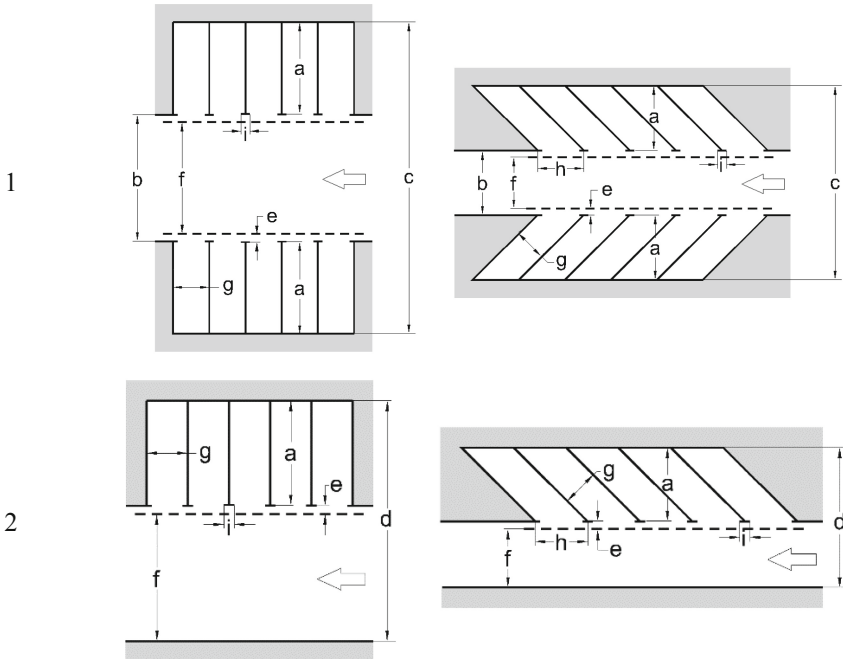
Fig. 6. Possible layouts of parking space 1- two-way parking; 2- one-way parking a - the depth of the parking space; b - the width of the passage between the rows of parking spaces; c - the distance occupied by the strip for parking and travel; d - the distance occupied by the strip for parking and travel; e - security band; f - maneuvering strip; g - the width of the parking space; h - the width of the parking module; i - markup line length 1.1; [own study]

given in Table 3 and Fig. 6. Recommended lengths of parking spaces for longitudinal placement of design vehicles are presented in Table 4. Recommended schemes and dimensions of parking of buses (type of rated car B) with longitudinal, saw tooth and perpendicular device of aprons are shown in Fig. 7. Considering the foreign experience of organizing parking spaces for large-sized vehicles, which provides for entry and exit to a parking without reversing (Fig. 8), as a result of research, it is recommended to take the dimensions of parking spaces in accordance with the values in Table 5.

Fig. 7. The scheme of parking spaces for city buses: a- when parallel; b-sawtooth; c-perpendicular placement in relation to the driveway or maneuvering zone [own study]

Fig. 8. Elements of breakdown of parking space for trucks α – β – parking angle; Ø – vehicle installation angle; B – D – maneuvering strip; C – parking module length [own study]

Table 3. Dimensions and average areas of one parking space [own study]

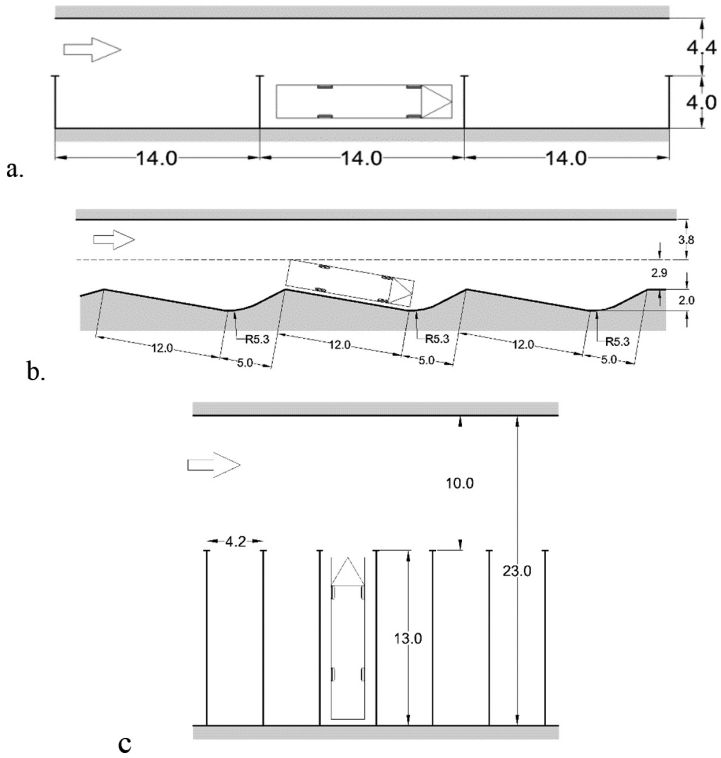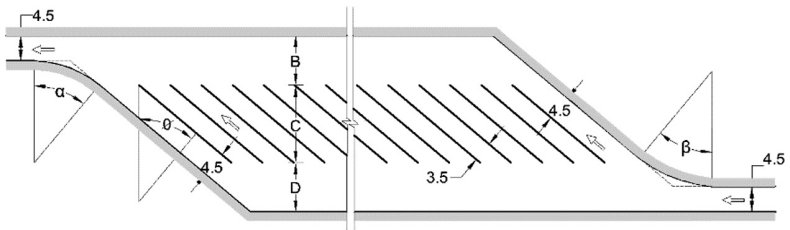| Vehicle installation angle, degree	Sizes of elements, m									Average area for 1 vehicle, m^2	
	a	b	c	d	e	f	g	h	i	Without maneuvering	With maneuvering
1	2	3	4	5	6	7	8	9	10	11	12
One-way car parking (**P**)											
90	5,0	7,0	17,0	11,5	0,5	6,0	2,5	2,5	0,5	12,5	28,7
60	5,2	4,2	14,6	8,9	0,5	3,2	2,5	2,9	0,5	15,1	25,8
45	4,8	4,0	13,6	8,3	0,5	3,0	2,5	3,5	0,5	16,8	29,0
Two-way car parking (**P**)											
90	5,0	8,0	18,0	12,5	0,5	7,0	2,5	2,5	0,5	12,5	22,5
60	5,2	5,2	15,6	9,9	0,5	4,2	2,5	2,9	0,5	15,1	22,6
45	4,8	5,0	14,6	9,3	0,5	4,0	2,5	3,5	0,5	16,8	25,5
Truck Parking (**T**)											
90	13,0	16,1	42,1	28,6	0,5	15,1	3,5	3,5	0,5	45,5	100,1
60	11,8	12,4	36,0	23,7	0,5	11,4	3,5	4,0	0,5	47,2	94,8
45	10,5	8,7	29,7	18,7	0,5	7,7	3,5	5,0	0,5	52,5	93,5
City bus parking (CB)											
90	13,0	16,1	42,1	28,6	0,5	15,1	3,5	3,5	0,5	45,5	100,1
60	11,8	12,4	36,0	23,7	0,5	11,4	3,5	4,0	0,5	47,2	94,8
45	10,5	8,7	29,7	18,7	0,5	7,7	3,5	5,0	0,5	52,5	93,5
Bus parking (**B**)											
90	16,0	19,0	51,0	34,5	0,5	18,0	3,5	3,5	0,5	56,0	120,7
60	14,3	16,1	44,7	29,9	0,5	15,1	3,5	4,0	0,5	57,2	119,6
45	12,4	11,7	36,5	23,6	0,5	10,7	3,5	5,0	0,5	62,0	118,0
Articulated bus parking (AB)											
90	19,5	25,1	64,1	44,1	0,5	24,1	3,5	3,5	0,5	68,3	154,3
60	17,3	20,3	54,9	37,1	0,5	19,3	3,5	4,0	0,5	69,2	148,4
45	14,9	18,5	48,3	32,9	0,5	17,5	3,5	5,0	0,5	74,5	164,5
Road train parking (**A16**)											
90	17,5	23,9	58,9	40,9	0,5	22,9	3,5	3,5	0,5	61,3	143,1
60	16,6	18,9	52,1	35,0	0,5	17,9	3,5	4,0	0,5	66,4	140,0
45	13,5	17,4	44,4	30,4	0,5	16,4	3,5	5,0	0,5	67,5	152,0
Road train parking (**A20**)											
90	21,0	33,0	75,0	53,5	0,5	32,0	3,5	3,5	0,5	73,5	187,2
60	18,6	23,8	61,0	41,9	0,5	22,8	3,5	4,0	0,5	74,4	167,6
45	16,0	21,1	53,1	36,6	0,5	20,1	3,5	5,0	0,5	80,0	183,0

Table 4. The length of parking spaces for longitudinal settlement cars [own study]

Design vehicle	Passenger car (**P**)	Truck (**T**)	Buses			Road Train	
			(**CB**)	(B)	(**AB**)	(**A16**)	(**A20**)
Parking space length, m	6,0	14,0	14,0	17,0	22,5	20,0	24,0

Table 5. Sizes of parking spaces at different corners of the parking of trucks [own study]

Installation angle, degree			Sizes of parking spaces, m (see Fig. 8)		
Ø	α	β	B	C	D
A 16					
30	30	30	7,5	12,0	7,5
35	35	35	8,5	13,0	8,5
40	40	40	8,7	13,5	8,7
45	45	45	9,5	15,5	9,5
A 20					
30	30	30	8,0	13,0	8,0
35	35	35	9,0	15,5	9,0
40	40	40	9,2	16,5	9,2
45	45	45	10,0	17,7	10,0

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