CETRA 2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

ORGANISATION

CHAIRMEN

Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering
Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Maja Ahac
Ivo Haladin
Saša Ahac
Ivica Stančerić
Josipa Domitrović

All members of CETRA 2012 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Ronald Blab, Vienna University of Technology, Austria
Prof. Vesna Dragčević, University of Zagreb, Croatia
Prof. Nenad Gucunski, Rutgers University, USA
Prof. Željko Korlaet, University of Zagreb, Croatia
Prof. Zoran Krakutovski, University Sts. Cyril and Methodius, Rep. of Macedonia
Prof. Stjepan Lakušić, University of Zagreb, Croatia
Prof. Dirk Lauwers, Ghent University, Belgium
Prof. Giovanni Longo, University of Trieste, Italy
Prof. Janusz Madejski, Silesian University of Technology, Poland
Prof. Jan Mandula, Technical University of Kosice, Slovakia
Prof. Nencho Nenov, University of Transport in Sofia, Bulgaria
Prof. Athanassios Nikolaides, Aristotle University of Thessaloniki, Greece
Prof. Otto Plašek, Brno University of Technology, Czech Republic
Prof. Christos Pyrgidis, Aristotle University of Thessaloniki, Greece
Prof. Carmen Racanel, Technical University of Bucharest, Romania
Prof. Stefano Ricci, University of Rome, Italy
Prof. Tatjana Rukavina, University of Zagreb, Croatia
Prof. Mirjana Tomičić–Torlaković, Univiversity of Belgrade, Serbia
Prof. Brigita Salaiova, Technical University of Kosice, Slovakia
Prof. Peter Veit, Graz University of Technology, Austria
Prof. Marijan Žura, University of Ljubljana, Slovenia

CRITICAL PLANNING AND DESIGN PARAMETERS FOR GARAGES

Rudolf Eger
University of Applied Sciences RheinMain,
Faculty of Architecture and Civil Engineering, Wiesbaden, Germany

Abstract

Acceptance and usability – and thus also the economic success – of garages are based on sufficiently designed parking lots, driving/manoeuvring lanes, ramps and entrance/exit control systems. International, especially European and German design guidelines define certain measurements regarding these major garage elements.. In many cases, garages have been and are being built by applying only the minimal requirements or even less. On paper (drawings) a maximum number of lots can thus be shown by minimizing the costs. In reality, after the start of the operation, problems arise, e.g.: two lots are needed for one (bigger) vehicle which reduces the projected revenue; scratches on cars and pillars might lead to litigation; customers complain for getting wet shoes; long queues occur at entrance and/or exit. This paper discusses the necessary design vehicles, depending on the customer demand for a certain garage. Measurements for such vehicles and new statistical data (from Germany) are presented and show – as one result – that a lot for an average personal car should at least be 2,50 m wide (at 90° to lane) and lanes at least 6,00 m wide. Based on a wide range of realised garages and presenting examples, typical tasks for planning garages are being discussed: manoeuvrability of lots and lanes; best practise of column grid versus lots and lanes; headroom over lots, lanes and ramps; slope and curves of ramps; slope/folding of garage floors and queue calculation at garage entrance barriers.

Keywords: garage, parking, design vehicle, parking lot, queue length

1 Introduction

Parking facilities can be open space, one–level, on–ground sites with dedicated stripes for lots and lanes or they are garage buildings above–, on–or under– ground. Garages are often not stand–alone buildings but parking levels integrated into a building – in city centres often underground.
Demand for parking lots has lots of variables. For city centres the number of necessary parking lots depends largely on the quality of the public transport system. Many big cities – at least in Germany – restrict the realisation of new parking lots to a certain percentage if the project is well connected to public transport, thus in the inner city of Frankfurt Main/Germany you are only allowed to build 10 % of the parking lots you normally would have to build at a site outside the city.[1] Nevertheless, despite a very good and very well used public transport there usually is still a high demand of good–quality parking lots which has to be satisfied to keep residents, customers, visitors and employees staying and coming. As an example, the map of the inner city of Frankfurt Main/ Germany shows both the main pt–stations and public garages, Fig. 1.

Figure 1 Pt–stations and garages in the city centre of Frankfurt Main/ Germany (Basic data: 11.700 public lots; i.e. 164 lots/km² built–up land; 17 lots/1.000 residents)

The following introduces some crucial criteria and tasks for a satisfying garage design.

2 Critical planning and design parameters

2.1 Vehicle design

Many older garages – but surprisingly some newly built garages too – provide lots and lanes which already cause problems if used by medium sized cars. Therefore, the first step of any planning process of a garage is to define a typical vehicle design for the actual garage project. The design vehicle for a public garage should usually be a personal car which represents 85 % of the currently running cars in the region where the garage is situated (e.g. in central Europe there is no need to consider provisions for the United States personal vehicle design, which is 5,80 m long; 2,10 m wide without mirrors); outer turning radius 7,30 m [2]).Some countries choose the 80 % and/or 90 %-percentile (e.g. Austria) to decide the size of the design vehicles. Despite widely talked–about small cars, the 85%-vehicles in Germany – and it can be assumed in other central–European countries as well – have increased in size quite considerably during the last decades. Mainly the width (+ 8 cm) and the height (+ 16 cm) have risen since 2000 (last data collection before 2010). The following table 1 shows the data for Germany [3, 4, 5, 6, 7]:

Table 1 Development of the personal car size in Germany (85 % car)

Year	Length [m]	Width (without mirrors) [m]	Height [m]
1975 / 1991	4,70	1,75	1,50
2000 / 2005	4,74	1,76	1,51
2010 / 2011	4,77	1,84	1,67

The resulting measurements, for the 2011, of 85 % design personal cars are shown in the following figure 2 (typical cars, approximately in the frame of the mentioned percentage, are the Mercedes–C class and the VW Passat 2010).

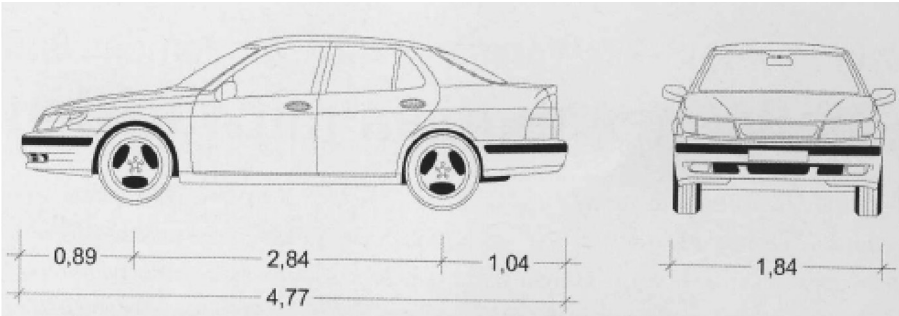

Figure 2 Design vehicle (personal car) in Germany 2010/11 (source: [7])

This car size has been derived from all new personal cars, including small and large ones, weighed with the number of registrations in the year 2010 in Germany.
Conclusion: For users with no clearly defined special needs, the design vehicle for a garage in central Europe – as an assumption based on the mentioned German data – is 1,84 m wide (without mirrors) and 4,77 m long.
For special purposes, e.g. a) garages in buildings with luxury apartments where more luxury cars and/or SUVs can be expected; b) garages or levels of garages designated for small–sized vehicles like Smart other design cars representing 85 % of a certain class should be chosen. The following Table 2 shows some of these classes:

Table 2 Special car–classes in Germany (85 % car of the class 2010/11)

Car–class	Length [m]	Width (without mirrors) [m]	Height [m]
Ultra–small (e.g. Smart)	3,64	1,65	1,56
Upper	5,20	1,95	1,49
SUV (with reeling)	5,15	1,93	2,06

2.2 Parking lots and lanes size

Parking lots and the adjacent area, respectively the lanes along the lots, must provide enough space to manoeuvre the above mentioned design vehicle into and out of the lot. In addition to the size of the car (width 1,84 m x length 4,77 m) there has to be enough reserves on all sides to allow a secure, comfortable and careful driving. The German guidelines for parking facilities ([6] chapter 4.2.1.6) consider 0,75 m between adjacently parked cars as comfortable and 0,55 m as acceptable for having the mirrors popped out and the door opened in an acceptable angle. At the front and the rear of a parked car 2 x 0,15 m = 0,30 m clearance is proposed. Together with the size of the design vehicle and assuming that all cars are parked right in the middle of the lots, the numerically deduced size of a parking lot perpendicular to the lane would be:
Length: 0,15 m clearance + 4,77 m car + 0,15 m clearance = 5,07 m
Width: 0,375 m clearance + 1,84 m car + 0,375 m clearance = 2,57 m

As cars are not always parked in the centre of the lot and drivers and passengers vary considerably in their behaviour entering and leaving the car, it can be rightly assumed that the size of a parking lot perpendicular to the lane should be:
Parking lot for 85 % design personal car: length x width = 5,00 m x 2,50 m

If upper class vehicles are chosen as a benchmark for a garage project, the proposed size – taking Table 2 under consideration and allowing more space for door–opening – should be:
Parking lot for 85 % upper class car: length x width = 5,20 m x 2,70 m

If a parking lot is directly marked along a wall, additional 0,20 m should be added to the width to make it possible for most cars to move into the lot forward and not to have to turn around first and then enter the lot in reverse.
Lanes along parking lots should allow a secure slow driving along and moving into and out of the lots. To make it possible to enter a parking lot of a certain width, from a lane with a certain width, the necessary space for turning curves of cars, the column grid of the garage construction and the angle at which the lots are aligned to the lane have to be considered (see figure 3).

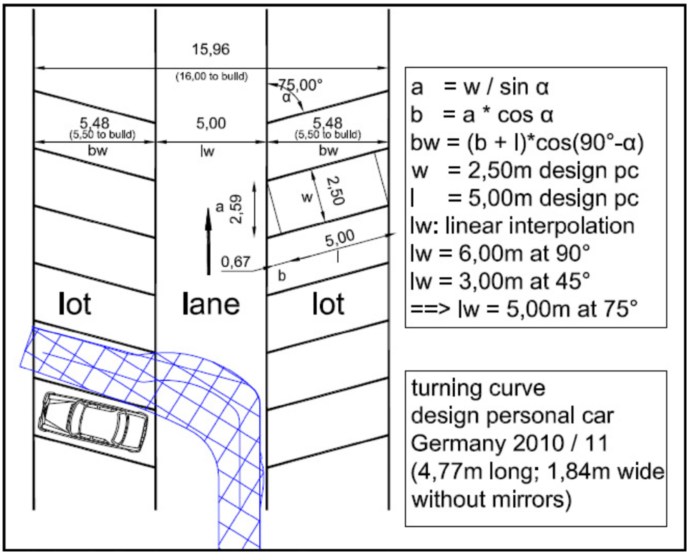

Figure 3 Geometry of parking lots and lane (example: lots at 75° angle)

Some regulations still allow lanes of 5,50 m width which is too narrow for today's car sizes. The above mentioned necessary length of a perpendicular lot is 5,07 m for the design personal car, of which 5,00 m are marked as bay, overlapping is 0,07 m into the lane.

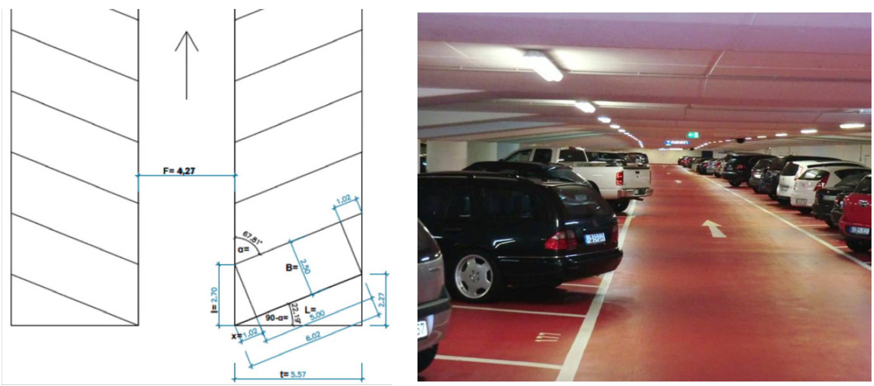

Figure 4 Parking lots and lane with cars overlapping into the lane

If the construction system of a garage is not open spaced without columns, the necessary space for columns, walls, insulation and technical installations has to be added to the measurements of lots and lanes shown in figure 4. As many garages are underground levels of residential or office buildings, the construction grid of the building has to be adjusted with the grid of the garage. A good example is shown in figure 5 with a quadratic grid of 8,10 m which is 5 x 1,35 m, a common module in architecture.

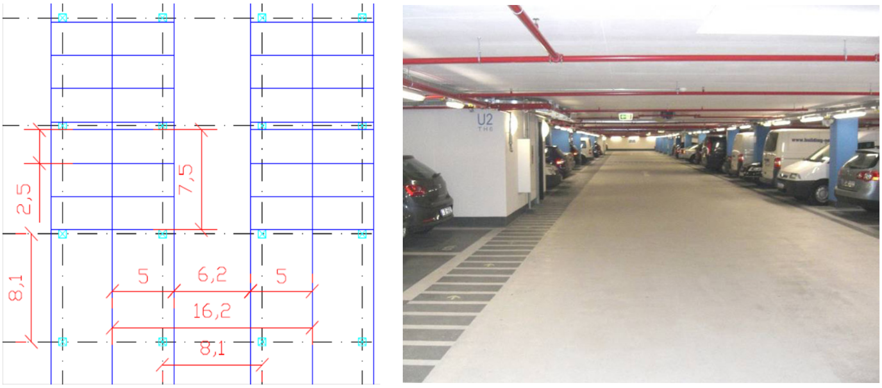

Figure 5 Example of a construction column grid for buildings with underground garage level(s). Realized: Opernturm garage, Frankfurt Main

2.3 Headroom

Sufficient headroom for a garage has to be defined properly for ramps and parking levels. At the entrance a sign has to show the allowed maximum height for a vehicle to enter (in addition a hanging girder should warn if a too high car tries to pass). The usual displayed height is currently 2,00 m. Newer data shows that the height of cars has increased considerably (see tables 1 and 2). If it is foreseeable that a garage will be used regularly by SUVs and/ or cars with roof tops, reeling's, sport facilities, the allowed height of a car to enter should be not less than 2,10 m.
As there are legally permitted tolerances between planned measures and actually realised measures (at least 0,02 m up to 0,05 m, depending on national regulations and the local construction), these tolerances should be considered. Also the actual height of a car can differ from the height printed in the car's papers (e.g. tire pressure, suspension). Therefore, as a sum of tolerances at flat garage levels at least 0,10 m should be added to the height displayed at the entrance (e.g. entrance sign 2,00 m height leads to planned headroom of 2,10 m at flat level). Along sloped ramps more headroom has to be provided: + 10 cm along the ramp (altogether 2,15 m if 2,00 m is displayed). Where the slope changes 8 % or more (e.g. from 15 % sloped ramp to 0 % flat garage level) + 20 cm at slope–changing points and 1,50 m along both sides of these points have to be considered (altogether 2,25 m if 2,00 m displayed).
Additional headroom can be necessary if the garage level is sloped for drainage (cleaning water, thawing ice and snow) and to avoid uncontrolled puddles and resulting danger of chloride impact. The necessary slope has to be at least 2 % to ensure water flowing in the right direction and having in mind the construction tolerance.

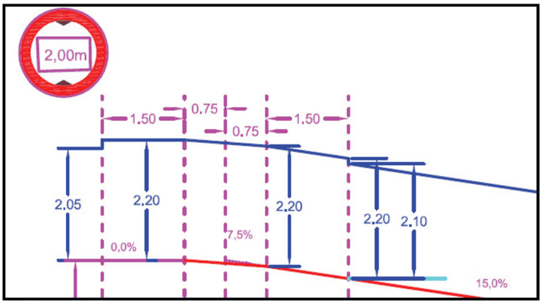

Figure 6 Example for calculating headroom along a garage ramp (5 cm construction tolerance not included!)

2.4 Ramps

Ramps are garage elements for changing levels upwards or downwards. For longitudinal section design a ramp should not exceed 15 % (in the middle of the respective lane) and short ramps inside a garage may be sloped up to 20 %. If the slope difference is more than Δs = 8 %, a flatter section with ½ s for 1,5 m at the top and 2,5 m at the foot of the ramp has proved to be sufficient to avoid car damages (e.g. see figure 6: a flatter section with 7,5 % between 15 % ramp slope and 0 % garage level slope) [6].
The horizontal design of a ramp has to comply with the turning curves of the chosen design vehicle with additional clearance to allow comfortable and secure driving. Linear ramps should at least have a lane width of 2,75 m and additional clearance of 25 cm on both sides should be provided. Curved ramps must have a radius of at least 5,00 m at the inner lane boundary with at least 3,50 m lane width. Additional clearance of at least 25 cm should be provided on both sides. Some sources demand for 3,70 m lane plus 30–50 cm clearance for more comfortable driving [6], [8]. The following Figure 7 shows a spiral ramp with (nearly) minimum size: inner radius 4,75 m, outer radius 8,75 m (= lane width 3,50 m + 2x 0,25 m). This ramp serves a 4–level underground garage with 1.400 lots with no known complaints.

Figure 7 Spiral ramp 4 m in width, inner radius 4,75 m (My Zeil, Frankfurt)

2.5 Queue length at barriers

Entrance and exit barriers can lead to considerable queue lengths and these can disturb traffic on the adjacent street and/or the inner garage traffic flow. The German guidelines for garage facilities ([6], annex K) introduce a method to assess the queue length based on known and proven capacity of certain control devices. Summarizing and compressing the data the following figure 8 gives an impression of the expected queue length (number of personal cars, each car can be assumed to be 6 m long including distance between cars) for a known volume of entering traffic flow. The results have proven to be quite reliable, leaning a bit to the safe side if tried with real traffic evaluations [9, 10].

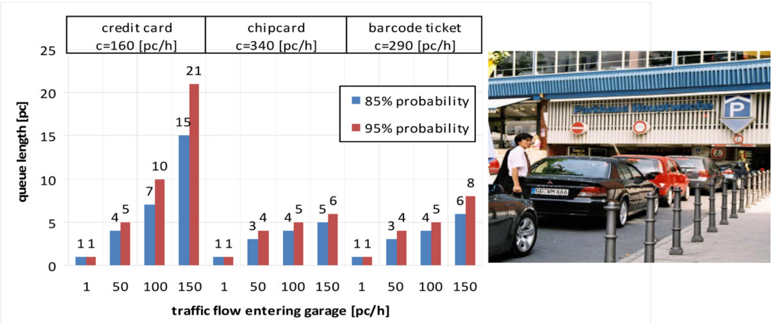

Figure 8 Queue length assumption (data from [6])

References

[1] Stellplatzsatzung und Stellplatzeinschränkungssatzung Frankfurt Main, 1998

[2] AASHTO: Geometric design of highways and streets. Chapter 2, 2001

[3] Richtlinien für Anlagen des ruhenden Verkehrs. FGSV, Köln 1975

[4] Empfehlungen für Anlagen des ruhenden Verkehrs EAR 91. FGSV, Köln 1991

[5] Bemessungsfahrzeuge und Schleppkurven zur Überprüfung der Befahrbarkeit von Verkehrsflächen. , Köln 2001

[6] Empfehlungen für Anlagen des ruhenden Verkehrs EAR 05. FGSV, Köln 2005

[7] Schuster, A., Sattler, J. & Hoffmann,S.: Neues Pkw-Bemessungsfahrzeug für den Entwurf von Anlagen des ruhenden Verkehrs, Straßenverkehrstechnik, pp. 5-10, 2012

[8] Pech, A., Jens, K., Warmuth, G. & Zeininger, J.: Parkhäuser – Garagen. Springer Verlag, Wien, 2006

[9] Bouhezzo, M.: Staulängen vor einer Garageneinfahrt. Thesis at Hochschule RheinMain, faculty of architecture and civil engineering, Wiesbaden 2011

[10] Afewerki, D.: Staulängen vor Garageneinfahrten. Diploma work at Fachhochschule Wiesbaden (now: Hochschule RheinMain), faculty of civil engineering, Wiesbaden 2004