PROPOZYCJA METODYKI OCENY JAKOŚCIOWEJ PARKINGÓW KUBATUROWYCH

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Streszczenie: *Jakość struktury układu parkingu w porównaniu do innych obiektów związanych z ruchem jest rzadko kontrolowana w procesie planowania. Nie istnieją zintegrowane procedury procesu kontrolowania. W artykule przedstawiono i przedyskutowano pierwsze podejście do takiej procedury. Podejście jest dwustopniowe: 1 - jakościowy audyt zaprojektowanej struktury parkingu i jeżeli jego wynik jest pokazuje spełnienie minimalnych standardów, 2 – określenie poziomu obsługi. Przedstawiono również pierwsze obliczenia i pierwsze wymagane parametry.*

Słowa kluczowe: *jakość parkowania, projektowanie parkingów*

1. Introduction

Car parks and underground garages are traffic buildings. The quality of those is hardly checked during the planning process, compared with other traffic buildings. Two examples should illustrate this:

1) A highway intersection is to be remodeled. The state office assigns the redesign of the intersection to an engineering office. In the same time it is expected, that it is being tested, if the intersection has enough capacity and keeps a certainLevel of Service (German term: Qualitätsstufe des Verkehrsablaufs– QSV) according Handbuch für die Bemessung von Straßenverkehrsanlagen (HBS) [6].
2) A parking structure should be built in acity. Aninvest or assigns an architecture office to build the car park. The office presents the layout to the authority. The authority is checking the design by structurally engineering and by regulations. They primarily check elements of the architectural building. The only check of traffic facilities are the minimum for access roads, ramps, parking stalls and the clearance. Those minimum values in the regulations are most of the time too small for these days' cars (see [16]). The traffic flow is being checked from time to time at the connection to the road network. The capacity of the gate is checked hardly, even though the HBS offers a method for this.For the planning and building permission it does not matter, what will happen in the car park after it has been built.

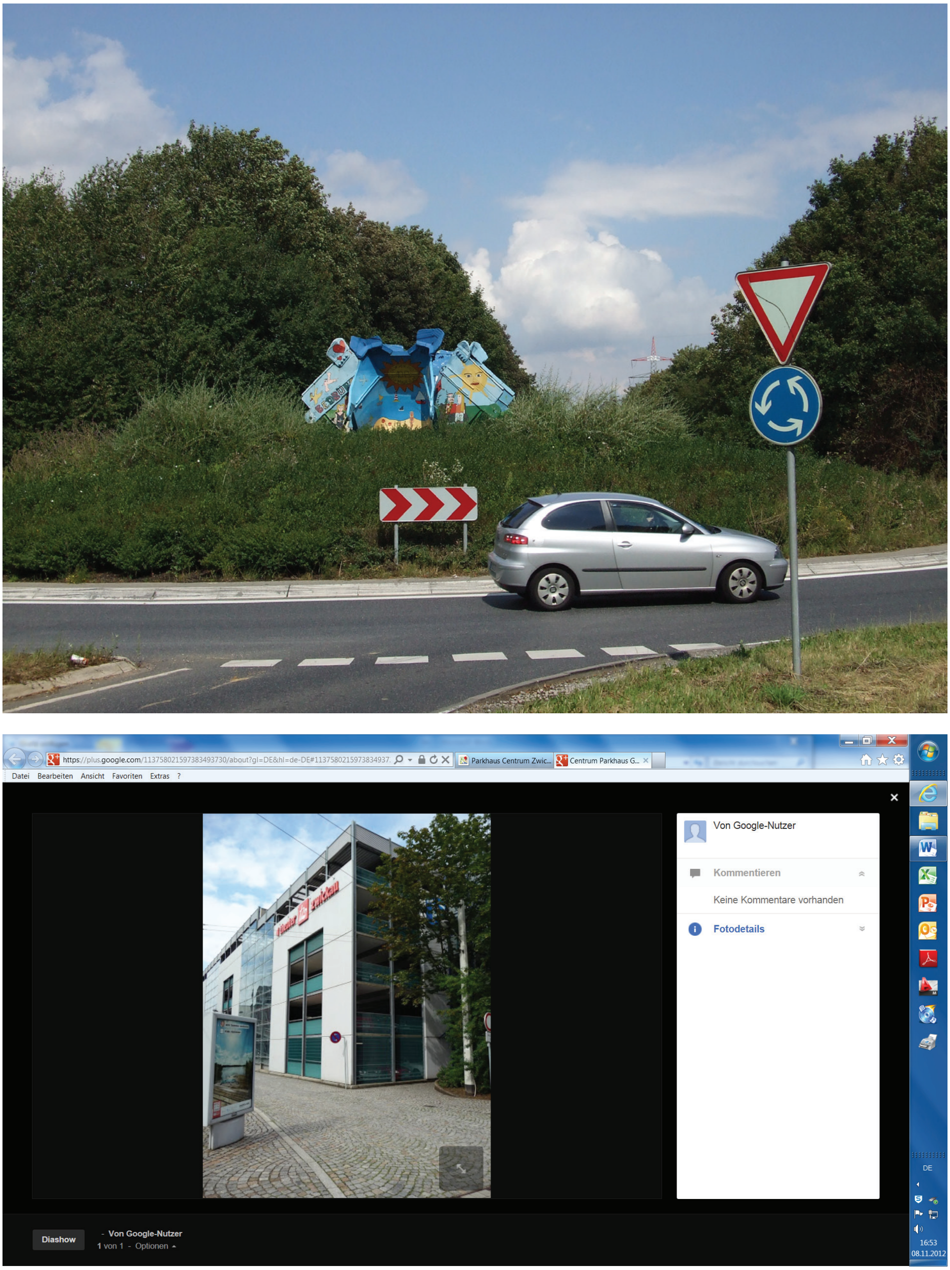


Fig. 1. Roundabout and parking structure – two traffic facilities with different quality check in the planning process
Photo sources: josupewo/pixelio.de and author

Those examples show that also the traffic quality of parking structures has to be checked already during the planning process.

2. Knowledge Rewiev

Like previously mentioned methods exist to evaluate the quality of gates of parking structures [6]. But it is still missing a method to assess the whole parking structure, compared to other traffic buildings. The ADAC is testing parking structures since a couple of years [1] and in the Netherlands are check listsbeing developed for the assessment of the quality of kerb parking[3]. But those methods are developedonly for existing parking structures. They are not suitable for parking structures that are still in the planning phase.

There are only very few studies and methodical thoughts on a method for a holistic quality assessment for parking structures [8, 10, 15, 16]. A few helpful facts have been discovered in correlation with the development of a method to determine the pollution of those parking structures [12, 13].

Since many years the Safety Audit for Streets (SAS) [7] is being used to check the safety of road designs in the planning phase.

3. Suggestion for a Procedure

3.1. Requirements

The quality check should already be happening in the planning process. There are only drafts at hand in this phase. A method has to be able to assess the parking structure on the base of such information – information about the geometries.

A method for quality assessment should pick up some parts from already existing methods or be at least compatible with them. For this topic the SAS and the HBS-Method seem to be good starting point. In one case checklists are to be used, in the other case alevel of service (QSV) could be determined.

Finally a principle of HBS should be applied: all those attributes and measurements should be determined by the quality sense of the users.

3.2. Basic Considerations

With the previous knowledge and the already existing methods in mind it would be wise to conduct the quality assessment of planned parking structures in two steps:

1) As a start it has to be checked if the planned parking is enough for the usual technical demands for traffic facilities. This first step could be conducted – analog to the safety audit of streets (SAS) – in a form of a quality audit of parking structures layouts (QAP).
2) If this is the case the level of service in the planned parking structure could be determined quantitative in a second step. This determination method could be based on the HBS.

Figure 2 shows the basic structure, schematic illustrated. The following describes the two steps closer.

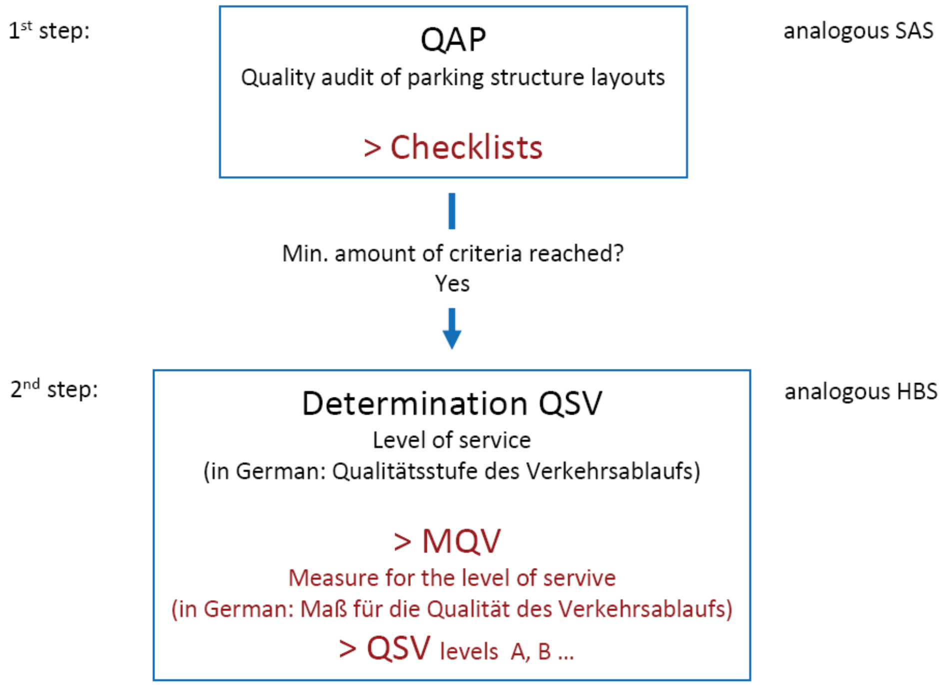


Fig. 2. Basic procedure of a quality check of parking structures

3.3. Quality Audit of Parking Structure Layouts (QAP)

Similar to the SAS there could be check lists for the QAP, which contain criteria that have to be checked in the parking structures layouts. It would be wise to use different check lists for different planning phases (e.g. preliminary planning, approval planning).

Already existing checklist, like those from the ADAC car park test [1] and the checklist for kerb parking from the Dutch Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek (CROW) [3], could be used as a guideline for the development of new checklists (see Fig. 3). Such criteria which can be checked in parking structure layouts must be selected. A selection of criteria cannot be stated at the moment. There is further research necessary for this.

3.3.3 Langsparkeren/parkeerhavens

Met langsparkeren wordt bedoeld parkeren op de openbare weg en langs de rijbaan. Parkeerhavens vallen hier ook onder.

Gehandicaptenparkeerplaatsen

Toetsvraag	Antwoord	Score
Must have		
248 Zijn er algemene gehandicaptenparkeerplaatsen ingericht?	Ja/nee	
249 Is de gehandicaptenparkeerplaats herkenbaar (met RVV bord E6)?	Ja/nee	Ja: Nee: N.v.t.:
250 Is de gehandicaptenparkeerplaats tenminste 3,5m breed?	Ja/nee	Ja: Nee: N.v.t.:
251 Is de lengte van een gehandicaptenparkeerplaats bij langsparkeren tenminste 7 m?	Ja/nee	Ja: Nee: N.v.t.:

Fig 3.Excerpt of the Dutch „Checklist keurmerk straatparkeren" {3}

3.4. Determining a Level of Service (German term: Qualitätsstufe des Verkehrsablaufs – QSV)

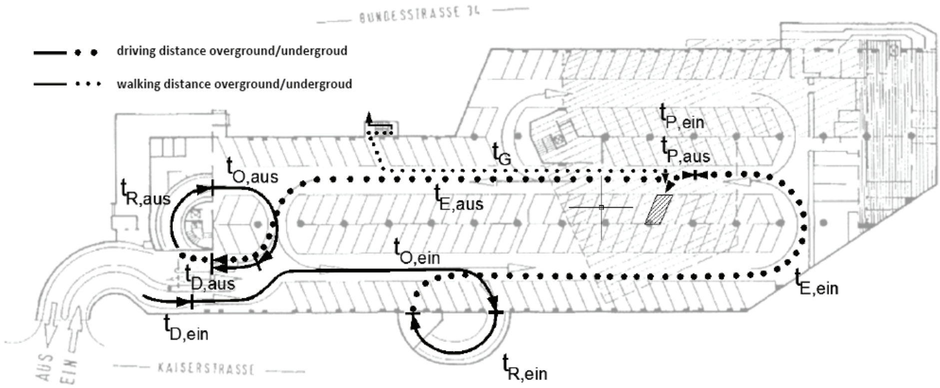
3.4.1. Measure for the Level of Service (German term: Maß für die Qualität des Verkehrsablaufs – MQV)

A measure is required to determine the QSV. It should – for to be HBS compatible – fulfil the following criteria:

- It should be quantifiable.
- It should be applicable to not yet existing traffic facilities.
- It should apply to a certainmeasured loading or to different loading levels.
- It should correlate to the actual quality feeling oft the user.

In the considerations of SCHUSTER and DOHMEN {15}, as well as from PEZELJ {10}, two studies, which conducted independent and without knowledge of each other, came to similar results, that the time it takes for the whole parking process is a suitable measurement. It is being suggested to use the time for the whole parking process as the MQV - with the assumption that the quality of the parking structure is rated as good when the required time for the parking process is short and it is rated as bad when the required time for the parking process is high.

The total parking time is composed of partial parking times. Those times are illustrated in Fig. 4.



Key:

$t_{A,ein}$: time in the structure, to get the entrance gate (German term: Einfahrzeit im Außenbereich bis zum Erreichen der Abfertigungsanlage)

$t_{D,ein}$:incoming gate crossing time (German term: Einfahrzeit für das Durchfahren der Abfertigungsanlage)

$t_{0,ein}$: time in the entrance level, to get the ramp (German term: Einfahrzeit auf der Einfahrebene bis zum Erreichen des Rampensystems)

$t_{R,ein}$: incoming time on theramp, togetthedestinationstorey(German term: Einfahrzeit im Rampensystem bis zum Erreichen der Ziel-Parkebene)

$t_{E,ein}$: incoming time on thedestinationstoreytogettheparking stall (German term: Einfahrzeit auf der Ziel-Parkebene bis zum Erreichen des Parkstands)

$t_{P,ein}$: parkingstall enteringtime (German term: Einparkzeit)

t_G :walking time between parking stall and exitand back (German term: Gehzeitzwischen Parkstand und Ausgang und zurück)

$t_{P,aus}$: parking stall leaving time (German Term: Ausparkzeit)

$t_{E,aus}$: outgoing time on the destination storey to get the ramp (German term: Ausfahrzeit auf der ParkebenezumErreichen des Rampensystems)

$t_{R,aus}$: outgoing time on the ramp, to get the exit level (German term: Ausfahrzeitim-RampensystembiszumErreichen der Ausfahrparkebene)

$t_{0,aus}$: time in the exit level, toget the gate (German term: Ausfahrzeit auf der Ausfahrebene bis zum Erreichen der Abfertigungsanlage)

$t_{D,aus}$:out going gate crossing time (German term: Ausfahrzeit für das Durchfahren der Abfertigungsanlage)

$t_{A,aus}$: time in the structure, toget the public street(German term: Ausfahrzeit im Außenbereich bis zum Erreichen der Erschließungsstraße)

Fig. 4. Partial parking times

Source background: {2}

3.4.2. Determining of MQV

3.4.2.1. Procedure Overview

A method for the determination of the total parking time could be executed as follows:

1) For each parking level a "significant parking stall" should be determined (for more information see section 3.4.2.2)
2) A"storey parking time"tPV,E is going to be determined for each of those significant parking stalls. It is composed of the partial parking times that are illustrated in Fig. 4 (for more information see section 3.4.2.3 and 3.4.2.4). Those partial parking times should be determined dependent of the loading, so a conclusion for the time needed for the parking process could be drawn for the different loadings of the parking structure.
3) In the end the "total parking time" tPVis going to be calculated across all levels of the parking structure (for more information see section 3.4.2.5).

How the individual steps could be executed is described below.

3.4.2.2. Determining of the Significant Parking Stalls

The significant parking stalls should be attractive parking stalls for the users. They should be located on spots, which are representative for the geometry and the location to the access system. The consideration of SCHUSTER and STEIN[17} showed, that parking stalls, that are easy accessible by the access system and/or are close to the exits, are being favored. The availability of those however depends on the loading of the parking structure. Because there are no findings about those connections, a pragmatic approach has to be found. There are two options for this:

1) Determination of the geometric center of the parking stalls on a certain level and determination of a group of significant parking stalls surrounding the center (touching the so called level centre area zone).
2) Determination of the two parking stalls on a certain level which are accessible on the shortest and longest distance on the level.

Figure 5 shows exemplary the location of significant parking stalls in the level centre area zone. A group of parking stalls has to be chosen, to avoid blurs and limit casesby selecting the significant parking stalls.

The level center area zone can be situated outside of the parking level, if the layout is unusual. That would mean that there could not be a parking stall group determined. The usage of the second method forecloses this problem. But it takes more effort because there are two widely apart lying significant parking stalls to consider.

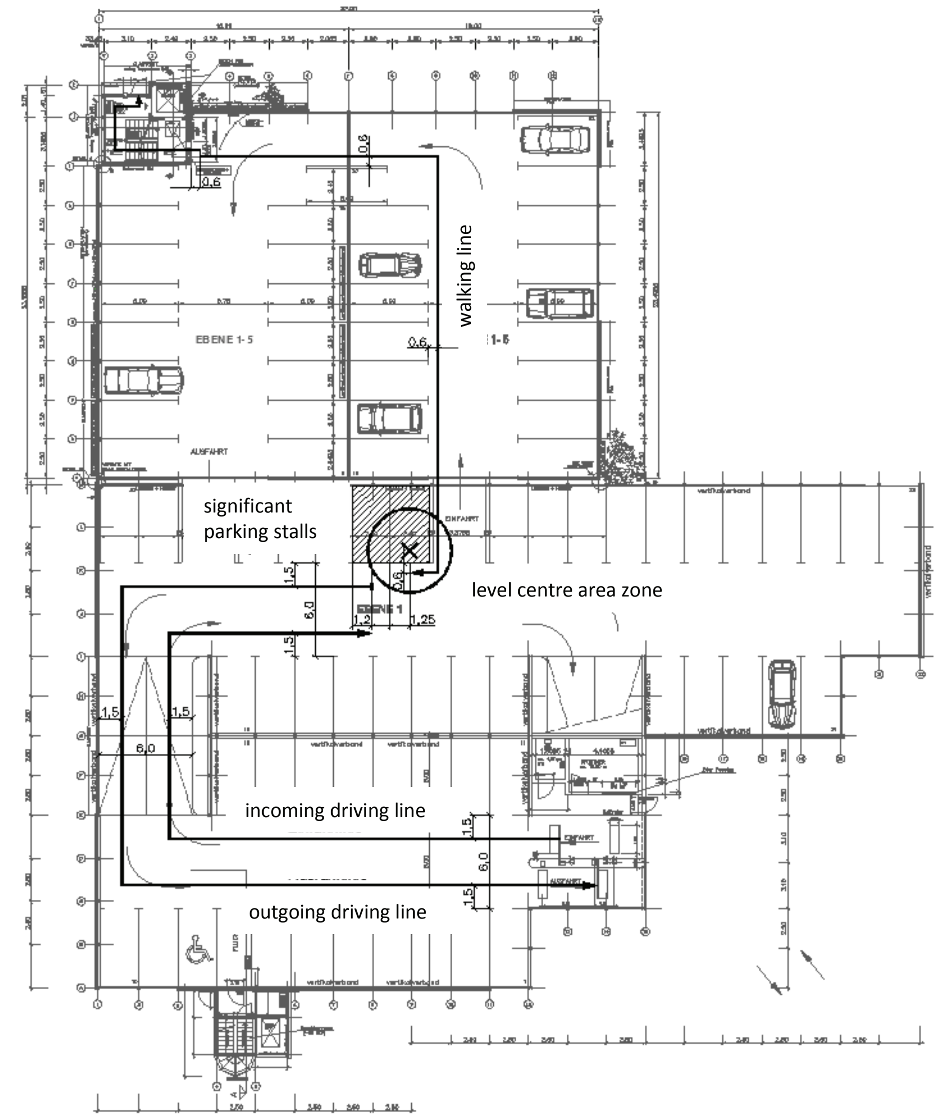


Fig. 5. Example of a significant parking stall accumulation and their routes
Source background: {11}

3.4.2.3. Determining of Partial Parking Times

Gate Crossing Time

There is already an existing method to determine the time to pass through the gate[6}. This method can be used.

Parking Stall Entering and Leaving Time

The parking stall entering time $t_{P,ein}$ and the parking stall leaving time $t_{P,aus}$ depend on the parking stall accumulation (angle), the width and the loading. The average times for the parking process for perpendicular parking, without considering the loading, are shown in table 1 and 2. Those times where measured only in two parking structures. There has to be more research to get more representative values for different geometries and different loadings.

Table 1. Average parking stall entering time $t_{P,ein}$ in perpendicular parking stalls

Parking direction	$t_{P,ein}$ ***[s]***	***Source***	***Quality of observation***
Forward	13,0	[8, 9]	Approx. 100 observations at different parking stalls in 2 parking structures
Backwards	30,5	[8, 9]	Approx. 100 observations at different parking stalls in 2 parking structures

Table 2. Average parking stall leaving $t_{P,aus}$ from perpendicular parking stalls

Parking direction	$t_{P,aus}$ ***[s]***	***Source***	***Quality of observation***
Forward	5,5	[8, 9]	Approx. 80 observations at different parking stalls in 2 parking structures
Backwards	16,4	[8, 9]	Approx. 90 observations at different parking stalls in 2 parking structures

Other Partial Parking Times

Some more partial parking timesmust be determined (see Fig. 4). Those times could be determined by the distances, measured in the design drawings and the driving or walking speed. Measuring instructions have to be developed for the measuring of the distances. Driving speed which depends on the width of the aisle, the type and the slope of the ramp, has to be compiled or explored.

Such distances are shown exemplary in Fig. 5. Following measuring instructions would be a proposal for the definition of the routes and paths:

„The driving line runs in a distance of a quarter of the width of the aisle or ramp, measured from the edge of the aisle or the ramp. It starts at the barrier and ends where the symmetry axis of the closest significant parking stall (belonging to a level centre area zone) crosses the driving line. For simplification the curve progressions should be transferred into square progressions.

The walking line represents the shortest paths between significant parking stalls and access doors to the staircase alongside the aisle or alongside separate sidewalks, however not between the parking cars. There has to be a 60 cm distance from the parking stall line or the walls (definition after recommendation for pedestrian traffic structures ([5], picture 4)). It continues from the access door across the staircase to the public space, measured in the middle of the staircase or the middle of the platform. It starts where the symmetry axis of the closest significant parking stall (belonging to a level centre area zone) crosses the walking line. It ends where it meets the public space. For simplification the change of directions can be transferred into square progressions.

First characteristic values for driving and walking speeds are compiled in table 3 and 4. There has to be more extensive research to get more representative values for different geometries and different loadings.

Table 3. Average speed in aisles and on ramps

Location and direction	*Average Speed [km/h]*	*Source*	*Quality of observation*
Parking area (in general)	17,2	[12]	unknown
Aisle, while entering	11,7	[9]	Approx. 300 observations on 1 reference section in 1 structure
Aisle, while leaving	13,4	[9]	Approx. 300 observations on 1 reference section in 1 structure
Ramp (in general)	8,8	[12]	unknown
Half storey ramp up	12,1	[9]	Approx. 300 observations on 1 reference section in 1 structure
Half storey ramp down	12,8	[9]	Approx. 300 observations on 1 reference section in 1 structure
Half spiral ramp up	2,4	[8]	Approx. 30 observations on 1 reference section in 1 structure
Half spiral ramp down	3,9	[8]	Approx. 30 observations on 1 reference section in 1 structure

Table 4. Average walking speed on parking storeys and on stairs

Location and direction	*Average speed [m/s]*	*Source*
Parking storey	1,5	[10]
Stairs up	0,61	[6]
Stairs down	0,69	[6]

3.4.2.4. Determining of Storey Parking Time

Figure 4 shows that the time for the level parking process is made up of the determined partial parking times. So it can be calculated as follows:

$$t_{PV,E} = t_{A,ein} + t_{D,ein} + t_{0,ein} + t_{R,ein} + t_{E,ein} + t_{P,ein} + t_{G} + t_{P,aus} + t_{E,aus} + t_{R,aus} + t_{0,aus} + t_{D,aus} + t_{A,aus} \quad (1)$$

3.4.2.5. Determining of Total Parking Time

In a closing step the total parking time $t_{PV,}$ for the whole parking structure, has to be determined out of the storey parking times for the significant parking stalls of the parking levels. This must happen in dependence of the loading and in dependence of the existence and quality of a guidance system. A first approach for this could be the following:

Total Parking Time without Parking Guidance:

$$t_{PV} = t_{PV,E0} + 1/n \cdot [(t_{R,ein,E1} + t_{E,ein,E1} + t_{G,E1} + t_{E,aus,E1} + t_{R,aus,E1}) + \dots + (t_{R,ein,En} + t_{E,ein,En} + t_{G,En} + t_{E,aus,En} + t_{R,aus,En})] \quad (2)$$

Total Parking Time with Parking Guidance:

$$t_{PV} = t_{PV,E0} + 1/n \cdot [(t_{R,ein,E1} + t_{G,E1} + t_{R,aus,E1}) + \dots + (t_{R,ein,En} + t_{G,En} + t_{R,aus,En})] \quad (3)$$

E_0:entrance level

E_1:level 1

…

E_n:level n

Those approaches consider the avoidance of drivingin certain levels (with no parking stalls available) due to a guidance system. It guarantees that - for instance - the total parking timein high but small-area or low but large-area designs is bigger than in compact designs. There is a consideration of the loading of the parking structure possible by using loading dependent partial parking times. There has to be more extensive research to get more representative methods for the determination of these times.

3.5. Determining the Level of Service

Analogous to the model in part 3.2 and the presentation in Fig. 2 the quality assessment should be carried out in two steps:

Step 1: With in a quality audit for parking structure designs (QAP) and with the help of checklist for the design elements that can be taken out of the parking structure layout (for instance minimum height for driving through, minimum longitudinal gradient of the ramp, minimum width of the ramp, minimum parking stall width, etc.) it has to be checked, if the parking structure has the required minimum quality(seepart 3.3). Only if this is the case, step 2 follows. If not, for the structure is no QSV determinable.

Step 2: With the help of the in part 3.4 described methodthe total parking time t_{PV} can be determined as MQV. Based on that the level of service (QSV) can be determined. A classification for which MQV which quality step is assigned cannot be stated at the moment. There is extensive and empirical research necessary for this.

In summary the approach for the quality assessment can be represented as follows:

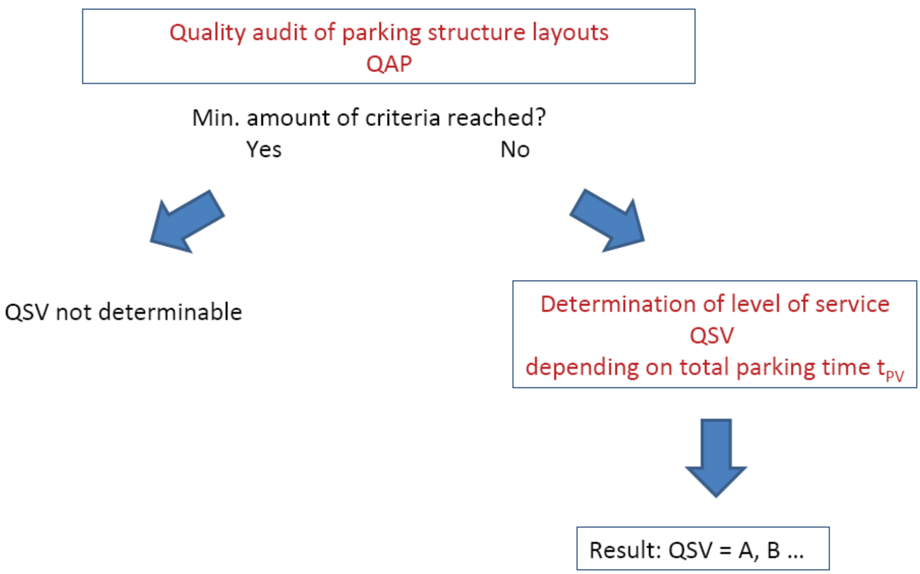


Fig. 6. Determining level of service of a parking structure layout

4. Open Questions and Need of Research

The drafted approach is a first proposal for an integral quality assessment method for parking structures. It was developed after the examination of a few examples and has to be checked by using them for more parking structure layouts. This process will raise more problems regarding the methodic approaches and measuring instructions, which have to be solved.

The necessary values are only known fragmentarily. There has to be done more research for this purpose too. The dependence of those values on the different geometries (form of the ramp, access system, parking stall accumulation) and on the different loadings is important.

The quality check of parking structure layouts in Germany is, like early mentioned unsatisfying. Other traffic building already have a higher standard. There is backlog demand. There is a hope that with the publication of this article an increased activity could lead to the achievement of such standards for parking structures. The first approaches that where shown have to be tested and developed further.

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