

# Methodology of the calculation of student capacities in Germany

- An introduction -



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## ***Introduction***

Capacity calculation is a mathematic approach which tries to determine the maximum possible number of students in specific study programs on the basis of the resources of teaching staff. The use of this methodology is very unique in Germany, thus not very known in other countries.

It arose in the year 1972 from a judgment of the German Federal Constitutional court, which strengthened the rights of prospective students, who were unlucky in finding study places due to admission restrictions determined by higher education institutions. This judgement stated that admission restrictions are basically contrary to German Basic Law, because Basic Law says that all Germans shall have the right to freely choice their occupation or profession, their place of work and their place of training. Nevertheless it was asserted that admission restrictions are necessary anyway in order to ensure well-ordered operations in higher education institutions. Therefore the Court decided that admission restrictions are only acceptable if they base upon the exhaustive utilisation of existing teaching capacities.

As a consequence of this judgement, a methodology for the calculation of teaching capacities was developed which has to be used obligatorily by higher education institutions if they need to restrict the admission to their study programs.

## ***Basic principles of the capacity calculation***

In general, the maximum possible capacity of students in a study program depends, amongst others, on different conditions:

- availability of teaching staff
- availability of rooms and facilities
- number of patients (in Medicine)
- student drop-out rates

As the availability of teaching staff is the most important condition, the methodology of the capacity calculation generally bases on this condition, others are considered subordinately.

The most important requirement of the German Federal Constitutional Court on the lawfulness of admission restrictions is that the maximum number of students expressed in an admission restriction must correspond to a number of students which fully utilizes the capacity of a specific teaching unit. In this context only the capacity of teaching staff in a teaching unit is considered.

This can be illustrated mathematically as follows:

$$\mathbf{Supply\ of\ teaching\ (S) \rightleftharpoons Demand\ for\ teaching\ (D)}$$

*[Equation 1]*

(The Supply of teaching, provided by the teaching staff, must be in balance with the Demand for teaching, consumed by the students)

The overall Demand for teaching (D) is determined by the amount, that one student consumes (d) and the number of students (A):

$$\mathbf{D = d \cdot A}$$

*[Equation 2]*

Inserting equation 2 in equation 1 results in:

$$S = d \cdot A$$

and rearranging this equation to solve for (A) results in:

$$A = \frac{S}{d}$$

This is the basic equation of the methodology of the capacity calculation, saying that it is possible to calculate a possible number of students if the Supply of teaching (S) and the consumption of teaching by one student (d) is known.

### ***Definition of measurement units and other terms***

In order to be able to apply the methodology it is necessary to use a measurement unit which can express Supply and Demand for teaching. There are several units which express the workload of students and teachers, by now Credit Poits (CP) is the most known and most used unit. In Germany exists another unit, called Semesterwochenstunde (SWS), which was used before study programs in Germany were converted to the Bachelor- and Master-structure, and is still used for the purposes of capacity calculation.

### **Explanation of the unit ‘Semesterwochenstunde (SWS)’**

‘Semesterwochenstunde’ means ‘credit hour’ or ‘semester load’. It is a unit for measuring the time scope needed for academic courses. It is defined as a time period of 45 minutes of contact between students and teachers of courses taking place weekly during a semester.

#### Example:

The lecture ‘Chemistry for beginners’ takes place every Monday from 9 a.m. to 10:30 a.m. during the summer semester. This lecture has a semester load of 2 SWS (2 x 45min every Monday).

It is important to know, that the time needed to prepare and follow up a course is kept unaccounted in this unit.

## **Explanation of the term 'teaching unit'**

The objective of the capacity calculation is to determine the capacities of all study programs of a higher education institution. In order to simplify the calculation it is necessary to unite study programs as well as teaching staff to larger units, which are technically similar. For this purpose virtual organisational units, so called teaching units, are created. A teaching unit contains the teaching staff of one subject and all study programs of the same subject. Thus, teaching units are subject-related aggregations of personnel and study programs. Usually the structure of teaching units corresponds closely to the departmental structure of a higher education institution.

### Example:

At Saarland University there exists a teaching unit 'Chemistry'. This teaching unit includes the whole academic staff of the department of Chemistry and all study programs related to Chemistry, e.g.

- Chemistry, Bachelor of Science,
- Chemistry, Master of Science,
- Chemistry (teaching career),
- Chemistry of Materials, Master of Science.

During the calculation process the capacity of the whole teaching unit 'Chemistry' is calculated first. In a next step, this entire capacity will then be apportioned to the several study programs.

## ***Step-by-step tutorial of the methodology***

### **Determination of the Supply of teaching (S)**

The supply of teaching is determined by the total number of credit hours (SWS) that the whole teaching staff of one teaching unit is able to provide. Generally every member of the academic staff of a higher education institution in Germany is obligated to give lessons to students. The amount of this obligation (measured in SWS) is regulated by law and depends on the category to which an academic employee belongs to.

Example for Saarland University:

<b>Staff category</b>	<b>Teaching obligation</b>
Full professor	9 SWS
Assistant professor	4-6 SWS
Scientific assistant, contract limited in time	4 SWS
Scientific assistant, contract unlimited in time	up to 8 SWS
Teaching assistant	12-16 SWS

To determine the total Supply of credit hours of one teaching unit, you easily need to count the number of persons in every staff category and multiply this number by the corresponding teaching obligation:

<b>Staff category</b>	<b>quantity</b>	<b>teaching obligation</b>	<b>total supply (category)</b>
Professors	4	9 SWS	36 SWS
Sc. assistants (limited)	3	4 SWS	12 SWS
Sc. assistants (unlimited)	4	8 SWS	32 SWS
<b>Total supply (teaching unit)</b>			<b>80 SWS</b>

The calculation gets a little more complicated for staff categories with no explicitly determined teaching obligation (e.g. Teaching assistants with a determined range of teaching obligation; Sc. Assistants with a determined upper limit of teaching obligation). In those cases the teaching obligation is not associated to a staff category but to a single person and is stated in the working contract of each person. Therefore the calculation has to be modified as follows:

<b>Staff category</b>	<b>quantity</b>	<b>teaching obligation</b>	<b>total supply (category)</b>
Professors	4	9 SWS	36 SWS
Sc. assistants (limited)	3	4 SWS	12 SWS
Sc. assistants (unlimited)	4	8 SWS	--
<i>Thomas Müller</i>		8 SWS	8 SWS
<i>Dr. Bruce Tanner</i>		6 SWS	6 SWS
<i>Dr. Theo Schneider</i>		8 SWS	8 SWS
<i>Albert Einstein</i>		4 SWS	4 SWS
<b>Total supply (teaching unit)</b>			<b>74 SWS</b>

**Consideration of part-time lecturers**

Part-time lecturers are usually no employees of an higher education institution and will therefore not be comprised in the table of staff of the institution. The number of

part-time lecturers also is quite variable, because the amount of part-time lecturers depends mostly on a flexible demand. To consider part-time lecturers anyway the methodology of the capacity calculation uses an examination which is oriented towards the past, by considering an average of credit hours provided by part-time lecturers of the past two semesters in order to predict the amount for the upcoming semester. For this determination it is necessary to record all the part-time lecturers and the credit hours they provided for each teaching unit.

Example:

Credit hours (SWS) provided by part-time lecturers (summer semester 2010):	24 SWS
Credit hours (SWS) provided by part-time lecturers (winter semester 2010):	16 SWS
<b>Average per semester (= predicted value for the future):</b>	<b>20 SWS</b>

**Consideration of reductions of the teaching obligation**

In some cases the mandatory teaching obligation can be reduced, e.g. if a professor is assigned with additional duties and responsibilities:

- Deans of Faculties
- Vice-presidents of the University
- Special tasks in research
- Activities in study counselling

These reductions must be considered in the determination of the total supply of teaching and are subtracted from the number of credit hours calculated.

**Summary of the calculation of the Supply for teaching**

<b>Staff category</b>	<b>quantity</b>	<b>teaching obligation</b>	<b>total supply (category)</b>
Professors	4	9 SWS	36 SWS
Sc. assistants (limited)	3	4 SWS	12 SWS
Sc. assistants (unlimited)	4	8 SWS	--
<i>Thomas Müller</i>		8 SWS	8 SWS
<i>Dr. Bruce Tanner</i>		6 SWS	6 SWS
<i>Dr. Theo Schneider</i>		8 SWS	8 SWS
<i>Albert Einstein</i>		4 SWS	4 SWS
<b>Total supply (employees)</b>			<b>74 SWS</b>
+ supply (part-time lecturers)			+ 20 SWS
- reductions			- 5 SWS
<b>Total supply (semester)</b>			<b>89 SWS</b>
<b>Total supply (year) x2</b>			<b>178 SWS</b>



## Determination of the Demand for teaching

### ***The curricular value***

In order to calculate the capacity as a number of students it is necessary determine the Demand of teaching as the amount of teaching that ONE student consumes during the whole duration of a study program.

To clarify this approach it is easier to examine one single course in the first step:

*“The lecture ‘Chemistry 1 for beginners’ takes place every Monday from 9 a.m. to 10:30 a.m. during the summer semester. This lecture has a semester load of 2 SWS (2 x 45min every Monday).”*

There is usually more than one student visiting a specific course. Considering the semester load, the whole group of students consumes a load of 2 SWS, but every single student only consumes a part of this load, which depends of the number of students visiting this course.

Thus, the load that one student consumes can be calculated by dividing the total semester load of a specific course by the group size of this course. For the example of the lecture ‘Chemistry 1 for beginners’ let’s assume that the group size is 100:

$$\text{Demand of one student (d)}_{\text{Chemistry 1}} = \frac{\text{semester load}_{\text{Chemistry 1}} [\text{SWS}]}{\text{group size}_{\text{Chemistry 1}}}$$

$$\text{Demand of one student (d)}_{\text{Chemistry 1}} = \frac{2 \text{ SWS}}{100} = 0,02 \text{ SWS}$$

In order to calculate these values it is necessary to standardize group sizes for different types of courses. Group sizes depend on the didactic approach of different course types, the way a teacher conveys knowledge to the students of the course. The next table shows some standardized group sizes for Saarland University:

<b>Course type</b>	<b>Group size</b>
Lecture	100 students
Exercise course	30 students
Seminar / Workshop	30 students
Practical course	15 students

The quotient 'semester load / group size' is called 'curricular value'. In the example above it was calculated for one course of a study program. For the capacity calculation for whole study programs it is necessary to calculate this curricular value for a whole program. Study programs usually consist of several courses which differ in their type (and thereby differ in their standardized group sizes) and in their semester loads (SWS).

To determine the curricular value of a whole study programs it is necessary to calculate the curricular value for every single course first and then sum-up all single values.

Example:

*Calculation of the curricular value for the study-program 'Chemistry, Bachelor of Science':*

<b>course name</b>	<b>course type</b>	<b>time scope (SWS)</b>	<b>max. group size</b>	<b>curricular value</b>
Chemistry for beginners	lecture	2 SWS	100	0,0200
Chemistry for beginners	exercise	1 SWS	30	0,0333
Physical chemistry	lecture	2 SWS	100	0,0200
Physical chemistry	exercise	1 SWS	30	0,0333
Practical: Anorganic Chemistry	practical course	2 SWS	15	0,1333
Chemical analysis	workshop	2 SWS	30	0,0667
...	...	...	...	...
<b>SUM</b>				<b>4,1747</b>

The resulting sum (4,1747) is called the 'curricular value' (CNW) of the study program 'Chemistry, Bachelor of Science'. It is defined as the amount of teaching, measured in SWS, that one student consumes during his academic studies from the beginning to graduation. It is a measure for the workload and the intensity of support of a study program. By using the curricular value, one can easily draw conclusions on how much supply of teaching is needed.

### **Curricular fragments**

In many cases not all of the courses of one study program are offered by the staff of the same teaching unit the study program is assigned to. In our example we might have a course 'Mathematics for Chemists' which is offered by teaching staff of the teaching unit 'Mathematics' and not by the staff of the teaching unit 'Chemistry'. As a consequence it is necessary to split up the curricular value of a study program into different fragments, depending on the teaching unit which offers single courses or larger parts of a study program.

In result we get one curricular fragment (CA) for each teaching unit, which is involved in the teaching of a study program. The several curricular fragments add up to the total curricular value (CNW) of the study program:

*Example: Curricular fragments for the study program 'Chemistry, Bachelor of Science':*

<b>Teaching unit</b>	<b>CA</b>
Chemistry	3,7600
Physics	0,2400
Mathematics	0,1267
Biology	0,0480
<b>TOTAL (CNW)</b>	<b>4,1747</b>

When calculating capacities of a study program it is important that only the curricular fragment of the teaching unit must be used to which the study program is assigned to, because only this part of the study program is covered by teaching staff of the same teaching unit.

### **Teaching export**

On closer examination of the idea of curricular fragments one would discover that the teaching staff of one teaching unit not only supplies own study programs, but also study programs of other teaching units. In our example this would affect the teaching unit 'Mathematics', whose teaching staff needs a specific amount of teaching load to supply students of the study program 'Chemistry, Bachelor of Science'. It is evident that this specific teaching load is not available for study programs which are assigned to the teaching unit 'Mathematics'. To consider this aspect in the capacity calculation, the amount of teaching load for foreign study programs must be subtracted from the

total supply of teaching of a teaching unit. For the determination of the required amount of teaching for foreign study programs the following equation is used:

$$\text{Export per semester (E)} = \text{curricular fragment CA}_q \bullet \frac{\text{No. of first year students (A}_q)}{2}$$

Example:

The teaching unit ‘Mathematics’ offers different courses for the study programs ‘Chemistry, Bachelor of Science’. This results in a curricular fragment  $CA_q = 0,1267$ . The study program had 86 first-year students in the last year. The resulting teaching export is then calculated using the formula above: 5,45 SWS are needed to supply students of the foreign study program.

The total teaching export of one teaching unit must then be subtracted from the total supply of teaching of this teaching unit. This adjusted supply is then called ‘clean supply’:

Example (teaching unit ‘Chemistry’):

Supply (employees)		74 SWS
+ Supply (part-time lecturers)	+	20 SWS
- reductions	-	5 SWS
= total supply (semester)	=	89 SWS
- export needed	-	21,9 SWS
= clean supply (semester)	=	67,1 SWS
= clean supply (year)	x2	134,2 SWS

**Calculation of the capacity:**

At this point all information needed to calculate the capacity of the teaching unit ‘Chemistry’ is available. By using the basic formula

$$A = \frac{S}{d}$$

all the previously determined values can be inserted:

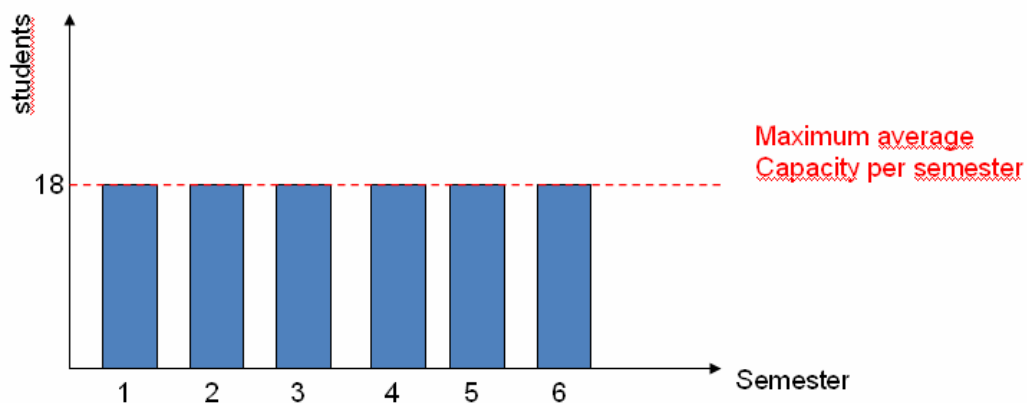
S = Supply = annual clean supply = 134,2 SWS  
d = demand of one student = curricular value (CA) = 3,7600

$$\text{Capacity (A)} = \frac{\text{Supply (S)}}{\text{CA}} = \frac{134,2 \text{ SWS}}{3,76 \text{ SWS/stud}} \approx 36 \text{ students}$$

### ***Understanding the model behind the calculation:***

The curricular value of a study program contains all courses that a student has to attend until graduation. This implicates, that the result of the capacity calculation in truth is not the capacity for first-year students, which would be needed to determine admission limits, but is an average capacity of a study program over its complete duration. In ideal case this average capacity would correlate exactly with the first-year capacity, because every first-year student would graduate after completing all courses of the study program:

$$\text{Capacity} = 36 \text{ students per year} \rightarrow 18 \text{ students per semester}$$

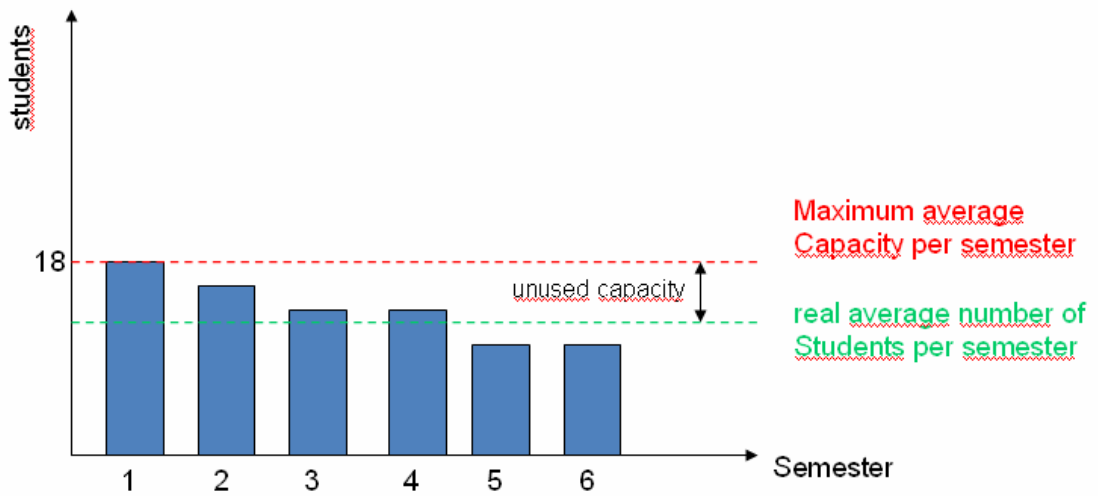


In this ideal model, the capacities of all semesters would be the same. This ideal model usually does not correspond with reality, because there will be a specific amount of students, who do not finish their studies (drop-out).

### ***Consideration of drop-out-rates:***

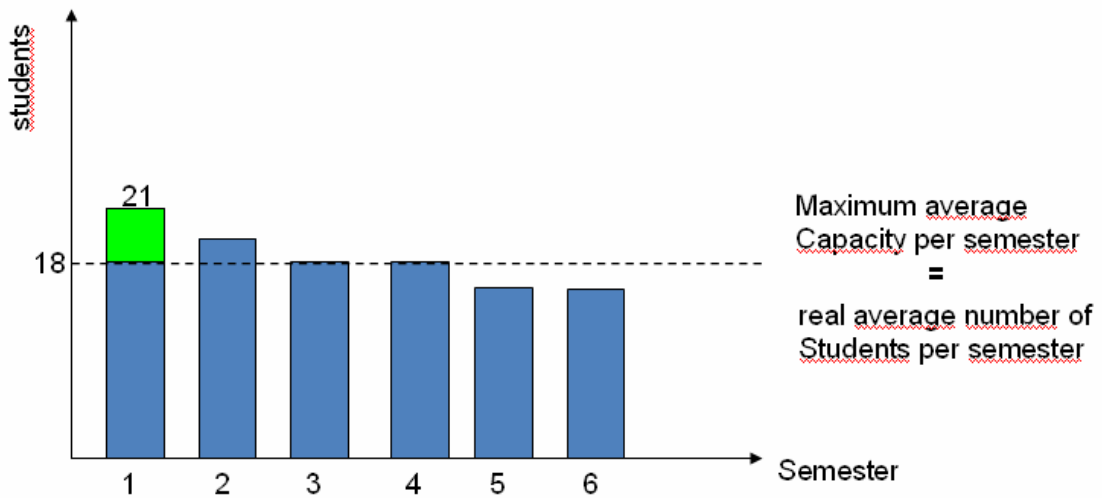
In almost every study program there occurs a loss of students during the duration of the program. In capacity consideration this would result in unused capacities in upper semesters, because the effective number of students in these semesters would always be lower than the calculated capacity:

Loss of students: drop-out before graduation



The methodology of the capacity calculation uses a quite simple approach to solve this problem. In order to avoid unused capacities the admission limits for the first semester is increased to a higher value than the calculated capacities:

- Solution: more admissions for the first semester than calculated capacity



The amount of this increase is calculated using drop-out-rates, which can be determined from matriculation data of past semesters. To be precise, not the drop-out rates are used, but the inverse values, which are in fact 'stay-in-rates'.

Using this rate, the admission limit can be calculated as following:

$$\text{admission limit} = \frac{\text{calculated capacity}}{\text{stay - in - rate}}$$

Example:

The 'stay-in-rate' for the study program 'Chemistry, Bachelor of Science' was calculated as 0,8641 (the corresponding drop-out-rate would then be:  $1 - 0,8641 = 0,1359 = 13,59\%$ )

$$\text{admission limit (Chemistry)} = \frac{\text{calculated capacity}}{\text{stay - in - rate}} = \frac{18}{0,8641} \approx 21 \text{ students}$$

**Conclusions:**

The methodology of the capacity calculation is a technique, which makes it possible to draw conclusions between the amount of teaching staff and the number of students in higher education institutions. It is a methodology which makes simplifications in many areas in order to keep the effort to use it manageable. Thereby it does not always correspond with the reality in higher education institutions. In Germany it must be used for the determination of admission limits and it can be used for other applications and problems (e.g. staff planning, utilization calculations). Due to its development in the seventies it would need revision in many points in order to keep it up to date and to ensure its fitting to a changed environment in higher education. Despite these weak points, the basic idea of the methodology can be very useful to approach different problems in higher education and is worth a further development.