Changes and Perspectives in University Education for Geodetic Engineers in Germany

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Key words: Geodetic Engineer, University Education, Geodetic and Surveying Curricula, Diploma Engineer.

ABSTRACT

In many countries the academic educational program has the objective to train students to perform tasks in all fields of the profession so that the Geodetic Engineer fulfils the necessary prerequisites for all possible professional activities. The nature of our surveying business is changing and new areas are developing very rapidly. But new technologies and the extension of the field of the profession require new concepts and structures in education; in particular, the problem has to be considered, how the increased number of subjects can be treated in the limited time budget. In our country we have not only to take national requirements into account but also the European ones, e.g. the General Directives of the European Council. Besides that needs of the international markets have to be considered. This paper wants to give an insight in the current status and perspectives.

ZUSAMMENFASSUNG

Wie in vielen anderen Ländern ist auch in Deutschland das Studium des Vermessungswesens so angelegt, dass der Vermessungsingenieur über alle Voraussetzungen verfügt, um in der beruflichen Praxis über die volle Breite seines Fachgebiets einsetzbar zu sein. Neue Technologien erfordern auch neue Konzepte in der Ausbildung, weil eine eventuelle Vermehrung von Fächern und eine Erweiterung der Lehrinhalte im vorgegebenen Zeitrahmen und Stundenvolumen zu erfolgen haben. Bei der Erstellung neuer Curricula haben wir in unserem Land nicht nur die rasante fachliche Entwicklung zu berücksichtigen sondern auch die durch die europäische Integration bedingten Vorgaben der EU. Ein Einblick in die wesentlichen Entwicklungstrends soll im folgenden Beitrag vermittelt werden.

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1. INTRODUCTION

One of the most obvious traits of the surveying profession in Europe is its market diversity between the different countries. Geodetic engineers in some countries provide professional services, which are provided by different professionals in other countries. This diversity of professional practice has led to a wide diversity in academic qualifications for geodetic engineers [Prendergast, W., 2001].

Traditionally, the surveying profession predominantly operated in niche markets, which were either local or national in character. Consequently, academic courses in the different countries were adapted specifically for these local and national requirements without any reference to the needs of the international markets in Europe or globally.

The EU wants the mobility of professionals between European countries using the EU concept of mutual recognition of qualifications. The rights of EU citizens to provide services anywhere in the EU are fundamental principles of EU law. National regulations, which only recognise professional qualifications of a particular jurisdiction present obstacles to these fundamental rights. These obstacles are overcome by rules guaranteeing the mutual recognition of professional qualifications between Member States, i.e. the sectoral and general Directives [European Council, 1988 and 1992].

The European Ministers of Education made a joint declaration ("Bologna agreement") in June 1999 [European Ministers of Education, 1999] to co-ordinate their policies to achieve within the first decade of the 21st century the adoption of a system of easily comparable degrees consisting to two main cycles:

a) an undergraduate cycle lasting a minimum of three years,
b) a graduate cycle leading to master's and/or doctorate degrees.

This declaration introduces the concept of a new undergraduate qualification, most likely to be at Bachelor level, although already in existence in Ireland, the UK, and to a lesser extent in some other countries. In our country we perceive this development as a threat to the high quality of our existing qualifications. We consider this way also as a threat to the standard of future professional qualifications. A threshold of at least four years is considered as more appropriate.

2. THE GENERAL SITUATION OF SURVEYING EDUCATION IN GERMANY

2.1 Traditional and Non-Traditional Ways

In Germany the academic educational program has the objective to train students able to perform tasks in all fields of surveying and geodesy so that the geodetic engineer fulfils all prerequisites for all professional activities in theoretical and applied surveying engineering or even in geodesy. In our country we did not follow the consecutive system of higher education, which is also called the Anglo-Saxon system. This means that our classical Universities grant a diploma after a minimum study time of 4.5 years (9 semesters). This diploma, called "Diplomingenieur", is comparable to a master's degree in other countries. Besides the classical universities there exists a great number of so-called "Universities or Colleges of Applied Sciences (Fachhochschulen)" with a study time of 3.5 years. Their diploma may be compared to the degree of a bachelor at honours level. But the diploma at these institutions, which is also called "Diplomingenieur", entitles the graduate to practice in nearly all fields of surveying with the exception of certain cadastral surveys.

The education of surveyors at the Universities of Applied Sciences (Fachhochschulen (FH)) differs from that at the Universities in the following principal characteristics:

The solution of practical problems is strongly emphasised in teaching, i.e. the education at FHs has a very strong practical basis. The time spent on practicals and exercises is over 35% of the total contact time. Relevance to practice is an overweening criterion in the selection of study content. The teaching of the theoretical scientific principles can therefore not be done with the same intensity as it is provided at the universities. FH graduates are therefore typical surveyors who can rapidly become productive in surveying firms or organisations without major teething troubles. The courses, which normally include one or two practical semesters as well as the completion of a diploma thesis, take four years to complete as a rule. Over 90% of students complete the course within this time frame. This is only possible because the organisation of the curriculum is somewhat rigid and allows the students less freedom than is found in the university courses. Apart from the formal course, students are required to have at least 13 weeks' practical experience in surveying firms, offices or institutions, 8 weeks of which have to be completed before the course can be commenced.

However, there are, since 1998, possibilities for both the classical Universities and the Universities of Applied Sciences to develop both kinds of programmes leading to Dipl.-Ing. TU or Dipl.-Ing. FH, or to BS and MS degrees. At a first stage the new courses will be introduced on a trial basis besides the existing ones. A final decision will be made after completion of this test run. The Universities are individually responsible when to put the change into effect. A very few have already chosen to go this way. The majority is waiting and observing how this new approach will be accepted.

The new courses will have a modular structure and will, as regards content, be measured against an EU-wide uniform system of marks, which can be compared to the Anglo-American “credit-point”-system, that is measuring the various modules in quantity by points and quality by marks. In case the courses fulfil certain minimum requirements, they can be

accredited by an accreditation agency. The issuing of accreditations is subject to systematic evaluation. The above agencies obtain the requirements as regards contents and formal procedures from an accreditation council assigned to the HRK. The accreditation aims at securing both transparency and standards of the offered courses and therefore stands beside the state approval of the study courses for the time being. More details are given in the paper of Wehmann, W. and Hahn, M.. [2002]. Because we are living in a transition time most students are pursuing the classical ways.

In order to get an impression about the total number of geodetic surveyors graduating every year from German Universities and Universities of Applied Sciences see figures 1 and 2.

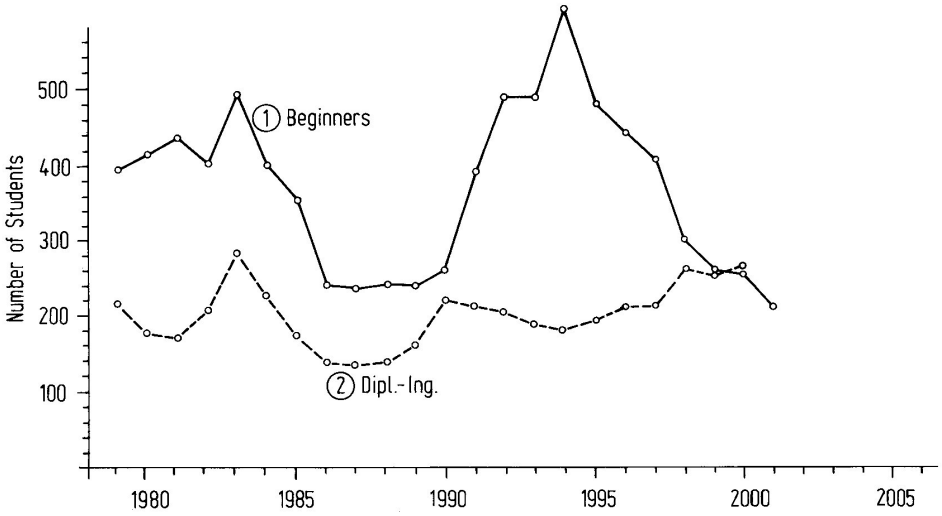

Figure 1: Number of German surveying students at the university level starting every year their academic career and total number of graduates also for every year.

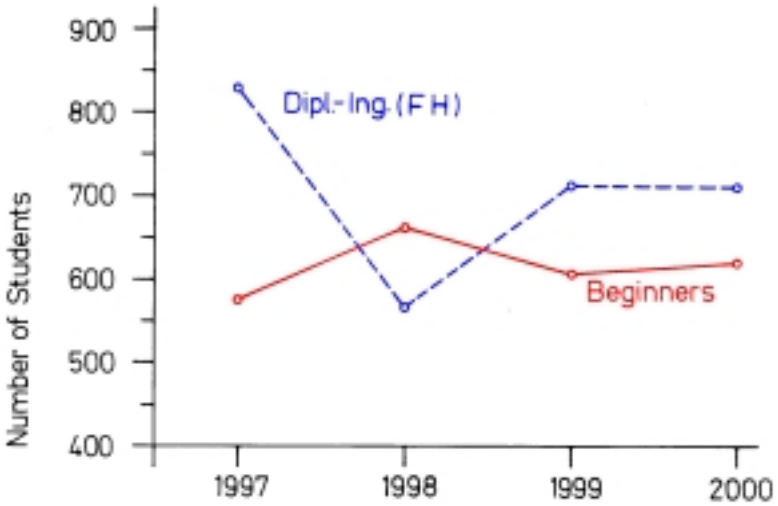

Figure 2: Number of German surveying students at the level of Universities of Applied Sciences (Fachhochschulen): Beginners and graduates

2.2 General Trends in the Profession

New technologies require new concepts in education. These new technologies may be summarized into five categories.

1. Today's technology trends towards fully automated survey systems which reduce the role of the surveyor to a mere operator whose skill can be provided by reading a well-written manual. This holds true for hard- and software systems.
2. New surveying technologies are no longer a mere refinement of old techniques; they are rather founded on completely different principles. Traditional expertise is being increasingly questioned. Examples are GPS, computer-aided mapping and geo-information systems.
3. The traditionally separate tasks of data capture, processing, presentation, and analysis will increasingly become complementary components of a single measuring and computing system.
4. The methods on land management and planning have come up from simply technical and administration procedures to comprehensive processes with social and environmental issues in order to obtain sustainability.
5. Management, marketing and staff controlling for surveyors are examples for new areas of study, which mirror the new trends.

One has to become aware that these developments lead to a certain contradiction between the increase of subjects and the intensity to be taught at universities and the time available for studies. The consequences for education are a permanent change of the curriculum. But this task has to be done in the framework of general regulations (Rahmenprüfungsordnung, 1999) for the way examinations have to be handled and what subjects have to be taught in surveying and geodesy. As far as the subjects are concerned each university can change one or two of them and can weight them differently. These general regulations were set up by a special commission consisting of members of nearly all Universities and Universities of Applied Sciences where geodesy and surveying is taught , as well as of members coming from surveying practice, i. e. the president of the association of chartered surveyors, the president (head) of a state government surveying office (Landesvermessungsamt) and further members.

There can probably be no surveyor who has been unaffected by the rapid pace of change which has influenced the surveying profession over the last two decades. There was a time when the university diploma was the ticket for a lifelong professional career. But today, every one must constantly qualify so that he or she can only keep up by a process of lifelong learning. We can say that there is only one constant and that is permanent change.

The aim of our academic surveying education is to provide our students with the necessary intellectual versatility in order to keep up with the future challenges in our profession, a task which can certainly be achieved with the help of Continuing Professional Development (CDP). The university graduation is therefore not the end in itself but the first step in a lifelong learning process.

2.3 Causes for Changes in Surveying Education at the University Level

Beyond any question the curriculum in surveying education must be continually re-examined and updated to reflect the changing technological demands and the developments in society and economy. A global perspective is certainly vital for a long-term success. Figure 3 may give an impression about the different influences concerning our profession and education.

As far as the methods of land management and planning are concerned the long history of development must be taken into account, which started in the 19th century and was reorganized in the 20th century. These methods are chiefly based on experiences by skilled planners and administration experts. However, the land management and planning problems have grown to a comprehensive process including social and environmental issues in order to obtain sustainable development. This task can only be solved by advanced scientific methods based on a planning process following the system theory.

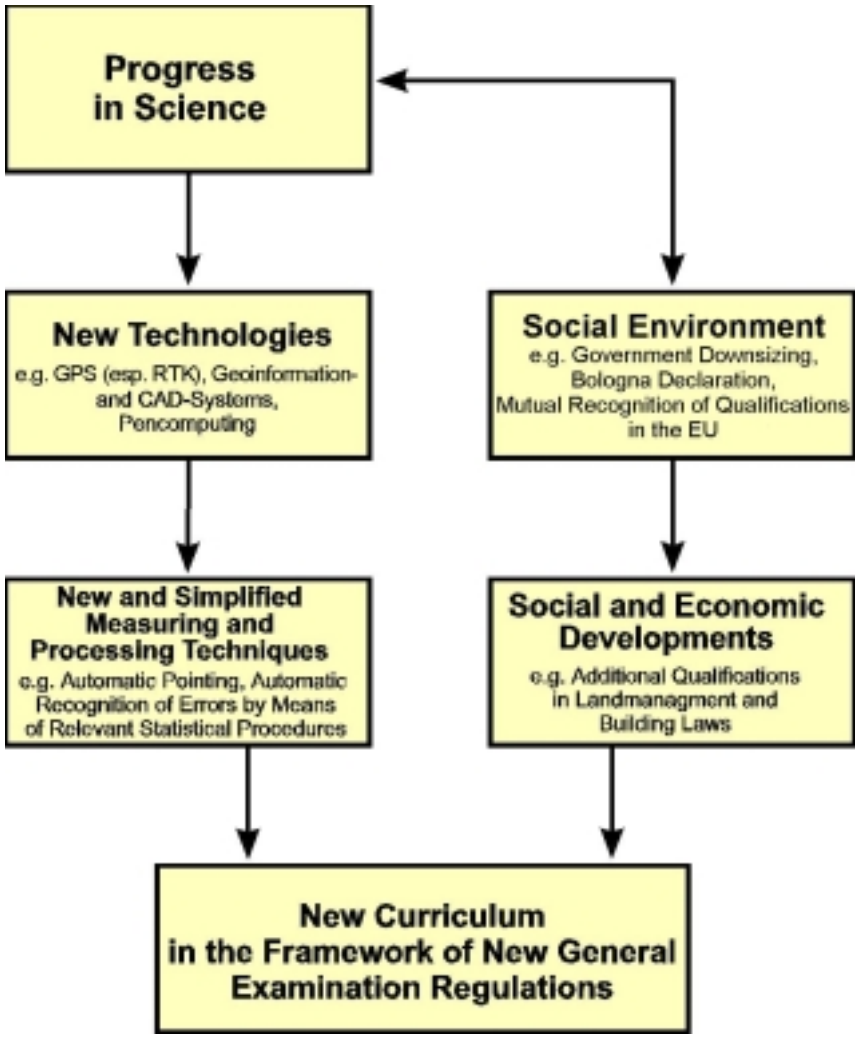

Figure 3: Causes for professional changes and their effects on surveying education

For the curriculum of surveying education with the objective to train students able to perform tasks in all fields of surveying this new challenge requires that additional topics are included, which are not so strongly correlated with natural science, mathematics and civil engineering. Therefore it is necessary to teach the principles of law and economics as well as land management. Real estate valuation and methods of local participation are as important as planning theory. However, best educational standards in these fields are not sufficient to qualify a planner. Management and marketing skills are required like in other surveying fields as well. The particular universities in Germany have set up different priorities in the curricula.

3. CHANGES IN CURRICULA

3.1 General Remarks

Taking these and other professional developments into account and besides that the overall political intentions about the university system in Germany and abroad, a curriculum framework and a corresponding set of general examination regulations for the study of surveying (Rahmenprüfungsordnung) is the result of the special commission. The framework contains basic and compulsory elements for the 9 surveying departments at the corresponding German universities.

For the first part of the curriculum (first four semesters) the main intention of the commission was to rely on the basics of our engineering background, i. e. mathematics, informatics, physics, geo- and social sciences. The amount of time and the quality of the individual course will differ from university to university. But the commission concluded that these subjects should be the same at each university. One third of the teaching time should be devoted to surveying and the basics of adjustment theory. The total contact time required to complete all courses of study is about 180 semester hours for the whole curriculum. The time devoted to the different subjects differs from university to university.

Subjects of the curriculum

The subjects for the first part (basics) of the curriculum (four semesters) are:

1. Mathematics (including Geometry)
2. Physics
3. Informatics (including Computing)
4. Surveying (including basics of Adjustment Theory)
5. Basics of Geoscience (Geology, Geomorphology, Soil Sciences)
6. Basics of Private and Public Law and of Economics

The second (main) part of the curriculum can be studied after having passed the relevant examinations in these six subjects.

The subjects of the second part (next four semesters) are:

1. Surveying and Engineering Surveying
2. Photogrammetry and Remote Sensing

3. Adjustment Theory and Mathematical Statistics
4. Cartography
5. Geo-information systems
6. Mathematical, Physical and Satellite Geodesy
7. Planning (City and Regional Planning), Cadastre, LIS, Rearrangement of Parcels
8. Civil Engineering

A period of up to six months is prescribed for the completion of the diploma thesis.

At a first glance you may have noticed that the commission on surveying education concluded not to go into specialization but to keep integrated knowledge as the best opportunity for later employment. We believe that for a relatively small group of engineers in comparison to the other engineering disciplines this is necessary in order to be known at all in society.

The question must be asked if this curriculum fits the foreseen market i.e. the needs of society. To determine the recognition of geodetic surveying in future it is of importance to work out which functions our profession has to fulfil in society. The following types of positions can be identified:

- The surveyor as the publicly visible representative of the profession, for example with terrestrial surveying, tracing out and deformation measurements (40 %)[1].
- The earth observer who is specialized in photogrammetry and remote sensing from airborne as well as from spaceborne platforms (5 %)[1].
- The geomatics engineer who is specialized in the design, management, and the visual representation maintenance of geo-information systems and in customer-tailored provision of geo-information (30 %)[1].
- The surveyor as a specialist in land management (20 %)[1].
- The geodesist (working in science) (5 %)[1.]

Besides these possible positions there are many others for which our graduates are well prepared, e.g. in navigation and telematics or in the development of traffic guidance systems.

3.2 Examples of Curricula

Based on the developments reported above the curricula at the different Universities in Germany have undergone strong changes in recent years. As an example, the new curriculum at the University of Karlsruhe will be elucidated in more detail below.

Starting in fall 1999 a new curriculum “Geodesy and Geomatics Engineering” (Geodäsie und Geoinformatik) has been introduced at the University of Karlsruhe for the students of the first semester. This curriculum will completely replace the existing curriculum “Surveying” (Vermessungswesen) after a transition period of five years. Hand in hand with the

[11] Percentage of Dipl.-Ing. of the last years working in one of the given fields based on a questionaire

modification of the name goes a far-reaching shift in the subjects and radical changes in the examination modes.

The reformed curriculum at the University of Karlsruhe is orientated at the vision of the surveying engineer of the future as a specialist for very precise measurements at the one hand and as an expert for spatial information at the other hand. Even more than formerly emphasis is given to the fundaments in mathematics, physics (orientated to geodetic measurement procedures) and computer science/informatics (with applications to geo-informatics in the second phase of studies). The backbone is still formed by the relevant knowledge in Surveying, Geodesy, and Photogrammetry/Remote Sensing.

According to the strategy paper "Geodäsie 2000++" [DGK 1997] it has been tried to observe the following principles in creating the new curriculum:

- Summary of the contents of lectures considering geodetic methodology. Restriction to common and essential features.
- Exemplary deepening of qualifications without claiming a complete imparting of knowledge of facts.
- Attribution of lectures to mainly four kernel areas:
  - Modelling, realization and validation of geodetic models
  - Measuring techniques and sensors
  - Data analysis
  - Presentation and application of geodetic data

- Strenghtening of future-oriented topics in the fields of GIS, GPS and sensorics.
- Maintaining features specific to the University of Karlsruhe such as
  - Remote Sensing and Image Processing
  - Strong cooperation with the other geosciences which are fully existent at the University of Karlsruhe.

For more details about the different topics and the lecturing time devoted to these subjects see tables 1 and 2.

The fundamental structure of the former diploma curriculum has been retained. The first phase of studies comprises four semesters and is finalized by a special examination, the "Vordiplom". The second phase consists of two parts, the basic studies in geodesy and geomatics engineering (concentrated in the 5^{th} and 6^{th} semester), and the advanced studies (concentrated in the 7^{th} and 8^{th} semester). The curriculum is finalized by a case study (1 month) and the diploma thesis (5 months), resulting in a total period of 9 semesters. While the subjects in the first phase and in the basic studies are compulsory, the subjects of the advanced studies (minimum of 20 hours per week per semester) can be freely selected from a list of subjects.

According to the principal intentions of the new curriculum there are a lot of significant changes with respect to the classical curriculum in Surveying. The number of contact hours

and the intensity of the subjects in computer science/informatics has been strongly increased. On the other hand, the number of contact hours in the field of planning and law has been reduced in consistence with the specialization in GIS. The course in "Adjustment Theory and Statistics" has been shifted to the 3rd and 4th semester. An introduction into GPS is provided in the lectures "Surveying I" and "Sensorics II", followed by an advanced presentation in "Satellite Geodesy"; practical aspects of GPS are treated in a GPS project in collaboration with a surveying firm or the Ordnance Survey.

	1st sem.	2nd sem.	3rd sem.	4th sem.
Mathematics				
Calculus I	6 + 2			
Calculus II		6 + 2		
Calculus III			2 + 2	
Differential Geometry				3 + 2
Physics				
Experimental Physics I	4 + 2			
Experimental Physics II		4 + 2		
Mechanics for Geodesists			2 + 2	
Computer Science				
Programming for Geodesists	3 + 2			
Informatics for Engineers I		2 + 1		
Informatics for Engineers II			2 + 2	
Data Bank Systems				1 + 1
Mathematical and Geoscientific Foundations of Geodesy				
Geometrical models in Geodesy			3 + 1*	
Signal processing in Geodesy				2 + 1*
Adjustment theory and statistics I			3 + 1	
Adjustment theory and statistics II				3 + 1
Basics of geosciences			2 + 1*	
Surveying and Sensorics				
Surveying I	2 + 0			
Surveying II		2 + 0		
Surveying Practice I, II	1 + 2	1 + 2		
Surveying Field Project I		2 weeks		
Geodetic Sensorics and Metrology I			2 + 1*	
Geodetic Sensorics and Metrology II				2 + 1*
Surveying Practice III				0 + 1*
Surveying Field Project II				2 weeks *
Basics in Photogrammetry&Remote Sensing				
Photogrammetry I				1 + 1*
Remote Sensing I				1 + 0*
Introduction to cadastre				1 + 0*
	16 + 8	15 + 7	16 +10	14 + 8
	24	22	26	22
				94 hours /week/sem.

* subjects to be examined in the second phase of studies

Table 1: Curriculum „Geodesy and Geomatics Engineering", University of Karlsruhe, first phase (hours/week for lectures and exercises)

Additional "soft" skills such as social competence, ability for team work, foreign language knowledge, competence in oral and written presentation are trained in the project work comprising 7 weeks, as well as in elaborating the case study. Management and structuring of information, especially by using the Internet, and independent personal learning are also emphasized in the new curriculum.

	5th sem.	6th sem.	7th sem.	8th sem.
Photogrammetry and Remote Sensing				
Photogrammetry II	2 + 2			
Photogrammetry III		1 + 0		
Digital image processing I	1 + 0			
Remote sensing II		2 + 1		
Surveying field project IIIb		1 week		
Geomatics				
Cartography	2 + 0			
Geo-information systems I	2 + 1			
Geo-information systems II		1 + 1		
Geo-information systems III			2 + 1	
Mathematical Geodesy				
Mathematical geodesy I	3 + 1			
Mathematical geodesy II		2 + 1		
Physical and Satellite Geodesy				
Physical Geodesy I	1 + 1			
Physical Geodesy II		2 + 1		
Satellite Geodesy	2 + 1			
GPS field project		1week		
Surveying and Sensorics				
Geodetic Sensorics and Metrology III	2 + 1			
Geodetic Sensorics and Metrology IV		2 + 1		
Analysis and planning of geodetic networks		1 + 1		
Surveying field project IIIa		1 week		
Engineering surveying		2 + 1		
Seminar A, B			0 + 1	0 + 1
Fundamentals of Civil Engineering				
Constructive and water engineering			2 + 0	
Urban and regional planning	2 + 1			
Traffic engineering			1 + 0	
Facility management			2 + 0	
Land Management				
Rearrangement and valuation of parcels I		2 + 0		
Rearrangement in rural space I		1 + 0		
Case study			1 month	
Diploma thesis (9th semester)				5 months
	17 + 8	16 + 7	7 + 2	0 + 1
	25	23	9	1
				58 hours /week/sem.

Advanced Topics:
Individual selection of 20 hours/week/semester, list to be approved by the Examination Commission

Table 2: Curriculum „Geodesy and Geomatics Engineering", University of Karlsruhe, second phase (hours/week for lectures and exercises)

After having passed the examinations (closely joining the courses) the academic degree "Diplom-Ingenieur(in) im Fachgebiet Geodäsie und Geoinformatik" is provided, which is equivalent to the international degree "Master of Science in Geomatics Engineering". Simultaneously with the diploma a transcript of records in English language is handed out. Students from other German or European Universities, studying for one of several semesters at the University of Karlsruhe, can transfer their credits to their home Universities in the context of an ECTS (European Credit Transfer System) agreement; an information package has been prepared for interested students. By these measures it is intended to improve the mobility of students in Europe.

If we compare this curriculum for instance with the new one introduced last year at the University of Bonn we can recognize similar trends. Therefore only some remarks concerning these major developments are given.

1. In Bonn we have also put a strong emphasis on informatics and on geo-information systems. But we didn't change the name of our study-program. It is still called surveying.
2. The fundamental structure is the same. But we didn't reduce the number of contact hours in the fields of planning and law. Besides that we don't have this strong cooperation with the other geosciences as in Karlsruhe.
3. In Bonn a credit-point system was introduced similar to the one used in the US or GB. We have an examination at the end of every semester and every course.
4. The first phase of studies consists of four semesters as it is in Karlsruhe but without the special examination, the "Vordiplom" .
5. The 7^{th} and 8^{th} semester is only devoted to advanced studies.

4. FINAL REMARKS

Surveyor education programmes are clearly very different profiled in Europe. This is probably due to the profession requiring different competencies, but also due to the strategy adopted for the study programmes by the Universities.

Another important question arises when looking at the study programmes. Are surveyors to use their knowledge of land for a more general purpose than that of just mapping it? [Mattson, H. 2001]. This applies above all for the education which has to include all core subjects, i.e. surveying, GIS, land management and property valuation.

What matters in the long term is that the Universities have a responsibility for the future. Finding the right direction is not easy. One way of predicting future needs is by observing the development of the profession, so that decisive changes can be discovered at an early stage and distinguished from more transitory events.

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