The role of the university in fire science

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THE ROLE OF THE UNIVERSITY IN FIRE SCIENCE

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1. GENERAL BACKGROUND

Historically, the fire safety code systems now in force had to be written without actually stating their objective level of safety and, still far less, without any analytical measurement of the objectives involved. For this reason, there is an urgent need for future attempts to evaluate the levels of safety inherent in present local and national fire protection regulations. Lack of knowledge with respect to analytical models describing the physical processes of design components and systems has for a long time effectively prevented efforts to quantitatively assess risk levels.

As a result of the powerfully increased extent of the international fire research, more and more components and systems are now becoming amenable to analytical and computer modelling. Considerable progress then has been made concerning such phenomena and procedures as, [1] to [5]:

* The fire growth in a compartment,
* the fully developed compartment fire,
* the reaction to fire of materials,
* the fire spread between buildings,
* the fire behaviour of building structures,
* the smoke filling in enclosures and smoke movement in escape routes and multistorey buildings,
* the interaction of sprinklers and a fire,
* the process of escape, and
* the systems approach to the overall fire safety of a building, in its most general form comprising human response models interacting with fire development models.

As a consequence of this progress, a rapid development now is going on in the field of codes, specifications and recommendations for a fire engineering design in a broad sense. Some typical trends in this development are:

* An improved connection to real fire conditions,
* an increasing extent of design, based on functional requirements and performance criteria,
* a development of new test methods, which are, as far as possible, material independent and directly related to well-defined properties and phenomena,
* an increasing application of analytical design - reliability-based in its most advanced form,
* an extended use of integrated assessments, and
* an introduction of goal-oriented systems of analysis of the total, active and passive fire protection for a building.

The most manifest, official verification of these trends of development probably relates to the fire engineering design of load bearing and separating structures.

An analytical procedure for a determination of the fire resistance of structural elements is now approved by the authorities, as an alternative, in several countries. In some countries, the authorities also have taken the next step to permit a general practical application of a direct analytical design procedure, based on the natural compartment fire concept [6]. In order to stimulate a further development towards a reliability based structural fire design, the Fire Commission of the Conseil International du Bâtiment (CIB W14) has prepared a State-of-Art Report [7] and a Design Guide [8] on this subject as an aid in the future drafting of corresponding national regulations or recommendations.

The described trends of development in fire safety science and in codes, specifications and recommendations for a fire engineering design, is accompanied by - and largely also influenced by - other trends towards a generally more complex society with a rapidly expanding use of advanced technology. Simultaneously, there is a strong, ongoing increase in the potential of hazards with the measures for fire prevention and fire fighting becoming more and more an integrated component of the overall concept of rescue services.

From the presentation above, it is evident that a qualified and optimum handling of the continuously more and more complex questions within the society, related to the fire and emergency hazards, requires a generally increased level of competence for all groups of professionals involved. This applies to those who have to deal with these questions as their principal task (senior officers of the fire and rescue service, fire safety consultants, fire safety managers) as well as to engineers and architects who have to integrate the fire safety engineering as an essential - and rather often - decisive component in the planning, design and construction of, for instance, a building.

Except a few universities, the role of the university in fire research and higher fire technical education is not very strong at present. There is, however, a growing international interest and efforts are made to improve the situation [9]. In order to meet the present and future demand of the society, the universities must extensively increase their responsibility for and engagements in research as well as undergraduate and postgraduate education within the field of fire safety science and engineering.

The following presentation will focus on how fire research and higher fire technical education have developed at Lund University, within the frame-work of a coordinated Swedish fire research, as an example. As an introduction, international definitions of some relevant scientific concepts are referred. The scientific requirements and the requirements of practical relevance and applicability of a research project are analysed and examples of rules are given which may contribute to a simultaneous fulfilment of the two types of requirements. Some fragmentary conclusions are drawn with respect to the role of the university in fire research and education.

2. DEFINITIONS OF SOME RESEARCH CONCEPTS. THE TWOFOLD REQUIREMENTS FOR RESEARCH

Internationally, the following definitions apply to the main categories of research and development:

* Basic research: Original investigation with the primary aim of a more complete knowledge or understanding of the subject under study. Basic research can be divided into:

  - Pure basic research: Basic research carried out without working for long-term economic or social benefits other than the advancement of knowledge and no positive efforts being made to apply the results to practical problems, or to transfer the results to sectors responsible for application.

  - Strategic basic research: Basic research carried out with the expectation that it will provide a broad base of knowledge necessary as the background for the solution of recognized practical problems.

* Applied or tactical research: Original investigation undertaken in order to acquire new knowledge, and directed primarily towards a specific practical aim or objective such as determining possible uses for findings of basic research or solving a recognized problem.

* Development work: Systematic work, drawing on existing knowledge, gained from research and/or practical experience that is directed to producing new materials, products and devices, to installing new processes, systems and services and to improving substantially those that are already produced or installed.

The reasons for research and development can be exemplified as follows:

* To satisfy the curiosity of people,
* to act as a motor for the development of the society,
* to act as a source for innovations - see figure 1, which illustrates the linear chain of innovation, composed of different categories of research and development,
* to act as a basis for qualified academic education.

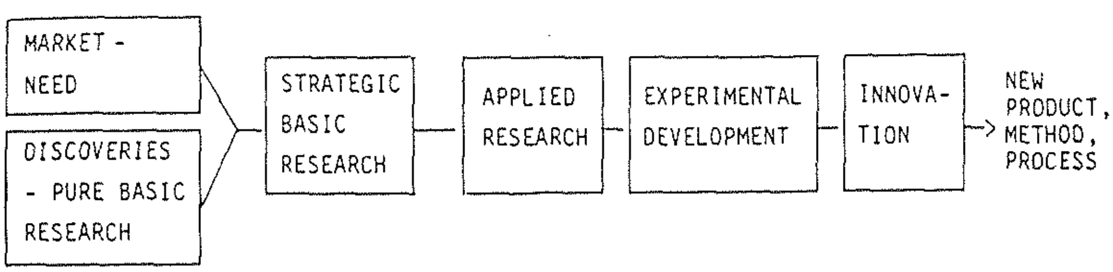

Figure 1. Linear chain of innovation

Confidence in research postulates that high scientific requirements as well as requirements of practical relevance and applicability are fulfilled. The relative importance of the different requirements depends on the actual category of research. In pure basic research, only the scientific requirements apply. Proceeding along the chain of innovation in figure 1, the importance of the requirements of practical relevance and applicability increases gradually.

The scientific requirement for a research project contains a series of sub-requirements with respect to

* distinct definition of the project, its object and role in, for instance, a design process,
* relevant analysis regarding input data and methods applied,
* stringency in presentation, analysis and report of results,
* originality in reference to knowledge and/or methodology, and
* capability to generalize the results obtained.

A presentation of research projects at international congresses and seminars and in renowned journals is a natural way for a critical examination of the scientific level.

The requirement of practical relevance and applicability of a research project comprises as sub-requirements that the method applied and results received should

* be presented in an easily comprehensible way with an accurate specification of the conditions for applicability,
* be supplemented with guidance on how the results can be generalized by, for instance, interpolation and extrapolation,
* have the potential to be used in a chain of innovation for a development of new materials, products or processes,
* be able to support qualified technical, economical and political decisions, and
* facilitate a development of codes and regulations towards functionally well-defined requirements and related criteria for control and verification.

The level and extent of practical application is a decisive measure of the fulfilment of the requirement of relevance.

As concerns those university fire research projects, which I have had the privilege to deal with, there are some rules - more or less selfevident - contributing to the fulfilment of the twofold requirements described. These rules can be exemplified by the importance of

* defining a major project as a coherent system of components, enabling a rational choice of more limited projects - if possible, on the basis of a sensitivity analysis of the contributions of the different components to the uncertainty of the system,
* planning a project in a way, enabling a step-wise reporting of practically applicable results,
* a balance in level of ambition or quality between input information, process model and formulation of practical requirements and criteria,
* an access to - at least a structure of - an analytical model before an experimental investigation is finally planned and performed,
* describing the practical application of the results of a project with respect to character and extent already in connection with the specification and planning of the project,
* a continuous connecting link to practice of the project from beginning to final reporting - via, for instance, a reference group, and
* a suitable choice of form of reporting of the project with regard to the scientific requirements on one side and the requirements of practical relevance and applicability on the other.

3. THE DEVELOPMENT OF SWEDISH FIRE RESEARCH. A NATIONAL FIRE RESEARCH PROGRAMME

Up to the very late fifties, very little fire research was conducted in Sweden. At this time only one research body, the Swedish National Testing Institute, was active in the field. Its projects were mainly related to the fire resistance of structural elements and the aim of the work was to produce fire test methods. Very few projects involving in-depth studies were initiated during this period.

The early sixties saw an essential improvement. At the request of the Inter-Scandinavian Building Research Conference (NBM) and the Liaison Committee of Scandinavian Fire Laboratories (NBS), a general programme for Scandinavian long-term fire engineering research was elaborated [10], focusing on the fire behaviour of building structures. The programme did not initiate any joint Scandinavian fire research projects of major importance but it gave the background and the matrix of the analytical method of structural fire design, later developed and giving Sweden an international reputation within this fire research field. The design method is entirely analytical, based on physical models of the design components and related to well-defined funtional requirements and performance criteria - figure 2. The structure of the design method systematically has directed the choice of research projects within the fire research group at Lund University for a long period with the aim to get the method adaptable for a practical application [11], [12]. The research projects comprise

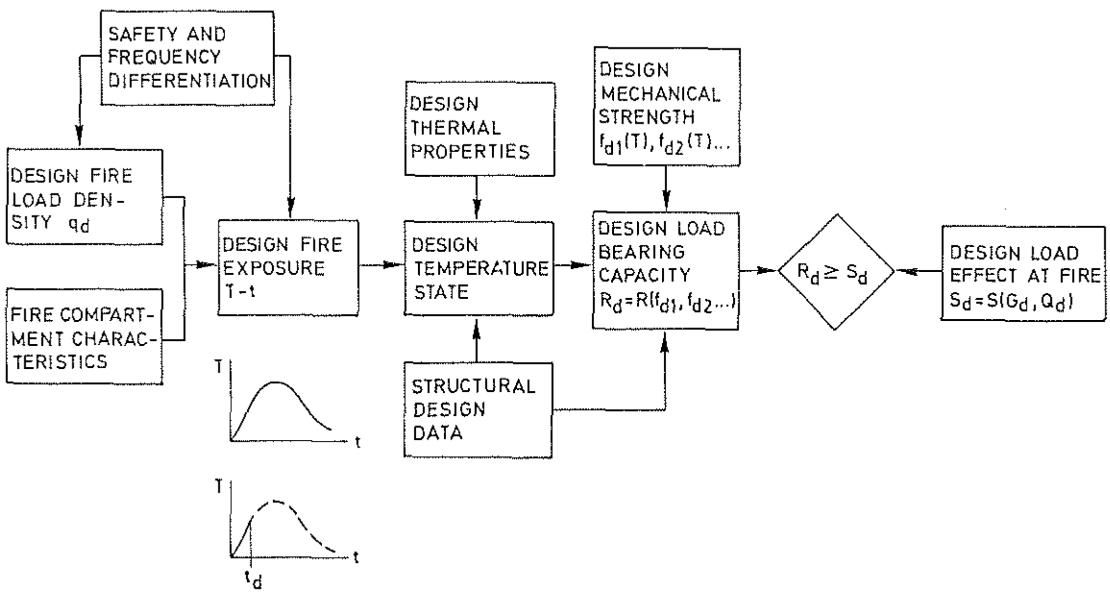

Figure 2. Procedure of a reliability-based design of a load bearing structure, exposed to a natural compartment fire. The factor of safety and frequency differentiation γ_n accounts for the influence of type of occupancy, type and size of building, number of floors, size and location of fire compartments, and the importance of the structure to the overall stability of the building as well as the frequency of a fully developed compartment fire, including the effect of envisaged alarm and sprinkler systems and available force of fire fighting brigades [8]

* surveys of the fire load density for different types of occupancies,
* experimental and theoretical studies and development of a computer model of the fully developed compartment fire,
* development of analytical models for the mechanical behaviour of structural materials at transient high-temperature conditions,
* development of analytical and numerical methods and related computer programmes for a determination of the thermal and mechanical behaviour of different types of fire exposed structures, and
* probabilistic analyses of the uncertainties of the various components of the design procedure as a basis for a development of a reliability based structural fire design.

Instrumental in sponsoring this research activity was the National Building Research Council (BFR).

In the late sixties, the first action was taken in order to establish a national council or board, responsible for a co-ordinated fire research [13]. The Swedish Civil Defense Administration conducted a survey on the need of fire research in co-operation with the National Defense Research Institute. The survey pinpointed the needs for an essentially broadened fire research and proposed a joint venture in order to formulate and realize a national fire research and development programme. As a modest beginning, attempts were made to establish a National Fire Research Council. These efforts, however, failed, the lack of proper funding being the major obstacle.

In spite of this, successful fire research projects were carried out in Sweden. The activity within the fire research group at Lund University expanded in the seventies to new fields of application. Especially, then the development of an analytical method should be mentioned for the design of dense small house areas with respect to the risk of fire spread from one house to another [5], [14], [15]. The analytical model derived includes three sub-models, viz.

* a model for the postflashover compartment fire, giving the gas temperature-time curve and the geometry and temperature of the flames emerging from the windows,
* a model, describing the radiation within an area of buildings at a fire in a single building, and
* a model, evaluating the time curve of the radiation on the adjacent building with respect to ignition of decisive combustible materials.

Figure 3 exemplifies the results of computer calculations, using the analytical model. The figure shows a set of simplified design diagrams for a quick determination of the required minimum distance c between parallel small houses as a function of the fire load density f, the opening factor $A\sqrt{h}/A_{tot}$ and the parameter γ_p, defining the ratio between the radiation area and the total opening area of the house in fire. A is the total area of window and door openings, h the mean value of the height of the openings, weighted with respect to each individual opening area, and A_{tot} the total interior area of the surfaces, bounding the fire compartment, opening area included. The diagrams apply to small houses with surrounding structures of concrete.

In the seventies, more and more, the interest turned from the fully developed fire and related applications to the early stage of the fire development - the preflashover fire. In this field, the fire research group of the National Defense Research Institute conducted extensive work [16] and also sponsored projects outside the Institute. Figure 4 presents the results of an experimental investigation on the occurrence of flashover in a room as a function of the mass loss rate R_{max} and the air flow factor $A\sqrt{h}$, where A is the area of the opening and h its height. The graph shows an area in which flashover occurred in the experiments.

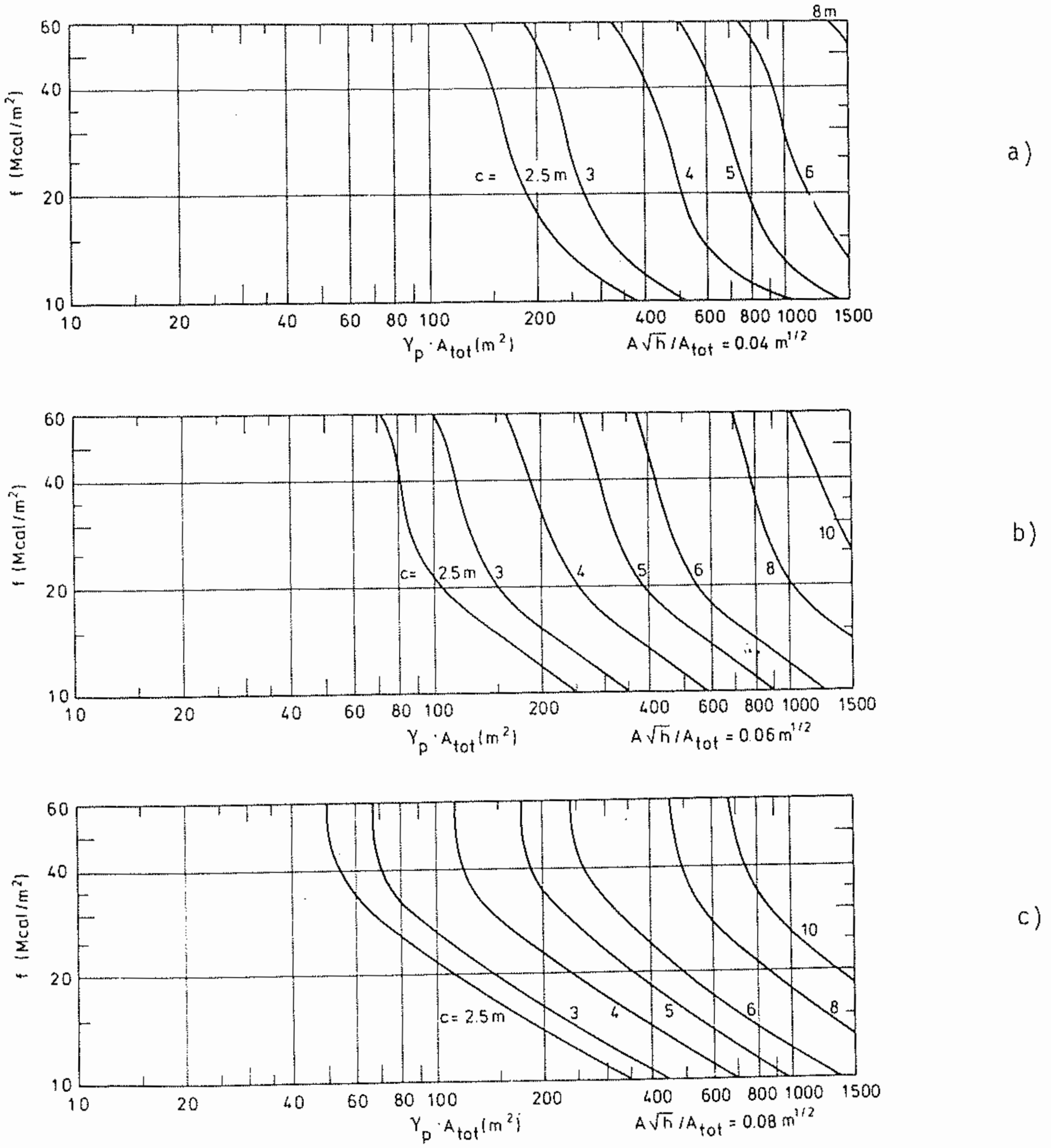

Figure 3. Minimum distance c between parallel small houses as a function of fire load density f (Mcal per m^2 surrounding surface), opening factor $A\sqrt{h}/A_{tot}$ ($m^{\frac{1}{2}}$) and the parameter $\gamma_p A_{tot}$ (m^2). Enclosing structures of ordinary concrete [15]

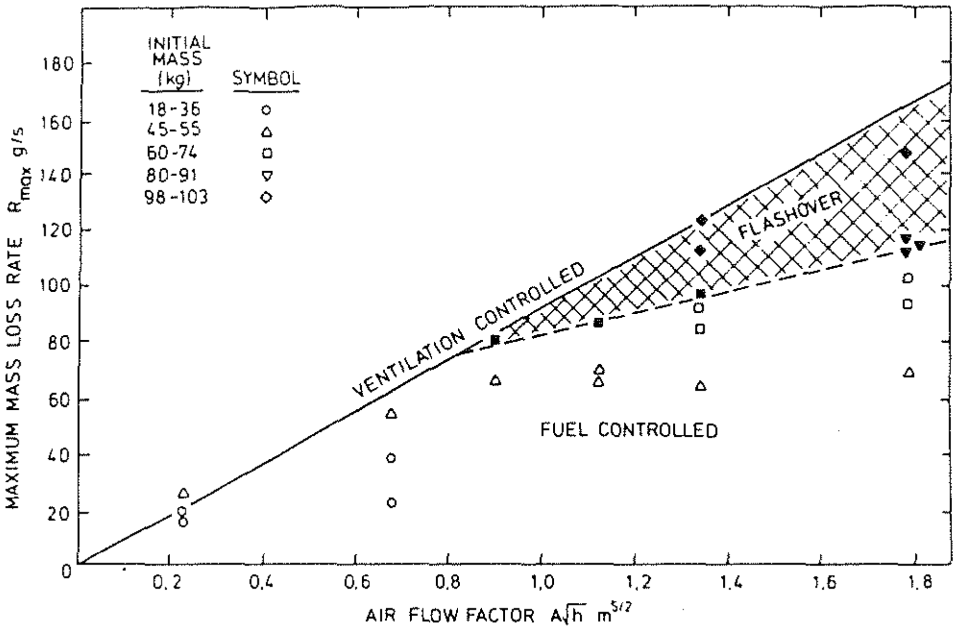

Figure 4. The relationship between the maximum rate of combustion R_{max}, the air flow factor $A\sqrt{h}$ and the occurrence of flashover in a fire compartment. Filled symbols denote experiments giving rise to flashover [16]

Another attempt to establish a national fire research programme was made in 1976. The background then was alarming. During a period of ten years, the national fire losses went up by some 100% in fixed prices. A number of large fires occurred with a fire loss in excess of 100 million SEK per fire. Some exceptional fires took up to 20 lives in one fire, so far an unknown situation in Sweden. The Swedish fire fighters complained about an increasing number of more intensive and unpredictable fires.

The Swedish government took a quick action. A new training system for fire officers was prepared. The Ministry of Housing ordered an extensive survey of the fire hazards in buildings to be performed. This was conducted as an inter-agency investigation, involving four governmental agencies under the supervision of the National Board of Physical Planning and Building. The aims of the survey were to identify the nature, frequency and severity of product related fire injuries and to investigate alternative remedial strategies, i.e. mandatory safety rules, voluntary product standards, information and education [17].

As a first step to establish a national fire research programme, the National Board for Technical Development was ordered to survey the fire research situation of that time, estimate the needs for fire research and propose actions. The task was handed over to the National Defense Research Institute. As result of this investigation, a proposal was left, including the aims, priorities and a summary content of a national programme, differentiated with respect to three levels of the annual cost.

A detailed, national, collective fire research programme for a three years period was then elaborated by a working group with Mr Arne Hägglund, Dr Sven Erik Magnusson, Dr Vilhelm Sjölin and Professor Kai Ödeen as members. The programme was based on the aims and priorities, given in the report of the investigation made by the National Defense Research Institute. The programme was related to the lowest cost level in this report.

The financing of the programme was solved by a joint funding between the government and private enterprises on a 50 to 50% basis.

The Swedish Fire Research Board, BRANDFORSK, was established in 1979 to realize the programme for the period 1979-81. The members of the board represent government agencies in the field of safety and a number of private interests.

The overall aim of BRANDFORSK is, with the aid of suitably directed research and development measures, to provide the neccessary basis for a better formulation and fulfilment of the requirements of the society with regard to the safety of people and the protection of property. Within this overall aim, the most important subjects were identified to give high priority to activity with a view to protect residents, industrial workers and fire fighters, and to contribute to a better understanding of the protection against major fires. Obviously, such a comprehensive aim calls for long-term and extremely variegated research efforts.

There was a further essential aim behind the formation of BRANDFORSK. For many years, appropriations of varying size had been made to fire scientists by a number of organizations such as the Swedish Council for Building Research, the Fire Insurance Companies Research Board, the National Defense Research Institute, the Civil Defense Board and the Swedish Board for Technical Development. The feature common to all these bodies was that they concerned specific sectors and lacked a long-term co-ordination. The national fire research programme of BRANDFORSK is an attempt to co-ordinate all fire research efforts within Sweden and decide on priorities.

The national fire research programme for the period 1979-81 included 26 research projects, covering the major research fields:

* Fire development and fire environment - sector B,
* impact on human behaviour - sector H,
* effect on materials and products - sector M,
* fire fighting and fire protection techniques - sector K,
* systems analysis - sector S, and
* general and overall functions and surveys - sector F.

11 million SEK were provided for the programme. Table 1 gives the cost level programmed and the number of projects for the individual fire research fields. To these cost items, the cost of the administration of the programme is to be added.

The programme for the period 1982-84 embraced two levels of ambition. The basic level - shown in table 1 - comprises 42 research projects related to the same major fire research fields as applied in the first programme. The total cost of the basic level amounts to 14 million SEK which roughly means an index-adjustment of the cost of the first programme. The higher level of ambition was estimated at a total cost of approximately 20 million SEK. As the supplementary cost would in all probability have to be financed by the industry and commerce, high priority was given in the additional part of the programme to industrial fire defence research. The basic level was sponsored - as for the first research programme - jointly by the government and the private sector.

For getting an increased flexibility, the research programme included a reserve fund of 1.5 million SEK to meet the need of carrying out a few unpredictable research projects of importance during the period.

The money received for the activity during the period 1982-84 corresponded roughly to the basic level of the research programme.

A third fire research programme is now running for the period 1985-87. The programme includes 40 research projects with an estimated total cost of 18 million SEK. With due regard taken to the index-adjustment, this roughly means a preserved level of ambition as compared to the two previous research periods. With respect to the structure of the programme, the research field "Fire fighting and fire protection techniques" has been split up into:

* Rescue service - sector R, and
* industrial protection techniques - sector I.

The first field embraces fire research and development directed towards the local and public fire brigades. The second field deals with fire research and development regarding the fire protection of industrial plants and processes. For the rest, the programme is structured in the same way as the previous programmes.

Table 1. National Swedish Programme for Fire Research

	1979-81		1982-84		1985-87	
Total cost (million SEK) *Number of projects*	11	*26*	14	*42*	18	*40*
B Fire Development and Fire Environment	2.8	*6*	3.35	*8*	2.9	*8*
H Impact on Human Behaviour	0.5	*1*	1.25	*5*	1.2	*5*
M Effect on Materials and Products	2.7	*6*	2.7	*7*	2.4	*5*
K Fire Fighting and Fire Protection Techniques	1.4	*5*	3.23	*10*	-	-
R Rescue Service	-	-	-	-	2.3	*6*
I Industrial Protection Techniques	-	-	-	-	2.7	*8*
S Systems Analysis	0.7	*4*	1.4	*5*	1.3	*4*
F General and Overall Functions and Surveys	1.5	*4*	2.05	*7*	0.8	*4*
Reserve fund to meet unpredictable, important research projects	-		1.5		2.7	

From the beginning, the Fire Research Board was aware of the fact that large parts of the activity, being financed by BRANDFORSK, were going to lie within research areas, to which small resources had been directed earlier. The need of a long-term building up of competence within new essential research areas consequently was very strongly pronounced. Hence, one important task of BRANDFORSK has been to meet this need. Accordingly, the main part of the grants within certain fields has been directed to one or a few research bodies.

Roughly, the present research situation, as concerns the national fire research programmes, can be summarized in the following way:

* In the main, the previous lack of co-ordination of the Swedish fire research is eliminated. The research contributions are now related to integrated estimations - frequently from a basis of long-term research programmes or special surveys.
* The extent of the total Swedish fire research has increased during the BRANDFORSK period. However, the cost level of the fire research is still very

low in relation to the total costs of fire damage and fire protection measures - roughly 1 o/oo.

* A joint centre for studies of the early stage of the fire development - the pre-flashover fire - has been set up at Lund University and the National Testing Institute in Borås. The studies involve measuring and recording of different reaction to fire properties of materials and products in full, reduced and small scale experiments as well as theoretical analyses and development of mathematical models and related computer programmes.

* A development of mathematical models and related computer programmes for the smoke filling of a room and for the spread of smoke and combustion gases between rooms and within a building is in progress at the National Defense Research Institute, jointly financed by the research institute, the Civil Defense Board and BRANDFORSK. The models are tested against full scale experiments.

* A research competence has been built up on the impact on human behaviour at the Royal Institute of Technology in Stockholm. Studies now are in progress concerning the physical conditions for fire escape, focusing on the evacuation of handicapped individuals, on one side, and of many people simultaneously, on the other - in stores, theatres, cinemas, etc.

* A research activity has been established on extinguishing agents at the National Testing Institute at Borås. Examples of projects dealt with are studies of the mechanisms of powder and light foam extinguishing agents and an investigation of the fire properties of hydraul-liquids.

* A group of projects, related to the protection of industrial plants and processes, are performed at the Swedish Fire Protection Association. At the Swedish Institute of Steel Construction, projects are carried out on materials used in the construction of industrial buildings (statistical survey) and on co-ordination of sprinklers with girders and integration of sprinklers with lattice girders of rectangular hollow sections in industrial buildings, among other things.

* Industrial, insurance and consultant companies are getting involved in the fire research and development activities to an increasing extent with grants from BRANDFORSK. Planning of industrial areas with respect to fires, explosions and rescue work, models for risk evaluation and leadership means for rescue service are examples of projects dealt with by these bodies. The origin and spread of explosive and toxic gas clouds are studied in a project, carried out at the National Defense Research Institute.

The aims and characteristics of the national fire research programme for the present period can be defined as:

* A strong increase of the research and development work on the protection of industrial plants and processes,

* a strong increase of the research and development work to meet the needs of the public rescue service,

* a continuation of the previous large contributions concerning research on the preflashover fire, particularly with regard to analytical methods for a simulation of the physical processes and for an evaluation of the fire hazard of materials and products as well as for a determination of the production and movement of smoke and combustion gases,

* a moderate increase of the research devoted to the role and behaviour of people in fire situations and to the relationship between this behaviour and the technical fire protection measures, and

* an establishment of a long-term, strongly co-ordinated research on the fire behaviour of wood and wooden structures - jointly financed by BRANDFORSK, the

Swedish Board for Technical Development, the Swedish Council for Building Research and the Foundation for Research of the Wood Working Industries. Research within this field now is in progress at Lund University, the Swedish Forestry Products Research Laboratory and the National Testing Institute. The long-term research programme enables a considerable enlargement of this activity [18].

4. THE ROLE OF THE UNIVERSITY IN FIRE RESEARCH

With reference to the definitions of some research concepts, given in chapter 2, the role of the university in fire research is to focus primarily on basic research. The financial support of the pure basic research then must be guaranteed by the government, while research boards and councils like BRANDFORSK are the natural organizations for initiating and financing the strategic basic research as well as applied research and development work. To some extent, is is necessary for the universities to combine basic research with applied research in order to get a close link to the application of the research results in practice and to get a feed-back from related activities within the society with regard to priority and relevance in the choice of research projects.

It is apparent that BRANDFORSK has agreed to this role of the university by supporting a research competence being built up on the impact by fire on human behaviour at the Royal Institute of Technology in Stockholm and a joint centre for studies of the early stage of the fire development being set up at Lund University and the National Testing Institute in Borås. The choice of a joint centre for the latter activity then contributes to a fruitful co-operation between theoretical and experimental scientists and to an effective use of an expensive test equipment.

The fire research projects, carried out at Lund University and related to basic research - and, to some extent, to applied research - have generally closely followed the rules, specified in chapter 2 and contributing to the fulfilment of the twofold requirements - the scientific requirement and the requirement of practical relevance and applicability. Particularly, it should then be emphasized the importance of defining a large research project as a coherent system of components and having access to - at least a structure of - an analytical model of the process in question before an experimental investigation is finally planned and performed. It is also of high importance to structure a research project in such a way that a reasonable balance is achieved in level of ambition or quality between input information, process models and formulation of practical requirements and criteria.

Two large fire research projects carried out at Lund University have been mentioned and fragmentarily exemplified previously. The projects dealt with an analytical design of load bearing and separating structures, exposed to a natural compartment fire, and the fire spread from one house to another within dense areas of small houses.

The long-term, ultimate goal of the research, now in progress, on the early stage of the compartment fire development, is to arrive at a situation in which the results of small scale reaction to fire tests can be used to predict the fire hazard of lining materials, furniture, etc. under real compartment fire conditions. This calls for access to functionally well-defined performance requirements and related criteria for control.

The fundamental characteristics for a description of the early stage of a compartment fire consist of:

(1) The ignition properties of exposed materials and objects as a function of the heat supplied, the exposure time, the presence or not of flames, the geometrical location and thermal data

and the time variation of

(2) rate of heat release, RHR,
(3) rate of surface spread of flame,
(4) gas temperature,

(5) smoke produced and its optical density, and
(6) composition of the combustion products, particularly toxic and corrosive gases.

The research project comprises a study of all these characteristics. The project is structured as a coherent system of components according to figure 5 [19] and includes the following types of activities:

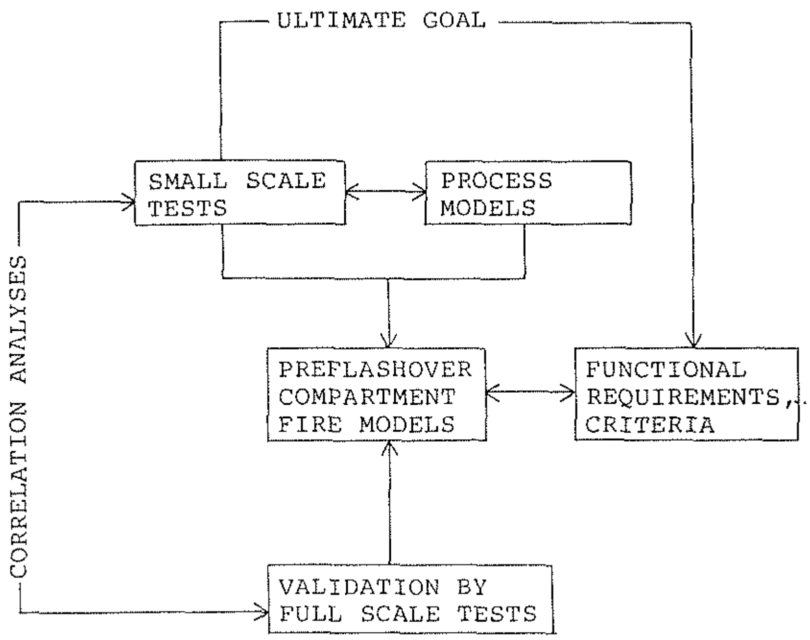

Figure 5. Structure of a Swedish joint research programme, in progress, concerning the fire hazards and the compartment fire growth

(1) Participation in the international development of small scale reaction to fire tests for materials with respect to ignition, spread of flame, rate of heat release and smoke production,

(2) development of mathematical models describing the processes of these tests,

(3) development of mathematical models for the preflashover compartment fire,

(4) validation of the mathematical models by full scale or reduced scale room fire tests with combustible linings and furniture, and

(5) computational procedures, developed to correlate the room fire test process and the results from the small scale laboratory tests.

The project also includes an intermediate, short-term goal related to a development of a standardized full scale room fire test for combustible linings and furniture. The purpose of this test is to measure the rate of heat release and production of smoke and toxic gases and to use this information for a calculation of the required time of escape at different geometrical configurations and ventilation conditions.

The project, which has been going on since 1980, deals with a highly complex area of theoretical and experimental research and, necessarily, the Swedish contributions can only be a limited part of the large international efforts within this field. Hence, a co-ordination with the international activities is a prerequisite for success.

Two examples of results obtained are given in figure 6 and table 2. Figure 6 shows, for one of the full scale room fire tests with furniture, a comparison between test results and corresponding values from computer simulations with the Harvard Computer Fire Code V [20] and with an improved version of this code, taking the effect of the heating of the lower surfaces of the room into account [21]. The burning item was a full-size mock-up model of a sofa with filling material of commonly available standard polyurethane foam and cover material of a textile of 100% acrylic fibres.

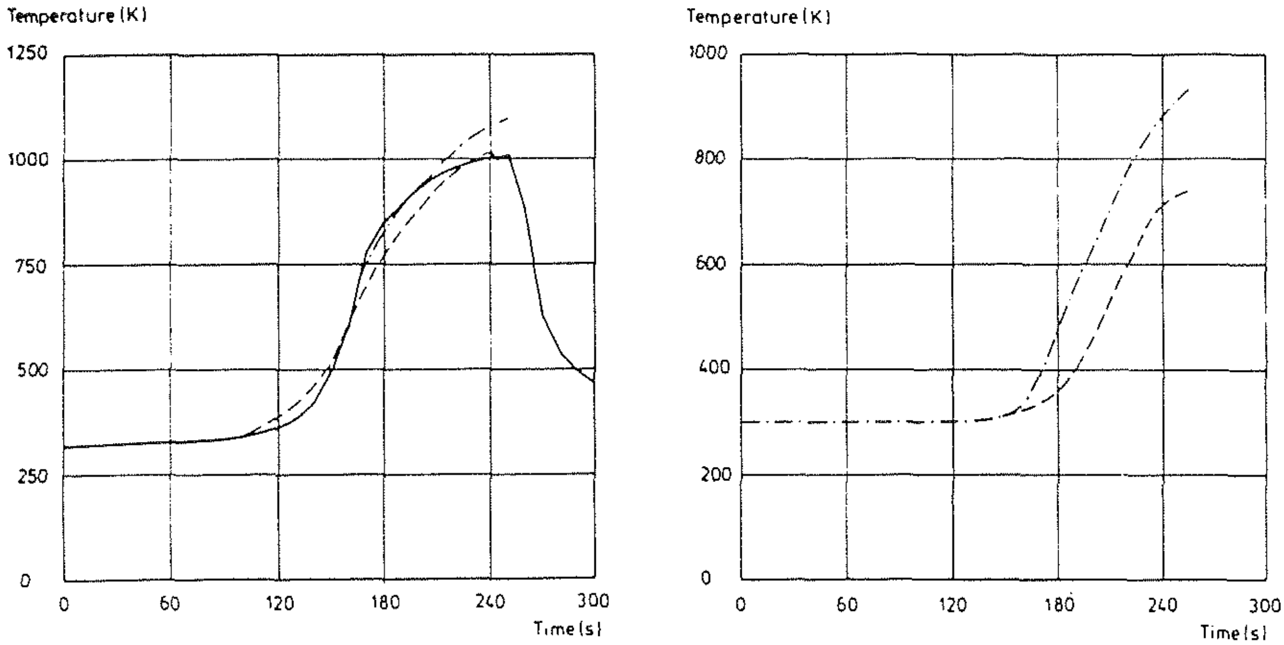

Figure 6. Upper gas-layer temperature (left) and surface temperature of the floor (right) for a sofa burning in the full scale room. ---- experiment, —— Harvard simulation, -·-·- Harvard simulation, including heating of the lower surfaces [21]

Table 2 refers to the full scale room fire tests with combustible linings on walls and ceiling and compares for seven of the tested materials the time to flashover, received experimentally and by a computer simulation [22]. The simulation procedure, developed within the research project, describes the full scale test fire as a concurrent flame spread phenomenon with the results of a small scale rate of heat release test as input data.

Table 2. Time to flashover (s), received experimentally and by a computer simulation, for seven of the full scale room fire tests with combustible linings [22]

Material	Experiment	Simulation
Insulating fibreboard	66	65
Medium density fibreboard	140	134
Particleboard	165	166
Melamine-faced particleboard	499	351
Rigid polyurethane foam	14	14
Wood panel, spruce	139	146
Paper wall covering on particleboard	148	~205

5. THE ROLE OF THE UNIVERSITY IN HIGHER FIRE TECHNICAL EDUCATION

In most industrialized countries, the total programme for higher education at, for instance, a technical university comprises the undergraduate as well as postgraduate level. At the Swedish technical universities, the education programme traditionally has been limited to the undergraduate level while the graduate level education normally has been an internal concern between the postgraduate student and his supervisor and examinator. The present trend of development is, however, towards a more coherent education system of the undergraduate and graduate levels.

Figure 7 exemplifies such a system, referred from an international civil engineering education, in the course of planning at present at Lund Institute of Science and Technology. The system comprises an eight years course of study and scientific work for arriving at the final level - Doctor of Technology. Below this level, there are two defined intermediate levels - the degree of licentiate of technology after six years and the degree of civil engineer (Master of Science) after four years study. The first three years are filled with obligatory, basic and branch courses and the following three years with optional courses, grouped into three branch directions, I to III - planning and management, construction, environment - and structured with a successively increasing depth. This system of optional courses is open for the fourth year of the undergraduate studies, the first two years of the postgraduate studies and for further education of people from industry and society.

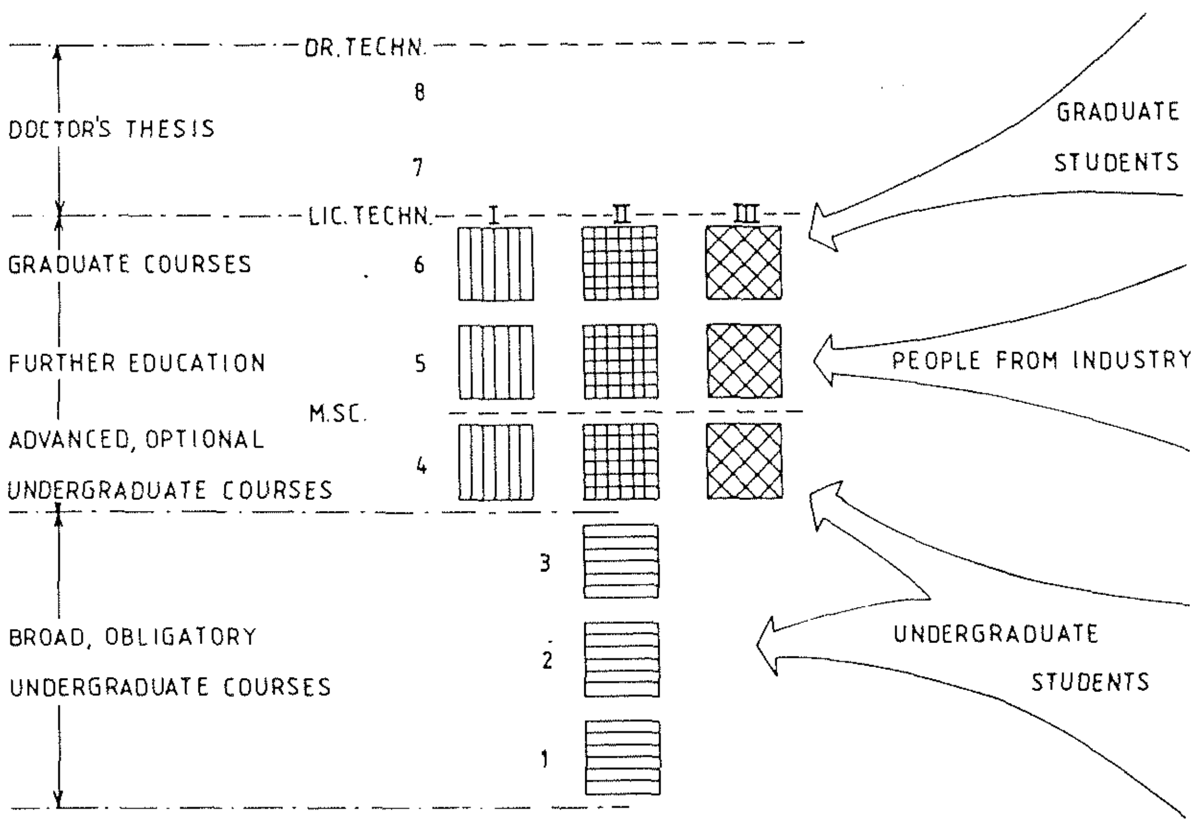

Figure 7 Eight years coherent system of undergraduate and graduate levels, including possibilities for further education of people from industry and society

Fundamental criteria for all levels of the coherent education system are

* a broad basis of knowledge and a qualified training in methodology, and
* good ability of formulation is speech and writing.

For the highest level of the education system - research studies for Doctor of Technology - a third criterion is added, viz.

* good ability to generate new knowledge,

involving a requirement of scientific originality for the doctor's thesis.

As stated in the introductory chapter, a qualified and optimum handling of the continuously more and more complex questions within the society, related to the fire and emergency hazards, requires a generally improved competence for all groups of professionals involved. In order to meet this demand of the society, the universities extensively must increase their responsibility for and engagements in undergraduate and postgraduate education within the field of fire safety science and engineering.

At Lund University, the higher fire technical education has developed in the following way.

For a long time, the students at the Schools of Architecture and Civil Engineering are offered a short, obligatory course in fire protection. The contents of the course is elementary and the course objectives are mainly to give the students a general survey on how building fire protection has to be dealt with as a component in the planning, design and construction process.

Fire research at Lund University was originally started within the Department of Structural Mechanics and Concrete Construction in the middle of the 1960's. As a consequence of the considerable expansion of this research, a Department of Building Fire Safety and Technology was set up in 1981 and one of the two professorships in structural mechanics was transferred to this department. The establishment of the department meant that for the first time the students at the School of Civil Engineering were offered a major course in fire safety technology as a part of their curriculum.

The course is offered to the fourth year students and covers a 7 week semester. It is mandatory only for the students specializing in building technology, for the other it is an elective course. The general course objectives are:

* To develop an understanding how building fire protection must be integrated into the overall building planning and construction process,
* to describe the background, practical application and limitation of building codes, and
* to demonstrate that in many instances practical problems can be solved in a more cost-effective way by application of fire physic principles and calculation procedures.

One of the largest problems involved in the introduction of a new course is to find suitable textbook material. In that aspect we were lucky to have access to an early version of the book by Douglas Drysdale, "Fire Dynamics", which formed the backbone of the fire physics part. Additional material was written for certain areas such as plume theory and smoke filling rooms, smoke spread in buildings, thermal actuation of heat detectors and extinguishing systems. The structural fire analysis was well covered by handbooks and compendiums written by the department staff. The additional material needed for the design exercise was taken from papers appearing in trade journals.

In September 1986, the first undergraduate education in Europe as part of the training of potentially senior officers of the fire service started at Lund University. The complete education consists of 2½ years (100 weeks) studies at the university, followed by a 1-year practical training at fire brigade and civil defence. The number of students admitted is 25 per year.

The university education is mainly theoretical and comprises:

* Basic science - 20 weeks,
* mass and heat transfer, hydraulics, building construction, HVAC-systems, geotechnology etc. - 30 weeks,
* theoretical background to fire and rescue service - 30 weeks, and
* business administration, miscellaneous - 20 weeks.

The 1-year practical training includes:

* Basic training in fire fighting and firemanship, other practical rescue operations,
* tactics for rescue operations,
* leadership, psychology,
* instructor training, and
* training as civil defence staff officer.

After finalized education and training, the fire engineers shall be capable to plan, organize and lead peace time rescue service, civil defence activities and war emergency planning on the municipal level. That defines the general goals for the university education and training. The supplementary specific goals include and refer to:

* Technical, personnel and economic management of local fire brigades,
* ability to master the theoretical background of fire processes, dispersion of gas clouds, explosions, extinction processes,
* ability to apply theory in fire prevention, building fire protection and practical rescue service operation, and
* some basic training as industrial fire prevention engineer.

The second and third specific goals then relate to that part of the university education, which deals with the theoretical background to fire and rescue service. In the present plans, this part includes the following courses: Fire chemistry, explosions, fire dynamics I and II, human reactions and evacuation, passive systems, extinguishment, active systems I and II, risk evaluation and systems analysis, chemical hazards operations, special problems.

Finally, some comments should be given concerning postgraduate fire education and educational requirements for fire researchers.

The required qualifications and educational basis for a fire researcher can vary widely depending on the type of problem and the category of research on which he is going to work. However, irrespective of a fire research activity of far-reaching specialization or of a more integrated character, it is essential that the fire researcher during his graduate studies has got a broad, qualified basis of knowledge in relevant subject areas. A direct participation in research projects before or during the work on the doctor's thesis is another important component of the graduate studies giving the prospective fire researcher an intimate knowledge of research methodology, of the requirements regarding scientific level, relevance and applicability of research and of the fundamental rules, described above in chapter 2, with reference to planning, carrying through and reporting of a project. The doctor's thesis then constitutes the final proof in the research education of the ability of the student to solve independently a research problem, including generation of new knowledge.

This leads to the following elements in a fire research education, based on the Master of Science level:

* Obligatory, supplementary courses in such subjects as mathematics, mathematical statistics, systems analysis, computer science and programming, physics, chemistry, information technics, research methodology and measuring technics,
* additional courses, individually chosen in order to give the postgraduate student a broad basic competence, covering those subjects of application relevant to his future fire research field,
* specialized courses, individually chosen and giving the postgraduate student the necessary scientific competence for his work on the doctor's thesis,
* participation in some research projects for a further preparation of the postgraduate student for the work on the doctor's thesis, and
* doctors's thesis.

The possibilities for a fire researcher to get an up-dating of his competence or any further education, rendered necessary by an altered aim and direction of research, in a coherent system of education according to figure 7 could be held up as a model.

6. SOME CONCLUDING REMARKS

As a result of the powerfully increased extent of the international fire research during the last two decades, more and more components and systems are now becoming amenable to analytical and computer modelling. Parallelly, a rapid development is going on in the field of codes, specifications and recommendations for a fire engineering design towards an increasing extent of application of analytical methods, based on functional requirements and performance criteria, an extending use of integrated assessments, and an introduction of goal-oriented systems of analysis of the total fire protection for a building. The trends of development in fire safety science and in codes, specifications and recommendations are accompanied and influenced by other trends towards a generally more complex society with an expanding use of advanced technology. An evident consequence by this, is a strong, ongoing increase in the potential of hazards with the measures for fire prevention and fire fighting becoming more and more an integrated component of the overall concept of rescue services.

To meet this situation in a qualified and optimum way, requires a generally improved competence for all groups of professionals involved in activity, related to fire and emergency hazards. This applies to those who are dealing with these questions as their principal task - senior officers of the fire and rescue service, fire safety consultants, fire safety managers - as well as to engineers and architects who have to integrate the fire safety engineering as a component in the planning, design and construction of, for instance, a building.

The consequential, present and future demand of the society can only be met, if the universities extensively increase their responsibility and engagements in research as well as undergraduate and postgraduate education within the field of fire safety science and engineering. That is the main message of this lecture.

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