Fire Engineering

in the european context of
Sustainable Human & Social Development

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1. Introduction

On Tuesday morning, 11th September 2001, more than 3,300 people were killed in the collapse of the **World Trade Center (WTC) Twin Towers** ...... including 2,830 building occupants, 157 airline crew and passengers, and 343 firefighter, police, medical and other emergency personnel ; the remains of many have never been found. An unknown number of people escaped that day, in spite of building management at the Complex ; people with activity limitations, however, were fatally disadvantaged. The environmental impact of the Incident was enormous.

With stunning impact, we were presented with a **Collapse Level Event (CLE)** in building technology. This is a common occurrence in parts of the world where bribery and corruption are features of life, but very unusual just a short distance from Wall Street, right in the glare of CNN and Fox News television cameras. As far as the general public in North America is concerned, these collapses remain unacceptable. And this is not just a 'domestic' issue either ...... a reasonable explanation is owed to the wider International Construction Community, and a common resolution must be found together !

That tragic day in Downtown Manhattan, a catastrophic failure in current practices, codes and procedures was exposed ......

- Architectural ;
- Structural & Fire Engineering ;
- Building Management ;
- Emergency Services ;
- Control Organizations Having Authority/Jurisdiction ;
- Fire Safety Objectives in Building Codes & Standards ;
- International Fire Research, Demonstration & Validation ;

...... on a scale many times worse than the 1912 Titanic Sinking for transport by sea.

In the middle of October 2001, the author visited Manhattan and stayed in Battery Park City - within the restricted Security Zone. A first cousin of his was working in one of the WTC Towers on 11th September and, by sheer chance, another two first cousins were elsewhere that morning. He also met with a senior structural engineer directly involved in the clear-up of the WTC Incident Site.

The pall of smoke coming from the WTC Incident Site on 11th September 2001 could be seen by satellite from outer space. Weeks later in October and in overcast conditions, the 'post-fire' smell was still very bad and a lot of sickening dust remained clogged in the air ; it has since been established that the United States Environmental Protection Agency had been persuaded to lie concerning air quality. Services, infrastructure and transport were knocked out in that entire section of Manhattan ; it was a ghost town south of Canal Street. Shortly afterwards, the World Health Organization issued a Guidance Note on 'Psychosocial Reactions to Catastrophe'. Some effects on the people of New York will be long-term. And, as if all of this were not bad enough, important technical lessons from the earlier World Trade Center Explosion and Fire [1], on Friday 26th February 1993, had not been heeded.

So how do we observe, pick up the shattered pieces, and start afresh with a 'reliability-based' and 'person-centred' approach to the design, construction, management and operation of our built environment - particularly from the perspective of everyday structural and fire engineering practice ?

Sustainable Design is the ethical design response to the concept of **Sustainable Human & Social Development**, i.e. designing the 'built' environment to meet the responsible needs of this generation, without stealing the life and living resources from future generations, especially our children ...... and their children. This is an ambitious target, but it must also ultimately result in a dynamic and harmonious balance with a flourishing, not just a surviving, 'natural' environment !

This Paper re-assembles the pieces, and presents 'Fire Engineering for People and a Better World', i.e. **Sustainable Fire Engineering**, in the context of the European Union's legal and institutional framework.

2. A Changing Global Context in the 21st Century

In the **1998 United Nations Human Development Report** [2], it was estimated that 20% of the world's population in the highest-income countries consumed 58 % of total energy, while the poorest fifth consumed less than 4 % - and that the burning of fossil fuels had almost quadrupled since 1950. Even as the process of **globalization** has continued to gather pace, with nation states being criss-crossed and undermined by enormous daily flows of investment and private capital, Transnational Corporations (TNC's), Non-Governmental Organizations (NGO's), the Internet, mass media, and the US Administration's Fundamentalist Crusade against Terror and Evil (Al-Qa'ida may just be an idea, not an organization) ...... we see before our eyes an increasingly fragmented built environment, with a social fabric which is threadbare and torn in many areas. It is also clear, at the time of writing, that the developed regions of the globe will not meet the first major environmental performance target of the new millennium - the **Kyoto Protocol** [3] to the United Nations Framework Convention on Climate Change (UNFCCC), which was agreed at the 3rd meeting of the Conference of the Parties (COP 3) in Kyoto, during December 1997.

Within this existence which human beings are themselves shaping, individuals and even large groups of people no longer feel that they have the freedom to remain apart from the rest of society. Furthermore, the health and happiness of everybody else now depends very much on which model of **capitalism** is being advocated by economic gurus in Wall Street. Is the emphasis being placed on capital and shareholders' value, or on human resources and added value ? These and other existing economic models, however, are extremely wasteful of resources.

Should a more 'person-centred' approach to how we organize and order our society be adopted ? A welcome addition to the European Plan of Integration - a **Charter of Fundamental Rights** - has been drafted in the European Union (EU). Social justice, solidarity and inclusion, the protection of human rights, and adherence to International Law, are fundamental principles of the Union, and a robust foundation for its growing legitimacy. An extensive body of EU legislation also exists relating not only to social concerns, but also to environmental, energy, economic, institutional and political matters - all of which fall precisely within the **'zone of pertinence'** for the concept of Sustainable Development. Where European Union legislation exists it is superior to, i.e. takes precedence over, the national legislation of its Member States.

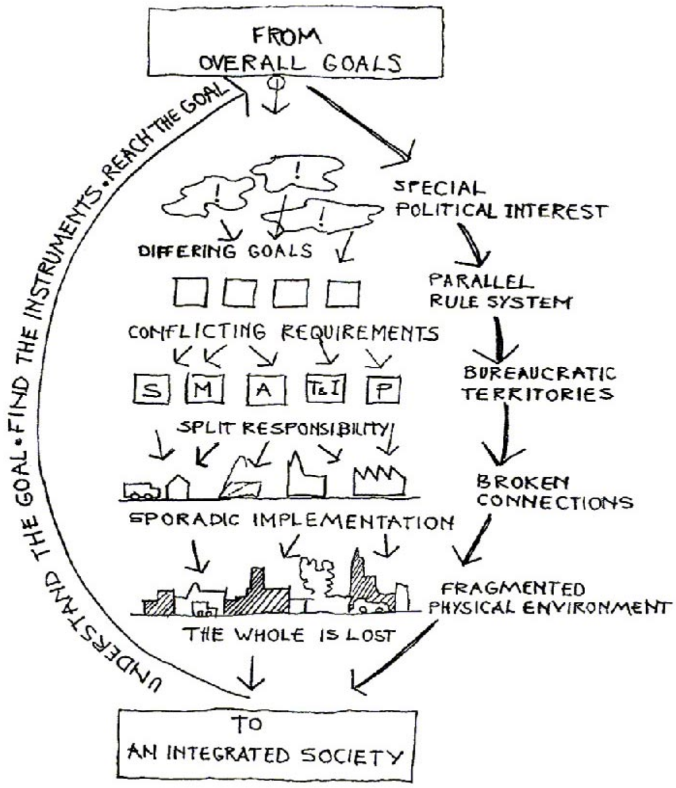

Figure 1 Fragmented 'Built' Environment (concept by a colleague E. Siré, Architect, Sweden)

Rooted firmly, therefore, in the elaborate legal framework of the European Union, international agreements and treaties to which it is a signatory, and the aims and objectives of international organizations in which it agrees to participate, it has been possible to make rapid progress with the construction of an interim, rational understanding of Sustainable Human & Social Development which makes sense for Europe - not for anywhere else - and to propose within that unique context how, for example, a more coherent and comprehensive future programme of common action in a discipline such as **fire engineering** might be implemented. This exercise also allows the robustness of the interim understanding to be tested, as it is developed and evolves.

3. Sustainable Human & Social Development

Significant resources have been devoted to drafting the primary legislation, or Constitution, of the European Union - the principle of 'sustainable development' was explicitly incorporated in the **1997 EU Amsterdam Treaty** [4], although it was not defined or expressed in the clearest terms. This concept was first presented, internationally, at a Stockholm Conference in 1972, but elaborated in a readily understandable form, only at the end of the 1980's, in a Report **Our Common Future** [5], produced by the World Commission on Environment and Development (also known as the Brundtland Commission, after the Norwegian Chairperson, Ms. Gro Harlem Brundtland).

It is appropriate, therefore, to start with that Report and to present the following, more developed definition of Sustainable Development based on Brundtland ....

' development which meets the responsible needs, i.e. the Human & Social Rights*, of this generation - without stealing the life and living resources from future generations, especially our children ... and their children '.

* As defined in the **1948 Universal Declaration of Human Rights** (UN OHCHR).

It is important, here also, to distinguish between the 'natural' environment and the 'built' environment, i.e. anywhere there is, or has been, an intrusion or intervention by a human being in the 'natural' environment - which may be urban, sub-urban, rural or marine, and which includes not only buildings, but also civil engineering and infrastructural works, service and support systems, transport, etc.

Principle 1 of the 1992 UN Rio Declaration on Environment and Development [6] states ....

'Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.'

Adding to the Rio Declaration, and supported by the 1995 UN Copenhagen Declaration on Social Development [7], the following two definitions are very useful ....

Social Environment :

' The complex network of real and virtual human interaction - at a communal or group level - which operates for reasons of tradition, culture, business, pleasure, information exchange, institutional organization, legal procedure, governance, human betterment, social progress and spiritual enlightenment, etc. '

It is the 'social' environment which shapes, binds together, and directs the future development of the 'built' environment.

Social Wellbeing :

' A general condition - in a community, society or culture - of health, happiness, creativity, responsible fulfilment, and **sustainable development**. '

The 1994 European Energy Charter Treaty [8] provides this important definition ....

Environmental Impact :

' Any effect caused by a given activity on the environment, including human health and safety (and welfare) , flora, fauna, soil, air, water, (and especially representative samples of natural ecosystems), climate, landscape and historical monuments or other physical structures or the interactions among these factors ; it also includes effects on (accessibility), cultural heritage or socio-economic conditions resulting from alterations to those factors. '

Finally, the World Health Organization in the preamble to its Constitution, defines 'health' as ....

'A state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity.'

Figure 2 Will Our Planet Cope With The Next 6 Billion People ?

A growing consensus in Europe is acknowledging that in order to accommodate further human and social progress, with an assured minimum quality of life and health for all of its peoples, harmony between the global regions, and world economic stability, it will be necessary to convert ....

- **From ...** current irresponsible patterns of human, social and economic development, with their attendant wasteful environmental destruction and societal stresses ;
- **To ...** Sustainable Human & Social Development ;

.... in order to achieve a high level of **Social Wellbeing** for every person.

Previous injury to the 'natural' environment must be healed in order to arrive at this outcome ; and initial damage repair by human intervention, sufficient only to promote a process of natural self-healing and self-management, will be necessary.

There are many facets to Sustainable Human & Social Development ....

Sustainable Human & Social Development	
Aspects	Essential Requirements
1 Social	Social Justice, Solidarity & Inclusion
2 Economic	Economic Equity
3 Environmental	Beneficial 'Environmental Impact'
4 Institutional	Institutional Openness & Transparency
5 Political	Political Accountability
6 Legal	Effective International Law
7 Judicial	Judicial Independence & Integrity
8 Lasting Peace !	

Yet, barely as we begin the 21st Century ...... events in New York, Bali, Afghanistan, Iraq, Guantanamo Bay in Cuba, Israel and Occupied Palestine have presented us with the criminal antithesis of Sustainable Development.

On 9-11, those two planes did not appear in New York without reason or socio-political context. The consequences of their impact on the WTC Towers continue to have enormous technical implications for the International Construction Community, particularly the discipline of Fire Engineering. This reality must be acknowledged, and digested, by Fire Engineers in our everyday design practice. Reliability must become a keyword. We must begin to understand the people who use our buildings. Our profession can no longer remain blinkered, remote and aloof !

4. The Sustainable Building

Slowly, a profile is emerging of what may be the Sustainable Building of the future ....

Figure 3 Design Concept Of The Future Sustainable Building

The Sustainable Building [9] will be :-

- 'person-centred' & socially inclusive ;
- 'flexible', 'adaptable' & 'accessible' ;
- spatially complex, with some ambiguity, and yet understandable, e.g. easy for building occupants to find their orientation and to 'connect' with the exterior ;
- electronically 'mature', yet energy efficient throughout ;
- a 'place' of stimulation and encouragement to human interaction and creativity ;
- always at the limits of economic viability & technical feasibility ;
- beneficial with regard to overall 'environmental impact'.

This is the world of Design .... an intuitive mixture of art and many sciences. Many of the innovative building performance characteristics listed above remain qualitative in nature - no numbers or equations can yet be invoked ! This does not mean that they can be dismissed by scientists and engineers. Fire Engineers, especially, must begin to feel comfortable with these new design concepts.

However, the pre-**WTC** fire codes, regulations and standards were already, typically, 10-15 years behind conventional architectural practice. Society cannot wait another 8-10 years for the next generation of codes ; and existing steel-frame multi-storey buildings, similar in construction to the WTC I & 2 Towers and WTC 5 & 7 Buildings [10, 11, 12], must be structurally appraised immediately.

At the beginning of the 1990's, the author had responsibility for the operation in Dublin of the 1988 Local Government (Multi-Storey Buildings) Act (Number 29 of 1988) - emergency national legislation enacted following the January 1987 collapse of Raglan House, a five storey apartment block. The total collapse, i.e. the disproportionate damage, had been caused by a gas explosion at ground floor level.

5.0 Sustainable Fire Engineering

'Reliability' and 'Person-Centredness' [13] are core values of Sustainable Design. So in the case of a building, let us begin to examine some of the implications of this new design language ....

5.1 Fire Engineering Design Objectives

Regrettably, the objectives in building codes still remain limited to the protection of able-bodied building occupants. Aware of this, and following careful examination of the nature and precise location of a particular construction project, a 'competent person', i.e. a **fire engineer**, should start by identifying, in consultation with the client and other members of the design team, a project specific range of **fire engineering design objectives**. Where practicable, direct and meaningful consultation should be undertaken with occupants prior to the implementation of the **fire engineering strategy**.

A professional fire engineer owes a general duty of care to his/her client. The following objectives cover a spectrum of relevant concerns and protect the full interests, legal and economic, of the client :

(i) protection of the health, safety and welfare of all building users, including people with activity limitations [14], visitors to the building who may be unfamiliar with its layout, and contractors or product / service suppliers temporarily engaged in work, or business transactions, on the premises ;

(ii) protection of property, including the building, its contents, <u>and</u> adjoining or adjacent properties, from loss or damage ;

(iii) protection of the health, safety and welfare of rescue teams and firefighters (refer to the requirements of EU safety at work legislation) ;

(iv) the **buildability** of necessary re-construction after a fire ;

(v) protection of the 'natural' environment from adverse or harmful **environmental impacts** (see definition above) ;

(vi) sustainability of the 'built' environment - including the proper selection and **life cycle assessment** (see definition in European Standard EN ISO 14040) of fire engineering related materials, products, components, systems, etc, fixed, installed or incorporated in the building.

An issue which is becoming increasingly critical, in striving to rationalize, analyse (as distinct from assess), improve and optimize fire performance in buildings, is that of **reliability**. Can we confidently depend on an element of construction, an installed product or component, or a building system to perform as expected whenever a fire might occur - at any stage in the life cycle of that building ? Design, construction workmanship, maintenance, 'real' intended use, and an economically reasonable working life for the building, are important considerations for the fire engineer, as an integral member of a project's design and construction teams. Can every fire engineer read and properly understand an architectural drawing ? Is every fire engineer familiar with what happens on a building site ?

5.2 Reliable Structural Design for Fire

In general terms, the reliability of a building structure, i.e. the loadbearing construction, is the ability to fulfil its architectural design purpose for some specified time under the actual environmental conditions encountered at any time during the full life cycle of the building. However, the performance of a whole structure or part of it, including its performance during and after a fire, may be more precisely specified in engineering terms by reference to a defined set of **limit states** beyond which the structure no longer satisfies the project's design objectives, be they architectural or fire engineering.

'Real' buildings comprise structure and fabric, i.e. non-structure, in an architectural relationship. Under fire conditions, this relationship becomes an intense and complex interaction, which in nearly all cases impacts on the functional efficiency, or fire performance, of both.

Fire Resistance :
' The inherent capability of a building assembly, or an element of construction, to resist the passage of heat, smoke and flame for a specified time during a fire. '

Fire Compartmentation :
' The division of a building into fire-tight compartments, by fire resisting elements of construction, in order ......
(a) to contain an outbreak of fire ;
(b) to prevent damage, within the building, to other adjoining compartments and/or spaces ;
(c) to protect a compartment interior from external fire attack, e.g. fire spread across the building's facade or from an adjacent building ;
(d) to minimize adverse, or harmful, environmental impacts outside the building. '

But what about the fire performance of structure in modern buildings ?

Structural Reliability (ISO 2394 : 1986 + Addendum 1 : 1988) :
' The ability of a structural system to fulfil its design purpose, for a specified time, under the actual environmental conditions encountered in a building. '

In structural design for fire, the concern must be that the structure will fulfil its purpose, both during the fire - and for a minimum period afterwards, during the 'cooling phase'.

And what about progressive collapse ...... which can commence before any breach takes place in the 'integrity' of a fire compartment's boundary ? Those skimpy, lightweight floors in WTC 1 & 2 ?

Progressive Collapse :
' The sequential growth and intensification of distortion, displacement and failure of elements of construction in a building - during a fire and the 'cooling phase' afterwards - which, if unchecked, will result in disproportionate damage, and may lead to total building collapse.

Is this what we all witnessed in the variety of structural failures from WTC 5 & 7 to WTC 1 & 2 ?

Disproportionate Damage :
' The failure of a building's structural system ......
(i) remote from the scene of an isolated overloading action ; and
(ii) to an extent which is not in reasonable proportion to that action. '

An adequate structural tie - in ambient or fire conditions - between vertical and horizontal structural elements is a fundamental principle of all structural design ! Poor connections between, on one end, the steel truss supported floor units and the vertical perimeter steel structure, and on the other end, between the floor units and the building core steel structure, were an important factor in the scale of damage to WTC 1 and WTC 2.

Those limit states mentioned above may be divided into the following two categories :

- **ultimate limit states**, which in 'cold form' (ambient) structural design correspond to maximum load-bearing capacity but, typically, in design for fire still correspond to the 'near-maximum' (?) loadbearing capacity intended to avoid damage to fire test laboratory furnaces caused by test specimen collapse - see definitions of 'failure' in fire resistance test standards ;
- **serviceability limit states**, which in 'cold form' design correspond to criteria governing function related use but, unfortunately, in design for fire are hardly yet even recognized.

Ultimate limit states in fire engineering should instead be equally understood to mean, for example ......
- rupture of critical sections of the structure caused by exceeding the ultimate strength (in some cases reduced by repeated loading), or the ultimate deformation of the material ;
- transformation of the structure into a mechanism (collapse) ;
- loss of stability (buckling, etc).

Serviceability limit states in fire engineering, which are of more immediate and direct relevance to the protection of both human health and property, and necessary re-construction after a fire, would correspond to, for example ......
- deformations which affect the efficient use, i.e. the fire performance, or appearance of structural or non-structural elements ;
- local damage (including spalling and cracking) which reduces the durability of a structure or affects the efficiency or appearance of structural or non-structural elements.

To control 'hot form' serviceability limit states by design, it is necessary to use one or more constraints which describe acceptable deformations (+/- deflection, expansion, distortion, etc), accelerations, crack widths, spalling, etc. **A fundamental starting point in structural design for fire, however, must be to properly separate the concept of 'fire resistance' from the concept of 'structural reliability'.**

5.3 Reliable Design for Fire Evacuation

Seeing the long lines of emergency vehicles which had been destroyed by debris from the collapsing buildings on 9-11 was an 'eye-opener'. There appeared to have been little understanding of building structural behaviour, and almost no grasp of the concept of 'place of safety'. The precise numbers of people who died on and after 11th September 2001, or who escaped, may never actually be known.

Place of Safety (Building Occupants in a Fire Situation / No Explosion Hazard) :
' Any location beyond a perimeter which is 100 metres from the fire building or a distance of 10 times the height of such building, whichever is the greater .... and .... where necessary medical care and attention can be provided, or organized to be provided, within one hour of injury .... and .... where people can be identified. '

Computer evacuation models continue to be churned out in many parts of the world. Although some efforts were made to raise the issue of **model validation** in CIB Working Commission 14 : Fire, there has been little tangible progress at international level. Instead of dealing with 'real' building occupants and the 'real' use of buildings, the approach of model developers tends to remain one of trying to control the movement of ballbearings in a slot machine. Yet, there is no standard, normal, average human being ...... anywhere. But scientists and engineers stubbornly persist !

People with Activity Limitations (2001 WHO ICF) :
' Those people, of all ages, who are unable to perform, independently and without aid, basic human activities or tasks - because of a health condition or physical / mental / cognitive / psychological impairment of a permanent or temporary nature. '

An examination of the space requirements in buildings for physical impairment, and how to design for accessibility, has been of immense value in designing for fire evacuation. To take just one small example from 9-11 : Photographs were taken inside one of the WTC Towers, in an evacuation stairway / staircase, during the actual evacuation. The following can clearly be seen :

- the staircase 'clear width' was too narrow, both for firefighter contraflow and any assisted evacuation of people with activity limitations - in a mega-high-rise building without fire evacuation elevators / lifts (!?!) - the minimum 'clear width' of an evacuation staircase (excluding the projection of handrails) should be two-persons wide, or approximately 1500mm ;
- the staircase was too steep, and there should have been no projecting nosings on stair treads ;
- there should have been handrails on both sides of each flight of stairs, and the handrails should have been continuous - of course, the evacuation staircases should have been continuos too (!?!) .

Target Fire Engineering Design Objective :

' During and after the process of **independent evacuation** to a 'place of safety' which is distant from a fire building, or partial evacuation to a 'place of relative safety' within the building, or **protection in place**, for example, in the case of health facilities - the individual health, safety and welfare of those people involved, including firefighters, should be assured. '

Because we may be asking people to remain in a building during a fire, far greater reliability is required of fire engineering related building performance !

We expect buildings to be designed for access, with beautiful entrance lobbies and immediately obvious elevators / lifts. But are buildings ever designed for fire evacuation, or is it usually necessary to have a magnetic compass, a map and a magnifying glass to find the nearest evacuation route ? An examination of the accessibility requirements for mental and cognitive impairment is revealing hidden dimensions to design for fire evacuation ....

1. Building 'Understandability' ;
2. Building Occupant Orientation, and Relationship with the Exterior ;
3. Panic Prevention, and Reduction of Occupant Stress during Evacuation Activity ;
4. Simple, Non-Conflicting Signage, with Graphics Instead of Text.

Cognitive Impairment :

' A deficiency of neuropsychological function which can be related to injury or degeneration in specific area(s) of the brain. '

Mental Impairment :

' A general term describing a slower than normal rate in a person's cognitive developmental maturation, or where the cognitive processes themselves appear to be slower than normal - with an associated implication of reduced, overall mental potential. '

By its nature, Fire Engineering must be widely multi-disciplinary. A higher level of professional competence (education, with relevant experience) must be demanded of those individuals involved.

6. Real Implementation of a Sustainable 'Built' Environment

The **European Charter on Sustainable Design & Construction** places great emphasis on 'real' and 'reproducible' implementation, by means of the informed use of construction related sustainability performance indicators, i.e. some understanding and competence is required.

In particular, Principle 26 of the Charter states ....

' Harmonized short, medium and long-term strategies in the policy areas of energy efficiency, environmental protection and sustainable development should be planned for implementation in the European Union over the following time frames :-

(i) up to 2010 ; (ii) between 2011 and 2040 ; (iii) between 2041 and 2100.

Such is the threat to quality of life and human progress caused by current environmental degradation, and such is the great timelag between implementation of corrective actions and resulting beneficial environmental impacts, that sustainability performance should be benchmarked at year 1990 in the Member States of the E.U.

Principle 26 continued ....

Detailed performance indicators for all stages of planning, design, construction / de-construction, maintenance and disposal should be used to target improvements in sustainability performance, verify target attainment, and continually re-adjust targets at appropriate intervals thereafter. '

The primary purpose of Construction Related Sustainability Performance Indicators is to commence, in earnest, the practical task of implementing a sustainable approach to the future development and modification of the 'built environment' in Europe, while also playing our part in ensuring a flourishing future for the 'natural environment' ....

- Principle 26 of the European Charter on Sustainable Design & Construction signalled that a futures scenario should be developed which would cover the short, medium and long-terms, at least until the end of this century ;
- Using this futures scenario, incremental improvements in construction performance required to achieve a sustainable 'built environment' within a flourishing 'natural environment' may then be plotted. The focus of attention must always be on 'real', rather than theoretical, performance ;
- Construction related sustainability performance indicators, 'harmonized' for application in the European Union, will allow us to target, reliably quantify and monitor construction performance in the built environment which, by general international agreement, has been benchmarked at 1990 levels. Rigorous procedures will be required to process the data and statistics generated in order to ensure that they, too, are reliable.

A secondary, short term purpose in Ireland will be to develop a **Sustainability Label Award Scheme** - initially for buildings - which will be a major departure from existing methods of energy and/or environmental rating systems. Based on an understanding of 'sustainable development' which is current and generally held at any particular time, an objective sustainability performance statement may be made about a specific building, the performance of different buildings may be compared, or more favourable working methods in the building design process itself may be identified ....

Figure 4 Harmonized European Sustainability Label for Buildings & Civil Engineering Works

The following are two examples of relevant Indicators ....

❖ **Equality of Opportunity for Every Person in Society**

To advance the principle of sustainable development , and in order to combat discrimination and remove restrictions on participation in society ~ by the year 2010, every new building shall be fully and independently accessible with regard to mobility, usability, communications and information.

❖ **Fire Protection in Buildings**

To advance the principle of sustainable development , and in order to provide a high level of protection and improvement of the quality of the environment ~ by the year 2010, every new building shall be designed, constructed and managed so as to ensure the least adverse **environmental impact** in the event of fire.

The underlined text in each Indicator is a direct quotation from the 1997 EU Amsterdam Treaty.

7. Fire Engineering - The Problem & Its Resolution

The author was one of the principal contributors to **CIB Report No. 269 : Rational Fire Safety Engineering Approach to Fire Resistance in Buildings**, published in October 2001. Especially in the aftermath of 9-11, this Report should have had something to say, however small, about progressive collapse and disproportionate damage caused by fire. These concepts were not new. Back in 1987, Dr. William Crowe presented a Paper at one of the Dublin International Fire Conferences ...... http://www.sustainable-design.com/fire/dublinfire.htm .

On 19th July 2002, the **BeneFeu Report : Potential Benefits of Fire Engineering in the European Union** was submitted to Directorate-General Enterprise in the European Commission (EC Contract EDT/01/503480). The following words did not appear anywhere in this Report : 'progressive collapse' ; 'disproportionate damage' ; 'limit state(s)' ; 'serviceability' ; 'panic' ; 'disability' ; 'people with disabilities' ; 'impairment' ; 'activity limitation' - 'life cycle' appeared once on Page 108, while 'sustainability' appeared (incidentally) three times on Page 60. Any design dimension to Fire Engineering was not elaborated. No attempt was made to outline a coherent Harmonized European Research Agenda.

Fire in buildings, however, are a complex phenomenon. Since nobody yet fully understands what is happening, and since experimentation on real buildings involving real people is, to a great extent, out of the question because of the inherent hazard and level of risk, we must first of all define the problem and analyse the operation of its resolution.

The system is dynamic ....

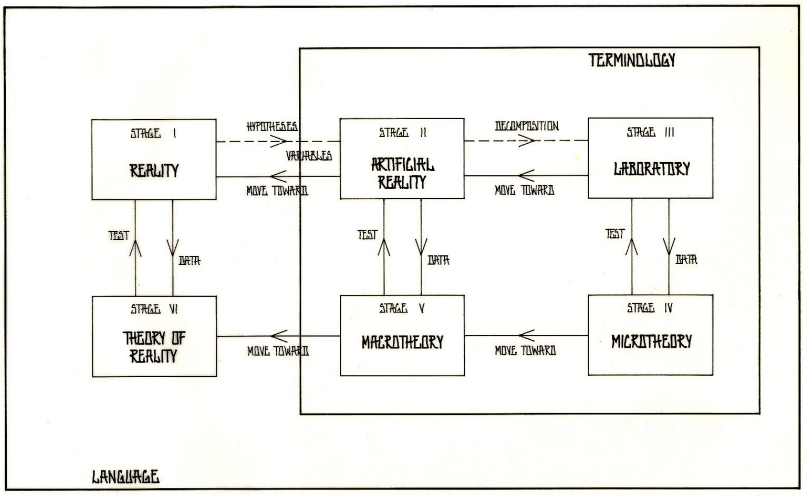

Figure 5 Towards A Common Fire Research Agenda in Europe

Stage 1

The realistic end condition, or 'reality', is a real fire in a real building with real building users. The building may or may not be occupied at the time of a fire. If the building is occupied, it should be assumed that approximately 20 % of building users are, at any ordinary time, impaired to some degree. See the definition of 'people with activity limitations' in Appendix III to this Paper. Obviously, this percentage will vary according to particular building types, e.g. health facilities (an establishment, or any unit of an establishment, which provides health care).

It may not be possible to identify a person with an activity limitation. Because of the social stigma attached to disability, some people may never wish to identify themselves. Other people may not even realize that they have a health condition or an impairment.

Literature dealing with 'reality' is reviewed. Investigation reports of real fires are thoroughly examined and studied. Relevant hypotheses are extracted and as many variables as possible are identified.

Stage 2

An 'artificial reality' is designed which is complex enough to permit testing of the hypotheses formulated in **Stage 1**. Observations must be detailed, and capable of description in quantitative terms.

Stage 3

'Artificial reality' is broken down into simple experimental situations at small and medium scale, i.e. reaction-to-fire tests, fire resistance tests, the room test, which generate test results under controlled laboratory conditions.

Stage 4

A simple theory, or microtheory, is developed to explain the test results. When this microtheory is tested and found valid, it is expanded to contain large scale test results in more complex situations, viz. 'progressive collapse' and 'disproportionate damage'. This process is repeated until a macrotheory is formulated which explains the 'artificial reality'.

Stage 5

'Artificial reality' is modified in the direction of 'reality'. **Stages 3 & 4** are repeated yielding a fresh macrotheory. The process is repeated again and again.

Stage 6

When a macrotheory is sufficiently developed it can be used to extrapolate an explanation of 'reality'.

It is essential that such a 'theory of reality' is accessible to all concerned with the design, construction, management and operation of buildings. A boundary to the use of terminology, therefore, is delineated.

Without continuing fire engineering research, development and demonstration, this system remains static and the problem of providing an adequate level of 'real' fire engineering performance in buildings cannot be fully resolved.

8. Conclusions

Television pictures, that sunny Tuesday morning in September 2001, of the plane impacts on the WTC Towers and the unexpected building collapses were beyond belief. Weeks later, some New Yorkers could still not bring themselves to talk about what had happened. Some of the negative economic impacts on the City will be permanent. The events of 9-11, however, crystallized and made dramatically public pre-existing weaknesses and failures in fire engineering principles, practices, codes and procedures ; the discussion in this paper is merely a beginning. Society in North America, and the International Construction Community, are not prepared to wait another decade for these problems to be solved ; working together, and more openly, solutions can and will be found more rapidly.

This paper has not been written to point a finger of blame or to apportion responsibility, but to define and elaborate a new design language, new concepts and new constraints for those of us involved in Fire Engineering. **The design dimension of Fire Engineering must now be fostered, and receive focus. Only then can Fire Engineering be integrated into the mainstream of Sustainable Design.**

9. Appendices

Appendix I	Passive Fire Protection Measures
Appendix II	Active Fire Protection Measures
Appendix III	People with Activity Limitations

10. References

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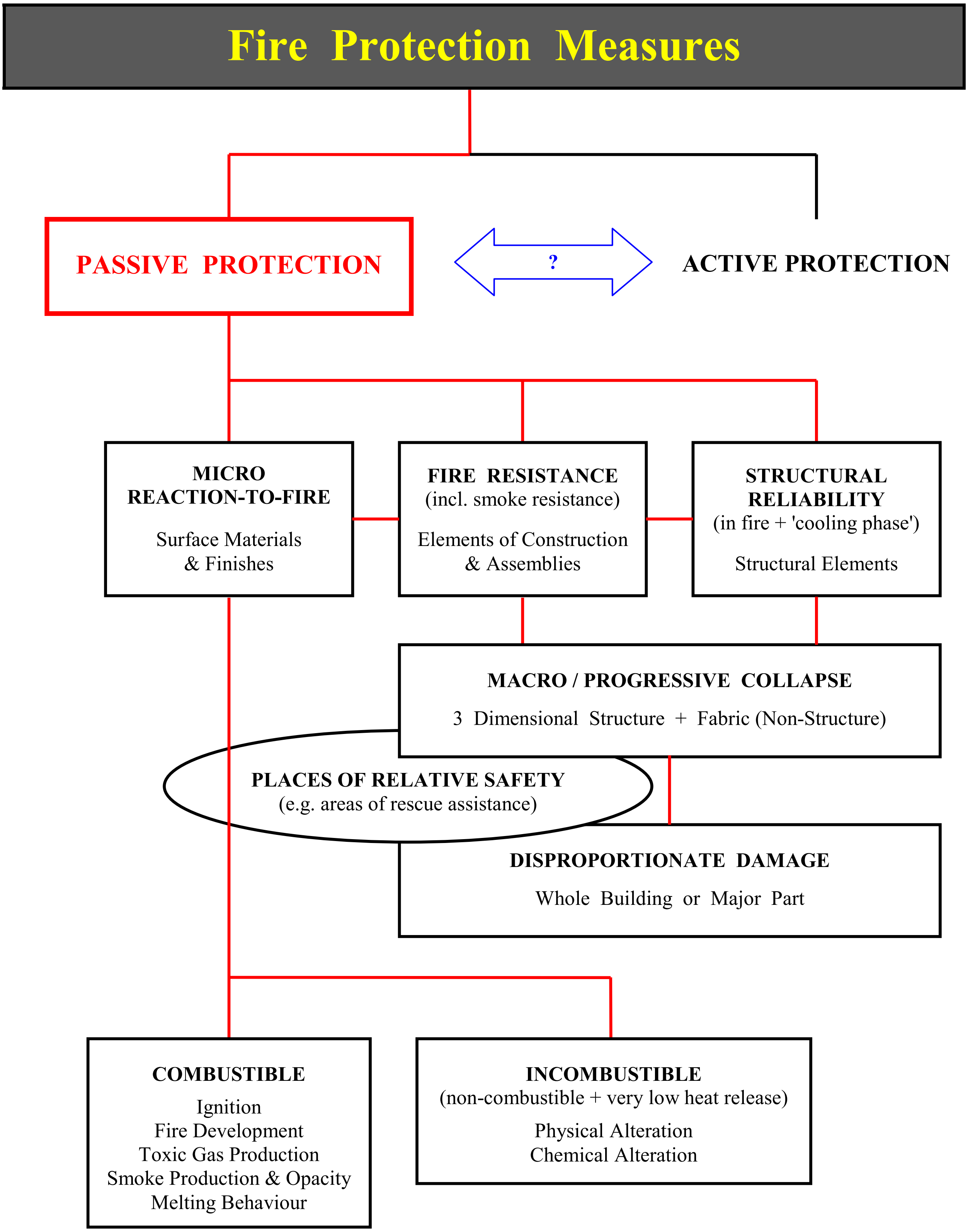
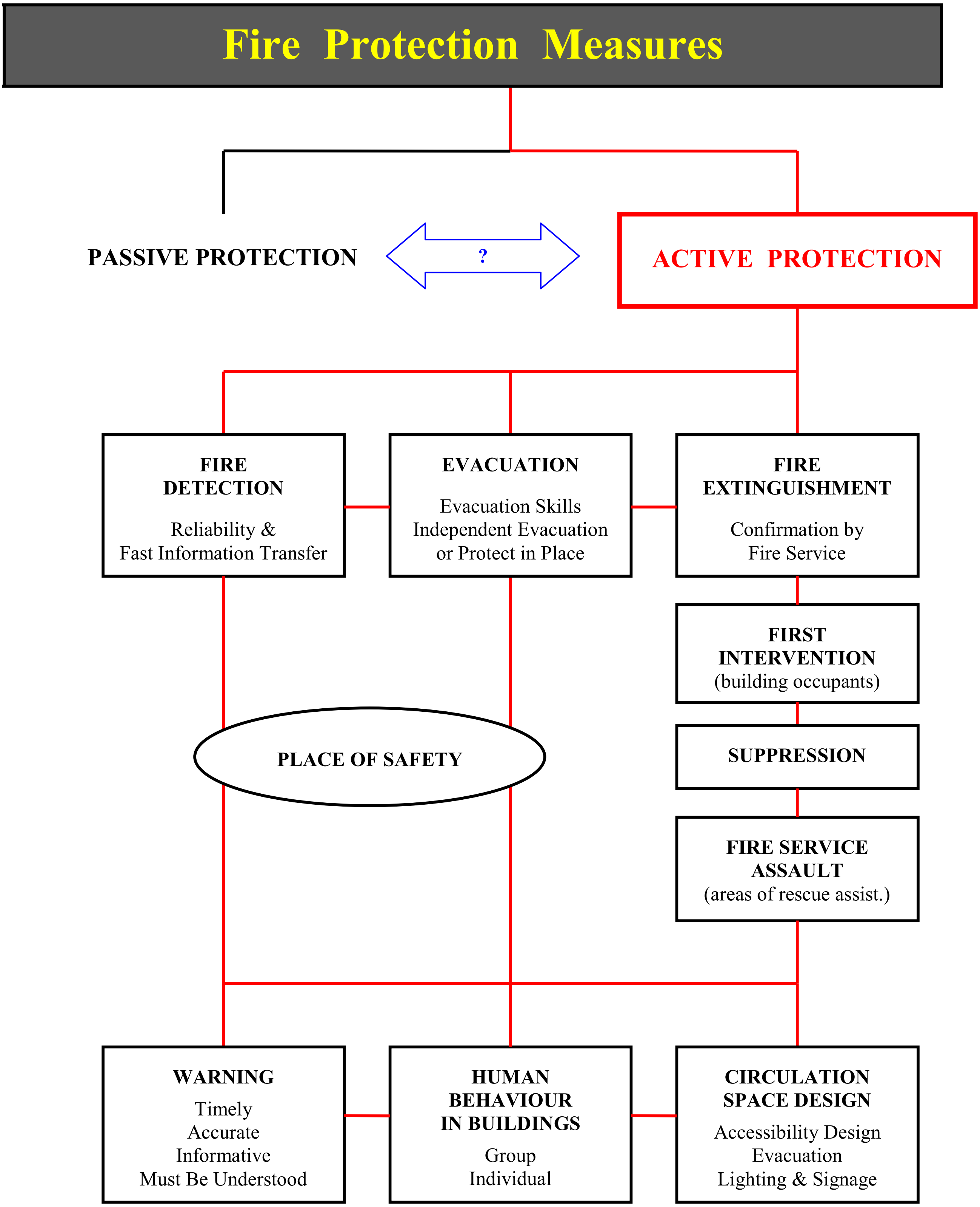
Appendix I


Fire Protection Measures
PASSIVE PROTECTION
?
ACTIVE PROTECTION
MICRO
REACTION-TO-FIRE
Surface Materials
& Finishes
FIRE RESISTANCE
(incl. smoke resistance)
Elements of Construction
& Assemblies
STRUCTURAL
RELIABILITY
(in fire + 'cooling phase')
Structural Elements
MACRO / PROGRESSIVE COLLAPSE
3 Dimensional Structure + Fabric (Non-Structure)
PLACES OF RELATIVE SAFETY
(e.g. areas of rescue assistance)
DISPROPORTIONATE DAMAGE
Whole Building or Major Part
COMBUSTIBLE
Ignition
Fire Development
Toxic Gas Production
Smoke Production & Opacity
Melting Behaviour
INCOMBUSTIBLE
(non-combustible + very low heat release)
Physical Alteration
Chemical Alteration

Appendix II


Fire Protection Measures
PASSIVE PROTECTION
?
ACTIVE PROTECTION
FIRE DETECTION
Reliability & Fast Information Transfer
EVACUATION
Evacuation Skills
Independent Evacuation or Protect in Place
FIRE EXTINGUISHMENT
Confirmation by Fire Service
FIRST INTERVENTION
(building occupants)
SUPPRESSION
PLACE OF SAFETY
FIRE SERVICE ASSAULT
(areas of rescue assist.)
WARNING
Timely
Accurate
Informative
Must Be Understood
HUMAN BEHAVIOUR IN BUILDINGS
Group
Individual
CIRCULATION SPACE DESIGN
Accessibility Design
Evacuation
Lighting & Signage

Appendix III

People with Activity Limitations
Personnes à Performances Réduites

Those people, of all ages, who are unable to perform, independently and without aid, basic human activities or tasks - because of a health condition or physical / mental / cognitive / psychological impairment of a permanent or temporary nature.

This definition is derived from the 2001 World Health Organization's **I**nternational **C**lassification of **F**unctioning, Disability & Health (**ICF**) , adopted on 22nd May 2001.

The above **terms** may include ....

- wheelchair users ;
- people who experience difficulty in walking, with or without aid, e.g. stick, crutch, calliper or walking frame ;
- frail, older people ;
- the very young (people under the age of 5 years) ;
- people who suffer from arthritis, asthma, or a heart condition ;
- the visually and/or hearing impaired ;
- people who have a cognitive impairment disorder, including dementia, amnesia, brain injury, or delirium ;
- women in the later stages of pregnancy ;
- people impaired following the use of alcohol, other 'social' drugs, e.g. cocaine and heroin, and some medicines ;
- people who suffer any partial or complete loss of language related abilities, i.e. aphasia ;
- people impaired following exposure to environmental pollution and/or irresponsible human activity ;

and ....

- people who panic in a fire situation or other emergency ;
- people, including firefighters, who suffer incapacitation as a result of exposure, during a fire, to poisonous or toxic substances, and/or elevated temperatures.