A study of the diffusion & adoption of the concept of smoke control in the U.K. and U.S.A

Malcolm Brooks

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Presented as a Thesis for a Master of Arts Degree

University of Durham

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ABSTRACT

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The purpose of this thesis is to examine the diffusion and adoption of smoke control in the U.K. and the U.S.A. in relation to the traditional Innovation Diffusion Adoption paradigm. The concept of smoke control as a method of public safety and building protection has been in existence in some form since the 19th Century. The generic term 'smoke control' covers any technique for dealing with smokey gases and protecting means of escape from buildings in the event of a fire.

Much of the research to date in Innovation Diffusion and Adoption has been in the consumer field and/or on a small scale i.e. spatially, product or project specific. The research conducted for this thesis is industry wide and as such is a useful extension of the many research projects in this field of study.

The diffusion and adoption of the concept of smoke control was found to follow the traditional paradigm in its process particularly before legislation was introduced in England in 1972. In addition, statistical analysis of the results provided a skeletal framework for a profile of an organisation likely to adopt an innovation. The factors in this profile matched those developed in the traditional paradigm for individuals.

Further development of this profile could provide a useful tool for companies involved in marketing innovations.

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CHAPTER 1

Research into the area of building safety known as smoke control was originally suggested by a first degree dissertation in which the author examined the problem associated with market entry into the industry. During research for that paper it became apparent that the diffusion of the concept of smoke control presented an interesting but confusing picture. Why, for example did a concept originally conceived in the early 1900's present such an uneven picture in terms of adoption by its users in the 1980's? Why did there appear to be such variations in its acceptance in different areas of business or commerce? What were the factors that influenced the rate of adoption? Was there any way in which the rate of adoption could be influenced? These four questions will be addressed in the final chapter of this thesis.

Chapter 2 contains definitions of the smoke control methods and includes a history of the development of the innovation.

In order to fully understand the innovation adoption process an in depth study of available literature was undertaken. This was backed up by interview and discussions with noted academics such as E.M. Rogers, L.A. Brown and others. This research is covered in Chapter 3 of the study.

Because the earliest trace of the use of smoke control was found in the USA it was decided to conduct research both in the USA and the UK to obtain some idea of the difference between the two countries although it was not intended that this should be a comparative study it was inevitable that some comparison should occur. The visit to the States also gave the opportunity to visit Prof. E.M. Rogers mentioned above, author of *"Diffusion of Innovation."* Research did reveal that the origin of smoke control occurred in Austria as far back as the 19th century.

The methodology for the research is described in Chapter 4 of the paper.

Chapter 5 gives the findings of the research by market segments and by country. It also attempts to define behavioural factors influential in the adoption process.

Chapter 6 analyses the research findings in relation to the traditional diffusion research paradigm whilst Chapter 7 examines the implications of the analysis of the research findings to the diffusion of the concept of smoke control, and concludes by giving recommendations for diffusion in the smoke control industry and proposing suggestions for further research.

It is hoped that this Thesis offers some clarification to a subject where the elements of adoption diffusion are to say the least, less than clear.

CHAPTER 2

2.1 Definition of Terms

The definition of terms is an area requiring clarification. It was obvious from the USA research trip that differences existed between the USA and the UK. In the USA smoke control was often used synonymously with smoke pressurisation. It also became obvious that there were some differences in terminology within the UK.

For these reasons an attempt to accurately define terms was undertaken. The definitions chosen are those offered by Howard P. Morgan of the Fire Research Station (FRS). These definitions taken from an F.R.S. interim report are given in Appendix (i)

It should be noted that the definitions as yet are not adopted as official Standards. They have been agreed by H.P. Morgan and a colleague in the Home Office Fire Service Inspectorate on an unofficial basis, but as H.P. Morgan states in his correspondence to the author:

> *"I enclose an interim version of our definitions. When an acceptable form of words is settled, the F.S.I. may put these definitions to B.S.I."*

He goes on to say:

> *"possibly an example of an invisible network feeding a visible network."*

2.2 History & Development of Smoke Control

This section is devoted to a description of the chronological progress of both the use of smoke control in buildings and the development of design methods. The real story starts in the 19th century and continues to the present day.

Reference can be made to smoke ventilation as far back as the Parthenon in around 28BC where a roof opening was put above the sacrificial altar. Moving a little nearer to the present, in Shakespeare's day the Globe Theatre had ventilation lanterns to allow smoke to escape from the oil lamp stage illumination. Both these cases could be regarded not so much as a safety method but simply arising from a need to dispose of the smoke created by controlled source (e.g. as with a chimney).

The first modern reference to the need to ventilate during fire fighting was made by Sir Eyre Massey Shaw in a fire fighting handbook published around 1800.

In 1881, a fire in the Ring Theatre, Vienna killed 449 people. This was studied by the use of small scale models in 1883 and experiments in 1905 to test ventilation design, by the Austrian Engineering Association. H.P. Morgan's opinion is that this was one of the earliest applications of depressurisation in its recommendations of the use of lantern and safety curtains. It would be defined under the generic term of smoke control as given earlier but not under the definition of smoke ventilation.

In 1905 a fire in the Iroquois Theatre, Chicago, USA, killed 571 people. This was found to be due to smoke logging and an explosion caused by the build up of carbon monoxide. Shortly after, legislation was introduced in most developed countries for the separation of auditorium and stage area by a safety curtain with roof lanterns operated by fusible link to provide automatic venting. After this initial application of smoke control there appeared to be no actual progress in smoke control application until the early 1950's.

In 1953 in Livonia, Michigan, USA, a four-year old General Motors factory was completely destroyed, killing 3 people.[(1)] It should be noted that the building covered 34.5 acres and was built to stringent building codes and insurance requirements. The building was designed to be non combustible. Company policy dictated that the works fireman attended any potentially dangerous operation within the building. Despite all these precautions, during an acetylene cutting operation, sparks set fire to an oil drip tray. This spread to an overhead solvent tray. The fire spread so quickly that immediate action by the fireman proved ineffective. Two minutes later the main fuses had blown and the building became smoke logged. The resultant loss was $55 million.

General Motors were convinced that a major factor in this disaster was the trapping of heat and smoke. They commissioned the Armour Research Foundation of the Institute of Technology in

Chicago to research into the fire with the specific objective of investigating the practicality of venting fires. The recommendations for smoke curtains (screens to divide the area into compartments) and smoke vents, published in March 1956, were the basis for the design of a smoke ventilation system for Vauxhall Motors in the UK the same year.

In 1957 a fire occurred at the Jaguar Plant, Coventry, the building quickly becoming smoke logged, preventing firemen from tackling and controlling the blaze which spread rapidly through the building. After one and a half hours 2 acetylene cylinders exploded causing partial collapse of the roof. Thus, the fire was vented and the firemen could perform satisfactorily and control the fire, but approximately one third of the building was destroyed at a cost of £3½ million. In a report, the Coventry Fire Chief called for additional automatic fire ventilation for all large individual buildings in the motor industry.

In the early 1960's a jointly funded research project was undertaken by the Joint Fire Research Organisation (of the Fire Officers Committee), the Ministry of Technology and private industry (Colt Ventilation). This resulted in Fire Research Paper 7(2) 1963 which dealt entirely with natural ventilation (unpowered) of buildings for smoke control. Paper 7 was followed in 1964 by Fire Research Paper 10(3), again dealing with natural ventilation smoke control, but designed in a format for easy absorption in order to popularise the use of smoke ventilation.In the USA in 1960, Factory Mutual, a major insurer, defined the use of Fire Vents. In New Zealand in 1965, the Council of Fire and Accident Underwriters Association declared insurance premium rebates where fire vents and screens (smoke curtains) complemented sprinklers and alarms. It should be noted that to this day there is still dispute over the combined use of vents and sprinklers. In 1966, Fire Research Paper 14(4) was published which checked criteria used in Papers 7 and 10 from data obtained from an actual fire at Vauxhall Motors. In 1967, Dutch insurers introduced premium reduction for fire vent installations. Also in 1967, Fire Research Paper 17 was published on the use of sprinklers. In the USA in 1969, the Factory Mutual Insurance Company published approved standards for Heat and Smoke Vents.

In 1969 a major fire at the Wulfrun Shopping Centre caused concern and was reported by Silcock & Hinkley in 1971. This fire, had it occurred in shopping hours, could have resulted in large loss of life. Fire spread from the carpet store across a covered bridge into the adjoining Mander Centre. This resulted in "The Home Office Town Centre Redevelopment Guide No. 1", 1972, which was produced by a joint committee of the Home Office and the Scottish Home & Health Department, with representation from the Fire Brigades (the Fire Research Station, etc). This was the first sign of 'regulation push'. From then on the large enclosed volumes found in shopping malls could not be accepted under building regulations because of the risk that occupants would not be able to travel the distances to fire exits in the event of a fire. In order to satisfy regulations the malls had to be the subject of special relaxation which specified the use of smoke control, the use of which created clear escape layers enabling occupants to travel the longer distances to the fire exits.

Thus, from 1972 to 1985, every shopping centre in the UK had to be referred to the Department of the Environment and therefore the Fire Research Station. This "advisory" work by the F.R.S. resulted in a common approach to smoke control design and a universal application of changes in design. Morgan states:

> *"it is the involvement in actual schemes that has led to nearly all of the actual research in smoke control that the F.R.S. has done in the last 15 years."*

Actual research into smoke control in shopping malls commenced around 1969/70 and single storey criteria was available by 1975.

The publication in 1979 of H.P. Morgan's paper entitled, "Smoke Control Methods In Enclosed Shopping Complexes Of One Or More Storeys"[(5)] was a combination of research, and earlier papers such as Fire Research Note 875[(6)] by P.L. Hinkley, entitled: "Some moves on the control of smoke in enclosed shopping centres," 1971. BRE 83/75[(7)] covering single storey applications, also by Hinkley, other papers were CP 48/75[(8)] and 45/76[(9)], 19/78[(10)] and 11/79[(11)]. H.P Morgan's paper superseded Chapter 7 in the Town Centre Redevelopment Guide No. 1 and helped reinforce the regulation push created by the Guide by ratifying design methodology for smoke control systems in shopping malls.

The 1970's saw an upsurge in the work being done on smoke control in shopping centres. This could be attributable to the onset of the covered shopping centres being put forward by developers. The current trend for Atria in buildings such as office blocks and shopping malls has also created design problems. The term 'Atrium' has its origin in Roman times and is defined as 'the central court of a Roman house.' This was a roofed- over courtyard surrounded by the building. The current use of the term 'Atrium' covers central roofed areas over one storey high. An upsurge in work on the question of Atria smoke control design is occurring during the current decade perhaps prompted by fires in a Brussels department store, the Regency Hyatt Atria, and the I.M.F. building in the USA. Controversy exists about the methods used to design smoke control systems in Atria and the F.R.S. are currently engaged on producing a paper on this subject.

There are other landmarks in the history of the development of smoke control methods. Some similar to General Motors' action in commissioning the Armour Research Foundation to research their fire. They appear to be prompted from a safety need and possible insurance loss, rather than a need to satisfy regulation; e.g. Citroen tested the merits of plastic versus aluminium roof vents at Champs sur Marne, France (aluminium found to be the best), the fire risks of warehouse racking and the use of sprinklers in fire and smoke control.

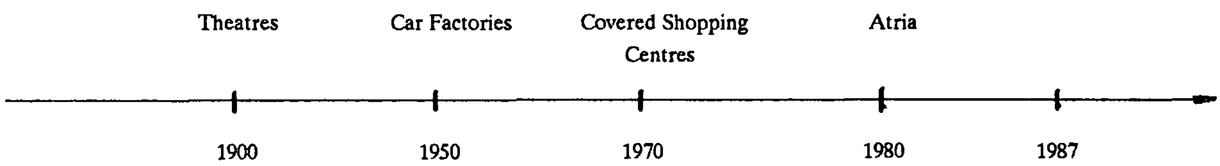
A very active promoter of smoke control are Colt Ventilation, who have conducted many tests on design and equipment from the early 1950's to the present day. Since the 1970's other companies, such as Nuaire, have also invested heavily in research into this potentially lucrative market.

Other countries have adopted some form of regulation or recommendation. The USA appears to operate autonomously from state to state. The UK operates more centrally. In the USA, various code bodies offer recommendation. The National Fire Research Centre, part of the National Bureau of Standards, Washington, offers a smoke control design guide; other contributors are insurers and the National Fire Protection Association. Scandinavia is currently using UK Fire Research Station (F.R.S.) design methods based on Paper 7(1) to formulate regulations, and Brandforsk (the Swedish Fire Research Board) with the F.R.S. are constructing computer models to simulate fire conditions. Papers 7 and 10 have also been used in the drawing up of German regulations published in 1982. Australia has conducted tests at the Australian Commonwealth Experimental Building Station in 1972, and in 1982 published fire venting standards.

In 1985, building regulations in the UK were changed, removing the need for referrals of shopping mall schemes to the D.O.E. This coincided with a cut back in the acceptance of referrals by the F.R.S. which started in 1983. Until 1985, only schemes of "special interest" were referred.

The use of smoke control has followed a catastrophe-littered path at the cost of lives and property. In addition, changes in building design have influenced the use of smoke control. The current picture is one of disagreement on various fronts such as whether sprinklers and smoke vents should be combined in a fire protection system; also there is disagreement over the design of smoke control systems in atria. Often, design data has been based on scale models and there is a general feeling that more accurate data is needed, particularly in the setting of fire sizes and outputs. In the USA, because industry is expected to fund large research developments of this nature, the Fire Research Centre tends to dwell on specific technical analysis of fire behaviour. In the UK, funding for large research projects again appears to require contribution by industry, but changes in building design can often alter research project parameters, or affect the willingness of industry to fund research. However, there is no doubt that development is occurring and appears to be increasing, but in a step form rather than in a continuous manner.

Fig 2.4: The development of Smoke Control Research



Chapter 2 - References

1. CROUCH Fire Research Paper 7, Ref.2.

2. Op. Cit. 1.

3. Fire Research Paper 10.

4. Fire Research Paper 14.

5. Smoke Control methods in enclosed shopping centres of one or more storeys, 1979.

6. Fire Research Note 875

7. Fire Research Paper CP 83/75

8. Fire Research Paper CP 48/75

9. Fire Research Paper CP 45/76

10. Fire Research Paper CP 19/78

11. Fire Research Paper CP 11/79

All Papers above are available from the Fire Research Station, Boreham Wood, Herts. *Tel: 01-953-6177.*

They are Department of Environment Publications.

CHAPTER 3

3.1 Introduction

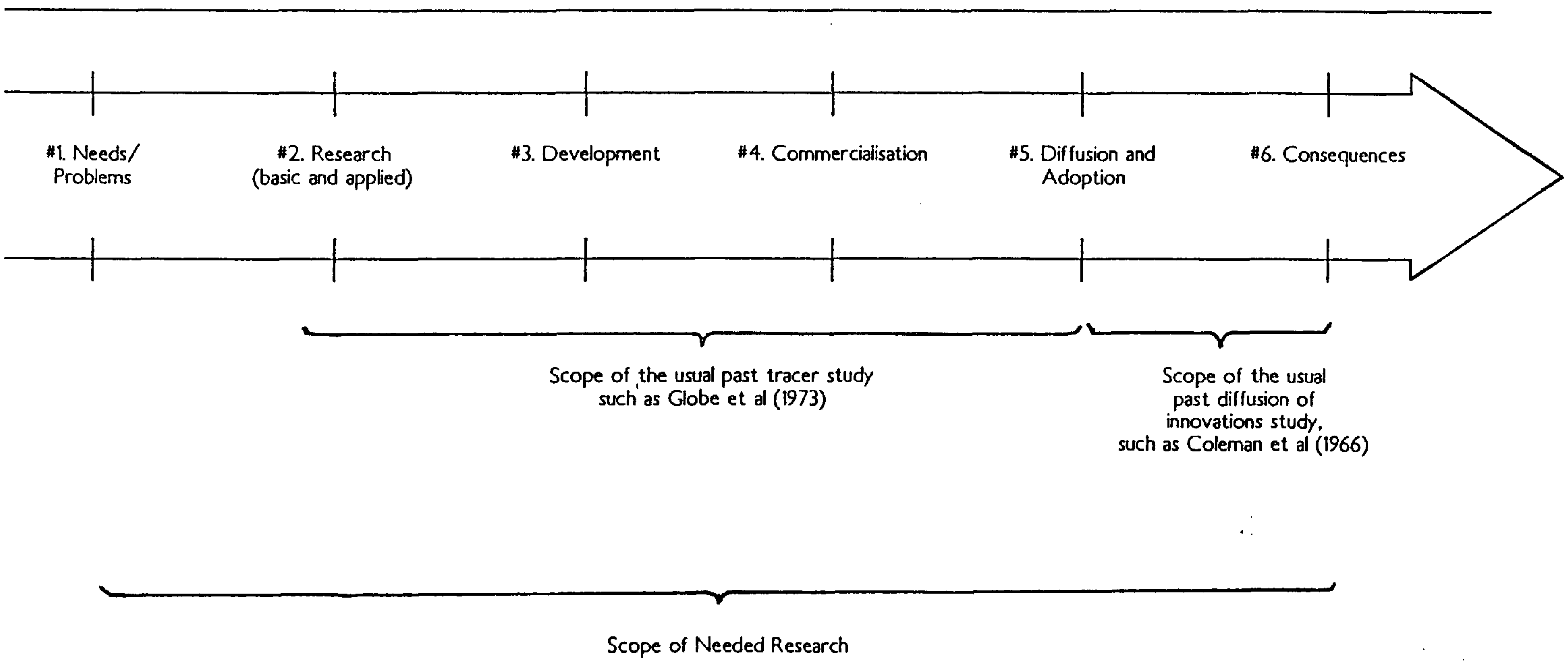
Extensive research has been undertaken into the innovation and diffusion of smoke control. An initial literature search revealed that leading academics on the subject of innovation diffusion, were situated in the United States of America. Because of this, during the field research trip to the U.S.A., the author contacted a leading authority on Innovation Diffusion, Prof. E.M. Rogers whose work on the diffusion of innovation goes back to the early 1960's(1). Other noted academics were contacted such as Professor Lawrence A. Brown(2) whose market infrastructure approach takes into account the unequal ability to adopt an innovation. Professor Marilyn Brown's work on Accelerating Adoption of Energy Conserving Building Technology(3) had some similarity with the problems encountered in the process of adoption in the construction industry.

Many other academics were contacted and these discussions together with the literature studied were used to give an assessment of the theory and argument to date on innovation diffusion.

3.1.1 Innovation

Zaltman and Lin(4) developed a model of social change which shows the process of innovation. This is one of a number of models developed and perhaps the only criticism is that the process of adaptation is not shown. A simpler model by Rogers(5) shows the six main phases of innovation development, from the recognition of a need or problem, to the adoption of an innovation, (Fig 3.1.1). This again is a linear model although Rogers acknowledges the process of adaption later.

FIG 3.1.1.



Six main phases in the innovation development process, showing the limited scope of past tracer studies and of past diffusion studies. Note that these six phases are somewhat arbitrary in that they do not always occur in exactly the order shown here, and certain of the phases may be missed for certain innovations.

The definition of innovation used in this research is the one chosen by Rogers:

> *"An innovation is an idea, practice or object perceived as new by an individual or other unit of adoption It matters little, so far as human behaviour is concerned, whether or not an idea is objectively new as measured by the lapse of time since its use or discovery. It is the perceived or subjective newness of the idea for the individual that determines his or her reaction to it. If the idea seems new to the individual, it is an innovation."*

The process of Diffusion and Adoption are interlinked; a logical end to a diffusion adoption study would be to develop a communication strategy. For this to occur, a detailed analysis of product perceptions and persuasion techniques would be needed. Again, work in this area is profuse, particularly in the consumer goods field. It is not the purpose of this thesis to look at communications strategy in detail.

3.2 Beginning of Diffusion Research

The body of literature relating to diffusion research is substantial, having developed over the last 80 or so years. It does not, however, come from one source, but has received contribution from many diverse areas of study

One of the earliest examples of diffusion research was published in 1903 by Gabriel Tarde. His book entitled "The Laws of Imitation," considered any, of one hundred different innovations conceived at the same time, "ten will spread abroad, whilst ninety will be forgotten[6]. Tarde, in his own terminology, identified various issues which would concern later diffusion researchers, the first being that adoption or, as Tarde termed it, "imitation", was a crucial research question. He also observed that the rate of adoption of an innovation or "new idea" usually followed the now familiar S shaped curve in terms of few early adopters followed by a sudden increase and final slowing down of adoption. He recognised the role of opinion leaders, in the acceleration of adoption; this indicates Tarde's awareness of Networks. One of his most fundamental laws of imitation was that the more similar to an acceptable idea an innovation was, the more likely an innovation would be adopted. These points, together with other observations and theories of diffusion, will be examined alongside the current theory of diffusion.

The origin of diffusion research was in the sociological field but over the years many other fields have become involved in diffusion research. E.M. Rogers [5] lists nine identifiable traditions which have been involved in the research and this table is reproduced overleaf (Table 3.2.1). A summary of Roger's discussion of the involvement of the different research traditions in the History of Diffusion research is given in Appendix (ii).

3.2.1 Types of Diffusion Research

Eight major types of diffusion research can be identified. These are:

1. The time knowledge of the innovation.
2. The rate of adoption of different innovations in a social system.
3. Innovativeness.
4. Opinion leadership.
5. Who interacts with whom in a diffusion network.
6. The rate of adoption in different social systems.
7. Communication channel usage.
8. Consequences of an innovation.

Rogers argues that acceptance of an intellectual paradigm by researchers imposes and standardises assumptions and it is easy to see how such a framework of ideas can influence the direction of research. Hopefully, however, by an open or questioning approach to the subject Smoke Ventilation, the author may avoid a stereotyped format. It was nevertheless felt necessary to outline where and what had been academically researched in diffusion research. The next section will deal with the identified elements of diffusion in an attempt to outline and define the research methodology.

TABLE 3.2.1. - Comparison of the Nine Major Diffusion Research Traditions

DIFFUSION RESEARCH TRADITION	No. OF DIFFUSION PUBLICATIONS	TYPICAL INNOVATIONS STUDIED	METHOD OF DATA GATHERING ANALYSIS	MAIN UNIT OF ANALYSIS	MAJOR TYPES OF FINDINGS
1. Anthropology	134	Technological ideas (steel ax, the horse, water boiling).	Participant and non-participant observation and the case study approach.	Tribes or peasant villages.	Consequences of innovations; relative success of change agent.
2. Early Sociology	10	City manager government, postage stamps, ham radios.	Data from secondary sources and statistical analysis.	Communities or individuals.	S-shaped adopter distribution; characteristics of adopter categories.
3. Rural Sociology	791	Mainly agricultural ideas (weed sprays, hybrid seed, fertilizers).	Survey interviews and statistical analysis.	Individual farmers in rural communities.	S-shaped adopter distribution; characteristics of adopter categories; perceived attributes of innovations and their rate of addition; communication channels by stages in the innovation-decision process; characteristics of opinion leaders.
4. Education	336	Teaching/learning innovations (kindergartens, modern maths, programmed instruction, teach Teaching).	Mailed questionnaires, survey interviews and statistical analysis.	School systems, teachers or administrators.	S-shaped adopter distribution; characteristics of adopter categories.
5. Public health and medical sociology	226	Medical and health ideas (drugs, vaccinations, family planning methods, CAT scanner).	Survey interviews and statistical analysis.	Individuals or organisations like hospitals.	Opinion leadership in diffusion; characteristics of adopter categories; communication channels by stages in the innovation-decision process.
6. Communication	372	News events, technological innovations.	Survey interviews and statistical analysis	Individuals and organisations.	Communication channels by stages in the innovation-decision process; characteristics of adopter categories and of opinion leader diffusion networks.
7. Marketing	304	New products (a coffee brand, the touch-tone telephone, clothing fashions).	Survey interviews and statistical analysis; field experiments.	Individual consumers.	Characteristics of adopter categories; opinion leadership in diffusion.
8. Geography	130	Technological innovations.	Secondary records and statistical analysis.	Individuals and organisations.	Role of spatial distance in diffusion.
9. General Sociology	382	A wide variety of new ideas.	Survey interviews and statistical analysis.	Individuals.	Characteristics of adopter categories; various others.
10. Other traditions	500				
TOTAL	3085				

3.3 Elements of Diffusion

"Diffusion is the process by which an innovation is communicated through certain channels over time amongst members of a social system."[5]

The four main elements of diffusion are:

1. Innovation

2. Communication Channels

3. Time

4. Social System

These are discussed below:

3.3.1 The Innovation

As given in 3.1.1. an innovation can be defined as follows:

> *"An innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption. It matters little whether or not the idea is objectively new, it is the perceived newness which is important. If an idea seems new to the individual it is an innovation."*

A technological innovation can create uncertainty in the mind of potential adopters, in terms of the change it proposes over previous practice. But it also represents an opportunity for reducing uncertainty as a result of the innovation's success in solving a problem. The innovation development programme could be represented as a linear process (see Fig 3.1.1). This process may be anticipated by research scientists seeing a forthcoming problem and launching research to solve that problem or as in smoke vent, a problem may arise which then precipitates research or development in the area of need.

It is worth drawing attention to a development which has some parallel with smoke ventilation, in its concern with safety. In the mid-60s in the USA, concern had increased for automobile safety due to the annual death rate of 50,000 and highlighted by highly publicised legislative hearings and the publication of Nader's "Unsafe at Any Speed."[7] A survey of car safety research specialists and decision makers was conducted by Havelock[8]. The researchers thought a solution should come from redesign of cars and highways so rejecting the traditional view of the driver as the culprit. The decision makers, members of national highway safety organisations, blamed the driver. This more traditional theory of blaming the driver was questioned. A federal law was passed requiring safer car design and safer road design.

A prime example of innovation by research and development is the semi-conductor industry. The communication aspect of diffusion is illustrated by the proximity of semi-conductor firms in Silicon Valley to Stanford University, the source of the research and development.

Mueller and Tilton[9] point out that sequential process occurs in the development of a new industry.

1. Innovation; a period of high uncertainty where trial and error problem solving leads to the innovation and a few new firms are founded.

2. Imitation; as new firms enter the market uncertainty decreases R & D and marketing improve the product. Often these firms are spin offs from the original firm.

3. Technological competition; where R & D laboratories improve the innovation through production process changes and thus create cost barriers to entry for smaller firms.

4. Standardisation; where a satisfactory product has been found, R & D concentrates on improving the production process and prolonging the product life cycle at this stage technological competition switches to price competition.

Also of interest is the concept of technology gatekeeping. The need for expensive research and development such as clinical trials in the medical field can act as a barrier to firms wishing to enter the market. In the case of Smoke Vent, the Fire Research Station in the U.K.

determine design parameters which can act as technological gates restricting entry into the market.

The innovation development process can be separated into two phases, the R & D phase and the decision to diffuse an innovation. The latter being the commercialisation of the research and development. This process is illustrated in Fig 3.3.1.

The need for smoke control was established by a series of catastrophes, first in theatres, then in factories. This led to R & D (mainly by the Fire Research Station in the U.K. (FRS)), which resulted in reports and publications on the design of smoke control systems. These results influenced diffusion agencies within this network such as the Fire Prevention Officers. Eventually, Regulations and Recommendations were developed, setting out design criteria.

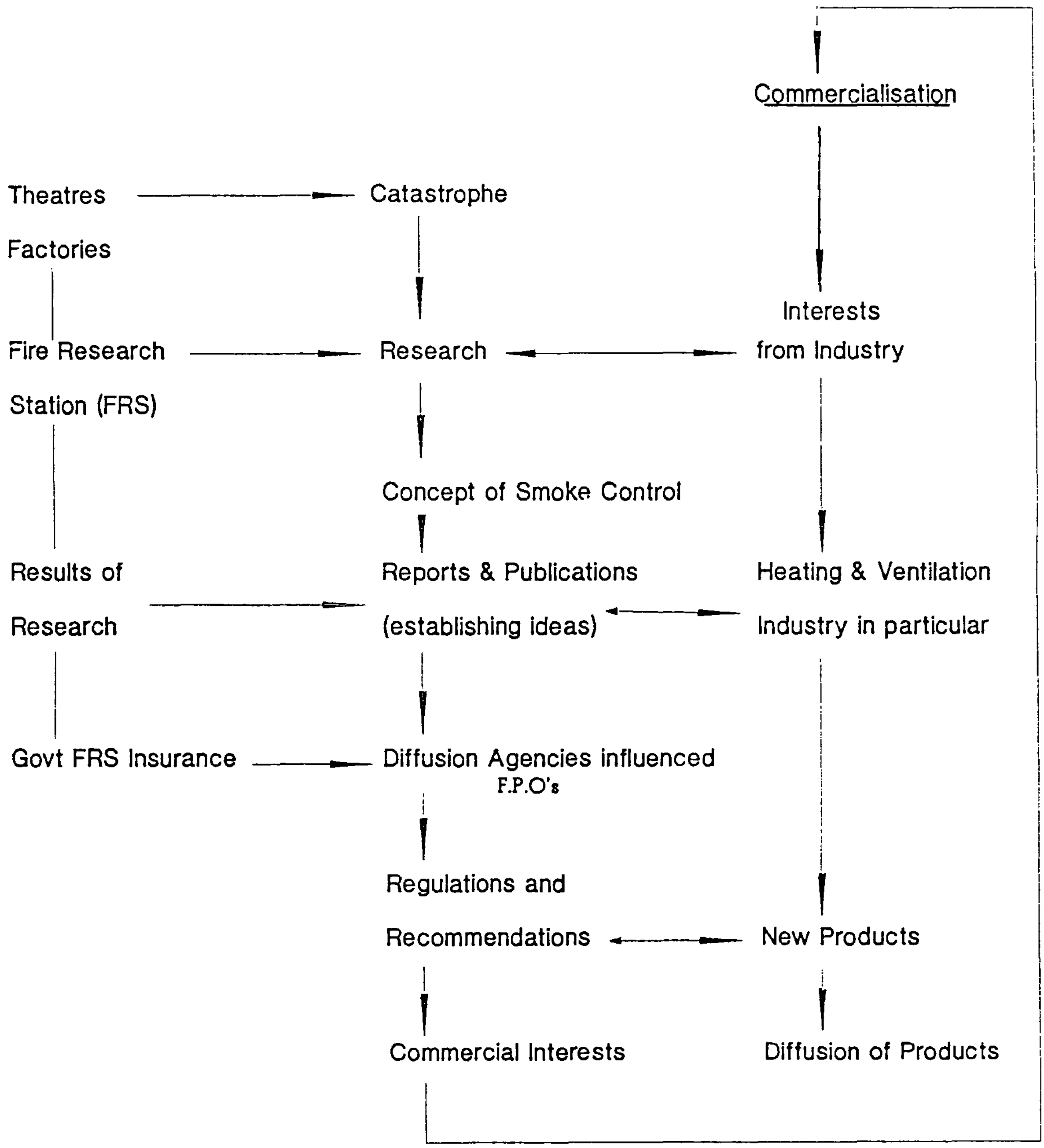
The commercial diffusion process occurs with the development of products to satisfy the regulations and recommendations developed by the R & D phase. It is not surprising that the Heating and Ventilation industry would be sensitive to new developments of this nature as the potential products fit the manufacturing and marketing capabilities of the industry.

The R & D phase is concerned with the development of ideas and design criteria and although the diffusion of these ideas occurs by the dissemination of information through publication and inter personal communication, it should be distinguished from the diffusion which occurs at the commercial stage when products are available.

The difficulty of influencing agencies such as government regulatory bodies is formidable and can require large resources. For this reason large firms may monopolise the market. Firms with specialist connections or existing networks will be at an advantage.

The Innovation Development of Commercialisation Process

R & D Phase



There has been much research on tracing the research, development and commercialisation of the innovation development process. One of the first of these studies was Project Hindsight[10] in 1969. This study investigated the role of various R & D variables in the research and development activities leading to twenty different weapon systems. Among the systems investigated were the Polaris submarine, the C-141 transport aircraft and the M-61 nuclear warhead. The major events and decision in creating each of these twenty technological innovations were identified. There was an average of thirty-five events per innovation. Most of these events resulted from the highly applied nature of the research funded to product the particular weapon system that eventually resulted.

The findings are not surprising in their general conclusion that applied research contributes more directly to the creation of technological innovation than does basic research; however the most important result of Project Hindsight is that it led to further innovation tracer studies such as Project TRACES (Technology in Retrospect and Critical Events in Science) by the Illinois Institutes of Technology Research, and later, TRACES II and III by Battelle Columbus Laboratories in 1976[11].

These tracer studies generally show that a major technological advance in such fields as military weapons, medicine or agriculture requires not one innovation but a cluster, often as many as a dozen, e.g. the heart pace-maker depended upon the invention of transistors and compact batteries. They also show that a lengthy period, often as long as twenty years, occurs between an invention in basic research and its application. The basic research results must age to become acceptable. Thus, an innovation has to go through the development process to reach a point where it is commercially useful. This is the diffusion decision point and is when communication about the innovation begins.

3.3.2 Communication Channels

Diffusion is a particular type of communication in which the information that is exchanged is concerned with new ideas. Simply stated the process is the passing of knowledge from an informed to an uninformed individual.

Two broad channels of communication exist;

1. Mass media

2. Interpersonal channels

Mass media channels are the most effective in creating awareness whilst interpersonal communication is a more effective means of persuasion.

From a marketing perspective Kotler[12] distinguishes between types of personal channels;

1. Advocate channels - these consist of company (or organisation) representatives in personal contact with buyers, trying to influence them.

2. Expert channels - these consist of independent persons (Consultants, Authorities) exercising influence on the buyers through their expertise.

3. Social channels - these consist of buyers, associates, friends or neighbours who may have influence on the buyers. The buyers referred to by Kotler could be termed potential adopters in the process of innovation diffusion. Kotler proceeds to distinguish between three types of non-personal influence channels:

    (a) Mass and selective media. This encompasses newspapers, magazines, radio, television, posters, etc.

    (b) Atmospheres. These are environments designed to create buyers' leanings to purchase or consume, e.g., the present general emphasis on health promotes health foods and fitness products.

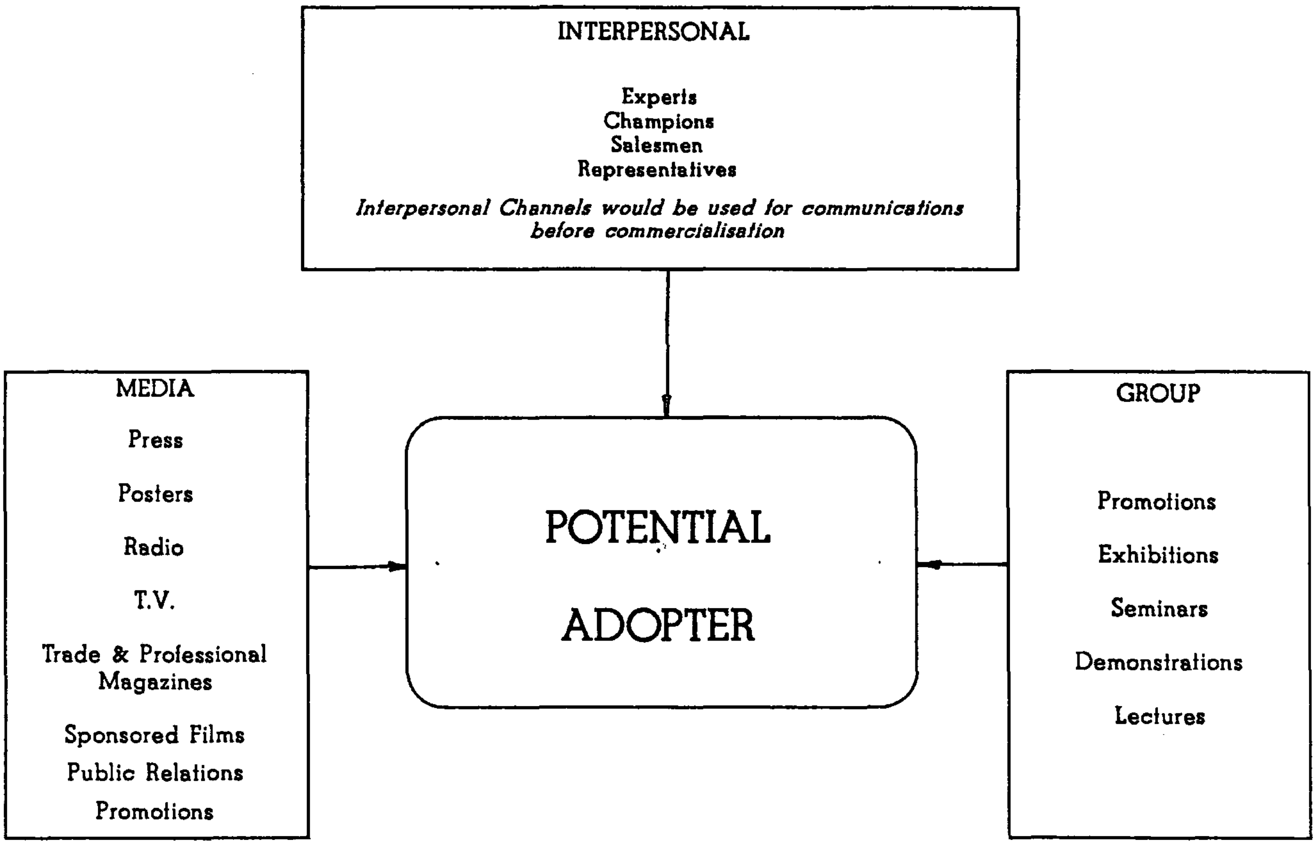
    (c) Events. These are occurrences designed to communicate particular messages to target audiences, e.g. P.R. departments often arrange events which they hope will be worthy of news coverage.

In reality there are many communication channels available to organisations. The Figure reference 3.2.2 gives some of these and an additional heading of Group channels has been added although it could be argued that channels under this heading could be allocated under interpersonal or media headings.

Diffusion prior to commercialisation would be largely interpersonal because of the technical nature of the innovation and would make use of experts with credibility acting as champions of the concept of smoke control.

FIG. 3.3.2

COMMUNICATION CHANNELS AVAILABLE TO ORGANISATIONS



There has been considerable discussion on the effectiveness of personal versus non-personal communication. Most observers believe that personal influence is generally more potent especially where the innovation is more expensive to adopt, is risky and of only periodic use, or where it has social character (e.g. Cars, Hi-Fi's). However, Klapper[13] points out that;

> *"Personal influence may be more effective than persuasive mass communication but at present mass communication seems the most effective means of stimulating personal influence."*

Whilst this may be true in the consumer field, industrial buying decisions are often heavily reliant on personal methods of communication.

One could conclude from this that technical concepts such as smoke vent would be more reliant on personal communications channels. However, the view that mass or media channels are unimportant can be questioned. It can perform several useful functions such as improving awareness, reminding, legitimisation and reassurance.

This discussion is focussed on three communication channels, mass media, interpersonal and group influences. This almost matches Websters[14] summary of three overlapping notions in communication.

1. Source message receiver model described by Schramm[15]. This model is the basic model of the communications process. However, problems highlighted by Schramm's comment that communication is "the process of establishing a commonness or oneness of thought between sender and receiver" focuses attention on the commonality of meaning of the message. This is more difficult if the message is complex. This often applies in industrial marketing.

2. Interpersonal or dyadic interaction summarised by Tosi[16] in 1966. Industrial marketing relies heavily on personal selling as the limited audience and the often complex nature of the product need interpersonal methods of communication. However, the basic communication model needs to be understood by the salesman.

Many of the concepts which surround the model such as credibility of source, the use of attention-getting devices and the repetition of the message, are used by the salesman.

3. Group Influences. A study by Coleman Katz and Menzel in 1966(17) focuses attention on the role that networks play in adoption. Innovative doctors who had more out of town medical meetings adopted earlier. Identified opinion leaders were influential in the early adoption of the drug. Thus we can assume that group involvement of the innovators and opinion leaders in networks were influential in the early adoption of the drug.

Considering that most industrial buying decisions are made by a group rather than individuals, this does highlight the importance of considering group interaction in general and the decision-making unit, a collection of people involved in the adoption of an innovation, in particular.

We can now look at some of the issues involved in the three identified communication methods.

1. <u>Mass media communication</u>

The size of the advertising business gives some indication of the importance of this communication channel. In 1978 the total expenditure in the UK on media advertising was 1843 million pounds and this represented a 27% increase from 1968. Nevertheless, problems arise in measuring advertising effectiveness. The time lag between advertising and sales makes correlation difficult. Other promotional factors such as the availability of product and the ability of salesmen also cloud the issue. In industrial markets advertising is not given the importance it has in consumer marketing because of complex products and limited audience. This results in marketing expenditure being directed mainly to sales as salesmen have known costs and set sales targets. Thus their effectiveness is easy to judge.

It is generally recognised that mass media channels are effective in creating awareness. Thus, publicity of such major disasters as the Kings Cross underground fire in 1987 serves to build awareness amongst the public of the dangers of smoke and fire. Specific information on industrial innovations however are more effective when directed towards the specific market segment or segments who are involved in the decision process to adopt. For example, the Fire Research Centre have produced videos showing the reconstruction of fires. These are directed at the Fire Service and associated professions involved in building safety, e.g. architects, engineers, safety officers, etc.

The concept of market segmentation is important. This should have direct effect on not only the communication channel used but also the section of that communication channel which relates to the target audience. Thus, when considering media communication it is not effective advertising a technical product for an industry, through the mass media. Trade magazines to that industry should be used to reach the target audience. The small samples and difficulties in obtaining response from buyers in the industrial market further exacerbates the problem of measuring the effectiveness of advertising.

2. Interpersonal Communication Channels

Individuals relate more easily to people who are similar to themselves. Triandis, 1959[(18)] discussed this in his paper "Cognition Similarity of Interpersonal Communication in Industry". Lazerfield and Merton, 1964[(19)] termed this similarity, homophilly.

Homophilly is the degree to which pairs of individuals are similar in certain attributes such as beliefs, education, social status, etc. In free choice situations there is a strong tendency for an individual to select someone who is most like himself or herself, more effective communication occurs in this situation. Empathy, described as the ability of the individual to project him or herself into the role of another, can counter the effects of hetrophilly, (hetrophilly is the opposite of homophilly) i.e., high empathy will eventually lead to homophilly. One of the most distinctive problems in the communication of innovations is that the participants are usually quite hetrophilous.

Arising as it has from research in the consumer field, the importance of homophilly in a technical or industrial marketing context can be argued. Although Rogers recognises that change agents have often a hetrophilous relationship with potential adopters, he argues that more effective communication depends on establishing a homophilous relationship.

Whether or not this is true is the question. It is not necessary to like or even relate to an expert to respect him or her and accept the concept presented, although it could be conceded that if empathy or homophilly exists, the concept will be much more easily communicated.

The above argument leads naturally into discussion of the change agents role and also to the role of opinion leaders in the diffusion process as influencers whatever communication channel is adopted. These and other issues will be discussed separately.

3. Group Influences (The Decision Making Unit)

There are many ways in which groups can be influenced in adoption, via seminars, lectures, exhibitions or group networks. In companies, the buying decision is often a function of groups of people composed of financial, technical and buying personnel. Furthermore, the composition of the group varies at different stages of the buying process. Thus, management may be involved in a strategic decision to enter a market by assessing investment requirement, technical staff may be involved in researching and assessing alternative products needed and recommending a solution to the financial and buying personnel. There are psychological factors at work within the DMU which can be related to psychological studies of group influences. These are discussed in more detail under persuasion. Studies of persuasion in general suggest that high credibility sources should be used along with substantiating argument and positive appeals to draw attention from the audience. The decision making unit will operate with some degree of acceptance of group norms, changing these norms is a difficult task. The study of group psychology offers some understanding of how groups may be influenced. Some members of the group have higher social status and it can be strategically important to approach these individuals to initiate opinion change. An individual's character is important in assessing whether or not he will stick to his or the group's viewpoint, i.e., independent characters are more likely to follow their own views than that of the group. The degree of conformity to group norms also depends on how much the individual values membership of that group. His resistance to change can also depend on the degree to which a group is present and prominent in the individual's mind (i.e. the group's salience). Thus it is important for the communicator to be aware of these group influences when he is introducing new ideas.

It is important to recognise buying as part of the adoption process. Of the number of models of the process, perhaps Campbells[19] which looks at a problem as an initiator, is the most closely related to smoke control.

1. Problem definition

2. Information Search

3. Information/Product Evaluation

4. Trial or Adoption

This process can be seen occurring if we refer to Fig 3.3.1 which closely resembles the sequence described when a problem is the initiator.

It is recognised that the Decision Making Unit, or D.M.U. is an essential concept in understanding buyer behaviour. As buying is almost synonymous with adoption it is an important concept in the diffusion process; for this reason further exploration of the D.M.U. is relevant.

Kotler[12] summarises the D.M.U. role models within the marketing field, as follows:

1. Users; these are often initiators of the buying or adoption process.

2. Influencers; these often help define specifications and evaluate alternatives - technical personnel often fall into this category.

3. Buyers; who have the formal authority to buy or adopt.

4. Deciders; who either have formal or informal authority to select final suppliers.

5. Gatekeepers; who control the flow of information to the others. This term can encompass switchboard operators at the lowest level and buyers at the highest level.

Other factors are also relevant in the composition and behaviour of the D.M.U. such as the size of the organisation it represents. Large organisations tend to have a more formalised structure of the D.M.U. Environmental and market conditions can also influence its composition, e.g., in dealing with safety methods the D.M.U. may incorporate some Government or Quasi Government representation or in respect to market conditions dynamic markets may demand a more flexible D.M.U. or may formalise the decision process to save time. The attributes of the innovation influence the D.M.U. composition and the process of decision making. For instance, if there is high technical content in the innovation, there will be high technical representation in the D.M.U.

The dynamic nature of the D.M.U. can be illustrated by looking at its changing composition of organisations which are involved in the decision to purchase smoke ventilation. If we look at a typical project a number of organisations are involved.

The Developer and/or User

The Architect

The Manufacturer

The Design Engineer

The Building Inspector

The Fire Protection Officer

The Contractor

1. Initially, the developer will employ an architect to prepare a building design.

2. The architect will employ an engineering consultancy to prepare designs for all the building services. These services include heating and ventilation for the building.

3. The engineer will prepare a smoke ventilation scheme. In the U.K. he will often involve a specialist manufacturer to help with, or fully prepare the design for the smoke ventilation scheme. The preparation of the design will involve the Fire Protection Officer.

4. The final scheme will be presented to the architect who will present it along with the rest of the building design for approval to the building inspector and specifically for fire protection, to the Fire Prevention Officer.

5. Finally, the project will go to tender with an approved design. The manufacturer then has to win the order from the contractor whose tender is successful.

This description is much simplified; for example there are a number of manufacturers competing in this process, all attempting to produce a smoke control system design which satisfies design criteria laid down by Fire Research Station and also the different parties involved in the project. Building designs often change during the course of a project. Thus Engineers, Architects, Fire Protection Officers, Building Control and Manufacturers will be involved in a continual consultation process involving redesign of the smoke control system to take account of these building changes.

Various members of the D.M.U. are important at different stages in the process.

1. The Architect and the Developer

2. The Architect and the Engineer

3. The Manufacturer, the Architect, the Engineer and the Fire Prevention Officer.

4. The Manufacturer, the Architect, the Engineer, the Fire Prevention Officer and the Building Inspector.

5. The Manufacturer and the Contractor.

It is possible to identify individual roles in this buying process.

Users: Although the developer may not always be the user of the finished building he certainly acts as the initiator of the buying process.

Influencers: Various people have influence at different stages in the process. Architects and Engineers are obviously responsible for final design and as such can accept or reject proposals put forward by the manufacturer. Thus, it is important to establish a relationship with them. Engineers are used to sell to engineers, thus the idea of cognitive similarity comes into play. The establishment of technical credibility by the manufacturer is important and use is made of high credibility sources. Fire Officers can refuse fire certificates so it is important to gain unofficial approval of design perhaps before the final scheme is submitted.

Deciders: This role may be shared by Architects and Engineers who will decide which manufacturers they consider competent.

Buyers: The Contractor who places the order is the buyer and he will often offer alternatives usually for cost savings, however these alternative manufacturers still need to be approved by Architects and/or Engineers, i.e., the deciders.

Gatekeepers: These are members of an organisation who control the flow of information. At its lowest level they could be telephone operatives. However, any member of the decision making unit can behave as a gatekeeper as they all have some information which a potential supplier may need to prepare his offer. A gatekeeper can hinder a supplier's chance of winning an order by withholding or restricting information.

A decision to purchase a smoke control system revolves around the acceptance of design. This is feasible if regulation is in place to insist on smoke control. Adopting an innovation in safety is much more difficult if this legislation is not in place.

3.3.3 Time

1. The Innovation, Diffusion and Adoption Process

Innovation, diffusion, adoption is a sequential process. Time is involved in diffusion in three ways. First, in the process itself as the individual or group moves from one stage to another. Second, in the degree of innovativeness of the individual, i.e., whether he is an early or late adopter. Thirdly, in the rate of adoption of the innovation. Campbell's model of the process was:

1. Problem Definition
2. Information Search
3. Information/Product Evaluation
4. Trial Adoption

Problem Definition

The development of smoke control design theory has arisen as a result of various disasters. The history has been summarised in Chapter 2. Thus designers are now presented with the task of incorporating smoke control into their building design. For this to occur the designer needs to have awareness of smoke control design theory (the innovation) or needs to gain access to experts in the field.

Information Search

For the information search the engineer will use a variety of sources such as Trade Magazines, Technical Publications and Professional Journals. In the medical field knowledge of a new drug needs to be disseminated through the medical profession before it reaches the patient. This can only be achieved by the use of Medical Journals and interpersonal networks.

Information/Product Evaluation

This can take place by a number of actions from the engineer, ie individual product evaluation by examining samples of technical reports.

Trial and Adoption

At this stage the engineer has been persuaded to adopt the innovation, some of the processes of persuasion particularly within groups are given in Section 2.

Mass media can play a large role in creating awareness but the benefits of the innovation need to be easily and simply communicable. Complicated issues communicated this way run the risk of being over-simplified with the danger of important aspects of the innovations effects being underplayed or missed. Thus, a new "wonder drug" such as Interferon, can seem to be the answer to all cancer victims and therefore create a demand pull from patients suffering from this disease. Unless the doctor is aware of the drug and its limitation and side effects, it would be difficult for him to prescribe. Thus, it can be seen that for technical and complex innovations a great deal of information dissemination by professional channels may need to be done before media channels are used, if they are worth using.

2. Persuasion

Manufacturers seek to persuade users to adopt their particular products and designs. This process occurs during the time the designer is searching for and evaluating information. Interpersonal networks and the influence of near peers are important at the persuasion stage of the diffusion process. Some of the behavioural characteristics relative to persuasion are worthy of note. Research has shown that opinion change can be directly influenced by source credibility(21) which can depend on trustworthiness(22), expertise(23) and status prestige, i.e.

prestige related to the role of the communicator, e.g. H.P. Morgan of the F.R.S. would carry a high status prestige.

Seminars or lectures are particularly useful in disseminating information prior to commercialisation, i.e. at the research and development stage when information is complex and needs to come from a credible source, i.e. opinion leaders. Relating products to the research of opinion leaders will also assist adoption at the commercial diffusion stage. In the smoke control industry seminars have been conducted using opinion leaders for source credibility. The studies of group psychology can be useful in understanding groups in this situation or in the D.M.U.

The Yale communication research programme conducted by Hovland, Janis and Kelly, circa 1950, resulted in a much referred to publication "Communication and Persuasion".[(24)] Many of the theories in this study are relevant to this thesis in its research of group behaviour.

A variety of motives are involved in attitudinal and behavioural conformity to group norms. Some of them have to do with maintaining social approval and avoiding disapproval, others have to do with the person's desire to understand his fellows. The degree of conformity exhibited by any given group depends in part on the importance of three factors[(25)].

1. Positive attractions within the group based on friendship for the other members and the desirability of the status and activities which membership makes possible. In a business group such as the D.M.U. it could be assumed that the latter is more important than the former.

2. Outside threats or deprivations which are avoided by maintaining membership of the group.

3. Restraints which act to keep the person within the group without regard for his desires in the matter.

In a business group the latter two factors could relate very much to the security offered by the job which gives the person access to the group. However, it is worth noting that the evidence for the above conclusions comes mainly from studies of groups where membership is voluntary such as Scout Groups, whereas membership of a business group such as the D.M.U. will arise as a result of the person's job. Therefore this membership is only voluntary in as much as job choice is voluntary. In other business groups such as Trade Associations the person has choice if not of membership at least of active participation and it will be seen later in this study that the choice to participate in the activities of trade associations can be an influential factor in early adoption of innovation. Festinger Schachter & Black(26) examined group cohesiveness among small social groups within a housing project and found that those of the group who valued membership highly were more likely to have uniformity of opinion on a controversial issue. Furthermore, high valuation members were less influenced by communications contrary to the norm, Kelly & Volkart(27). In a study by Kelly(28) which looked at college students of a Catholic faith it was found that public communication as opposed to expressing views anonymously highered the tendency for low valuation members to conform. However, Festinger(29) believes this does not mean the member has privately accepted these views.

Social Status

Hovland, Janis & Kelly(24) hypothesise that those persons with high social status within the group may be permitted greater nonconformity to group norms before being criticised or rejected by the group, although previous evidence suggests that the high valuation members are more likely to have uniformity of opinion on controversial issues, i.e., more likely to conform to group norms. Hughs(30) reports on an industrial work group in which the degree of conformity required of a member proved to be inversely related to the extent to which he was accepted by others. Thus the general conclusion could be that the person of high value to the group will be freer to deviate from group norms if he wishes to. The implications of this in a D.M.U. seminar or other business group is obvious, such an individual would be a strategic person to approach to initiate opinion change.

Asch[31] conducted experiments which studied the social and personal conditions that induce individuals to resist or yield to group pressures when the latter are perceived to be contrary to fact. He employed the procedure of placing an individual in a relation of radical conflict with the other members of the group. In the first experiment each member of the group was asked to match the length of a given line with three unequal lines. Each member of the group had previously been instructed to respond at certain points with wrong and unanimous judgements. Towards the end of the experiment each subject was informed fully of the purpose of the experiment of his role and that of the majority. The experiment established the existence of independent and suggestible characters. The results showed that suggestible members will conform to the majority whilst independent members will not. Independent subject's reactions were grouped into the following main categories:

1. Independence based on confidence. These individuals vigorously resisted group opposition.

2. Independent and withdrawn. These did not react spontaneously and emotionally but rather on the basis of explicit principles concerning the necessity of being an individual.

3. Independents who manifested considerable tension and doubt but adhere to their judgement on the basis of a felt necessity to deal adequately with the task.

Yielding subjects were grouped into the following categories:

1. Those subjects who exhibited distortion of perception. A few subjects yielded completely, but were not aware that their estimates had been displaced or distorted by the majority.

2. Those subjects who exhibited a distortion of judgement. The factor of greatest importance in this group is a decision these subjects reached that their perceptions were inaccurate. They suffered from primary doubt and lack of confidence and on this basis felt a strong tendency to join the majority.

3. Those subjects who exhibited a distortion of action. They yielded because of an overpowering need not to appear different or inferior to others. They did not suffer modification of perception nor did they believe they were wrong. They simply suppressed their observations in favour of the majority.

The experiment was varied to include one true partner for the critical subject, this markedly increased the independence of the subject. Thus it was concluded that the presence in the field of one other individual who responded correctly was sufficient to deplete the power of the majority. Dissenters in a large group may now join the smaller minority group. Asch also looked at the size of the majority and found that after a majority of three there was little further effect by increasing this majority. However, it was found that the majority effect grew stronger as the situation diminished in clarity.

Thus Asch's study points out the importance of one individual character in conforming to or resisting group pressure. Identification of independent characters within a group and persuasion of these characters especially if there are more than one, will influence the group. However, yielding members will be more easy to persuade. Couple this with the majority effect being at its most effective with only three more members and it may be possible to influence the group through the yielding members.

Situational Cues and Salience of Membership

An individual's potential conformity is determined by his knowledge of group norms and by the types of predispositional factors discussed above, ie. valuation of membership, social status and as Asch points out, character traits. But in any specific situation the actual conformity depends somewhat on situational cues which evoke the relevant motives and knowledge. The degree to which, in a given situation, a specific group is present and prominent in a person's awareness can be referred to as the salience of that group.

This section has concentrated on the research related to the influence of groups. In the smoke control industry, as in other industrial situations, buying decisions are not confined to individuals. However, it is the influencing of individuals within these groups which assists in the diffusion of new concepts and therefore it is important for the communicator not only to understand the basic rules of successful interpersonal communication, but also the influences at work on these individuals as members of a group.

3. **Trial and Adoption**

The decision to adopt or reject the innovation will be a result of the information search and evaluation in which, as mentioned, interpersonal networks and the influence of peers and peer groups play a large role. This decision can be reversed, thus an adoption decision may be rejected later. This may occur because the innovation is replaced by a better innovation or because of dissatisfaction with the innovation. Similarly, a decision to reject can be reversed, then later adoption occurs during the confirmation stage of the innovation decision process.

Much of the information gathered with regard to time in diffusion studies has relied on the recall of the interviewee. One way of attempting to counteract this is by comparison of recall data with facts, but this does require availability of records which are often difficult to obtain in an industrial situation.

There are two other time related areas to examine in the diffusion process. These are adopter categories and the rate of adoption.

4. **Adopter categories**

Innovation is an expression of newness or originality. The degree to which a potential adopter is prepared to adopt new or original ideas can be termed as his innovativeness.

Thus arises a definition of adopter categories:

1. Innovators (the first 2.5% to adopt)

2. Early adopters (the next 13.5%)

3. Early majority (the next 34%)

4. Late majority (the next 34%)

5. Laggards (the final 16%)

These have been divided under a distribution curve into the percentages indicated. There is some argument about the shape of distribution curve by Mahajan and Muller(32) but in the context of time these divisions serve to identify the different types of adopters. Rogers offers some generalisations of the personality traits and in the communication behaviour of earlier adopters.

These generalisations suggest that in personality earlier adopters differ from late adopters in that they have greater rationality, less dogmatism, a greater ability to deal with abstractions and greater intelligence. In addition, their attitudes are more favourable towards risk and change, education and science. They also tend to be less fatalistic and have higher levels of achievement motivation and therefore they have higher aspirations in education and career, etc.

The communication behaviour which can be observed possibly as a result of these personality traits suggests that earlier adopters again in comparison to later adopters, are more highly connected in the social system and are more cosmopolitan, i.e. their networks are likely to be outside rather than within their own social system. In addition, they tend to seek information more actively, have greater exposure to change agents and have more exposure to mass media communication channels. They also are likely to have a higher degree of opinion leadership and finally they are likely to have a greater knowledge of the innovation.

These are behaviour patterns which can be compared with the behaviour of the earlier adopters identified in this research and are supported in this study. It must be said, however, that the emphasis of Rogers' generalisations is on individuals whilst this study deals also with organisations.

The stage of diffusion can be seen to be important if influence is to be used to persuade potential adopters. In the early stage, innovators need influencing. In later stages, early adopters need supporting and late adopters need convincing, thus identification of the time period in relation of adopter categories can help direct persuasion at the appropriate individuals in a buying group.

5. Rates of Adoption

When individual new ideas are plotted on a cumulative frequency basis over time, the resulting distribution is in the form of S shaped curve. An issue addressed by diffusion research is why some innovations have a rapid rate of adoption and others are adopted more slowly (see Fig 3.3.3.)

This problem splits down into basically five elements:

1. The perceived attributes of the innovation in terms of relative advantage and compatibility.

2. The characteristics of the adopters, i.e. whether they have innovativeness.

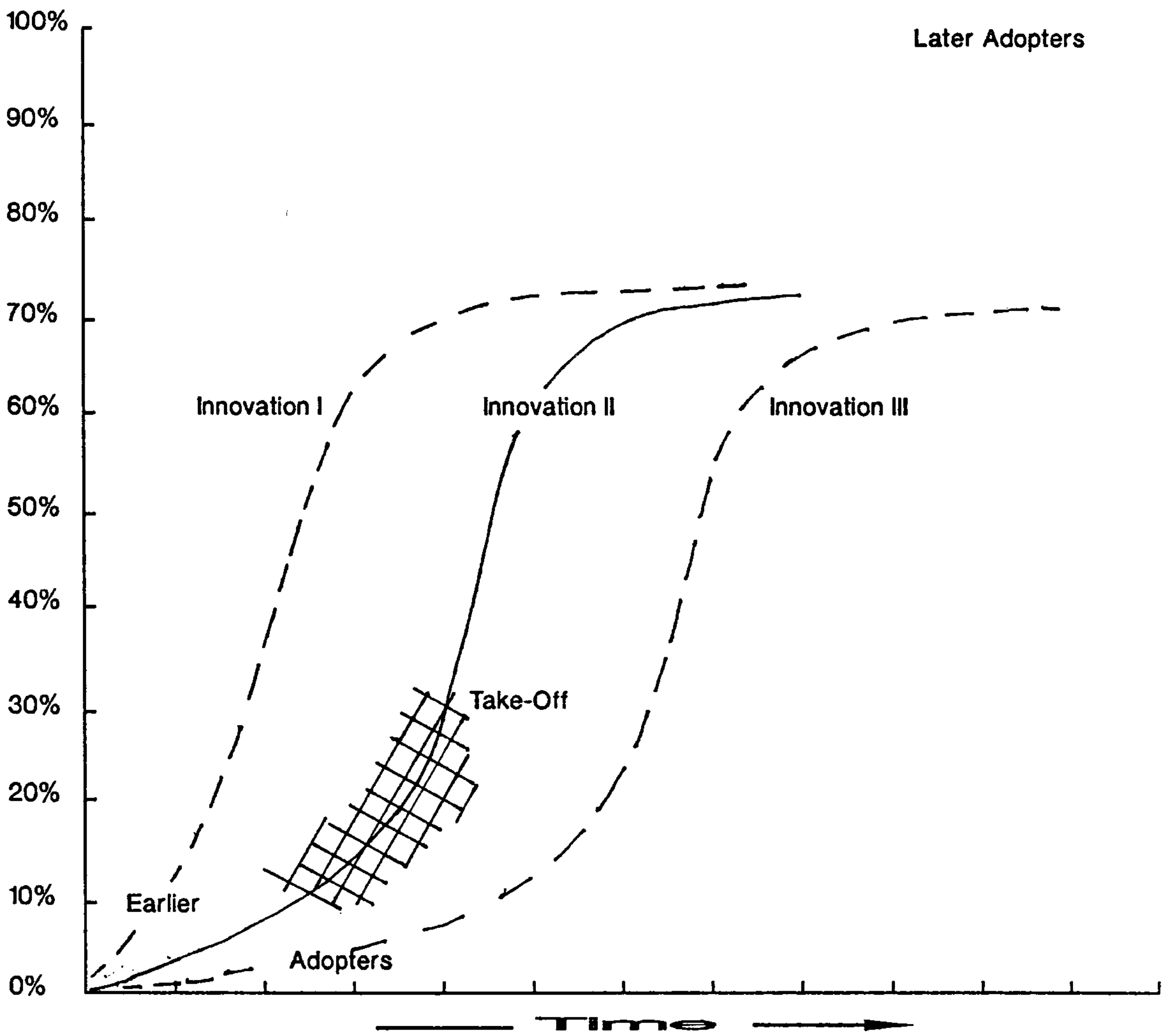
3. What communication channels are being used and how they are being used. The diffusion curve takes off at about 10%/25% when interpersonal networks become activated.

4. The differences in social systems as an effect on the rate of adoption.

5. The individual characteristics of an adopter also can have effect on the rate of diffusion, e.g., High influence opinion leaders or experts can accelerate or decelerate the diffusion process.

Adoption Rate of Different Innovations

FIG 3.3.3



3.3.4. Social Systems

A social system may be defined as

> *"A set of interrelated units that are engaged in joint problem solving to accomplish a common goal."*

Brown[3] criticises the traditional approach to innovation diffusion in its assumption that all adopters have an equal opportunity to adopt. He proposes a new market infrastructure perspective. This takes the view that the opportunity to adopt is unequal and in many cases purposely so.

Brown's view is important in this study as it collects the problems of unequal ability to adopt under one heading. This covers unequal or inefficient communication channels, selective interpersonal networks as well as unequal availability of the innovation. As Brown points out, this perspective does focus attention on the diffusion agency rather than the adopter. It prompts closer and more directed study of aspects of the diffusion process such as change agents, networks, product availability, centralised or decentralised diffusion.

It is important to recognise that the social system creates its own inequality in terms of the hierarchical positions of its members and the informal networks or communication channels developed by homophilous members. This structure can, as a whole, have an effect on the diffusion of the innovation. The relationship of an individual to the system can also affect his individual propensity to adopt. The different adoption decisions apparent in a social system have been identified as

1. Optional innovation decisions; made by the individuals which are dependent on norms and interpersonal networks.

2. Collective innovation decision; made by consensus, e.g., voting for a particular action

3. Authority innovation decisions; imposed by a small number of individuals who possess power. Company decisions and regulatory decisions can fall into this area.

4. Contingent innovation decisions; in which the choice to adopt or reject can only be made by an individual after a prior innovation adoption decision.

3.3.5 Adaptation

This is defined as

> *"The degree to which an innovation is changed or modified by a user in the process of its adoption and implementation."*

Until the 70's adaptation was thought not to occur or was thought infrequent. As the definition indicates, most adaptation occurs at implementation stage of the innovation/diffusion process and therefore could not be researched until data was gathered about implementation. Recent findings indicate a great deal of adaptation occurs.

The process of adaptation is well recognised in industry. After laboratory and field testing, most innovations are developed further by adopters. An investigation of innovations in scientific instruments by Von Hippel, 1976(33) found that in about 80% of the cases the innovation process was dominated by the user (adopter). The user might even build a prototype model of the new product and then turn it over to a manufacturer.

A study by Chanters and Pellegrin, 1972(34) brings to light the question of the definition of innovation. The researchers traced the adoption and implementation of the educational innovation of differentiated staffing. They concluded that;

> *"differentiated staffing was just a word for most participants, lacking concrete parameters with respect to the role performance of participants ... the word could (and did) mean widely differing things to the staff and nothing to some..."*

From this arises the point that accurate definition of the innovation, in its function and what it encompasses, is a very important part of the communication process.

Rogers itemised five reasons for adaptation, three of which are of interest to this study. These are:

1. Innovations that are relatively more complex and difficult to understand are more likely to be modified.

2. Adaptation can occur owing to the adopter's lack of detailed knowledge about the innovation such as when there is relatively little direct contact between the adopter and change agents.

3. An innovation that is a general concept is more likely to be adapted.

3.3.6 The Market and Infrastructure Perspective

Brown has developed a framework for considering the market and infrastructure perspective. This is given below:

1. Diffusion Agency Establishment

2. Diffusion Agency Strategy

3. Adoption

Brown describes action on this perspective as taking place on the supply side of the diffusion process rather than on the demand side, (the demand side considers the adopters and their characteristics). In the establishment of a diffusion agency, he focuses on where the locus of decision making is. He gives two extremes, one a centralised structure, the other a decentralised structure with a coordinating propagator.

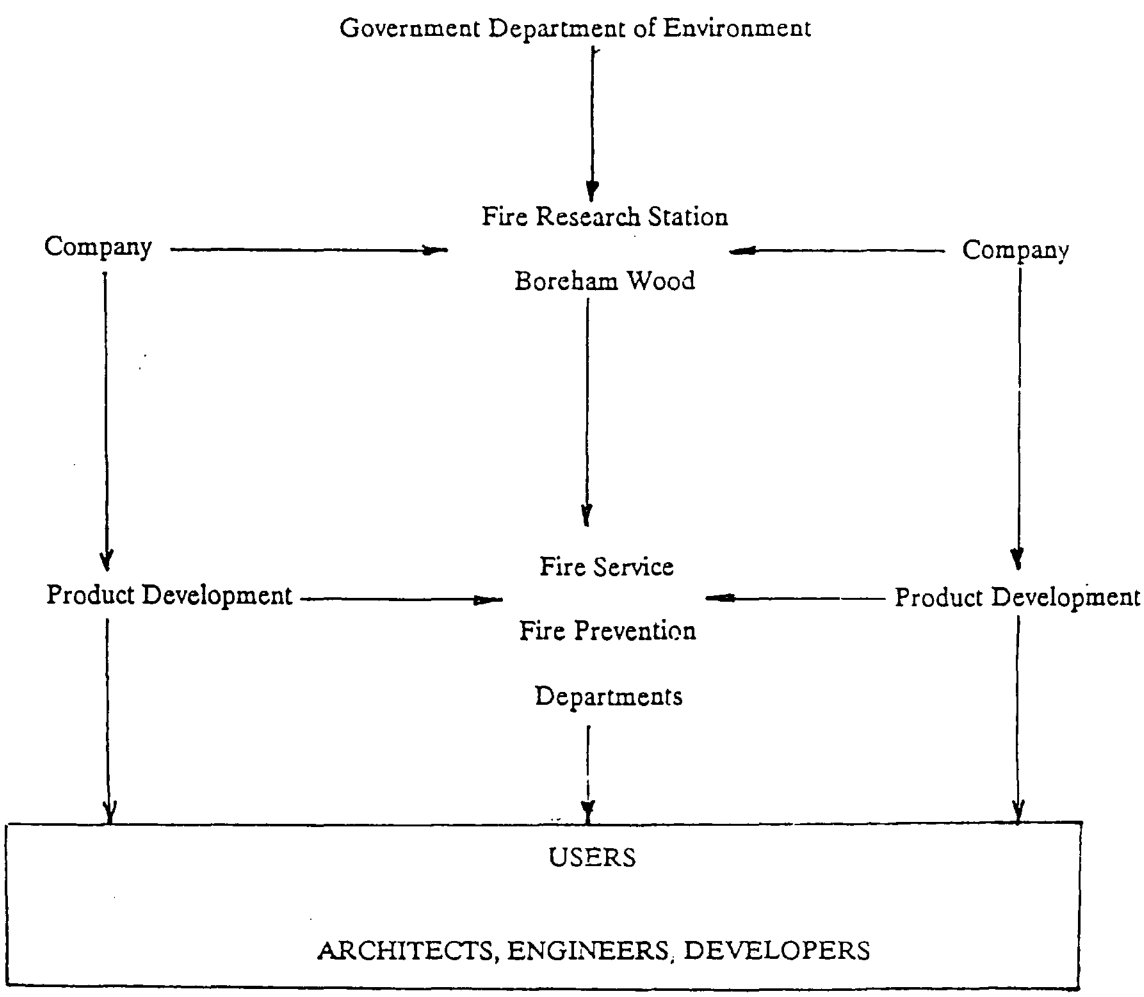
1. Diffusion Agency Establishment and Structure

The diffusion of smoke control has been described as in two phases, i.e. the R & D phase which developed the concept and commercial diffusion. With smoke control the natural development agency was the Fire Research Station and its natural diffusion agency the Fire Service Fire Prevention Departments.

In a commercial context decisions upon what type of diffusion agency structure to employ would depend on such factors as resources, market penetration strategy and market segmentation strategy.

Brown suggests that commercial or profit making diffusion would be its nature be centralised. But as smoke control as a concept has been developed by Government organisation, commercial interests can be seen to tie in to this existing structure forming a structure composed of both Government organisation and commerce, see Fig 3.3.6 In the U.K. companies have formed links with the FRS in order to keep abreast of research developments. These links can be as involved as jointly funded research. The results of the product research and development are diffused through the Fire Prevention Officers in the county and local Fire Stations and the users such as Architects, Engineers and Developers, etc.

FIG 3.3.6 – DIFFUSION AGENCY STRUCTURE



The setting up of new agencies will incur most cost. Thus existing agencies may be used, e.g., the use of supermarkets as change agencies by food manufacturers. In this case the structure would be that of decentralised structure with a coordinating propagator (i.e., at the food company). An example of centralised structure using existing change agencies is tied public houses.

The problem of using existing networks is obvious, they are unlikely to be specifically matched to the potential adopters.

2. Diffusion Agency Strategy

Brown(2) considers four strategy elements - related to the spatial pattern of diffusion. These are:

1. The development of infrastructure and organisational capabilities which permits the diffusion process to be implemented, maintained, expanded and spatially channelled.

2. Price, which is likely to change over time and to vary over space and as it affects the density of adoption may influence its spatial variation.

3. Promotional communications which are employed to provide information and persuade potential adopters.

4. Market selection and segmentation, i.e., identifying the clientele for the innovation and targeting in different ways upon segments of that clientele. (In addition, the selection of markets may exclude some potential adopters.)

There is obviously interaction between all these elements and it is their orchestration which bring about the efficient manipulation of the diffusion process.

Brown continues by discussing the affects of the diffusion agency activities upon the potential adopter's beliefs about and evaluation of these attributes.

Rogers[5] itemises the attributes of the innovation as:

1. Relative advantage

   The degree to which an innovation is perceived as being better than the idea it supersedes.

2. Compatibility

   The degree to which an innovation is perceived as consistent with existing values, past experiences and needs of potential adopters.

3. Complexity

   The degree to which an innovation is perceived as relatively difficult to understand and use.

4. Trialability

   The degree to which an innovation may be experimented with on a limited basis.

5. Observability

   The degree to which the results of an innovation are visible to others.

Brown's discussion now centres on the individual elements of the diffusion strategy. Of particular interest in relation to this study is whether an existing diffusion infrastructure is available, as adoption will generally occur where the infrastructure is. The development of a new infrastructure can be expensive.

Other aspects of interest are communication channels which have already been discussed in section 3.3.2 and also the characteristics of the adopters.

In relation to market selection and segmentation and the division of the adopters into innovators, early adopters, early majority and laggards. There are three basic choices.

1. Undifferentiated Marketing

2. Differentiated Marketing

3. Concentrated Marketing

In undifferentiated marketing the same strategy is employed for the whole market. Differentiated marketing may attack several segments but attacks each differently. In concentrated marketing the firm goes after a large share of one or a few sub markets. There are of course many ways to segment a market, e.g., geographically, demographically, etc. (for a fuller list see Kotler[12].)

The interplay between the strategic elements of the diffusion agency affect the efficiency of the diffusion process and it is important that they are coordinated to match both the innovation and the target adopters. For example, the nature of the adopters will affect the communication channels. The infrastructure of the agency will affect the spatial diffusion and its appeal to adopters. The strategy will also be interdependent on the following:

1. The nature and complexity of the innovation.

2. The type of agency and its relationship to corporate or institutional propagators.

3. The extent of market penetration and competitor imitation reflect the progress of the innovation's life cycle.

Thus, consideration of market and infrastructure can put a realistic view to the problem of diffusion by relating diffusion to the environmental structure of the market.

3.3.7 Change Agents

It is important to look at the individual aspects of innovation diffusion in terms of the change agent. Apart from an established agency with employed representatives as change agents, there can be many other forms such as teachers and consultants. The change agents form a link between the innovation and the potential adopters. For this type of communication to be effective the innovation must be selected to meet the potential adopter's needs and problems.

It is the social or technical gap between the diffusion agency and the potential adopters which create the need for the change agent Therefore, the diffusion agency system is usually composed of individuals who possess a high degree of expertise regarding the innovation. For the change agent to be successful it is important that the link be two-way, so that the client's needs can be fed back to the diffusion agency.

Homophilly, discussed in interpersonal communication needs to be considered not only technically but on a socio-economic and behavioural level. The change agent must also be selective in the information he gives, to avoid information overload (particularly true in highly complex technical innovations), matching the information to the adopter's needs and problems.

Rogers(5) identifies seven sequential roles a change agent undertakes. These are:

1. Developing a need for change; by helping the clients to become aware of a need to alter their behaviour. The change agent points out new alternatives to different problems thus initiating the move towards adoption.

2. Establishing an information exchange relationship by developing a rapport with the client. This he can enhance by creating credibility in his competence, trustworthiness and empathy with clients' needs and problems. This emphasis on the interpersonal relationship underlines the importance of the role of the change agent.

3. Diagnosing their problems; by analysing clients' problem situation, in order to determine why existing alternatives do not meet their needs. At this point Rogers brings in the question of ethics stating that *"many of the ethical problems (of the change agent) centre on this role of diagnosing clients' problems."* The question arises as to the right of a change agent to change the behaviour of another individual. Further ethical consideration could be given to selective solutions to problems. The

change agents may tend to be biased in favour of a particular solution to a problem and thus fail to point out, or be ignorant of, other solutions to the clients' problems. This is most obvious in the case of company representatives who are paid to further company business, but may equally apply to non-commercial change agents who may be committed to a particular ideology.

4. Creating intent to change in the client. After a change agent explores various avenues of action that the clients might take to achieve their goals, the change agent seeks to motivate an interest in the innovation. But the change must be 'client centred' rather than innovation orientated.

5. Translating intent into action; by influencing the client's behaviour in accordance with recommendations based on the client's needs. In achieving this, the role of interpersonal network influences from near peers are most important in the persuasion and decision stage of the innovation decision process. Thus the change agent operates indirectly by working with opinion leaders to activate peer networks.

6. Stabilising adoption and preventing discontinuance. A change agent may effectively stabilise new behaviour by reinforcing messages to those clients who have adopted, thus freezing the new behaviour. This assistance is frequently given when the client is at the implementation or confirmation stage in the innovation decision process.

7. Achieving a terminal relationship. The end goal for a change agent is to develop self-renewal behaviour on the part of the client system thus shifting the client from a position of reliance on the change agent to self-reliance.

Rogers suggests that a change agent's relative success is dependent upon:

1. The extent of change agent effort in contacting clients; there are various studies supporting this rather obvious statement, e.g., Whiting[35].

2. Client orientation rather than change agency orientation. The change agent is subject to role conflict situated as he is between the bureaucracy to which he is responsible and the client system within which he works. A change agent's success is more likely if he has empathetic relationship with the client and therefore leans towards the client rather than toward the change agency in his orientation.

3. The degree to which the diffusion program is compatible with clients' needs. Diffusion campaigns often fail because change agents are more innovation minded than client orientated. It is not easy to establish clients' needs, often needs seen by diffusion agencies are not perceived as actual needs by clients. Many change programs fail because they fail to take account of cultural values.

4. The change agents empathy with clients. As empathy is more difficult when clients are very different from the change agents, it would suggest that careful selection of change agents in terms of their similarity to the clients they are dealing with will improve the chance of establishing empathy.

5. The change agents homophilly with clients. As previously mentioned, homophilly is the degree to which pairs of individuals who interact are similar in certain attributes, and heterophilly is the degree to which they differ. Rogers states that change agents usually differ from their clients in most respects and this general statement has led to a number of other generalisations:

    a. Change agent contact is positively related to higher social status amongst clients.

    b. Change agent contact is positively related to greater social participation amongst clients.

    c. Change agent contact is positively related to higher education amongst clients.

d. Change agent contact is positively related to the cosmopolitan nature of clients.

The assumption Rogers makes regarding the difference between change agents and clients can be seen in many of his sociological studies in the third world countries. However, in a commercial situation great care is usually given to the degree of similarity between change agent and client, thus engineers are employed to change engineers, but there can be little argument that more effective communication occurs when client and change agents are homophillous.

6. Credibility in the eyes of the client. Credibility can be divided into two aspects; these have been discussed in 3.3.3, Part 2 on persuasion and are trustworthiness and expertise. Hetrophillous sources may have expertise but trustworthiness is more attributable to homophillous sources.

7. The extent to which the change agents work through opinion leaders. The change agent can hasten the rate of diffusion by concentrating his limited resources of time and energy on opinion leaders. As mentioned previously, the network messages from near peers like opinion leaders are regarded as credible in convincing an individual to adopt. Rogers points out that it is important to distinguish between innovators in terms of adopter categories and opinion leaders. Although they may be the same, opinion leaders have followers where innovators are simply the first to adopt.

It is apparent that the change agent provides an indispensable service in the diffusion of innovations. Successful diffusion and adoption can depend almost wholly on how successful the agent is.

3.3.8 Opinion Leaders

Opinion leadership can be defined as

> *"The degree to which an individual is able to influence informally other individuals' attitudes or overt behaviour in a desired way with relative frequency."* (5)

It is obvious from previous discussions that the role of the opinion leaders in activating diffusion networks is an important one. Their influence is disseminated mainly through the diffusion networks to which their followers belong.

1. Opinion Leaders and Communication

The role of opinion leaders in the communication process is important, in fact data seems to indicate that in the communication process, ideas often flow from radio and print to opinion leaders and from these to less active sections of the population[36], thus leading to the two-step flow hypothesis and focussing attention on the interface between mass media and interpersonal influence. Thus, one may be exposed to a new idea through mass media or interpersonal channels and then engage in communication exchanges about the message with one's peers. The fact that the two-step flow model oversimplifies the communication process does not detract from the recognition of the importance in the communication process of the opinion leaders. The process is usually far more complex or, in the case of straight adoption from mass media advertising, more simple. Knowledge of the concepts of homophilly and hetrophilly are useful in understanding the nature of communication flow and although communication is more effective when source and receiver are homophillous, hetropillous communication can have special informational potential. Hetrophillous links often connect two cliques as implied by Granovetter's theory[37]: *"The Strength of Weak Ties."* It can be concluded that communication between cognitively similar or homophillous individuals may be easy and frequent but may not play as important a part in the diffusion of innovations as less frequent communications between dissimilar persons.

This statement must not be taken out of context as it is related to the role of opinion leaders and refers to the likelihood that communication across cliques is most important. This assumption is reinforced by Rogers.[5] He discusses homophilly as a barrier to diffusion and states that homophillous individuals tend to interact amongst themselves, creating a horizontal spread of new ideas rather than a vertical one, thus slowing down the rate of diffusion. Recognition of this fact could lead to change agents selecting opinion leaders at various levels within the social system to which the innovation is offered. Indeed, as previously stated in 3.3.2 it is recognised that change agents often have a hetrophillous relationship with potential adopters. Rogers looks at a series of generalisations that specify characteristics of leaders and followers when a certain degree of hetrophilly occurs.

When interpersonal diffusion networks are hetrophillous, followers seek opinion leaders who are:

1. Of higher socio-economic status
2. More educated
3. More exposed to mass media
4. More cosmopolitan
5. In greater contact with change agents
6. More innovative

Thus it can be concluded that followers tend to seek information and advice from opinion leaders who are more technically competent than themselves. Thus, where hetrophilly occurs it is usually in the direction of greater competence (but not too much greater). Rogers points out that the general pattern is one of homophilly in interpersonal communication.

2. Characteristics of Opinion Leaders

Generally, these are related to four factors which are:

1. The degree of external communication
2. Accessibility
3. Socio-economic status
4. Innovativeness

1. The degree of external communication

Opinion leaders generally have more exposure to mass media channels. They may act as opinion leaders for a single topic or a variety of topics.

Opinion leaders also tend to have greater change agent contact. Given that the effort of the change agent is maximised by seeking out opinion leaders, this outcome would be expected.

2. Accessibility

Opinion leaders must also be accessible for spreading messages about an innovation to their followers through their interpersonal networks.

3. Socio-economic Status

Opinion leaders tend to have higher social status.

4. Innovativeness

Opinion leaders are recognised by their peers as being knowledgeable about innovations. They tend to adopt new ideas before their followers. However, there is no evidence that opinion leaders are necessarily innovators. This apparent contradiction is explained by the fact that opinion leaders tend to conform to system norms. Thus, when system norms favour change, opinion leaders are likely to be innovators. Where norms are more traditional the innovators are often different from opinion leaders and may be regarded with suspicion.

There are a number of ways of measuring the influence of opinion leaders:

1. Socio-metric Methods

> This consists of asking respondents who they ask for information. Opinion leaders are those who receive the greatest number of socio-metric choices. Rogers points out that usually respondents are limited in the number of choices, eg., they are asked to suggest the 3 or 4 with whom they discuss the innovation. It may be better to give

unlimited choice as Granovetter's "Strength of Weak Ties" suggests that less frequent contacts may be crucial in diffusion.

2. Roster studies

In this, the respondent is presented with a list of all other members of the social system and asked with whom he has most contact. This method may be impossible in a large or informal network.

3. Special knowledge

This asks informants who have special knowledge of the communication networks of a system to identify opinion leaders. Experience has shown this can be almost as successful as more formal socio-metric techniques.

4. The self-designating technique

This asks respondents to indicate the tendency for others to regard them as influential.

5. Observation

In which an investigator identifies and records the communication behaviour in a system. This is most useful in small systems but can be obtrusive.

In practice, the most used is survey socio-metry. Where two or three types of opinion leadership measures have been used with the same respondents, positive correlations amongst measures have been obtained. Although these are less than perfect, the findings suggest the choice of method can be based on convenience. (A typical distribution of respondents shows that high opinion leadership is located with a small number of individuals.[38] [39] [40]

3.3.9 Diffusion Networks

Evaluation of innovations mainly flow through interpersonal networks. They are important connectors to informational sources. In recent years advances have been made in methods of investigating communication networks[41]. These structures consist of cliques and their interconnections whose complexity can be illustrated by using the formula $\frac{N(N-1)}{2}$

where N is the number of individuals in a system. For a 100 member network there are 4950 possible links.

A number of concepts are useful when discussing communication networks. Communication proximity - this is judged by the degree to which members of an individual's network are in contact with members of another individuals' network[42]. Personal communications networks of which two types have been identified - interlocking personal network and radial networks. Members of interlocking networks interact with each other, whilst members of radial networks do not. Perhaps this concept is better understood if one recognises that one's closely linked peers as an interlocking network seldom possess much information that one does not already know.

The analysis of networks, because of its complexity, is more easily handled by computer. However, the main problem in informal networks is the identification of all its members.

3.3.10 Regulation and Diffusion

There is little available literature in this field. Reference to regulatory influence can be found in Ezra's 1975 paper on Technology Utilisation Incentives and Solar Energy[43] in relation to Federal regulation which states that where Federal regulations are based on federally funded research they are powerful incentives to technology utilisation, but when they are not based on research they may be technically impossible or so unnecessarily demanding as to prove harmful.

There may be extensive defensive litigation by industry instead of willing compliance. Examples are in the area of water pollution control and efforts to regulate automobile exhaust emission and automobile safety. Other evidence by Marilyn Brown et al[3] suggests that lethargy in Government regulatory bodies can hinder the diffusion process.

> *"Millions of dollars have been spent on the development of energy conservation technologies for building applications, yet Federal Government has been erratic in its efforts to promote the widespread adoption of its results."*

Another paper by Ashford and Heaton[44] on the effect of environmental regulations in the chemical industry gives further examples of the problems encountered by both industry and government.

There appears to be a lack of a conceptual framework in this area, one of the problems being that the stimulus for regulation is considered as a single uniform event. Also there is little attempt to distinguish between innovation for compliance purposes and innovation for corporate purposes.

However, it is clear that regulation does encourage technical change; indeed, it is almost a tautology since regulations are intended to ameliorate the adverse effects of technology by changing technology itself. It is also clear that regulations create new market opportunity. But they also can impose restraints on markets and divert resources from other development.

The regulatory stimulus should be regarded as a broad term and should include all forces, governmental and non-governmental that are related to ameliorating the environmental or safety problems.

Consideration should be given to the stringency of the regulation and also the multiplicity of the regulation stimulus coupled with the regulating process. This determines the pressure for regulation and the importance of compliance.

In conclusion, the regulation process is a very complex time dependent and variable signal which depends for its effect on the factors mentioned above. Thus it is obvious that innovations are not easily absorbed by bureaucracy and regulations have a time lag effect. Recent regulations in the UK regarding polyeurethene foam fillings for furniture did not come into being until 30 years after the discovery of the problem and even then only after considerable pressure from the media and the Fire Service.

3.3.11 The Consequences of Innovation

Although this study does not consider the consequences of the innovation, the safety brought about by using Smoke Control will have direct effect on lives saved in the event of a fire, and that improved profits can accrue to companies who enter the market.

3.3.12 Conclusion

This Chapter has examined the nature of innovation diffusion and adoption and looked at innovation, communication channels, social systems and time, as well as briefly looking at the history of diffusion research.

In addition, various issues within the diffusion process such as adaptation, market infrastructure, change agents, opinion leaders and diffusion networks have been examined in an attempt to outline the academic basis for the research project.

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CHAPTER 4

4.1. Introduction

The research was conducted in both the U.S.A. and the U.K. and centred mainly around design engineers and Fire Protection Officers (Fire Marshals in the U.S.A.). In the U.S.A. additional information was sought from the Centre for Fire Research at the U.S. Department of Standards, the National Fire Protection Association and Factory Mutual (the latter two representing insurance influence) and various code setting bodies within the U.S.A. In the U.K. further information was sought from the Fire Research Station, the Loss Prevention Council, the Fire Service College and Edinburgh University.

The information was gathered by a combination of questionnaires and personnel interview. Only a limited number of interviews were undertaken because of geographical dispersion. These interviews did include, however, key people involved in fire protection.

4.2. Establishment of Framework for the Questionnaire

From the literature search in chapter 3 the following areas were selected for investigation. They formed the basis of the questionnaire.

1. What was the awareness level of the smoke vent concept?
2. How did this awareness arise?
3. When did this awareness arise?
4. What source or sources did the information come from, i.e., what organisations or individuals were involved?
5. What use was made of the information?
6. Were searches made for knowledge and information?
7. Which agencies were contacted?

8. Are there formal search methods within the company?

9. Any external influencing bodies?

10. Any internal influencing bodies?

11. To determine the degree of innovativeness of individuals and organisation. The basis of this attempt was the generalisations suggested by Rogers and covered in Chapter 3, section 3.3.3. It involved assessment of the respondent's membership and degree of involvement with professional organisations.

12. Changes over time in design concepts of available products.

13. Availability of training in smoke control design and application.

4.2.1 The Construction of the Questionnaire

This is shown in Appendix (iii) and consists of three sections:

1. Organisation and information.

2. Personal information.

3. Smoke ventilation research information.

1. <u>Organisation Information</u>

The purpose of this section was to identify the organisation, its size and type. To look at the amount of contact with professional bodies, i.e. what group networks are involved. Identify the structure of the organisation and the degree of autonomy in design allowed to the individual engineer in incorporating smoke control in building design.

2. <u>Personal Information</u>

The purpose of this section was to identify the individual and establish his age and position within the organisation. To look at the amount of contact he had with professional organisations and the level of educational and professional training he had undergone, and finally to establish his attitude to smoke ventilation and the level of training he had in that field. Later analysis examines the usefulness of membership of professional organisations and its influence in early adoption.

3. Smoke Ventilation Research Information

The purpose of this section was to track the adoption process by sourcing and dating the respondents first awareness of smoke ventilation, identifying in what capacity he had been involved and examining successful and unsuccessful proposals to use smoke ventilation to discover information sources and influencing factors involved in the process. In addition market information was sought in terms of products and competitive firms in the business.

The questionnaire/interview was piloted in the U.K. with two engineering consultants and one fire prevention officer. This suggested a number of alterations to wording, structure and layout which were incorporated in the final draft, (see Appendix (iv)). The final draft was used to interview a further consulting engineer and found to be acceptable.

4.3 U.S.A. Field Research

A research visit to the U.S.A. was arranged and took place from the 12th March through to 23rd April 1987. A route was carefully planned to visit major centres of design engineers along with visits to code setting bodies, and included a visit with Professor E.M. Rogers at the Annenberg School of Communications, University of Southern California, Los Angeles.

In New York a number of Design Consultants were interviewed using the interview/questionnaire discussed in 4.2.1. Interviews were conducted with Fire Officers and a code setting body from Los Angeles. Research then moved to Chicago where a number of Design Engineers including a Fire Prevention specialist were interviewed and also a code setting body.

Discussion took place with J. Klote of the National Bureau of Standards, Washington, regarding the current state of the art, and the structure of code setting and regulatory influences in the U.S.A. J. Klote is co-author with J.W. Fothergill of "Design of Smoke Control Systems for Buildings."(1) This guide is currently used by ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers).

From the above a picture of the structure of the industry related to fire regulations emerged. This is given in the results in Chapter 5.

4.3.1 Sample Size U.S.A.

Because of the time, distance and cost, and the author's unfamiliarity with the structure (discussed above), it was impossible to obtain a statistically significant sample in the U.S.A. Thus in the U.S.A. fourteen interviews were conducted. Appendix V gives a breakdown of the different areas researched.

4.3.2 Additional Research Information

Additional information concerning Fire Chiefs, Fire Marshals and Code Officials, was obtained from the Sumner Rider report on Heat and Smoke Venting, 1987(2). Information on the current state of design techniques was found at the Fire Research Technical Library at the National Bureau of Statistics, Washington.

4.4 U.K. Field Research

Interviews/questionnaire were completed with Design Engineers and Fire Prevention Officers throughout England, Wales and Scotland. In addition, discussions took place with Howard Morgan of the Fire Research Station, Borehamwood, the Fire Service College, and the Loss Prevention Council (representing the insurers) Borehamwood. Discussions also took place with manufacturers who were helpful in identifying the groups and individuals involved in the buying process and the sales methods used. Seminars were attended; these were held by manufacturers to inform the groups involved in the Smoke

Control Industry, i.e. Architects, Engineers and F.P.O's, of smoke control design and products available.

4.4.1 Sample Size (U.K.)

In the U.K. it was possible to obtain a larger sample size. The approximate population of major private engineering consultants' organisations is 150. Response was obtained from engineers in 18 of these organisations, representing a 12% sample. From a population of 63 senior County Fire Prevention Officers the response was somewhat better at 30%, representing 20 completed interview/questionnaires.

4.5 Administration of Interview/Questionnaire

Interviews were conducted with 11 consulting engineers; the remainder were posted. Interviews were conducted with 2 Fire Prevention Officers; the remainder were posted.

4.6 Additional Research Information

Much of the technical information on the current state of design was found at the Fire Research Station Library at Borehamwood.

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CHAPTER 5

5.1 Introduction

This Chapter analyses the findings produced by research in the U.S.A. and United Kingdom. There are sections dealing with each country. In addition, some analysis by segment in terms of Consulting Engineers, F.P.O's, Insurance and Government Bodies and Code Setting Bodies is undertaken. Discussion of these findings is given in Chapter 6 and Chapter 7.

5.2. U.S.A. Research

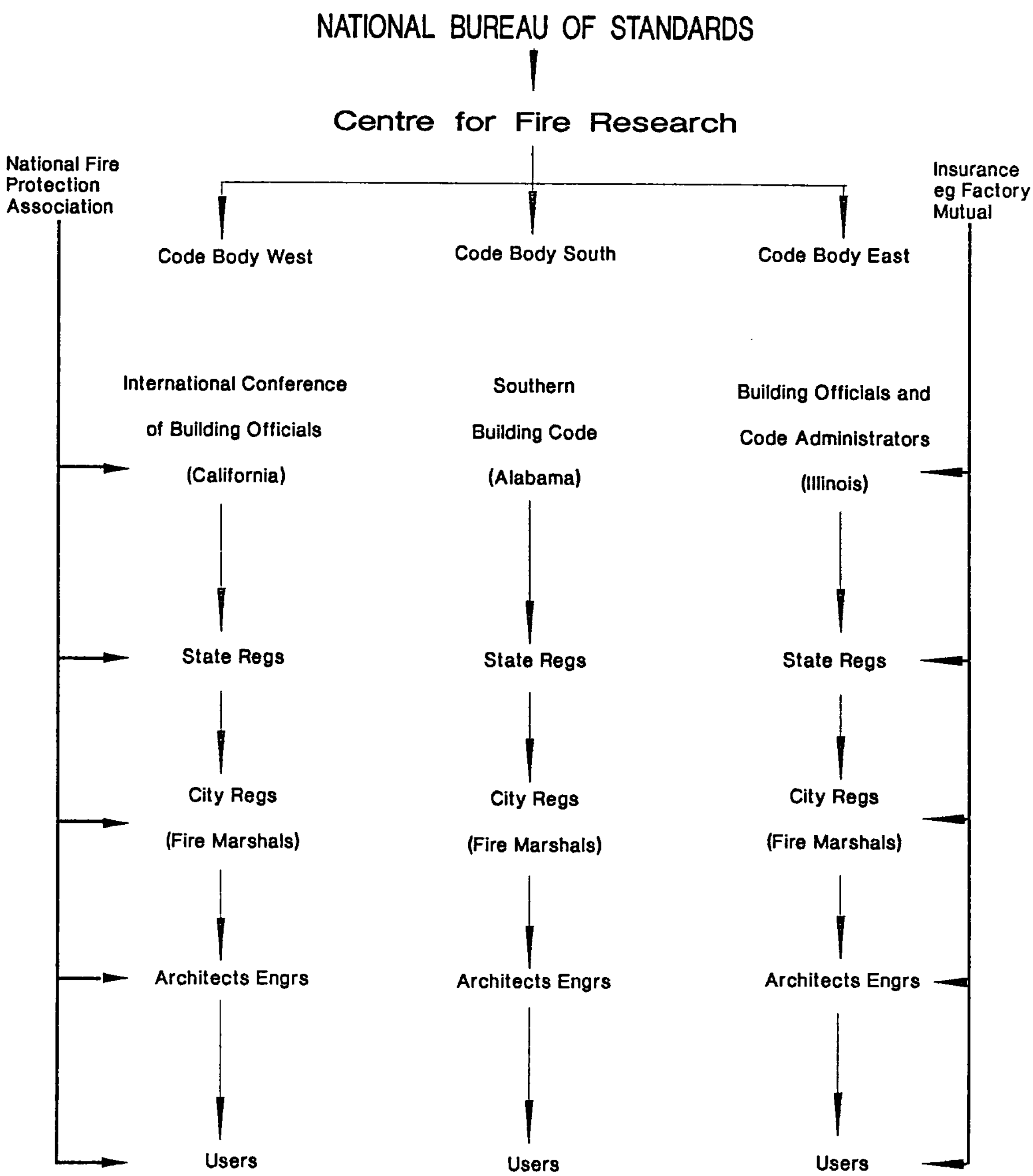
The structure of the industry based on research is shown in Figure 5.2. In all, fourteen interviews were held in the six week research trip. For analysis, the interviews were divided into five areas, these are:

1. Design Engineers
2. Fire Marshals and Fire Chiefs
3. Code Officials
4. Government Agencies
5. Insurance Agencies

In addition to the research interviews, additional information regarding Fire Chiefs, Fire Marshals and Code Officials was obtained from the Sumner Rider Report (1987)[1]

Fig 5.2

U.S.A. Industry Structure



5.2.1 Design Engineers

In total, interviews were conducted with five consulting engineers. The centre for consulting engineers is New York, although large industrial cities such as Chicago also boast a fair number of these practices. In Chicago an interview with one of the two main independent fire consultants was undertaken and some segregation of the results from this interview was necessary in view of the possible bias in favour of all fire prevention methods. Because of the small samples in the U.S.A. due to time limitations the results are not seen as definitive but more as a general guide.

<u>Section 1: Company Information</u>

Table 5.2.1 summarizes the results obtained from the Design Engineers.

A number of observations can be made from this. First the structure of the companies was the same regardless of size, all companies had 4/5 levels of hierarchy. With the exception of the Fire Prevention Consultant, autonomy in design existed in the small companies (1-150) but not in the large (201-500). There was little pattern to the number of professional organisations that each company belonged to, however membership was thought to be useful by smaller companies and only by some or none of the larger companies.

The smaller companies had more contact within the profession which tended to match their view of usefulness of membership of professional organisation and also their tendency to autonomy in design.

The smaller companies tended to have frequent interchange of information within the profession whilst the larger firms had only some or none. There was an anomaly, where the smallest firm had no interchange of information, but the engineer interviewed did have a strong, personal information network referred to in Section 2.

DESIGN ENGINEERS U.S.A.

Table 5.2.1.

Size	Structure	Design Freedom		Membership of Organisation/Assoc				Contact within Profession			Is there much exchange info?		
No. of Emps.	No. of Tiers	Autonomy	Control	Number	Use	Some	None	Often	Some	None	Yes	Some	None
30	5	x		1	x			x					x
68	5		x	40	x			x			x		
150	4	x		4			x		x		x		
250	4		x	8			x		x			x	
500	5		x	2		x			x				x

Section 2: Personal Professional Relationships

As Section 1 on the Company looked at the kind of inter-organisation relationships within the profession, Section 2 looks at the interpersonal relationships within the profession.

The age range of the interviewees varied from 31 to 67. All were members of trade organisations. The main organisation was ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers). The fire prevention consultant was a member of the N.F.P.A. (National Fire Protection Association), as well as the American Institute of Architects. Only one engineer thought professional membership was not useful. Discussions with this interviewee revealed an old established, fairly rigid company. Thus, his attitude appeared to match that of his firm. However, it was revealed that he had fairly close personal and social contact with other members of his profession. This informal network was viewed as much more important.

All of the respondents, when asked to give the primary function of fire protection systems, considered people safety first and smoke ventilation as very high in importance in relation to other fire protection methods. The Fire Prevention Consultant was the only dissenter in not regarding smoke ventilation as the highest, his rating of 5 (on a scale of 1 to 10) compared to 10 of all the other Consultants, perhaps indicated his greater involvement in all methods of fire protection.

All respondents had university degrees with comparable job experience; no respondent had ever had any formal academic training in smoke ventilation. This aspect of engineering design appeared to be neglected by academic institutions. Again, the Fire Prevention Consultant had attended design seminars and had more job related training in the field.

Section 3 : Awareness of Smoke Ventilation

This section attempts to assess the respondents involvement and attitude to smoke ventilation and also to discover when and where the concept was originally adopted.

With the exception again of the Fire Prevention Consultant, the adoption date of the concept was between 1965 and 1973. The age of the Consultant (31) explains his late adoption date of 1980, as he was studying. Most became involved with the concept through a project involving smoke ventilation. Although one engineer originally heard of the concept in 1965 via an Insurance Agency (Factory Mutual) in connection with industrial risk. This was the same engineer referred to earlier who had a personal informal information network, although belonging to a company with few contacts, he was allowed to be more innovative than any other respondent. The methods of smoke ventilation used varied considerably, but in general reflected the emphasis on high rise design in the U.S.A. in its concern with multi- storey office blocks and therefore compartment smoke ventilation. There was some low rise and atria ventilation which, along with the office blocks used mechanical ventilation systems. Only one case of natural ventilation was mentioned, this was a single storey warehouse.

In view of the current controversy regarding the combined use of sprinklers and smoke ventilation, it was of interest to note that all offices and atria projects discussed used sprinklers as well as vents. This does not reflect concern about the interaction of sprinklers and vents which has been expressed by various noted experts(2). The search for the influencing factors in the use and adoption of smoke ventilation revealed them as:

Fire Prevention Agencies

Government Regulations

Insurance Agencies

Obviously the building type and specification affected the use of smoke ventilation but one other influencing factor provided by one engineer was that of liability, which is relevant in view of the emphasis on litigation in the U.S.A. The use of Fire Prevention Agencies transferred liability from the Building Services Consultant to the Fire Prevention Agency and in the rather open legal climate of the U.S.A., this was seen as very desirable, and may be why the Fire Prevention Agencies are used. It also may indicate a lack of confidence in current design ability on behalf of the Building Services Consultant.

The search for information by Building Service Engineers concentrated on Fire Prevention Agencies, although journals and code setting bodies were used. Some engineers had experience of smoke ventilation proposals being rejected largely due to cost, again the date of 1970 came up as an adoption date, one engineers was told not to use smoke ventilation before 1970 but after this to recommend it. In Chicago, automatic smoke ventilation was turned down for a 45 storey office block because the fire department wanted full control and feared false alarms by such a system. This, in a city with a history of fire disasters could indicate a stretched fire department.

In researching changes in design it was found that air change rate (which takes no account of fire size and development) was still the method most often used, despite Factory Mutual defining fire hazard in 1960.

The type of ventilation most often used was mechanical and although a number of specialist firms were identified, engineers tended to use standard rather than specially designed equipment. In the U.S.A. manufacturers did not have the dominance apparent in the U.K.

All design engineering companies had systematic updating systems as had most individual engineers.

5.2.2 Fire Marshals and Fire Chiefs

In this section use has been made of research sponsored by the American Architectural Manufacturers' Association completed by Sumner Rider and Associates and published in 1987 under the title: "Heat and Smoke Venting Report"(1). It surveyed Fire Marshals, Fire Chiefs and Code Officials in an attempt to establish the knowledge and attitudes of these groups about heat and smoke venting.

Sample Size

2568 questionnaires were sent to Fire Marshals and Fire Chiefs, and 3088 were sent to Code Officials. Of the 2568 sent to Fire Marshals and Fire Chiefs, 778 were returned - 30% response rate. Of the 3088 sent to code officials 790 were returned, a 26% response rate.

Conclusions from the Summary of the Report

The most important conclusion is that there was no major area of negative perception to heat and smoke venting amongst Fire Chiefs or Fire Marshals. Indeed, 80% were positive in support of heat and smoke venting. The Fire Marshals and Fire Chiefs also believed that Codes of Practice were a major factor in determining whether buildings were vented or not. In fact one third said Codes of Practice mandated vents and one quarter said they established guidelines. Only one fifth said Codes of Practice did not require venting.

Fire Marshals played little part in specifying heat and smoke vents. They did play a greater role than Code Officials in reviewing and recommending smoke control designs and had more experience with venting, this experience was only small and described in the report as "little" or "some". 15% of the Fire Marshals said they insist on venting where necessary against 8% of the code officials.

Publications were the greatest source of information on heat and smoke venting with direct experience coming second. Significantly, only 9% named training as their first source of information, 12% as a second and third source. Manufacturers did not feature at all in first sources but scored high as second and third source of information.

Most of the sample preferred automatic venting. Half the sample sometimes preferred manual venting, whilst half said they sometimes preferred to cut holes in the roof. Most of the sample (80%) were in favour of venting as opposed to keeping the building closed in the event of fire. Over half of the sample were in favour of using vents on buildings with or without sprinklers.

5.2.3 Code Officials

The general conclusions which can be drawn from the report are given below.

There was no major area of negative perception to heat and smoke venting amongst code officials. The code officials also matched the Fire Marshals in their belief that codes were a major factor in determining whether buildings were vented or not.

Code officials played almost no part in specifying heating and smoke venting and less part in reviewing and recommending them than the Fire Marshals. Only a quarter of the sample had experience in venting.

Publications were the greatest source of information on heat and smoke venting, matching the fire Marshals, code hearings (see note) came second. Training again scored low in this respect, although featuring more significantly as top of the third source of information. Manufacturers did not feature as a first or third source and scored lower as second source than with the fire marshals.

Note: Code hearings take place at individual code body level and are also held nationally. The individual code body's hearings are committee hearings composed of approximately 14 officials and give groups such as trade associations and government bodies (e.g. centre for fire research) chance to put forward proposals such as standards for smoke ventilation. The national hearing is composed of officials from all three code bodies. This is about 400 strong and reviews codes accepted by the individual code bodies.

The Code Officials viewed the importance of these different sources as follows:

1.	Publications	56%
2.	Code Hearings	40%
3.	Training	35%
4.	Manufacturers	31%

Almost half thought automatic venting was very useful and almost a third thought they were sometimes useful. Nearly a half were in favour of using vents on buildings with and without sprinklers.

5.2.4 Government Agencies and Quasi Official Bodies

It should be clarified at this stage that in the U.S.A. building codes are offered by three main agencies, Building Officials and Code Administrators (BOCA), International Conference of Building Officials (ICBO) and Southern Building Code (SBC); these are private, non-profit making corporations and rely on the adoption of their codes by the cities and states for income.

The only body which can be termed fully, a Government Agency is the National Bureau of Standards and the department within this body which is concerned with fire is the Fire Research Centre.

Another body which could be regarded as quasi official is the National Fire Protection Association although the NFPA has as its statement, *"no power or authority to police or enforce compliance......."* nevertheless the NFPA guide reference 204M[2] has been approved by the American National Standards Institute.

1. <u>Fire Research Centre</u>

The visit to the Fire Research Centre revealed a wealth of research on the behaviour of fire and smoke and many analysis documents of fire disasters. The main reference publication for the design of smoke control systems is NBS Handbook 141[3] prepared by John H. Klote in 1985. This guide has been adopted by the professional body of design engineers in the U.S.A., ASHRAE, and is also adopted in legislation by certain states.

Indeed, this document is important in the diffusion of smoke control design dealing as it does with the fundamental laws of smoke behaviour and methods of control, such as pressurisation and ventilation. This is the source of information for the U.S.A. design engineer. The guide echoes the general view of caution with relation to the use of fire suppression systems (e.g. sprinklers) with smoke control systems. Other areas mentioned as having insufficient test data to ensure validity of design are pressurised elevators, pressurised corridors and atria.

The NFPA Guide 204M 1985 is a much more limited publication and deals with natural as opposed to mechanical (fan powered) vents. On the subject of the use of vents with sprinklers the guide states in section 6.3:

> *"A series of tests was conducted to increase the understanding of the role of automatic roof vents simultaneously employed with automatic sprinklers. The data submitted did not permit consensus to be developed or whether sprinkler control was impaired or enhanced by the presence of automatic (roof) vents of typical spacing and area."*

5.2.5 Insurance Agencies

Contact was made with Factory Mutual Research Corporation who have spent considerable effort in smoke venting research. However, a planned visit to their facility in Boston did not occur due to lack of time and resources. The Factory Mutual Research Corporation has the function of giving approvals, setting standards and conducting research for Factory Mutual Insurance Companies who deal with "highly protected risk."

It has already been noted in Chapter 2 that in 1960, Factory Mutual defined the use of fire vents, and in 1969 that they published approved standards for heat and smoke vents.

A questionnaire was completed by Mr Gunnar Heskestad, chief scientist at the Factory Mutual Research Facility. Heskestad proved to be active with other organisations (such as the NFPA) and had contact with other members of his profession. However, he rated smoke ventilation only 4 on a scale of 1 to 10 in his assessment of the importance of fire protection methods whilst sprinklers were rated as most important (10). In fact smoke ventilation scored lowest from a list of seven methods including fire alarm systems, staff training, escape route provision.

Heskestad has had considerable influence in his position as chief scientist of Factory Mutual although his results may be disputed, his influence in his position cannot be disregarded.

5.3 U.K. Research

The structure of the industry based on research is shown in Figure 5.3. It differs from the U.S.A. in that in the U.K. regulations and recommendations are set by Government sponsored bodies, thus there are no privately funded code setting bodies. Therefore the various Government departments all under the general heading of "Home Office" set the pace for the diffusion of safety standards. Even insurance opinion appears to stem from the Loss Prevention Council which is based at Borehamwood (where the Fire Research Station is situated) and includes the former Fire Insurers Research and Technical Office body.

It should be noted that whilst the Fire Research Station are active promoters of smoke control, the Loss Prevention Council appear to take a somewhat uncommitted view.

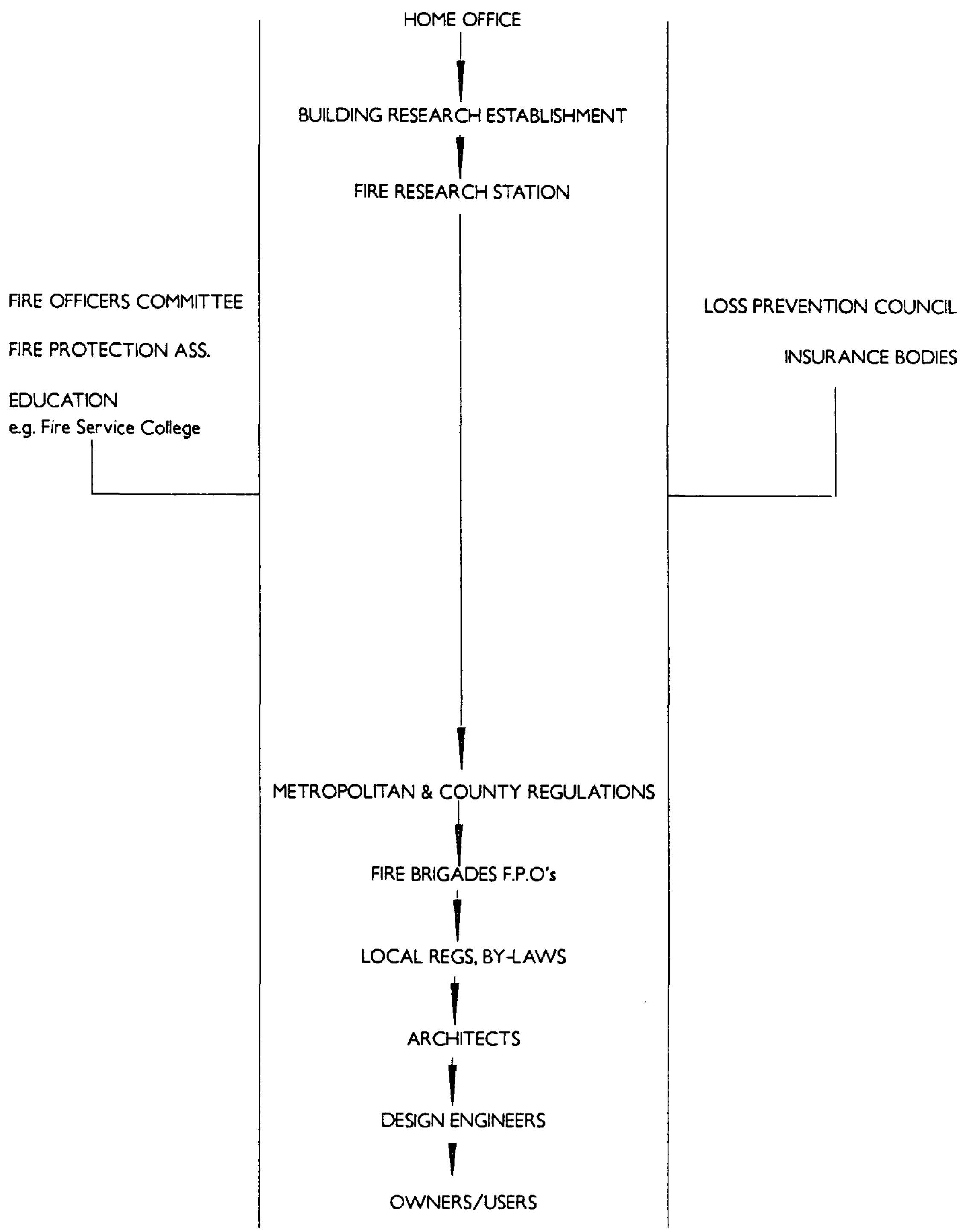
The analysis in the U.K. is divided into five areas. These are:

1. Design Engineers
2. Fire Prevention Officers
3. Government Agencies
4. Education
5. Insurance

There was little opportunity to examine the educational influence in the diffusion process in the U.S.A., except in the interview question, "Have you had any specific training in smoke ventilation?" This did reveal that apart from seminars, no training or very little of this type of training appeared to be available in the U.S.A. In the U.K. evidence suggested that there was some input into the diffusion process from this source.

Fig 5.3.

U.K. INDUSTRY STRUCTURE



5.3.1 Design Engineers

A total of 18 design engineers were surveyed in the U.K. A summary of the results obtained is in Appendix (vi)

Section 1 : Company Information

Table 5.3.1 summarises company information from this group. The companies are arranged in order of size on the table.

The first observation that can be made is that the companies in the U.K. tend to be smaller than those in the U.S.A. Unlike the U.S.A. they did have a tendency to vary in structure according to size, the smaller companies having 3 to 4 tiers, the larger 4 to 5 tiers (as compared with 4 to 5 tiers throughout, in the U.S.A.)

It was noticeable that autonomy existed in the 8 companies of up to 30 employees. The remaining 3 companies below 50 employees had come form of control. From 50 to 1000 employees, the results were mixed.

The question on the number of professional organisations that each company belonged to revealed just one main organisation, the Association of Consulting Engineers (A.C.E.). Only two companies belonged to more than this organisation. Most thought that membership was useful in terms of running their business.

Medium size companies (50 - 140 employees) and larger (51 - 1000 employees) companies had more contact within the profession and had more interchange of information than smaller companies (0 - 50 employees). This lower rate of contact and interchange of information on the part of the smaller companies appears to contradict their view of the usefulness of membership, as all thought membership useful. It could reflect the lack of time and resources of these companies.

Company awareness and adoption of smoke control is discussed in Section 3.

DESIGN ENGINEERS U.K.

Table 5.3.1.

Size	Structure	Design Freedom		Membership of Organisation/Assoc				Contact within Profession			Is there much exchange info?		
No. of Emps.	No. of Tiers	Autonomy	Control	Number	Use	Some	None	Often	Some	None	Yes	Some	None
12	3	X		1	X				X				X
16	3	X		1	X							X	
18	4	X		1	X				X				X
20	3	X		1	X					X		X	
22	4	X		1	X				X			X	
30	4	X		1	X				X				X
30	3	X		1		X			X			X	
30	3	X											
35	3		X	1	X				X			X	
40	4		X	2	X			X			X		
45	4		X	1		X			X			X	
50	3	X											
60	3	X		1	X			X			X		
65	3		X	1	X			X			X		
140	?		X	0									
350	4/5	X		1	X			X			X		
1000	5		X	2	X			X			X		
-								X				X	

Section 2: Personal Professional Relationships

As Section 1 looked at the kind of inter-organisational relationships the company had within the profession, this section looks at the interpersonal relationships within the profession.

The age range of the interviewees varied from 26 to 55. One third were either partners or associates, over half were engineers. Of the 14 who were members of professional organisations, 6 found membership useful and a further 4 found membership some use. But this was seen as general usefulness rather than specifically related to smoke ventilation. This was possibly due to lack of contact between the Fire Research Station (F.R.S.) and the Chartered Institute of Building Services (C.I.B.S.E.), and may be linked back to the fact that there is little input from universities in training engineers in the field of smoke control.

The Design Engineers contact within the profession was high, 11 had contact often, and a further 5 had some contact. Of these sixteen, 6 had a high rate of information exchange whilst a further 9 had some interchange of information. This highlights the importance of this network as a vehicle for diffusion. There appeared to be no relationship between age, usefulness of membership or interchange of information.

Smoke ventilation rated relatively high in importance in relation to other fire protection methods, 6.2 on a scale 1 to 10. When asked to give the primary function of smoke ventilation, 8 gave life protection, a further 8 gave life and property protection. Only one of the engineers had had some training in smoke ventilation.

Section 3 : Awareness of Smoke Ventilation

This section attempts to assess the respondents' involvement and attitude to smoke ventilation and also discover when and where the concept was originally adopted.

Of the four responses to the question on the date of company awareness of smoke ventilation, 2 were in the 1950's and 2 in the 1980's. The result from the individual engineers revealed that over a third of the sample became aware of smoke ventilation before 1975 but the largest number, 11, only became aware from 1980 onwards.

The major sources of the awareness were the Building Research Establishment (the F.R.S.), 3 (17%), literature and trade magazines, 4 (22%), manufacturers and project involvement, 4 (22).

Thirteen engineers were involved in a design capacity with smoke ventilation. The date of this involvement or adoption, almost matches the date of first awareness of the concept. Thus most engineers' awareness coincided with a design project between the years 1980/1987. As would be expected, because of this project involvement, company adoption followed the same pattern.

The major type of buildings smoke vented was shopping centres. Design temperatures were from 74 deg.C to 350 deg.C. Atria smoke ventilation systems combining natural and powered vents were found. Many other building types were mentioned - warehousing, factories, film studios, health clinics, banks, prisons, etc.

The major factors influencing implementation of the system were Fire Prevention Agencies, 11 (61%), Government Regulation, 7 (38%), and Building type and Specification, 6 (33%) and 5 (28%) respectively, although Design Methods, 4 (22%) and Insurance Agencies, 4 (22%) were significant.

The main source of information was given as the F.R.S., but manufacturers were almost equal, indicating the importance of their role in diffusion.

All unsuccessful proposals to use smoke ventilation were because of cost, no other reason was given.

Almost half of the companies had a systematic way of updating information whilst one third of the individuals had an updating system. This is notably different from the U.S.A. where all companies and most individuals had this facility.

With regard to design methods, over one third had used F.R.S. information direct and almost half (8) had used manufacturers' information which was largely derived from the F.R.S. publications.

Some indication of basic fire size/building occupation being used as a design basis was found (2) and computer designed gas flows were mentioned (1). The majority did not know of design method changes. Most were aware of natural and powered vents (12) and most thought natural vents were the most often used.

One manufacturer was regarded by the engineers as best known, 14 (77%), with another close second, 10 (50%) and a third at 7 (38%). Below this were seven further manufacturers.

The check in bodies or regulations influencing in design decisions did not reveal any areas not previously found.

5.3.2 Fire Prevention Officers

The sample was obtained from Fire Prevention Officers in 20 of the 63 County Fire Brigades in the U.K. A summary of the results is given in appendix (vii)

<u>Section 1 : Organisational Information</u>

Table 5.3.2 summarises organisational information from this sector. The brigades are arranged on the table in order of size and range from 20 to 2600 personnel. A close examination of the size reveals some misunderstanding by the respondents. The smaller, at 20 personnel, only detailed the Fire Prevention Officers in the brigade. The follow up interview revealed this to represent a possible average fire prevention department size.

Other brigade sizes appeared to vary according to population density thus Norfolk fire service had 320 personnel, whilst West Midlands had 2600 personnel.

Questioned on the structure, the respondents varied in their descriptions. Those who described the structure of Fire Prevention Departments gave a structure involving 3 or 4 tiers, whilst those describing the structure of the fire brigade gave structures involving 5 or 6 levels. The brigades of 800 and 1100 personnel who gave three tiered structures only gave levels to divisional heads, one could assume that they would fall into the 5 to 6 levels referred to above. Most felt they had some discretion in giving approval to fire prevention schemes as long as they observed Home Office recommendation and codes of practice. They referred to B.R.E. reports, building regulations and legislation. It was mentioned that the degree of discretion would vary according to seniority, thus the senior F.P.O's would be called in on a major discretionary item. The example given was where the installation of smoke ventilation allowed the Fire Prevention Officer to consider allowing longer for the Fire Brigade to reach the site.

There was a greater professional involvement by Fire Prevention Officers than that of the engineers. They averaged a membership of 2.4 organisations against the 1.3 of the engineers. There were three main organisations. The first was the Institute of Fire Engineers (I.F.E.), the second the Chief and Assistant Chief Fire Officer Association (A.C.F.O.A.), the third the Fire Protection Association (F.P.A.). The F.P.O's were stronger in support of the usefulness of this membership than the engineers, only one thought it not useful, this respondent only belonged to one organisation, the I.F.E. and the Brigade to which he belonged was in a relatively remote area. All had frequent contact within the profession and good information exchange (contact within the profession by the engineers tended to be by larger organisations).

F.P.O's - U.K.

Table 5.3.2

Size	Structure	Design Freedom		Membership of Organisation/Assoc				Contact within Profession			Is there much exchange info?		
No. of Emps.	No. of Tiers	Autonomy	Control	Number	Use	Some	None	Often	Some	None	Yes	Some	None
20	4	X		3	X			X			X		
320	4	X		4	X			X			X		
320	6	X(frs)		4	x			x			x		
350	4		x	3	x			x			x		
418	5	x		2	x			x			x		
460	3	x		1	x			x			x		
496	5			2	x			x			x		
500	5			1	x			x			x		
600				2	x			x			x		
650				3	x			x			x		
700				1	x			x			x		
700								x					
800	3(5/6)			1			x	x			x		
1100	3(5/6)	x		4		x		x			x		
1505			x	3	x			x			x		
2000			x										
2600				2	x			x			x		
-								x			x		
-		x		4	x			x			x		
-				1	x			x				x	

Section 2 : Personal Professional Relationships

The age range of the respondents varied from 32 to 59, the average being 45.5, some 10 years older than the engineers' sample.

Over half were senior F.P.O's or Assistant Senior F.P.O's, a quarter were Divisional Officer rated F.P.O's. All were members of professional organisations, the main organisation being the Institute of Fire Engineers 19 (95%). Only 2 (10%) were members of the Fire Prevention Association. A large proportion 13 (65%) found this membership useful or some use in terms of running the department, compared with less than half of the engineers with this view. All had contact within the profession and had a good interchange of information. (Only one third of the engineers had contact within the profession and less than half thought it useful).

The F.P.O's rated the importance of smoke ventilation in relation to other fire protection methods as 6 on a scale 1 to 10. This is almost identical to the engineers rating. When asked to give the primary function of smoke ventilation, 7 (35%) gave life protection, 12 (60%) gave warning or fire fighting assistance.

Questioning on specific training in smoke ventilation revealed a large proportion (15) had had some training. This compares with only 1 of the engineers who had had this training.

Section 3 : Awareness of Smoke Ventilation

This section attempted to assess the respondents' involvement and attitude to smoke ventilation and also to discover when and where the concept was originally adopted.

Unlike consultancy companies over a half of F.P.O. organisations were aware of the concept before 1975. Even more of the individual F.P.Os (13) were aware before that date. Since the majority of information became available from the late 60's to the early 70's, it was thought to be interesting to discover if this early dissemination of information had significantly affected the older age group. The consultants who were aware before

1975 had an average age of 44, whilst the F.P.O's who were aware before this date had an average age of 46.8, hardly a significant difference. Thus it appears that early dissemination did not impact on the older age group, rather there was a gradual diffusion over the period.

The main sources of information were:

1. The B.R.E. Reports (4) 20%

2. The Fire Service College (4) 20%

But other areas were significant. Trade journals 3 (15%) and manufacturers 3 (15%), project involvement also scored 3 (15%) (this requires officers to refer to the reports published by the BRE/FRS). More F.P.O's than consultants had a wide range of information sources.

The majority of the F.P.O's, both as organisations or as individuals (12 from 20) were involved with smoke ventilation before 1979 whilst the majority of the engineers (10 from 18) were involved from 1980 onwards. This earlier adoption by the F.P.O's is understandable considering their direct links with the F.R.S. Some criticism of the engineers is justified for their late adoption.

The capacity in which the F.P.O's were involved was largely that of approval, 12 (60%) compared to advice 5 (25%) but it should be noted that the F.P.O's were approving recommendations from BRE/FRS reports not regulations. However, shopping centres which required relaxation of building regulations were by virtue of the town centre redevelopment guide No. 1 (1972) referred to the Fire Research Station for approval.

On data regarding the types of buildings smoke vented and methods of smoke ventilation used, F.P.O's were reluctant to divulge information. Often quoted was Section 21 of the Fire Precaution Act 1971 as a reason for not supplying this information. The information gathered however tallied with consultants' experience in that the largest involvement was shopping centres and the design temperature used was between 64 deg C to 300 deg C (compared with 74 deg C - 380 deg C from consultants). A combination of natural and/or powered systems were used. Other building types mentioned were warehousing, banks, hospitals, manufacturing facilities and air terminals.

The major factors involved in acceptance of the proposals to use smoke ventilation by the client, were the same as consulting engineers. The sources of information for recommendation in design were the BRE/FRS, 9 (45%) the major source with the Fire Service College coming an interesting second, followed by manufacturers and trade literature. Nearly half the F.P.O's had more than one source of information - this was similar to the engineers.

Of the 8 (40%) of the sample who had had unsuccessful proposals to use smoke ventilation, half were rejected because of lack of enforceable regulation, over a third gave cost as the reason, and one gave the reason as design consideration (he gave the example of surrounding buildings creating pressure which prevented the use of natural ventilators). Where the client decided not to use smoke ventilation the major reason was cost (only 5 of the sample responded to this question).

The majority of Brigades had a systematic way of updating information but only 30% of the individual F.P.O's had this facility.

In the process of approving design methods F.P.O's used information provided by BRE/FRS. The engineers also used this source.

The question on design method changes showed an awareness of changes in design of smoke ventilation systems for shopping mall and atria, and an awareness of the problems of the interaction of smoke ventilation and sprinklers.

An appreciation of the distinction between product areas such as natural and powered smoke ventilation systems was negligible. It appears the choice was made on the basis of the manufacturers.

F.P.O's identified two major manufacturers of smoke ventilation equipment, Colt and Nuaire. In answering the question the F.P.O's perceived the split between natural and powered ventilation as 75%/25% respectively.

When questioned on which companies were offering smoke vent systems, consultants and manufacturers were both regarded as offering systems, whereas consultants offer a design service, not products. This may arise from the confusion by the F.P.O's between manufacturers and their design service and independent consultants.

5.3.3 Government Agencies

In the U.K. there are a number of authorities responsible for determining how a building may be built and with what safety precautions. The central body at the head of regulations and recommendations is the Home Office. They control building regulations and health and safety regulation. Most research on building design is undertaken at the Building Research Establishment. The part of the establishment which is responsible for fire safety is the Fire Research Centre at Borehamwood.

Local bodies such as the G.L.C. and the Greater Manchester Metropolitan Council, although working to Home Office guidelines, often develop additional regulations based on experience. An example of this is the G.L.C's stringent regulation on atria and regulations affecting smoke ventilation which depended on floor area rather than fire size. Both of these have now been challenged. The F.R.S. research has superseded design based on floor area although atria smoke control design is still subject to arguments. The Lloyds Building, London, did not follow G.L.C, design but used smoke control design recommended by consulting engineers Ove Arup, based on their scientific research. For a summary of recommendations and regulations current in the U.K. see Appendix (viii)

Information given in Chapter 2 on the Fire Research Station does not cover the information networks emanating from this body. The networks have played an active role in disseminating research. These networks fall into basically three areas:

1. Academic

2. Government Agency

3. Commercial

1. <u>Academic</u>

The F.R.S. have strong connections with the U.K's official Fire Service College at Moreton in Marsh, Gloucester. The content of training courses shows the influence of personal contact between officials of the F.R.S. and tutors. The F.R.S. also have contact with South Bank Polytechnic and strong links with Edinburgh University. Both institutions are active in fire research. Individuals at the F.R.S. also contribute to trade journals such as the Fire Safety Journal.

2. <u>Government Agencies</u>

There is official contact between the Home Office and the Department of Environment Construction Industry section in England and the Scottish Development Agency (S.D.A.) in Scotland. The S.D.A. is responsible for administering the Scottish Building Regulations. It should be noted that the Home Office is responsible for common standards within the Fire Brigades and have a fire protection section which is linked to the F.R.S. and directly responsible for the Fire Service College.

3. <u>Commercial</u>

Involvement in joint funding of research by private companies with the F.R.S. have resulted in strong links with the industry and in particular with one company in the U.K., Colt International. In addition, the nature of F.R.S. position prior to 1985 in being a central "clearing house" for smoke control design in the rapidly increasing development of shopping malls has created links with design engineers and architects. It can be seen that the F.R.S. plays a central role in the diffusion process.

5.3.4 Education

As mentioned in the previous section, various institutions are involved in education in the use of smoke control. Contact with some of these institutions revealed interesting views on the subject.

The Fire Service College incorporate in their Junior Officers Advancement Course, training in the need to ventilate during fire fighting. Included in the courses are exercises involving manual and automatic fire ventilated buildings and a one and a half hour session on design and installation of automatic fire ventilation using visual aids prepared by Colt International. This particular input is also given to junior officers who are not expected to progress beyond sub officer rank. If an officer enters the fire prevention branch of the service he undergoes a fourteen week course of which ten weeks is in college and this includes a three period input on the philosophy of Atria Ventilation.

During 1985 and 1986 the college gave lectures on how fire prevention officers could more readily understand fire ventilation calculations. Recently Colt International have begun to run one week courses for Fire Officers dealing with the whole spectrum of smoke ventilation. Atria and shopping mall design courses have been undertaken. Mr Peter Robinson, Head of the Fire Prevention Study Group at the Fire Service College, has been the main force behind this move. Some of the educational publications used by the Fire Service College are in the Appendix (ix).

The University of Edinburgh has a unit of Fire Safety Engineering within the Department of Civil Engineering and Building Science. Dr. Marchant is the head of the Civil Engineering Department.

Dr. Marchant's comments are very relevant in considering the subject of education in smoke control. Dr. Marchant identifies a number of educational omissions in the training of the principal users of smoke ventilation. These are:

1. Fire Safety Consultants

A large proportion of Fire Safety Consultants have a fire brigade background which does not educate them in understanding the engineering problems involved with design and specification of smoke control systems. The Consultants and the Fire Service should be recruiting more graduates. There are some engineering graduates in this field who do have a greater understanding of the physics and dynamics involved in the smoke control problem.

2. Architects

In schools of architecture little attention is paid to fire safety design. The average total lecture time devoted to the subject on a five year architectural course was five hours. This time did not necessarily include smoke control as a specific subject.

3. Building Services Engineers

The Building Services Engineers need to have a better awareness and technical expertise in the design of smoke control. Some aspects of smoke control are included in courses for building services engineers, but, "it has become clear that only those students with work experience involving smoke control systems have any knowledge of the problems and their possible solutions."

4. Product Manufacturers

"It has become apparent that although people involved in selling components understand the capability and performance of these particular components, they have no real idea of the method of selection of system or the dynamics of smoke control systems." Some companies have recognised this and have spent time and effort in education (e.g. Colt International).

5. Fire Prevention Officers

Knowledge in this group varies from person to person and area to area. The efforts of Peter Robinson have improved the dissemination of information on smoke ventilation design. Finally he comments:

> *"I do not remember having seen a substantial short course for post experienced persons in smoke control subject that has been held since 1979. We will be planning a short course later this year."*

5.3.5 Manufacturers

Active in the education field particularly in relation to architects and engineers are two product manufacturers, Colt International and Nuaire Limited. The courses offered go from basic concepts of smoke control through shopping malls and atria design. It is difficult to assess the success of these education programmes as they are privately funded and tend to educate in favour of the company giving the seminars. Nevertheless, they do attack an area pointed out by Dr. Marchant as lacking in expertise and therefore are important in the diffusion process.

5.3.6 Insurance Bodies

Direct information from insurance companies proved impossible to obtain in the time scale of this research, therefore national bodies involved in insurance regulations were contacted. These were headed by the Loss Prevention Council(4), which is described as the technical arm of Commercial Insurance in the U.K. They combined a number of departments:

F.I.R.T.O. Fire Insurers Research Department

F.P.A. Fire Protection Association

I.T.B. Insurers Technical Bodies

Insurers are generally concerned with property loss as opposed to life, and although they are aware of development in smoke control and in particular shopping malls and, more recently, atria, they have avoided giving a definite statement on the need for smoke control. Their view is generally building specific and would probably take BS 5588 by Home Office as a guide. This does not correspond with the insurers view on sprinklers where premium reductions are available where they are installed, they are considering atria at the moment.

The Fire Protection Association in reference to sprinklers and vents refers to papers by A.J.M. Heselden(5) and P.L. Hinkley(6) (which conclude that in most cases the effect of venting on the opening times of sprinkler heads and the capacity of the sprinkler system to control the fire are unlikely to be of practical significance). Letters in the Fire Prevention Journal appear to echo the insurers view that sprinklers are a better investment than smoke vent since smoke ventilation is installed mainly to help people escape and to assist the brigade to get to the fire.(7)

5.4 The Search for Factors Influential in the Adoption Process

5.4.1 Method

The results of a number of questions from the U.K. for both engineers and fire protection officers were analysed using the Fisher exact probability test(8). A control date of 1972/73 was suggested because of legislation in that time period, i.e. the 1972 "Home Office Town Centre Redevelopment Guide No. 1."

Notes on the questions and tables of results are given in Appendix (x).

5.4.2. ANALYSIS OF RELEVANT RESULTS

1. U.K. Engineers

As the few awareness dates obtained matched the adoption dates of the companies concerned, the test was applied using adoption dates only.

Question 6, Section 1, Company information

What kind of contact is there within the profession?

	Adoption Dates before and after legislation		
	1972 and before	1973 and after	Total
Often	3	2	5
Some/None	0	9	9
Total	3	11	14

The chi squared test is significant at the 0.05 level with a single tailed test.

Thus those of the sample who often had contact within the profession before 1973 (3) adopted the concept of smoke ventilation. After 1972 the matrix shows adoption mainly in the group with little contact within the profession. This corresponds to the introduction of "The Home Office Town Centre Redevelopment Guide No. 1" introduced in 1972. Thus legislation appears to have overridden the tendency of frequent contact to positively influence adoption.

Question 7, Section 1, Company Information

Is there much interchange of information (within the profession)?

	Adoption Dates before and after legislation		
	1972 and before	1973 and after	Total
Yes	3	2	5
Some/None	0	9	9
Total	3	11	14

The chi squared test is significant at the 0.05 level with a single tailed test.

The results matched those obtained from the previous question indicating that those who often had contact within the profession found this contact useful, furthermore this positive perception of the usefulness of membership positively influenced adoption before 1973. Those involved in the professional organisations from an earlier stage seem to use this contact as a source of information on their work situation. This is possibly associated with their participation in meetings which leads to the development of a network of personal contacts with experience of a range of projects. The results also reinforce the influence of legislation.

Question 9, Section 1, Company Information

How much personal discretion is allowed in design?

	Adoption Dates before and after legislation		
	1972 and before	1973 and after	Total
Some	1	10	11
None	3	3	6
Total	4	13	17

The chi squared test is significant at the 0.05 level with a single tailed test.

The distribution of this matrix shows that before 1973, the majority (3 from a total of 4) had no discretion in design. In the group after 1972 the reverse applies, the majority being the group with some design discretion (10 from a total of 13). This suggests that adoption before 1973 was due to company influence, whilst after, although engineers with discretion in design adopted the concept, this was primarily because of legislation.

The analysis of other factors, although not giving significant results, indicate that they have some effect on adoption before 1973.

Question 11. Section 3.

Does the Company have a systematic way of updating information?

Adoption dates before and after legislation

	1972 and before	1973 and after	Total
Yes	4	5	9
No	1	8	9
Total	5	13	18

The majority of those who adopted before 1973 had company information systems (4 from a total of 5). Again the influence of regulation can be seen after 1972 reversing the pattern of distribution, the majority now being with the companies with no information system (8 from a total of 13).

Question 5. Section 1. Company Information

How useful is membership of organisations?

Adoption dates before and after legislation

	1972 and before	1973 and after	Total
Yes	3	2	5
No	0	8	8
Total	3	10	13

Again, the majority of those who adopted before 1973 had a positive perception of the usefulness of membership of organisations. After 1972 the pattern is reversed as before reinforcing the influence of legislation.

When the results of individual engineers' personal/professional relationships was examined no significant result was found, however one question did show a change in response to adoption after 1972. This was similar to the change in balance previously found.

Question 6, Section, Individual Information

Do you personally have much contact with other members of the profession?

	Adoption dates before and after legislation		
	1972 and before	1973 and after	Total
Often	3	2	11
Some/None	1	5	6
Total	4	8	17

The majority of those individuals who adopted before 1973 (3 from a total of 4) had frequent contact with other members of the profession, whilst after 1973 the distribution reverses again as a result of legislation.

The overriding factor in all the results examined above is the affect of legislation. Adoption is greater in all cases after 1972.

2. U.K. Fire Prevention Officers

The sample was tested using both adoption and awareness dates.

Question 4, Section 1, Organisational Information

	Adoption Date before and after legislation		
Membership of Professional Organisations	1972 and before	1973 and after	Total
Above 1	1	11	12
1 & 0	2	1	3
Total	3	12	15

The chi squared test is significant at the 0.05 level with a single tailed test.

The majority of those who adopted before 1973 were members of more than one organisation. It is difficult to attach any significance to this in isolation, in view of the small numbers (2 from a total of 3). However, when this is viewed in relation to results after 1972, it can be seen that as with the engineers the distribution reverses, showing again the influence of legislation. It could be surmised that those who were members of more than one organisation showed more interest in the profession and the knowledge from this association gave them the opportunity to consult on legislation thereby exerting more influence on its implementation.

From the Fire Prevention Officers survey results, the above was the only case where the results proved significant. However, a number of other cases are worth examination.

Question 5, Section 1, Organisational Information

How useful is membership of organisations?

Adoption dates before and after legislation

	1972 and before	1973 and after	Total
Useful	3	10	13
Some/None	1	1	3
Total	4	11	16

On the question of usefulness of membership of professional organisations the majority of those who adopted before and after legislation thought membership useful. This result differs from that obtained from engineers for the same question. The engineers' result gave a reversal of distribution after 1972. It could be argued that the nature of the Fire Prevention Officers job necessitates and assists useful involvement in other allied organisations and this therefore explains the difference. Finally, the overriding influence of legislation on adoption is evident.

Question 4, Section 1, Organisational Information

Membership of organisations?

	Awareness dates before and after legislation		
	1972 and before	1973 and after	Total
Above 1	7	3	10
1 & 0	3	2	5
Total	10	5	15

With regard to awareness dates, the majority of the sample belong to the group with membership of more than one organisation as was the case when the results were based on adoption dates. However, the influence of legislation is no longer evident with the majority of those with awareness belonging to the group 1972 and below.

The results show that Fire Prevention Officers had awareness before the engineers, suggesting they had more personal interest in their professional activities than the engineers. This also reinforces Dr. Marchant's view that engineers lack knowledge of smoke control. (Chapter 5, Ref 5.3.4.).

Question 5, Section 1, Organisational Information

How useful is membership of organisations?

	Awareness dates before and after legislation		
	1972 and before	1973 and after	Total
Useful	9	4	0
Some/None	1	1	2
Total	10	5	12

This almost echoes the previous result, thus the majority of the sample who were aware before 1973 thought membership of organisations useful. Perhaps this supports the suggestion of greater interest in professional activities.

When the results of the F.P.O's opinion of personal professional relationships were examined significant result was found; however evidence supporting the above conclusions was present. The majority, ie. 8 of the 13 who had awareness before 1973 were members of more than just one organisation. Furthermore, 10 of the 13 thought this membership useful. Of the 13 who were aware before 1973, 11 had had training at the Fire Service College.

Question 4, Section 2, Individual Information

	Awareness dates before and after legislation		
Membership of any professional organisations?	1972 and before	1973 and after	Total
Above 1	8	1	9
1 & 0	5	1	6
Total	13	2	15

Question 5, Section 2, Individual Information

How useful is this membership?

	Awareness dates before and after legislation		
	1972 and before	1973 and after	Total
Useful	10	2	12
Some/None	3	0	3
Total	13	2	15

Questioned on education those who said they had attended the Fire Service College were the majority of those who were aware before 1973.

Question 10, Section 2, Individual Information

What training have you had?

	Awareness dates before and after legislation		
	1972 and before	1973 and after	Total
Training F..S.C.	11	3	14
Degree etc	2	1	3
Total	13	4	17

When the individual F.P.O's response was examined using adoption dates it matched previous results obtained from both Engineers' company information and F.P.O's organisational information in that the majority adopted after 1973. This reinforces the effect of legislation on adoption.

5.4.3 Various factors were found to have influence on the adoption process.

1. The degree of contact within the profession. The companies with more contact adopt earlier.

2. The amount of interchange of information. The companies who exchanged information adopted earlier.

3. The amount of discretion allowed in design for engineers. The companies who gave little discretion in design adopted earlier.

4. Whether the company has a systematic way of updating information. The companies who had a systematic way of updating information adopted earlier.

5. The membership of other professional organisations both by company and individual. The companies and individuals with membership of more than one professional organisation adopted earlier.

6. The view of the usefulness of that membership by both company and individual. The companies and individuals who viewed membership as useful adopted earlier.

7. Education specific in the case of the F.P.O's from the Fire Research Institute. Those who had attended courses at the F.R.S. were aware earlier.

The results in general show the influence of the 1972 legislation superseded the above factors influencing adoption.

Prior to 1972 the adoption and awareness were related to membership of organisations. This illustrated the importance of professional organisations in the diffusion of innovation. Also very relevant is the information possessed by the organisation, early adopters had a system for updating information.

The importance of the organisation in overriding the individual as an early adopter is indicated by the fact that those companies who gave no discretion in design adopted earlier. Finally, the importance of the Fire Service College as a source of awareness is highlighted.

5.4.4 A Company Profile for Early Adoptors

The above results enabled the development of a company profile for Early Adopters, this is given below:

A COMPANY PROFILE FOR EARLY ADOPTERS

The company would have a higher than normal presence in associated professional organisations and would view that presence as useful. It would have a higher than normal degree of contact and exchange of information within the profession. It would be systematic and up-to-date in its information system.

CHAPTER 5 - REFERENCES

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CHAPTER 6

Introduction

This chapter discusses and analyses the research findings in relation to the process of diffusion and adoption established in chapter 3. It concentrates on the U.K. where sample size and research material gave a much better chance of meaningful analysis. Chapter 7 relates this analysis to both the U.K. and the U.S.A. The process of innovation, diffusion and adoption has been studied widely but little attention has been paid to industrial diffusion and adoption. It was the recognition of this neglect and an interest in the subject matter which prompted this research.

6.2. The Innovation

The first point to determine is whether the subject under study, ie the concept of smoke control, qualifies for the term innovation. From chapter 2, which defines smoke control and describes the history of development, it can be seen that it has been in existence since circa 1900 (ignoring the Parthenon and the Globe Theatre which, it can be argued, are merely applications of smoke control for comfort, not for safety.) It is apparent however that the design capability and the concern for safety of life and property and buildings other than theatres has only existed since around 1940/50. From that date concern and capability have increased to the present day, spreading to new and different types of building as they have been developed (e.g. shopping malls and atria). This development has resulted in a lag in awareness of design methodology on the part of the Design Engineers, and others. It is this lag in awareness which helps define the concept of smoke control as an innovation.

6.3 Diffusion in the U.K.

Having defined smoke control as an innovation in safety design the process of its diffusion can now be followed. It should be noted here that the study examined awareness of smoke control on the part of the individual Engineer and Fire Protection Officer (F.P.O.) as well as their companies and organisation. With the F.P.O's there was no significant difference between the time of individual awareness and the awareness of their organisations. In the case of the Engineers there were only four replies to the question of organisational awareness, therefore the individual's awareness has been used as a basis for the analysis. These result can be found in Appendix X.

6.3.1 The Rate of Diffusion

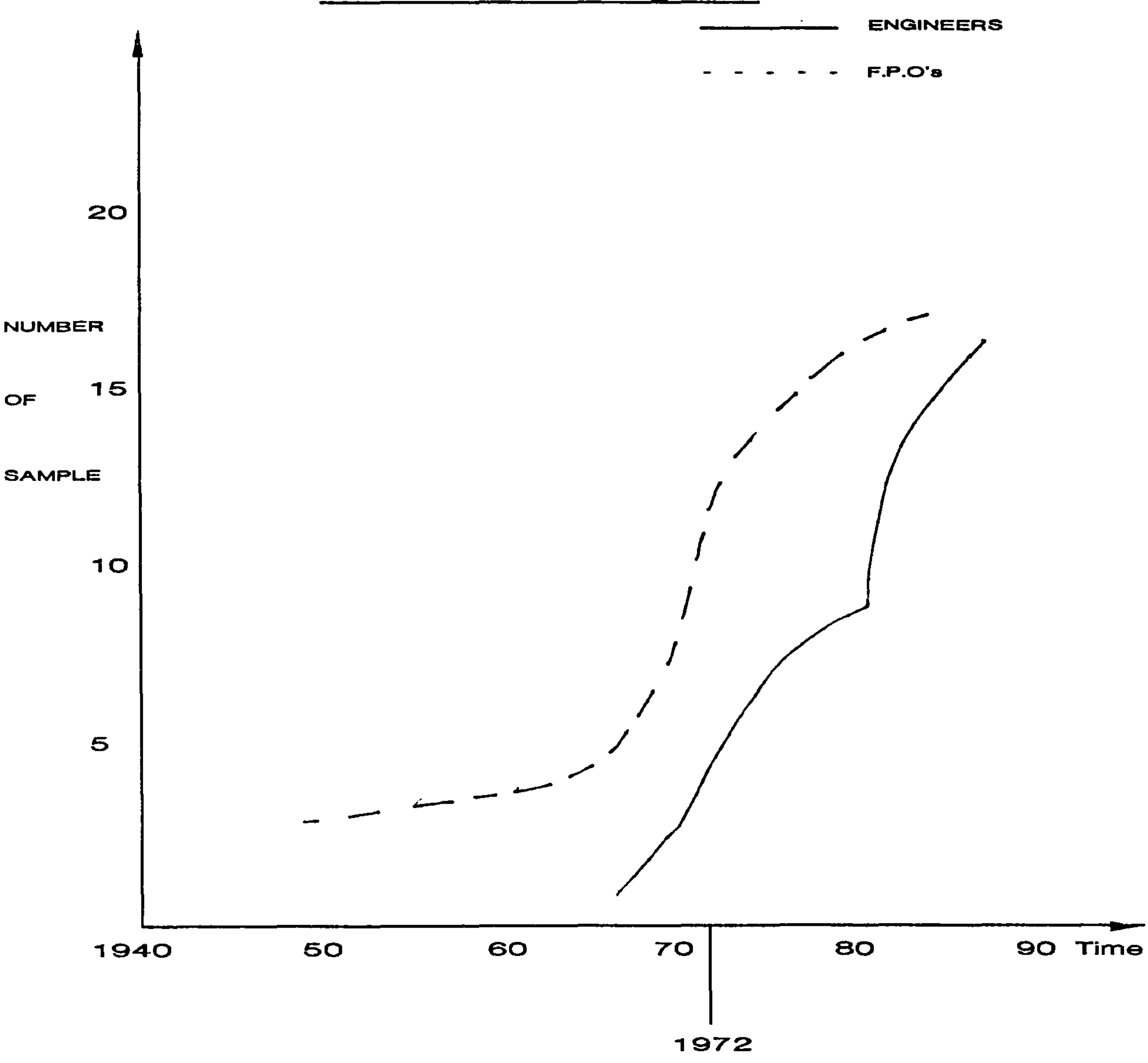
The results, when plotted, show diffusion rates for both the Engineers and the F.P.O's which follow the traditional 'S' shaped curve (see Fig. 6.3.1.) The diffusion curve for the Engineers commenced much later than that of the F.P.O's. This difference is the result of a number of factors such as differences in education and the onset of legislation. Also Engineers were not as close to the central diffusion network (the F.R.S.) These factors will be discussed later. Awareness began in 1900 and was initially confined to theatres. In 1050 a series of fires in factories created interest in its application to industry. The development of indoor shopping centres in the 60's and 70's carried awareness of smoke control into its application in the retail sector. The development of the smoke control industry built up throughout this diffusion period closely resembles the model developed by Mueller and Tilton. The early stages of the industry in the 1950's was a period of uncertainty when few manufacturers became involved in smoke control and those that did were companies who were already involved in ventilation. The fact that smoke control was merely an extension to their product range reduced the risk of entering the market. As the market became more definite and more research was done by the Fire Research Station (F.R.S.) on design, and by manufacturers on products, other firms entered the market, the process of imitation. At the present time there is technological competition with firms producing more sophisticated and differentiated products, in fact some products have now reached standardisation, e.g. there is little to choose now between one manufacturer's ventilation louvres and another's.

6.3.2 Diffusion Agency Establishment and Strategy

Because the manufacturers involved in the smoke control industry were mainly companies who were already in ventilation they had established sales teams serving that industry. There were involved in the diffusion of smoke control together with the central government diffusion agency, the Fire Research Station, whose publications were the main source of smoke control design information for F.P.O's, Engineers and Architects involved in the design of buildings.

FIG. 6.3.1

Diffusion of Smoke Control for Engineers and Fire Protection Officers in the United Kingdom



Manufacturers sit along side this central diffusion agency obtaining from it information that enables them to develop products which will satisfy the design criteria laid down by the F.R.S. The relationship with the F.R.S. can be close enough to involve jointly funded development programs. How the different segments of the market, e.g. Architects, Engineers, F.P.O's are approached by manufacturers, is a marketing decision in which there are three basic choices, undifferentiated, differentiated or concentrated marketing.

Discussions with manufacturers revealed that although most of their advertising material was common to both the Engineers and Architects, sales presentations were tailored to the individual segment, i.e., presentations to Architects emphasised the appearance of the products, Engineers were shown much more technical detail. It was found, however, that whilst one company concentrated its sales effort on Architects, another concentrated on Design Engineers. This differentiation within a market, i.e. segmentation is one choice in diffusion agency strategy. It can, however, lead to some segments of the market being neglected and therefore having an unequal ability to adopt an innovation. It was found in discussions with one company that they had difficulty in having their particular smoke control products accepted because they had little presence with the Architects or F.P.O's in the early stages of their entry into the market. Establishing a presence in these areas has cost implications which could have acted as a barrier to entry into the market.

6.3.3 Tracer Studies

It is interesting to refer to the conclusions of the tracer studies covered earlier in Chapter 3, ie. that a major technological advance requires not one but a number of innovations. This has some parallel to the development of smoke control. Problems in controlling smoke were experienced and their solutions explored in different countries at about the same time, factories in the UK and the USA suffered fires in the 1950's, shopping malls in both these countries had problems in the 1970's, at the moment attention is focused on the smoke control of atria (large covered multi-storied areas). It was not so much a cluster of innovations, but a cluster of problems which determined what research and development was necessary. In the

Figure 3.3.1 in Chapter 3, the development of smoke control, was traced through its research into the development of regulations, recommendations and finally through to its commercialisation. Although the process is shown as linear, some manufacturers were producing smoke control products as early as the 1950's. Thus the process of commercialisation can be seen to run alongside research and development.

6.3.4 The Role of Members of the Smoke Control Network in the Process of Diffusion

1. The Building Design Team

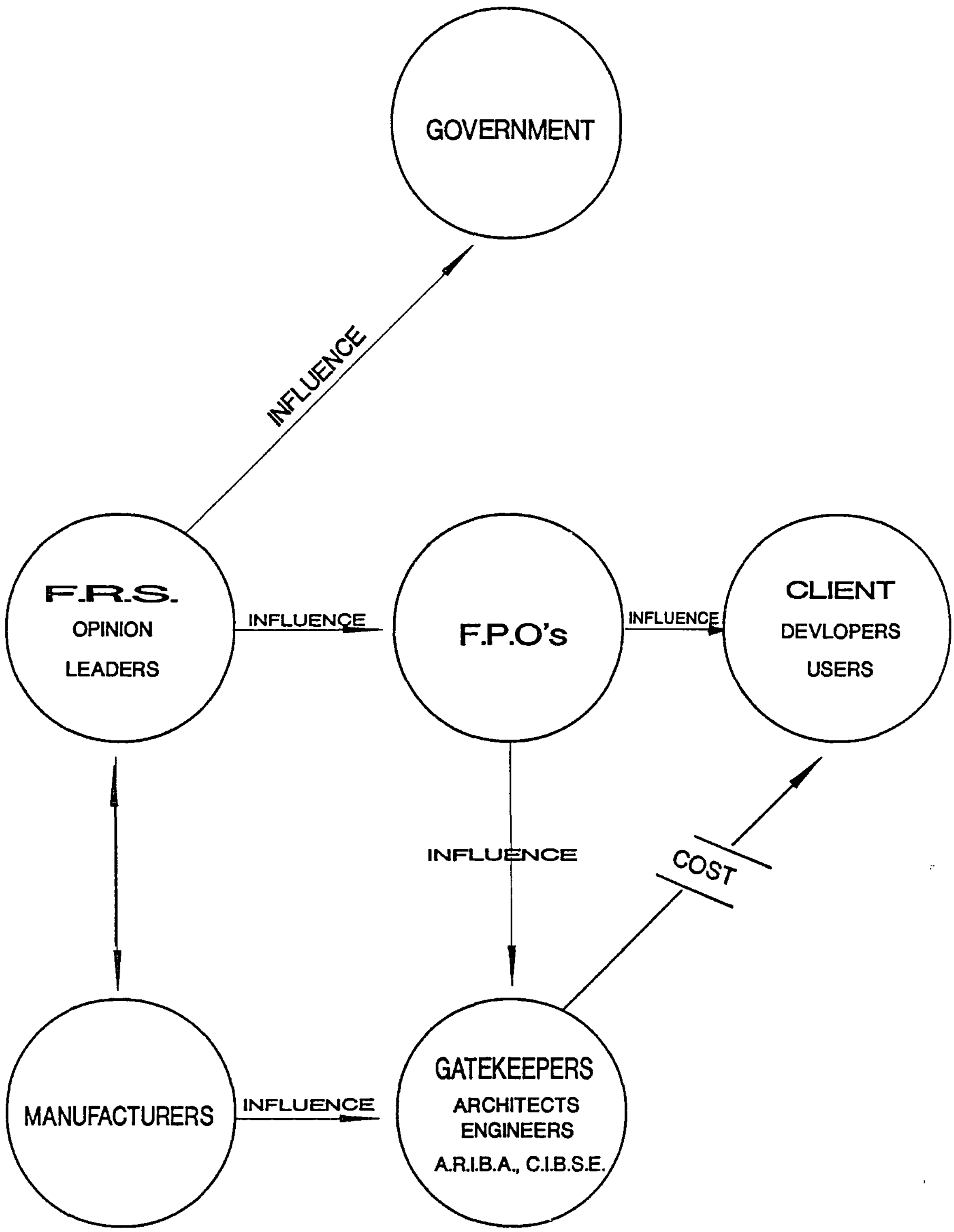
Figure 6.3.4 shows how the different groups within the diffusion network interacted prior to the Town Centre Redevelopment Guide in 1972 which effectively mandated smoke control in shopping centres. The F.R.S. played the major role in influencing Government to bring about this legislation. The Fire Prevention Officers acting from the sixty plus Fire Prevention Departments in the UK are the enforcing arm of fire prevention legislation, but before 1972 there was little the F.P.O's could do to ensure smoke control was installed in shopping centres. They could only act as influencers to the members of the Building Design Team. Indeed, because of the cost of smoke control installations, proposals to incorporate it in buildings were turned down. The Engineers and Architects involved in the design of buildings were reluctant to add cost to a project and run the risk of project cancellation. Because of this reluctance the engineer's role could very much be seen at this stage to be one of gatekeeping, i.e., the reluctance to pass on information on smoke control to the client. In other areas than shopping centres, for example factories, impetus to use smoke control came from the client (e.g. General Motors) because of the perceived risk to building and contents in the event of a fire.

2. The Fire Research Station

The Fire Research Station (F.R.S.) was the most powerful influence on the diffusion of smoke control in the UK. Indeed, they played the central role in the diffusion process.

FIG 6.3.4.

The Roles of Members of the Smoke Diffusion Network after Legislation



The F.R.S. diffused its research through its close contact with the F.P.O's as well as through the medium of its Fire Research Publications. (In the USA a similar role was undertaken by the Fire Research Centre). In fact most Engineers and F.P.O's gained their knowledge of the subject from these publications.

3. Opinion Leaders

Individuals from the F.R.S. became very influential. H.P. Morgan stands out in particular because of his research on smoke control for covered shopping centres. Opinion leaders such as Morgan were very important in the early states of diffusion and the behavioural characteristics of these individuals almost matched the established profile of opinion leaders. It was found they had good communication with all the members of the smoke control network. Discussions with H.P. Morgan revealed that he and his colleagues at the F.R.S. had extensive contacts in industry and education. They were innovative by definition, ie. most of the basic design methods for smoke control originated at the F.R.S. They were accessible, in fact, between 1972 and 1985 all schemes for shopping centre smoke control were referred to the F.R.S. even before the F.P.O's and Engineers contacted the F.R.S. direct for advice on smoke control design. However, socio-economic status had no influence on their position as opinion leaders, instead their position was based on technical ability and research. This variation in the traditional profile of opinion leaders would be normal for this type of technical development.

Other influences supported the opinion leaders in the diffusion process. Publicity attached to the catastrophes instigated research and development into smoke control. These events usually hit the mass media. There is no more recent example of this than the publicity surrounding the Kings Cross disaster in 1987.

4. Manufacturers

Diffusion has also been helped by manufacturers who, realising the business opportunity presented by smoke control, have developed design methods and products based around this research undertaken by the F.R.S. Some manufacturers have promoted their systems and products at seminars attended either by groups of Architects, Engineers or Fire Prevention Officers. As mentioned earlier it is important to differentiate between these groups, as each requires differences in presentation, e.g. Architects would have more interest in aesthetics and therefore the appearance of the equipment; Engineers would have more interest in the function and performance of the products; F.P.O's would have more interest in the functioning of the final design. Attending seminars in the cause of this research it was found that the manufacturers constantly referred to opinion leaders in order to give source credibility. The lecturers were always individuals who were very experienced in smoke control design. In fact the manufacturers fielded people not only experienced in smoke control design but also in sales techniques. This enabled them to identify the independent characters in the group and tailor the seminar to cope with these characters. The communication skills possessed by the lecturer enabled him to establish an empathic and often homophillous relationship with the audience. Breaks from the seminar were used to form associations with these potentially influential characters in order to influence the majority. All delegates at the seminar were asked to voice their opinions and objections, not only at the end of, but also during the session. This did identify those who had some doubts about the concept or application of smoke control and enables the process of persuasion to take place. Often these independent individuals matched the profile of opinion leaders identified in the research in that they were higher in status within the group, e.g. Section Leaders or Senior F.P.O's who had more knowledge of the subject and because of their position more likely to have contact with other groups. Identification of these influential individuals also enabled the manufacturers' representative to concentrate their efforts on persuading these individuals on subsequent visits, ie. via inter-personal communication.

5. Education

Also at work in the diffusion process was education although research revealed that this was very limited. The Fire Service College taught smoke control design to Fire Prevention Officers. In the private sector Edinburgh University has a special section devoted to fire safety engineering. Dr Marchant, the head of this faculty, demeans the small amount of time devoted to the subject for Architects (however this view tends to ignore their large curriculum.) South Bank Polytechnic, London, have also been involved in the teaching of the subject, they have strong links with the F.R.S. This imbalance, (all F.P.O's go to the Fire Service College whereas only a small number of Architects and Engineers go to Edinburgh or South Bank) has led to more knowledge of the subject by F.P.O's and this is reflected in the results, i.e. 8 of the F.P.O's were aware before 1972 compared with only 3 of the Engineers. This does suggest that more time and effort should be devoted to the teaching of smoke control design to Architects and Engineers.

The end result of diffusion is adoption and, as will be seen next, this process of adoption commenced in the UK around the 1950's. Diffusion and adoption in the UK received a boost with legislation introduced in 1972.

6.4 Adoption

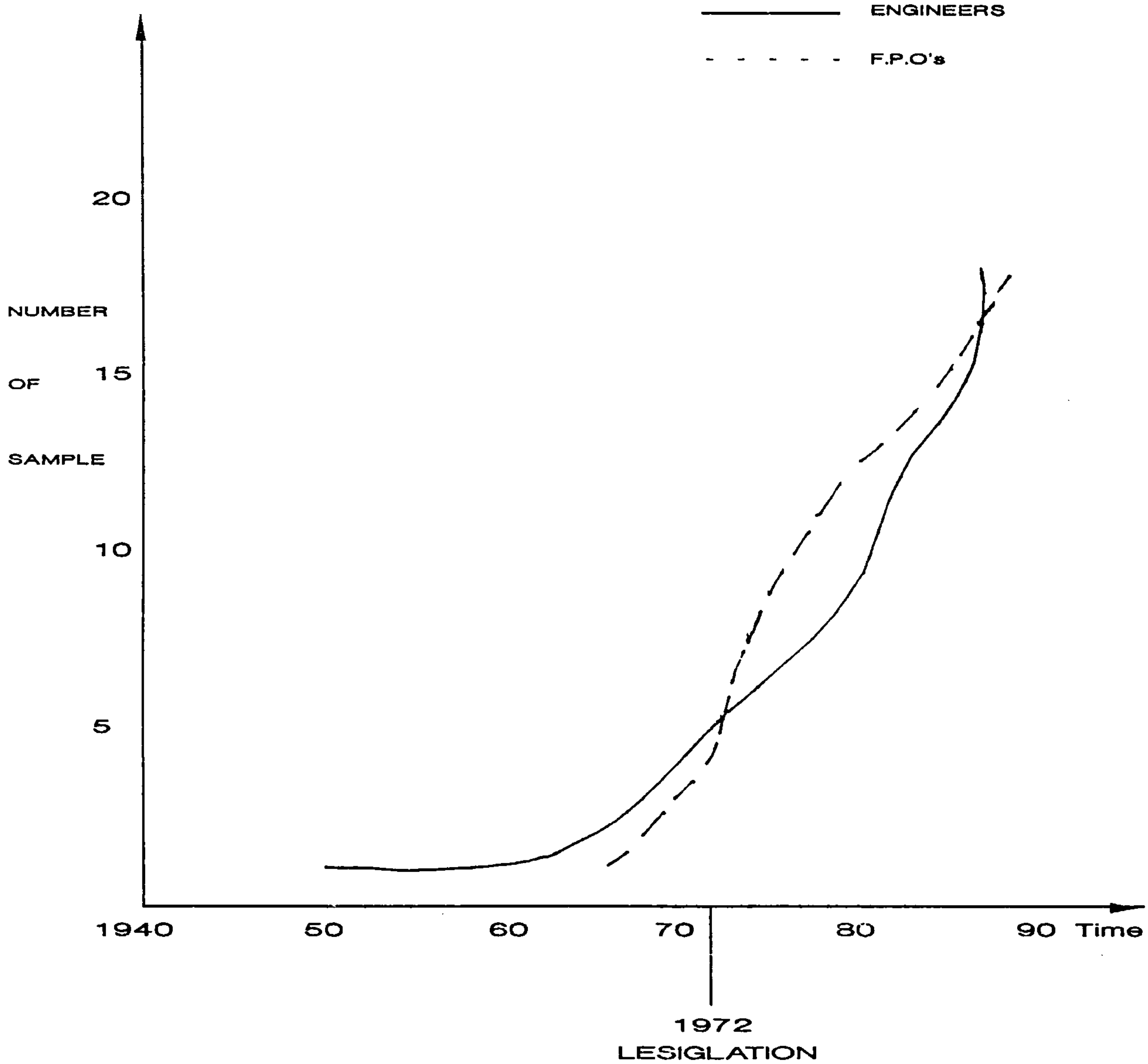
The research results gave adoption rates for Engineers and F.P.O's as individuals and on the part of their companies and organisations. There was no significant difference between individual or organisational adoption dates. These results can be found in Appendix X.

6.4.1 Adoption Rate

Figure 6.4.1 shows the adoption curves for the UK Engineers and F.P.O's. The curves are almost identical for both groups and illustrate the increase in adoption after 1972 which occurred largely as a result of legislation. Of particular interest is the early part of the curve; this identifies the innovators and early adoptors. The research did establish that 15% - 16% of the sample.

FIG. 6.4.1

Adoption of Smoke Control for Engineers and Fire Protection Officers in the United Kingdom



fell into this category. This matched the traditional distribution pattern given below:

Innovators - the first 2.5%

Early adoptors - the next 13.5% - 16%

Early majority - the next 34%

Late majority - the next 34%

Laggard - the last 16%

The research also shows that the rest of the sample followed this distribution pattern in that the majority of the sample adopted after 1972 with the last 16% adopting after 1985/6.

6.4.2 Identification of Early Adoptors

It is the behaviour, with particular regard to communication, of the early adoptors which is of interest. Previous work by Rogers shows that early adoptors are more highly connected in the social system and are more cosmopolitan,ie their networks are likely to be outside rather than within their social system. In addition, they tend to seek information more actively, have greater exposure to change agents and have more exposure to mass media communication channels. They are also likely to have a higher degree of opinion leadership and, finally, they are likely to have a greater knowledge of the innovation. Analysis of these behaviour patterns in Chapter 5 revealed that the early adoptors identified in the study had communication behaviour which was similar to the above profile but can now be seen to relate to the behaviour of companies as well as the individual behaviour on which Rogers based his theories.

6.4.3 The Communication Behaviour of Early Adoptors

Early adoptors had more contact and more information exchange with professional bodies, they also viewed their membership of these bodies as useful. Early adoptors also had up-to-date information systems. There is also some indication that the organisations themselves were innovators as those who gave little discretion in design adopted earlier, ie. they acted as early adopter organisations rather than leaving adoption to the individual Engineer. Finally, those organisations who adopted earlier tended to have up-to-date company information systems.

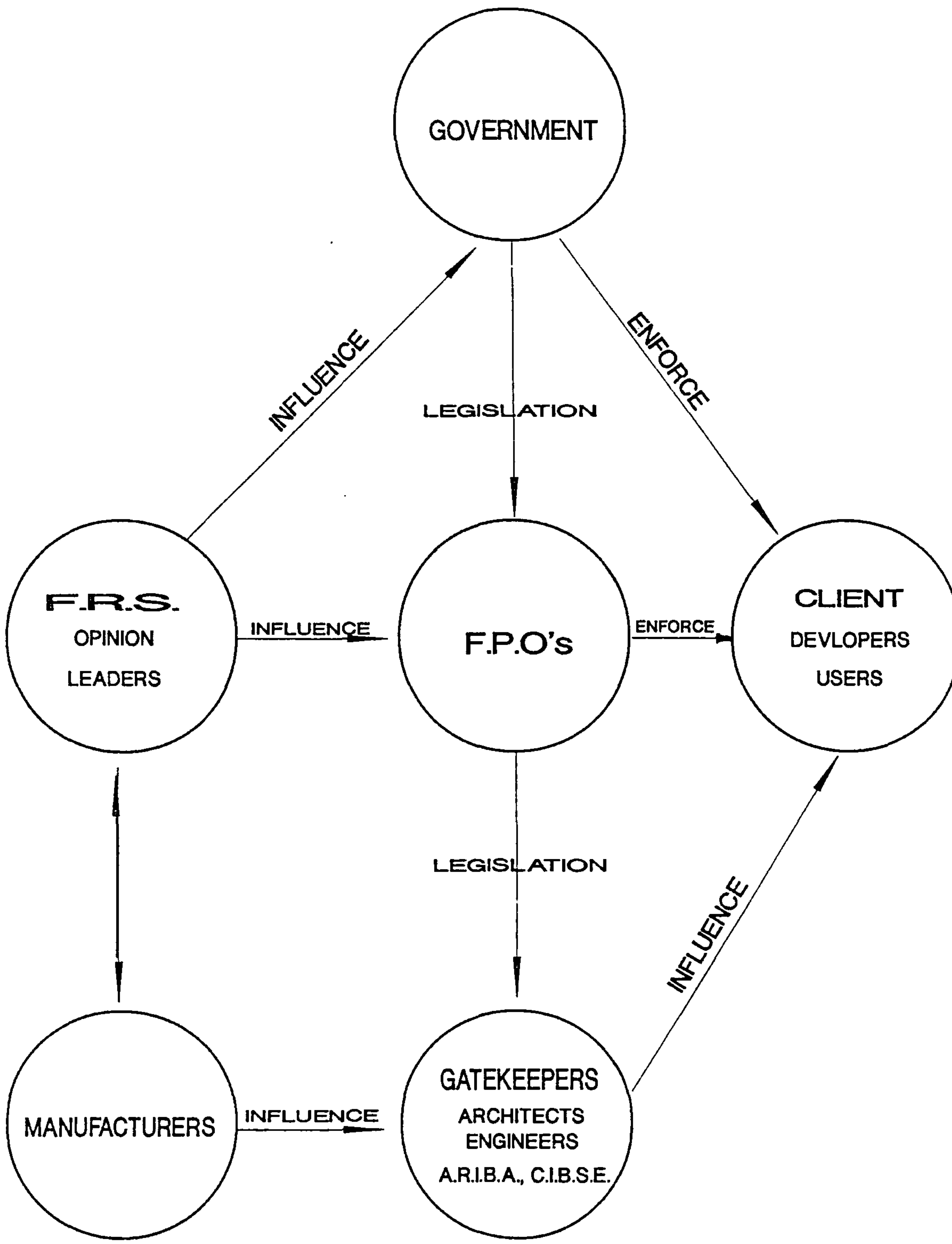
These conclusions are summarised into a skeleton profile for the behaviour of early adopter companies, given in Chapter 5 and shown again in Chapter 7, which summarises the conclusions and gives recommendations and suggestions for future research.

6.4.4 Adaptation

One of the problems with both the diffusion and adoption of smoke control is accurate definition of the innovation. In Chapter 2 it was shown that there was disagreement on the definition of different types of smoke control. This can lead to potential adoptors defining the concept in their own terms and thus modifying the concept. This process of adaptation was identified in one Local Authority. In the early days of diffusion the Local Authorities' regulations used floor area as a basis of design criteria. This meant that designs for smoke control systems approved by that Authority took little account of fire size and risk of combustion. In the U.S.A. smoke control as a term is often used to describe pressurisation, therefore the ill-informed may believe pressurisation is the only form of smoke control and thus not apply the concept to other methods of fire safety, again a form of adaptation. There are enough problems in diffusion without the added complication of lack of clarity of the definition of the innovation, but with continually developing technological innovations this lack of definition is likely to occur.

FIG 6.4.5.

The Roles of Members of the Smoke Control Network after Legislation



6.4.5 The Changing Roles of Members of the Smoke Control Network

The roles of the members of the smoke control diffusion network prior to the 1972 legislation have been discussed earlier and shown in Figure 6.3.4. The roles of some members of the diffusion network changed after legislation and this is shown in Figure 6.4.5. The F.P.O's role changes after legislation from that of an influencer in the diffusion process to enforcers of the adoption of smoke control. Now Engineers and Architects who may have formally acted as gatekeepers of smoke control information became positive influencers and promoters of its use, as a building without an approved fire safety system will not obtain a fire safety certificate and will not be allowed to open by the Building Inspector.

6.4.6 The Decision Making Unit

Involved in a building project are the Developer, the Architect, the Manufacturer, the Design Engineer, the Building Inspector, the Fire Prevention Officer and the Contractor. In Chapter 3 it has been shown how these members of the building project act as a decision making unit (D.M.U.) and how each member can change in importance during the buying process, ie. in the initial stages the Architect and Developer play an important role in terms of the decision to build and approval of design. As the process moves on, Design Engineers, Manufacturers, Fire Prevention Officers and Building Control become involved and, finally, the Contractors are appointed to construct the building; it is at this stage that actual buying takes place although much work has already taken place on the persuasion of different members of the D.M.U.

Manufacturers seek to persuade the D.M.U. to adopt a smoke control scheme by techniques such as the use of source credibility, e.g. they would refer to their design as approved by or based on F.R.S. design criteria and possibly refer to opinion leaders such as H.P. Morgan to establish status prestige. They would develop trustworthiness by quoting or even arranging visits to completed and successful projects and arranging demonstrations of their products. Seminars which have been discussed under diffusion would also be used to show their expertise in design. In addition, the salesman will be expert at the identification of independent characters within the group and attempt to influence them. They will also be aware of group norms and whether in fact the group views smoke control positively or not, (there are still some who believe it is wrong to ventilate a fire because the increase of oxygen brought about by ventilation, encourages combustion and thereby intensity and duration of fire. However, this argument does not help individuals caught in a smoke filled building. Most deaths in fires are as a result of asphyxiation due to smoke.)

6.4.7 Change Agents

In his role selling to a D.M.U. the manufacturer's representative acts very much as a change agent. The change agent's role is that of developing a need for change in the potential adopter. With smoke control this could be moving people from the view that fires should be sealed and not ventilated thereby establishing the need for smoke control, or by simply bringing awareness to the client of legislation and recommendation surrounding the necessity for smoke control. Change agents also need to establish an information exchange relationship and develop a rapport with the client. This he can do be creating credibility in his competence and trustworthiness and by identifying with the client's needs and problems. It is here where the concept of homophilly (cognitive similarity) is perhaps at its most important. Engineers were selected to sell to Engineers as their similar background provided this cognitive similarity. The representative also was able to provide a design tailored to suit the building thus helping to diagnose and solve problems. His success would be very much related to his degree of effort in terms of contacting clients and using all his persuasion skills. The research did not examine the change agent's efforts but it was evident from discussions with manufacturers that there was variation between salesmen.

Thus the change agent moves his client through the process of diffusion to adoption. Although the change agent's role has been described with reference to manufacturers' representatives, many of the opinion leaders in smoke control have in fact contacts within industry and in fact have undertaken a change agent's role particularly at the early stage of diffusion, ie. from 1950 to 1970.

CHAPTER 7

7.1 Introduction

This chapter examines the implications that the analysis of the research findings in Chapter 6 has to the diffusion and adoption of Smoke Control. It concludes with recommendations for the smoke control industry and suggestions for further academic research.

7.2 Diffusion and Adoption in the U.K.

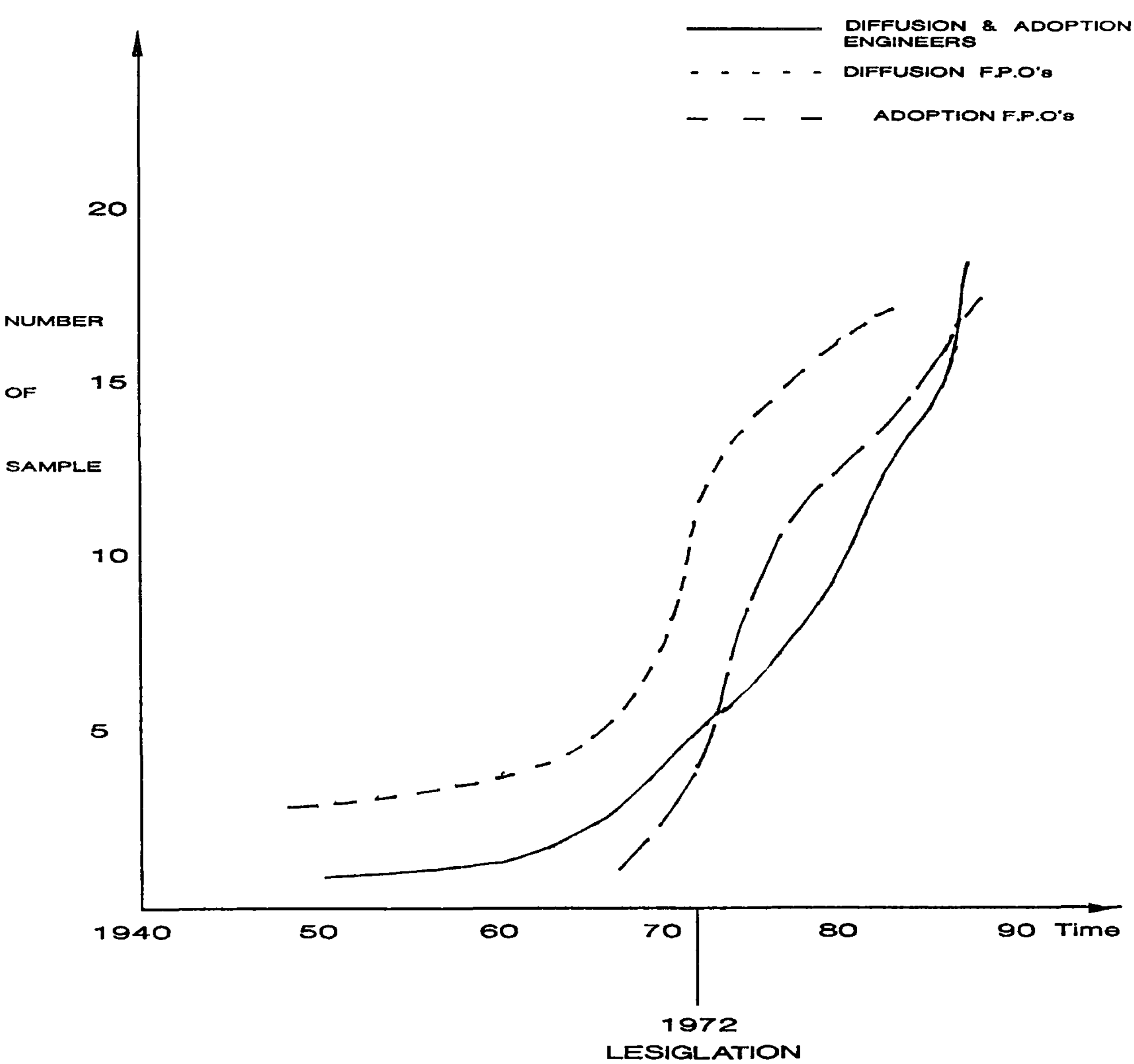
Both the diffusion and adoption of the concept of smoke control in the U.K. has been traced from its application to factories in the 1950's through to shopping centres in the 70's and 80's. Of course there was diffusion and adoption before 1950; Chapter 2, which describes the history of smoke control shows how there was a need for theatre smoke control from as early as the 1900's. But as the study relied on recall for its information on diffusion and adoption no evidence of this was recorded. If Figure 6.3.1 and 6.4.1 are superimposed, (see Figure 7.2), the relationship between adoption and diffusion can be seen. There is a noticeable difference in the diffusion rate between the two groups examined, ie. Engineers and F.P.O's. Examination of this difference leads us towards answers to the first question posed in Chapter 1.

7.2.1 The Unevenness in Diffusion and Adoption

Why did a concept originating in the 1900's present such an uneven picture in terms of adoption in the 1980's? The reasons behind this are two-fold: First the F.P.O's are directly connected to the F.R.S. and in fact are part of the central diffusion network. Secondly, attached to this is the influence of education. The Fire Service College served all F.P.O's and is a continuous source of up-to-date information on the latest developments in fire safety.

FIG. 7.2

Diffusion and Adoption of Smoke Control for Engineers and Fire Protection Officers in the United Kingdom



The Engineers who were not closely connected with this diffusion network relied on 'ad hoc' access to publications and manufacturers to supply their information needs. Furthermore, before the 1972 legislation requiring smoke control in shopping centres the Engineers could act as gatekeepers of smoke control information, either ignorantly, ie. if there was no statutory need for smoke control why should they find out about it? Or actively, by not passing information on to their clients, Architects and Developers. This is illustrated by the fact that F.P.O's were aware earlier than the Engineers. One could summise from this that if the Engineers had been closer to the central diffusion network, ie. the F.R.S. and F.P.O's they would have had greater awareness of the subject. At whose door should this lack of awareness be placed? There are a number of candidates. The Engineers and Architects have a trade association, respectively The Chartered Institute of Building Services Engineers (C.I.B.S.E.) and the Royal Association of British Architects (R.I.B.A.), who could have played more active roles in the dissemination of information and on education in the subject. Formal education could also have assisted diffusion more. The research revealed that little attention had been paid to the subject in architectural courses (it is true that some evidence was uncovered of effort in this direction in Edinburgh University and South Bank Polytechnic). Little has been said about insurers, as they tended to be uncommitted in the view of the need for smoke control. However, insurance discounts for buildings with smoke control have helped diffusion and adoption. There is an organisation devoted to Fire Protection, and perhaps they could have been more active in the promotion of smoke control. Finally, the faster legislation is introduced the faster smoke control is adopted. Legislation evens out adoption and this can be seen by the similarity between adoption curves of F.P.O's and Engineers. To summarise, closeness to the central diffusion agency, more education and quicker legislation would help address the unevenness in awareness of safety innovation.

There are many forces at work other than education in the diffusion process and these too will affect diffusion. Perhaps the most important related to closeness to the central diffusion network that is the presence of opinion leaders. These have been identified and are concentrated at the F.R.S. Also the decisions of manufacturers in diffusion agency strategy may single out one group instead of another; this can affect diffusion and in fact there is some evidence that this has occurred. Finally, the efforts of change agents can have effect on the rate of diffusion between different groups. If he relates more to one group than another that group will have better access to the diffusion network.

7.2.2 The Variation in Acceptance of Smoke Control in Different Areas of Commerce

Turning now to the second question: Why is there such variation in acceptance in different areas of commerce? The answer to this question appears to lie in the way the smoke control industry has developed. It has been catastrophe led! In 1881 a fire in the Ring Theatre, Vienna, killed 449 people; in 1905 another fire in the Iroquois Theatre, Chicago, killed 571. This resulted in legislation requiring auditorium smoke ventilation. In 1953 a fire at General Motors killed 3 people and cost $55 million. This was followed by a fire at Vauxhall Motors in the UK, damage £3.5 million. This resulted in recommendations for smoke ventilation in factories, from the F.R.S. In 1969 a major fire at the Wulfrun Shopping Centre in the UK occurred after shopping hours. The loss of life which could have occurred had this fire taken place during the day could have been tremendous. This resulted in the Town Centre Redevelopment Guide 1972 requiring smoke ventilation in covered shopping centres followed by a further research paper on shopping centres by Morgan in 1979. Thus, legislation has followed tragedy and has been the result of disasters in specific areas. Smoke control is now accepted in theatres, factories and shopping centres. There is also Home Office legislation requiring smoke ventilation in prisons. Other areas such as warehouses have no requirements. Banks, office buildings have some legislation for escape ways but little for work areas. It appears then, that for smoke control to be applied in areas other than those above, there will need to be a disaster. This was illustrated dramatically in 1987 at Kings Cross underground. This disaster prompted a complete examination of fire safety in the underground and resulted in replacement of escalators and a smoking ban. It is hoped that underground transport authorities in other areas and in other countries will take note of the disaster and react similarly.

Of course, other factors can have influence in diffusing smoke control to other areas of commerce. Diffusion agencies of manufacturers may identify risk areas not yet covered and attempt to diffuse the concept to them. Change agents may be active in sourcing these new market areas. However, the main influence in deciding which areas of industry and commerce have smoke control is disaster, and the following legislation.

7.2.3 Factors Influencing Adoption

What were the factors that influenced adoption? These have been well summarised previously in this chapter when we have identified the roles of the F.R.S. and the F.P.O's. Opinion Leaders, Manufacturers, Change Agents, etc. We also looked at how persuasion techniques have been used both in seminars and to persuade decision makers in the D.M.U. To summarise - the central diffusion agency in the U.K. was the F.R.S. through research publications and its network of F.P.O's. Alongside this were the manufacturer diffusion agencies working to persuade the Architects, Engineers, etc, to adopt smoke control. Publications from the F.R.S. were the main influence towards the use of smoke control.

7.2.4 The Acceleration of Diffusion and Adoption in the U.K.

Already the study has identified areas which have affected diffusion such as legislation, education and closeness to the diffusion network. However, a most important result of this study was that early adopter companies could be identified by their communication behaviour. This analysis is summarised earlier in Chapter 6 under Adoption, and a profile for companies or organisations who may be likely early adopters is given in Chapter 5. The profile for these early adopters is given again in the conclusion of this chapter. Identification of early adopters would greatly assist organisations and companies involved in the diffusion of innovation.

7.3 Diffusion and Adoption in the U.S.A

The analysis thus far has been almost wholly concentrated on the U.K. and we can now examine what relationship there is between diffusion and adoption of smoke control in the U.S.A. to the process in the U.K. Does it present the same uneven picture in terms of acceptance between different members of the diffusion network and with different areas of commerce? Are the factors influencing adoption similar to those in the U.K? Finally, can diffusion and adoption be accelerated in any way?

7.3.1 The Unevenness in Diffusion and Adoption

The position in the U.S.A. is somewhat worse than that in the U.K. and the main reason behind this is the much more autonomous way in which its States and Cities operate. In Chapter 5, Figure 5.2, the structure of the U.S.A. smoke control industry is given, this shows how recommendations and regulations are disseminated through three code setting bodies, the International Conference of Building Officials (I.C.B.O.) in the west of the country, the Southern Building Code (S.B.C.) in the south, and the Building Officials and Code Administrators (B.O.C.A.) in the east. Thus, the Fire Research Centre at the Bureau of Standards, Washington, does not play as central a role in diffusion as its U.K. counterpart, the F.R.S. Indeed, the code bodies themselves decide what recommendations go in their codes. The code bodies are independent organisations and are not officially tied to the Government. They take their input from trade associations and other interested bodies such as the Insurance and The National Fire Protection Agency (who are also part of the diffusion network), as well as from Government. Furthermore, there is choice for the State or City to adopt a particular code body or not. The F.R.C. appears to concentrate more on basic research and less as a champion of diffusion than the F.R.S. This leaves the code bodies as the main arm of diffusion of smoke control design recommendations. From the Sumner Ryder report only 31% of all these bodies mandated heat and smoke vents, whilst a further 24% established guidelines for vents - a total of 55%. Thus the code bodies themselves are very uneven in their acceptance of smoke control and this is bound to result in uneven diffusion and adoption by Engineers and Architects.

Discussions with Engineers in the U.S.A. revealed a mixed picture with little evidence of direct connection to anything other than the prevailing codes in the geographical area they were operating in. One Engineer in Chicago was very active in his pursuit of information but he seemed to be the exception as an early adopter. The research did identify a fire consulting firm who had direct representation at the F.R.C. and on other bodies concerned with Fire Protection Codes. However, the total picture seemed very mixed from state to state and city to city. It may be that because of this variation in codes over the U.S.A. that Engineers tended to act in a similar manner to the Engineers in the U.K. before legislation, ie. as gatekeepers of smoke control information.

7.3.2 Variation in Acceptance of Smoke Control in Different Areas of Commerce

Of the two main smoke control design guides identified, one, published by the National Fire Protection Association in 1985, Ref. 204M, dealt with only natural smoke ventilation and not powered, (natural smoke ventilation is simply the provision of louvres or other devices which open in the event of fire whereas powered includes fan assisted smoke ventilation). A similar publication in the U.K. covers both. The other, published by The National Bureau of Standards in 1983, was a much more comprehensive design guide but did concentrate on pressurisation, a method most commonly used for smoke control in high rise buildings, which is understandable, given the prevalence of this type of building in the U.S.A. Nevertheless, these guides leave many areas of design confused, eg they do not cover shopping mall smoke control design in any detail; also, problems which are common to the U.S.A. and U.K. ie. Atria smoke control design and the use of sprinklers and vents together, are not dealt with. This guide, however, is the most comprehensive available in the U.S.A. and has been adopted by the American Society for Heating Refrigeration and Air Conditioning Engineers (A.S.H.R.A.E.). This is a step in the right direction for the diffusion of smoke control. John Klote, the author of this publication is active in persuading States and Cities to adopt the guide into regulation. Thus he is an opinion leader by virtue of his and his colleagues' research and has taken the role of a change agent by actively promoting smoke control. It is worthwhile commenting on the dates of these publications, they are much later than the dates of similar U.K. publications and thus lead to the conclusion along with the uneven adoption on the part of the code officials, that the U.S.A. is still at the research and development stage of smoke control design. There would be much support from the Fire Service in the U.S.A. for a wider incorporation of smoke control requirements into codes, 80% were positive in support of heat and smoke venting and thought that codes were the major factor in determining whether buildings were ventilated or not.

7.3.3 Adoption Rate

The Engineers interviewed mostly adopted between 1965 and 1973. This similarity with adoption in the U.K. seems to emanate from a general rise in interest in the subject in both countries brought about by disasters. However, it was not clear what the Engineers had adopted, ie what they regarded as smoke control, as there were no standards set at that time. Engineers presented a confused picture in their descriptions of smoke control design.

7.3.4 Factors Influencing Adoption of Smoke Control in the U.S.A.

Already mentioned are the F.R.C. and opinion leaders such as Klote, although they seemed to play a reduced role in relation to their counterparts in the U.K. Perhaps of as much, if not more importance, was the Fire Protection Consultant who had high presence in all bodies involved in the smoke control industry, thus acting as both opinion leader and change agent. Because of the high cost and increased likelihood of litigation in the U.S.A. there was a great incentive for Engineers to off load responsibility to such a specialist.

As far as manufacturers were concerned most Engineers did not identify smoke control with any particular company and indeed selected individual components from a variety of manufacturers who in themselves were not particularly devoted to smoke control products. Thus, manufacturers played a less active role in the diffusion process. One manufacturer was identified who specialised in smoke ventilation however, their products were behind in design and technical sophistication in relation to those in the U.K. A reflection not so much on the manufacturer, but on the undeveloped nature of the smoke control industry in the U.S.A.

7.3.5 Acceleration of Diffusion and Adoption

Diffusion and adoption of smoke control in the U.S.A. appears to depend on similar factors to those identified in the U.K., ie. education and legislation. However, the less centralised diffusion network, ie. three code bodies and the less defined nature of smoke control design method presents different problems, these will be summarised in the conclusions. The research in the U.K. identified a company profile for early adopters; this could be as used in the U.S.A. to help manufacturers identify early adopters. However, the norms will be different, e.g. all engineering design firms visited had up-to-date information systems, unlike the U.K., all Engineers were qualified to degree level, many Engineers in the U.K. were not. Thus, an accurate survey would be needed, based around the profile, to establish these norms, before the potential early adopters could be identified.

Thus, the basic questions which the research addressed have been answered. These conclusions can now be summarised.

7.4 Conclusions

1. Diffusion and adoption curves were developed for the U.K. smoke control industry. These showed that the main push forward in diffusion and adoption occurred in the late 60's and 70's. Legislation mandating smoke control in shopping centres in the U.K. was the main factor behind this acceleration in adoption.

   This time period coincided with diffusion and adoption of smoke control in the U.S.A. although this did not appear to emanate so much from particular legislation but from a rise in interest brought about by the development of more sophisticated buildings such as covered Malls and Atria which entailed more fire risk.

2. That connection to central diffusion agency was desirable for agencies and companies involved in the diffusion of smoke control in the U.K., this agency, the F.R.S., was relatively easily accessible. In the U.S.A. because of the large geographic area and the split of code setting authorities into 3 regions, east, south and west, it could be more

difficult; however, it still could be beneficial. This was reinforced by the close connection of a leading Fire Consultant with the F.R.C. and code bodies as well as its other contacts with the N.F.P.A. and the insurance industries.

3. Adoption of smoke control in different areas of commerce has largely been as a result of disasters in that particular area. Thus smoke control is accepted in theatres, car factories, covered shopping centres, and in the U.S.A. in particular, high-rise office and hotel developments. Thus, other types of buildings which have not suffered disaster or have had disasters which have not been sufficiently publicised, will be later in having smoke control incorporated in their design.

4. There were a number of other factors identified in the research which affected diffusion and adoption. The action of opinion leaders in the central diffusion agencies in both countries was important. These opinion leaders almost matched the behaviour profile of opinion leaders identified in the study. Manufacturers in the U.K. seemed fairly active using their representatives as change agents to persuade the building designers to adopt smoke control. There was little evidence of manufacturers taking such a role in the U.S.A. Education also had a part to play in the U.K. The F.P.O's who had formal training in smoke control at the F.R.C. were aware earlier than the Engineers. This was not matched in the U.S.A. where little evidence of formal education was found for any group. It is suggested that the professional organisations of Engineers and Architects, etc, should be more involved in the teaching of smoke control design.

5. Design methods in the U.K. were more developed than in the U.S.A. It is agreement on design criteria which would make more universal the acceptance of smoke control by the different code bodies in the U.S.A. However, in both countries there was argument about design methods of some areas of smoke control.

6. Analysis of the U.K. results revealed a framework for a company profile for early adopters.

A COMPANY PROFILE FOR EARLY ADOPTERS

The company would have higher than normal presence in associated professional organisations and would view that presence as useful. It would have a higher than normal degree of contact and exchange of information within the profession. It would be systematic and up to date in its information system.

The development of this profile as applied to companies and organisations as opposed to individuals could be very useful as a marketing tool for manufacturers who wish to diffuse innovations. In fact the profile could be developed even further and perhaps be refined to enable manufacturers to more easily identify the innovators and early adopters within a particular industry.

However, it is important to define the 'norms' of the particular target organisations. These can only be established by a survey of particular groups or companies involved in the industry. Indeed, evidence showed that there were differences in the norms of information and education between the U.S.A. and U.K.

7.5 Recommendations and Suggestions for Further Research

7.5.1 Recommendations for the Smoke Control Industry

1. Lack of mandatory requirement which still exist today focuses attention on the process of transferring innovation in safety from technical design recommendations to regulation. This is more apparent in the U.S.A. than in the U.K. It is the acceleration of this process which could save life and property. This is shown by the advent of shopping centre smoke control legislation which brought adoption forward. Further research is needed for other types of buildings.

2. For mandatory requirements on smoke control to be set, agreement on design methods is necessary, particularly in the U.S.A.

3. More effort needs to be put into education in smoke control design both in the U.K. and the U.S.A.

4. Manufacturers and other organisations active in the diffusion of innovations which have a central diffusion agency, should have close contact with this agency.

7.5.2 Suggestions for Further Research

1. The company profile for early adopters could be further developed by research into different industries to test the profile and to search for other factors to fill it out. Further development of this profile could be of immense use to the acceleration of the adoption of innovations in industry.

2. Further study of group behaviour in industrial buying situation, ie, the D.M.U., would be of interest, to test existing theories which are largely based on voluntary groups.

3. Research into the problems of setting up overall "champion" bodies to diffuse and supervise the diffusion of particular safety procedures in smoke control is suggested. This would concentrate on various Government bodies such as Health and Safety.

ADDENDUM

A review of the interrelation of Building Regulation and Fire Certification was published this year, 1990. The review entitled "Fire and Building Regulation" by Bickerdike Allen Partners, was commissioned by the Department of Trade and Industry. Its recommendations largely agree with the conclusions of this thesis in that two main areas need addressing, regulation and education. Extracts from some of its recommendations are summarized below:

Recommendation No. 1

A comprehensive national guidance document on achieving approvals of fire safety should be published to clarify for building regulation applicants all relevant legislature and procedural matters.

Recommendation No. 2

A comprehensive design guide should be prepared covering all aspects of fire safety in most types of building as a basic text for professional use.

Recommendation No. 9

The educational development of building designer, building control officers and fire prevention officers should be encouraged by the early establishment of a national network of professional development courses.

Thus it appears that the Department of Trade and Industry has taken the role of champion in the issue of fire safety. Action on the recommendations is awaited.

Ref. Fire and Building Regulation. A Review by Bickerdike Allen Partners, H.M.S.O., 1990.

APPENDIX (i)

Definitions of Smoke Control

1. <u>Smoke Control</u>

The generic term, smoke control, covers any technique for dealing with smokey gases, protecting means of escape, or any other objective, and includes the following:

2. **Smoke Ventilation**

Technique using the buoyancy of hot smokey gases, above escape routes, or any other objectives, in the same space as the fire. This is achieved by removing smoke from the buoyant layer and replacing it with fresh air below. Smoke ventilation can be divided under two headings:

(a) Smoke Venting - the removal of smokey gases from a space using natural ventilation;

(b) Smoke Extraction - the removal of smokey gases from a space using powered extraction.

3. **Smoke Dispersal by Cross Ventilation**

A technique using air passing through a corridor, stairwell or other space to continuously dilute the smokey gases to a safe level.

4. **Smoke Clearance**

A process using any method for removing smokey gases from any space when smoke is no longer entering that space.

5. **Smoke Containment**

Any system of physical barriers limiting the smokey gases passing from one space to another.

6. **Pressurisation**

Raising the pressure in a space sufficiently to prevent smoke entering that space from an adjacent space.

7. **Depressurisation**

Lowering the pressure in the space containing the fire sufficiently to prevent smoke entering adjacent spaces that must be kept free of smoke.

APPENDIX (ii)

The Research Traditions Involved in Diffusion Research

Diffusion Research spread from anthropologists in Europe to anthropologists in the U.S.A.[1 & 2] around 1920.

1. **Anthropology**

The anthropological school concerned itself in the main with the transfer of technology from one culture to another and as such considered an innovations compatibility to existing cultures important, e.g. the failure of a water boiling campaign in a Peruvian village[3] suggested difficulty in adoption for culturaly incompatible innovations.

2. **Sociology**

The 1920s/40s saw the rise in sociological diffusion studies. These were generally concerned with the diffusion of a single innovation over a geographical area. Two points regarding these early sociological studies are worth noting. The first is the use of quantative data analysis; a methodological approach that was to be followed by other research traditions. The second is the discovery of the importance of inter-personal channels in comparison with mass media was greater for late adopters than for early adopters, Bowers[4].

3. **Rural Sociology**

Perhaps the greatest influence on diffusion research was made from rural sociology. To date it still accounts for 26% of all diffusion studies, the largest single identifiable school of diffusion research, although its popularity has declined from its peak in the mid-sixties when it accounted for 45% of all studies. Since 1974, rural sociology has accounted for only 8% of new diffusion studies, indication of the tendency towards other schools or more multi-disciplinary research. It is basically concerned with diffusing the results of agricultural research through to farmers and it is therefore not surprising that this research field proved very popular with colleges of agriculture. Perhaps the most influencial of the rural sociological diffusion studies was the Hybrid Seed corn study by Ryan and Gross, 1943.(5) This study looked at the diffusion of a new corn seed, with 20% increased yields, amongst farmers in Iowa. The adoption was rapid, as one would expect, and after 13 years the innovation was adopted by 100% of the farmers. Ryan and Gross asked farmers by interview when they adopted and the communications channels used at each stage of the innovation diffusion process. In addition, personal data was collected from the farmers regarding education, age, farm size, income, travel, which were correlated in the study to innovativeness.

Thus, this important study headed later diffusion scholars towards pursuing certain research questions, such as what is the rate of adoption, and what factors explain this rate? What role do communication channels play in the process? What variables are related to innovativeness? These research directions are dominant to this day and form the basis of the accepted diffusion research paradigm. The study also established a prototypical methodology for diffusion investigation. Single interviews with the adopters based on the recall of the adopters regarding behaviour and decisions regarding the innovation. To a great extent the methodology used in this study follows that tradition.

As well as the upsurge in rural sociological studies in the 1920s/40s, the 1950s saw a major increase in the studies as pioneered by Prof. Eugene A Wilkeng in North Carolina, and later in Wisconsin,(6) and also Dr. Herbert F Lionberger of University of Missouri(7), e.g., agricultural diffusion was also studied at Iowa State University by Prof. G.M. Beal and J.M. Bohlen who carried forward the work of Ryan and Gross. Rogers was one of the "research missionaries" as he terms it, dating from the 1950s.

This invisible college of diffusion researchers numbering some 221 was studied by Crane(8) and it was concluded that it was a highly interconnected network of scholars who shared a common theoretical methodological framework.

The American rural sociologists expanded research in developing nations in the 1960s with funding from the U.S. agency for International Development (Rogers et al) and it is only natural that research expanded into health, nutrition and family planning.(9)

During the 1970s a radical book by James Hightower, "Hard Tomatos, Hard Times: the failure of American Land Grant College Complex,"(10) called into question the state colleges of agriculture for creating the agricultural revolution by the development and diffusion of farm innovations. "Hard Tomatos, Hard Times," studied the failure of a mechanised tomato harvesting innovation which needed harder tomatos which were lower in vitamins and created unemployment on the part of the farm labourers, as well as driving smaller farmers who could not afford the expensive machinery, out of business.

The direction of professional resources in public supported land grant colleges into innovation and diffusion ignored the consequences of the adoption of the new technologies and the ensuing social problems. This appears to have stemmed the rapid increase of rural sociological diffusion studies and resulted in redressing the balance towards the results of technology.

4. Education

Rogers(11) although recognising the importance in quantity of diffusion research from education regards it as less important to the theoretical understanding of the diffusion of innovations because the teachers' decisions are less likely to be able to influence the decision process. However, educational diffusion studies offer insight into the most complex diffusion problems; diffusion in formal organisations. It is here where sociological and anthropological research may begin to meet this complexity.

A large part of early educational diffusion studies were completed under the direction of Dr Paul Mort at Columbia University Teachers' College 1953(12) and work undertaken identified different rates of adoption for various educational innovations, e.g. Adoption of Kindergartens. Mort's work originated in the 1920/30's studying innovativeness in relation to local control over school financial decisions and continued by looking at the rate of adoption for new educational ideas. Later studies have examined intra school, inter- school diffusion, educational diffusion in developing nations and teachers as respondents rather than administrators. The latter view does hint at the organisational diffusion problem, even in authoritative situations persuasion techniques are needed. Carlson's study of the spread of modern maths in Pennsylvania and West Virginia[13] is most interesting in its study of diffusion networks.

5. **Public Health Medical Sociology**

In the 1950's, interest was being shown in the diffusion of drugs and other medical innovations to doctors and health innovations and family planning to the public.

The classic study of the diffusion of a new antibiotic by Menzel and Katz[14] of Columbia University had many parallels to the Hybrid Corn Study, (Ryan and Gross, 1943). Of particular interest was the study of networks and the role of opinion leaders in the process of adoption. Also interesting was the use of an objective measure recording adoption times thus avoiding use of recall data. The criticism of the use of recall data from the respondants is valid but often unavoidable in the absence of records or in the case of the adoption of an idea less easy to objectively record.

The C.A.P. studies of the 1960s which were surveys of knowledge attitudes and practice internationally, are regarded with one exception as being poor in their contribution to the scientific understanding of human behaviour by Rogers [15] The exception was the Taichung experiment in Taiwan[16] in which four different communication programmes were introduced in approximately 2400 neighbourhoods, each composed of 20/30 families. The programme with most success involved the use of personal change agents. The change agents reinforced the neighbourhood meetings mailed information and posters by calling on individual respondents. The spectacular success of this experiment led to an over optimistic view by development officials responsible for national family planning programmes. These were introduced in other developing nations with less success in the 60s and 70s. The experiment shows how the researcher can draw on diffusion theory to plan and initiate communication interventions. The data is analysed and used to select more effective diffusion programmes.

6. **Communication**

By 1968 diffusion research into communication had increased to second in numbers of diffusion studies. This has continued to grow to the present day.

Communication as a scientific field of study probably originated in 1949 when the "Mathematical Theory of Communications" was published by Shannon & Weaver[17]. Naturally the field of mass communication was the focus of early research. Initially, scientists from political, sociological and psychological fields began studying communications. Soon communication was established in its own right with the establishment of a communications department in many universities.

In the 1960s communication researchers began to investigate the transmission of technological ideas in a fields such as agriculture, health and education. The advantage of a communication research was that it studied the process regardless of discipline.

7. **Marketing**

Alongside the communication research in the 1960s came marketing diffusion research. The failure rate of new products (only 8% of 6000 new products have a life expectancy of even one year,[18]) shows why companies have shown an increase in interest in the research. Many of the studies undertaken are for the private use of the companies involved. In terms of numbers it accounts for the 4th largest field of diffusion research at the present day. There are ethical arguments against marketing's credibility as an academic research field. For instance, the research may be used to influence consumer adoption behaviour or that there is a bias in favour of the marketeer's motive to diffuse the innovation. How this could be distinguished from sociological diffusion is difficult to see except in individual cases and even then the view would be subjective.

8. Geography

This is one of the smallest of the research traditions accounting for only 4% of the total of publications. It boasts some respected and highly regarded contributors to diffusion although the criticism mainly directed at the school is its obsession with the spatial aspect of diffusion.

The earliest and since most closely followed of the geographical diffusion researchers was Dr Torsten Hagerstrand of Sweden whose work originated in 1952 with the Propogation of innovation waves.(19)
An empirical study in 1953 led Hagestrand to believe that the spatial order in adoption was so striking that theoretical simulation models could be created. This led to "Innovation diffusion as a spatial process" published in 1967 in English in the USA.(20)

Acknowledging Hagerstrand as a catylist, Prof. L A Brown went on to develop what he saw as an anomaly in Hagerstrands work of the paradigm developed and empirical reality in relation to diffusion on a regional scale.(21) This later developed into what is an interesting and innovative view by Brown which he termed the Market and Infrastructure perspective. It basically looks at diffusion characteristics rather than adopters characteristics. Its basic premise is that: "The market and infrastructure perspective takes the stance that the opportunity to adopt is egregiously and in many cases purposely unequal."(22) Accordingly, Brown focuses on the process by which innovations and the conditions for adoption are made available. Thus the characteristics of the adopter could be seen to be less important perhaps, than the diffusion methods used.

9. **General Sociology**

This is really a catch all for studies not included in medical, rural or the earlier sociological works, but in size it does represent a sizeable proportion of the studies to date, about 12% of the total.

10. Other Traditions

Naturally, some research areas are so small in numbers that it is easier to put them together, although as a total they represent 17% of the 3085 publications to date, these concern diverse areas such as economics and industrial engineering.

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APPENDIX (iii)

Smoke Ventilation Interview Notes and Format

Basic Questions to be answered:

1. The awareness level of the smoke ventilation concept.
2. How did this awareness come about?
3. When did this awareness come about?
4. What source did the information come from?
5. What use was made of the information?
6. Were searches made for knowledge and information?
7. What agencies were contacted?
8. Are there formal search methods within the company?
9. Any external influencing bodies?
10. Any internal influencing bodies?
11. Degree of innovativeness in

    (a) Individual

    (b) Company
12. Changes over time in design concepts or product availability.
13. Any training in Fire Protection in general or Smoke Vent in particular either in obtaining formal job qualifications or in on the job training.

Summary of Market Framework

1. **Chain of Construction**

   Owner (or funder)

   Architect

   Consultant

   Contractor

   Sub Contractor

   End user (sometimes owner)

2. **Influencing Bodies**

   Fire prevention agencies

   Government regulations

   Insurance agencies

   Public opinion

3. **Influencing Factors**

   Building type

   Geographic location

   Building specification

   Past experience

   Product availability

   Competitive firms

   Design methods

STRUCTURED INTERVIEW PLAN

SECTION 1

COMPANY

1. Name of Company or Organisation and Address

2. Number of Employees

3. Type of Company or Organisation

4. Membership of any Organisation or Association

5. How useful is membership in terms of running the business or organisation?

6. What is the Company Structure and what responsibility do different levels of the hierarchy have?

7. How much personal discretion is allowed in design?

SECTION 2

Interviewee

1. Name of Interviewee

2. Position

3. Age

4. Membership of any Organisation or Association

5. How useful is membership in terms of doing your job?

6. When you thinking of Fire Protection could you give the relative importance of different aspects of fire safety systems?

7. Education. What training have you had?

8. Have you had any specific training in Smoke Ventilation?

SECTION 3

1. When was first awareness of smoke vent concept? Year

   (a) Company

   (b) Individual

2. What was the source of sources of above awareness?

3. Have you been involved with smoke ventilation? When was this?

4. In what capacity were you involved?

5. Could you describe a successful implementation of a smoke ventilation system?

6. What were the major factors involved in the successful implementation?

7. Any unsuccessful proposals to use smoke vent systems?

8. What were the major factors involved?

9. Where did you obtain information used to influence the client to either use or not use smoke ventilation?

10. Does the Company have a systematic way of updating information?

11. Do you have a personal updating system?

12. What design methods have been used in the past?

13. What changes have occurred to date?

14. What products are on the market?

15. What product area is most often used?

16. What companies are in the Market? Note some assessment of these companies/products could be useful.

17. What bodies, regulations or recommendations are influenced in design decisions?

18. Any other comments.

APPENDIX (iv)

Structured Interview Plan - Final Draft

SECTION 1 - COMPANY

1. Name of Company or Organisation and Address

2. Number of employees

3. Type of Company or Organisation

4. Membership of any organisation or association

5. How useful is membership in terms of running the business or organisation?

6. What kind of contact is there within the profession?

7. Is there much interchange of information?

8. What is the company structure and what responsibility do different levels of the hierarchy have?

9. How much personal discretion is allowed in design?

SECTION 2 INTERVIEWEE

1. Name of interviewee

2. Position

3. Age

4. Membership of any organisation or association

5. How useful is membership in terms of doing your job?

6. Do you personally have much contact with other members of your profession?

7. Is there much interchange of information?

8. What would you consider the primary function of Fire Protection Systems?

9. The following is a list of Fire Protection Methods - you may know others. Could you assess their relative importance in relation to Question 8 on a scale 1 - 10?

   A. Escape route provision

   B. Hose Reels

   C. Smoke Ventilation

   D. Sprinklers

   E. Fire alarm systems

   F. Training of staff

   G. Structural integrity

   H. Any other

10. What training have you had -

A. Academic

B. Job training

11. Have you had any specific training in Smoke Ventilation?

SECTION 3

1. When did you first become aware of the Smoke Vent Concept?

   Year

   A. Company

   B. Individual

2. What was the source of sources of above awareness?

3. Have you been involved with Smoke Ventilation? When was this?

4. In what capacity were you involved?

5. Could you give details of any smoke ventilation projects with which you have been involved?

Name of Job

Date

Building Type or use

Construction

Fire Protection

Systems Installed

Type of Smoke Vent System

Smoke Temperature

Any other details

Name of Job

Date

Building Type or use

Construction

Fire Protection

Systems Installed

Type of Smoke Vent System

Smoke Temperature

Any other details

Name of Job

Date

Building Type or use

Construction

Fire Protection

Systems Installed

Type of Smoke Vent System

Smoke Temperature

Any other details

Name of Job

Date

Building Type or use

Construction

Fire Protection

Systems Installed

Type of Smoke Vent System

Smoke Temperature

Any other details

6. What were the major factors involved in the successful implementation?

Fire Prevention Agencies	Building Specification
Government Regulations	Past Practise
Insurance Agencies	Product Availability
Public Opinion	Competitive Firms
Building Type	Design Methods
Geographic Location	

7. Where did you obtain information influential in the use of smoke ventilation?

8. Any unsuccessful proposals to use smoke vent system?

9. Why was the project or projects not implemented?

10. If applicable, what information influenced the client not to use smoke vent, and where did it originate?

11. Does the company have a systematic way of updating information?

12. Do you have a personal updating system?

13. What design methods have been used in the past?

14. What changes have occurred to date?

15. What products are on the market?

16. What product area is most often used?

17. What companies are in the market? Note some assessment of these companies/products could be useful.

18. What bodies, regulations or recommendations are influential in design decisions?

19. Any other comments.

APPENDIX (v)

Organisations Researched in the U.S.A.

Design Engineers	5
Code Setting Bodies	3
Fire Marshals	1
Manufacturers	2
Nation Bureau of Standards	1
Insurance Bodies (Factory Mutual)	1
National Fire Protection Association	1
TOTAL	14

APPENDIX (vi)

RESULTS OF THE UK SURVEY

DESIGN ENGINEERS

SECTION 1

Question	2.	Average No. of Employees			139
	3.	Consultants			16
		Design Manufacturers or Retail Design			2
	4.	Membership of Organisations to order			
			ACE		10
			CIBSE		1
			LBC		1
			BISRA	}	1
			BRE	}	
			FOC		1
			No Response		4
		Of those who responded average membership			1.3
	5.	Usefulness of membership	Useful		12
			Some use		2
			No use		0
			No response		4
	6.	Contact within the profession			
			1-3 months	some contact	12
				None	1
				No response	5
	7.	Is there much interchange of info		Yes	5
				Some	6
				None	3
				No response	4
	8.	Structure of organisation		Pyramidical	10
			Pyradmidical/Horizontal		1
				Horizontal	5
				No response	2
	9.	Autonomy		Yes	11
				No	6
				No response	1

SECTION 2

Question	2	Position in organisation	Partners	2
			Ass	6
			Engineers	9
			F.P.O.	1
	3.	Average Age		39.2
	4.	Membership or organisation or Association	CIBSE	13
			FTA}	
			FOC}	1
			CIBSE IMechE	2
			None	4
	5.	Usefulness of Membership	Useful	6
			Some use	4
			No use	4
			No response	4
	6.	Contact with the profession	Often	11
			Some	5
			None	1
			No response	1
	7.	Is there much interchange of info	Often	6
			Some	9
			None	2
			No response	1
	8.	Primary function of fire protection	Life	8
			Life & Property	8
		Stop or reduce fire Risk		2
	9.	Rating of smoke vent amongst other fire protection methods		
		On scale 1 to 10 average 10 = highest		6.2
	10.	Training	Degree	5
			Technical only	13
	11.	Specific Academic Training in Smoke Vent	Some	1
			None	16
			No Response	1

SECTION 3

Question 1

Date of first awareness of smoke vent concept

	Company	1948/49	2
		1980/87	2
	Response	22%	
	Ind knowledge	1965-69	1
		1970-74	5
		1975-79	1
		1980-87	10
		No response	1

2. Source of awareness

Source of awareness	BRE reports	3
	Manufacturer literature, trade mags	4
	Specific Colt	2
	Specific Nuaire	1
	Projects	4
	GLC	2
	Local Regs	2

3. Date of first involvement in smoke (adoption) ventilation

Company	1948/69	2
	1970/74	4
	1975/79	2
	1980/87	10
Ind. knowledge	1945/50	1
	1950/69	1
	1970/74	4
	1975/79	2
	1980/87	10

4. Capacity of involvement

Capacity of involvement	Design	13
	No response	5

5. Details of smoke ventilation projects

Building Use	Vent Type	Smoke Design Temp
Shopping Malls}	natural & powered	74-350 deg C
Atria}	auto control with	
Depart.Stores}	sprinklers	

Shops & Offices}

Car Factories	natural	1	250 deg C
Film Studio	natural	1	180 deg C
Prison	natural	2	-
Courthouse	-	1	-
Bank	-	1	400 deg C
Health Clinic	-	1	-

6. Major factors involved in successful implementation of smoke ventilation

Fire prevention agencies	11
Government Regs	7
Insurance Agencies	4
Public Opinion	-
Building Type	6
Geographical Location	1
Building Specification	5
Past Practise	2
Product Availability	1
Competitive Firms	2
Design Methods	4

7. Source of information influential in the use of smoke ventilation

FRS Home Office	10
FPA Association	1
F.P. Officer	3
Manufacturers	10
Trade Press	1
GLC	1
No response	1

8. Any unsuccessful proposals to use of smoke ventilation

Yes	4
No	10
No response	4

9. Reason for project not being implemented

22% response of which Cost was 100%

10. What information influenced the client not to use smoke ventilation

No response100%

11. Does company have a systematic way of updating information

Yes	8

	No	10
12. Does individual have a personal updating system		
	Yes	5
	No	13
13. What design methods have been used in the past		
	FRS Methods	7
	Manufacturers	8
	Fire sized building occupation	2
	Computer design gas flow	1
14. What changes have occurred to date		
response rate 16%	Morgan Paper	1
	Computer dsgn	1
15. What products are on the market		
	Louvres & Powered	12
16. What product area is most often used		
	Louvres	12
	Louvres & Powered	1
	Powered	2
	No response	3
17. What companies are in the market		
	Colt	14
	Nuaire	10
	Gradwood	7
	Airstream	2
	Actionaire	1
	Trox	1
	Robertson	1
	Woods	1
	Myson	1
	Engert	1
	Lydyard & Skelton	1
18. Check in bodies and regulations influential in design decisions		
	Morgan and F.R.S.	
	Local Authority Regs	
	F.P.O's	
	Insurance Bodies	
	C.I.B.S.E.	
	Manufacturers	

APPENDIX (vii)

Results of U.K. Survey

FIRE PREVENTION OFFICERS

SECTION 1

Question	2.	Average number of employees concerned with fire fire prevention in each are	916
	3.	Fire Brigades County	19
		Health Authority	1
	4.	Membership of Organisations in order	
		Inst. of Fire Engineers	10
		Chief & Assistant Chiefs Fire Officers Association	7
		Fire Protection Association	6
		Fed. British Fire Services	2
		National Assoc. of Hosp Fire Officers	1
		Home Office	1
		Bedfordshire Fire Liaison Committee	1
		Association for Petroleum & Explosive Administration	1
		Association of County Councils	1
		Association of Metropolitan Councils	1
		Loss Prevention Council	1
		No response	3
		Of the numbers that answered the question the average number of organisations belonged to was	2.4
	5.	Usefulness of membership	
		Useful	15
		Some use	1
		No use	1
		No response	3
	6.	Contact within the profession	
		Some contact	19
		None	-
		No response	1
	7.	Is there much interchange of information	
		Yes	17
		Only some	1

	None	-
	No response	2
8.	Structure of Organisation	
	Divisional & Hierarchical	14
	No response	6
9.	Autonomy	
	With codes of practice	
	or with X check	7
	None	3
	No response	10

Section 2

Question	2.	Position in organisation	
		Senior F.P.O.	10
		Ass Senior F.P.O.	1
		Divisional Officer F.P.O.	5
		District F.P.O.	2
		Station Officer	1
		Area Health F.P.O.	1
	3.	Average Age	45.6
	4.	Membership of Organisations	
		Institute of Fire Engineers	19
		Fire Prevention Association	2
		F.B.I.M.	2
		International Inst. of Risk and Safety Management	1
		National Assoc of Fire Officers	1
		Inst of Hospital Fire Engineers	1
		National Assoc of Hospital Fire Officers	1
		British Fire Officers Association	1
	5.	Usefulness of membership	
		Useful	13
		Some use	3
		No use	1
		No response	2
	6.	Contact within the profession	
		Often	19
x		Some	0
		No contact	0
		No response	1
	7.	Is there much interchange of information	
		Yes	20
		Some	0
		No response	0
	8.	Primary function of fire protection	
		Life protection	7
		Life and property	12
		Fire Control warning)	
		Fire fighting assistance)	1
	9.	Rating of smoke vent amongst other fire protection method	

		On scale 1 - 10 average (10 highest rating)	6
		Other response "depends on risk"	
		No response	1
10.	TrainingF.S.C.		15
		Degree	4
11.	Specific academic training in smoke vent		
		Training	11
		Some training	6
		No response	3

Section 3

1. Date of first awareness of smoke vent concept

	Organisations	Individuals
1945 - 1949	3	1
1950 - 1959	0	0
1960 - 1964	1	2
1965 - 1969	3	5
1970 - 1974	5	5
1975 - 1979	4	3
1980 - 1984	1	1
No response	3	3

2. Source of awareness

BRE reports	4
Trade Journals and Technical Publications	3
Manufacturers (Colt only)	3
Fire Service College	4
Projects	3
Job Experience & Training	3
Manual of Firemanship	1
No response	2
Percentage with more than one source	7

3. Date of first involvement with smoke ventilation

	Organisation	Individual
1965 - 1969	3	3
1970 - 1974	1	1
1975 - 1979	8	8
1980 - 1984	5	5
No response	3	3

4. Capacity of involvement

Approval	12
Supervisory	1
Consultant advice	5
Special interest	1
No response	1

5. Details of smoke Ventilation Projects

Building Use	Vent Type	Smoke Design Temp
Shopping Centres}	Powered and	64 - 300 deg C
Atria Offices}	natural sprinklers	
Warehouse	Auto control	
Hospital	Nucleus design powered	
Manufacturing (BNFL)		
Banks		
Air Terminals		

Information was restricted in this area under Section 21 of the Fire Precaution Act 1971.

6. Major factors involved in successful implementation of smoke ventilation

Fire Preventiaon Agencies	12
Government Regulations	6
Insurance Agencies	2
Public Opinion	0
Building Type	8
Geographic Location	0
Building Specification	9
Past Practice	5
Product Availability	3
Competitive Firms	0
Design Methods	8

7. Source of information influential in the use of smoke ventilation

FRS/BRE		9
Fire Service College		5
Manufacturers: -	Colt	3
	Nuaire	1
Trade Literature		4
More than one source		9

8. Any unsuccessful proposals to use smoke vent

Yes	7
No	8
No response	5

9. Reason for project not being implemented - response rate 40%

Lack of regulations	4
Cost	3
Design	1

10. What information influenced the client not to use smoke vent

Response	5
of which cost represented	4
could not be influenced	1

11. Does company have a systematic way of updating information

Yes	18
No	1
No response	1

12. Does the individual have a systematic way of updating information

Yes	6
No	11
No response	3

13. What design methods have been used in the past - response rate 8 - 40%

BRE	3
Natural & Mech	1
See manufacturers	2
Each scheme on own merits	1
specified by Mech Eng	1

14. What changes have occurred to date

Atria Design	1
Shopping Mall Design	1
Interaction of vents with sprinklers	1
Consideration of fire size and smoke behaviour	2
Powered now more practical	1
Design by engineers	1
Legislative forces	1
No response	11

15. What products are on the market - response rate 5

Colt	2
Nuaire	2
Powered or natural	1
Various	1

16 What product area is most often used - response rate 9

Colt	3
Nuaire	2
Colt, Nuaire and others	1
75% Natural}	
25% Powered}	1
Natural	1
PVC and Natural	1

17. What companies are in the market

Colt

Ove Arup

Nuaire

Airflow

Envirotec

18. Check on Bodies and Regulations influention in design decision.

Building Regulations 1985

Fire Regulations

Fire Prevention Act 1971

FRS/BRE

Fire Safety of Places Act 1987

APPENDIX (viii)

Summary of Smoke Vent Recommendations & Regulations

BRITISH STANDARDS INSTITUTE

2 Park Street

London BS 5588 Part 4	Smoke Control in protected escape routes using pressurisation

BUILDING RESEARCH ESTABLISHMENT

Garston,

Watford Current Papers

CP 83/75	Works by the Fire Research Station on the control of smoke in covered shopping centres. Hinkley P.L.
CP 13/76	The movement and control of smoke on escape routes in buildings. Heseldon and Baldwin R.
CP 45/76	Smoke hazards in covered muti-level shopping malls. Some studies using a model 2-storey mall. Morgan, H.P., Marshall, N.R. and Goldstone,B.M.
CP 19/78	Smoke hazards in covered mutli-level shopping malls: A method of extracting smoke for each level separately. H.P. Morgan, N.R. Marshall.
CP 11/79	Smoke control in a covered two-storey mall having balconies as pedestrian walkways. H.P. Morgan, M.R. Marshall.
IP 32/79	Information on same subject
IP 30/80	A study of large fire in a covered shopping complex: St Johns Centre 1977.
Fire Research Notes 1010/74	Smoke extraction by entrainment into ducted water spray. H.P. Morhan, M.L. Bulmer
BRE Digests 173	Smoke control in single storey shopping malls 1975.
BRE Reports, H.P. Morgan	Smoke control methods in enclosed shopping complexes of one or more storeys, a design summary 1979.

LEGISLATION/BUILDING REGULATIONS

London Building (Amendments)

Act Bye Laws, 1939	Great London Council Section 20 on Atriums
Home Office H.M.S.O. Gov.t Bookshops	The Town Centre, Redevelopment Guide No.1. 1972, covering fire precautions in town centre developments.

Hampshire Act

Greater Manchester Act

The Building Regulations (Northern Ireland) 1973

The Building Regulations 1976

U.S.A.

204 M	Guide for Smoke and Heat Venting
N.F.P.A. Codes of Standards National Fire Protection Association 470 Atlantic Avenue, Boston, U.S.A.	
ASHRAE	
American Society of Heating Conditioning Engineers, 1791 Tullie Circle ATLANTA, U.S.A.	Design of Smoke Control Refrigeration & Air Systems for Buildings September 1983 J.H. Klote and J.W. Fothergill

APPENDIX (ix)

Summary of Teaching Publications used by the

Fire Service College

1. A simplified approach to smoke ventilation calculations

   BRE 19/85 H.P. Morgan, November 1985

2. Smoke movement in buildings

   Fire Service College, April 1986

3. Air conditioning and ventilation systems

   Fire and the Architect, Fire Protection Association, 1982

4. Atrium Buildings - calculating smoke flows in atria for smoke control design

   precis of paper by Morgan & Hansell

   Fire Service College, 19th August 1985

5. Latest on the Parnell/Butcher front - Atrium

   Fire Service College, 12th February 1986

6. Atrium design in hotels

   Fire Service College, 14th August 1985

7. Revision of equation solving and the use of scientific calculators

   Fire Service College - undated

8. Fire and smoke control in atrium buildings

   Colt International, G.O. Hansell, 1987

APPENDIX (x)

The Search for Factors Influential in the Adoption Process

Notes & Tables

Method

The Fisher exact probability test with the table of critical values for D or C was used. Source 'Non Parametric Statistics for the Behavourial Sciences.' S. Segal Macgraw Hill, 1956 p.56. This test was used because of the statistically small sample.

Results from the U.K. for both Engineers and Fire Prevention Officers were analysed using 1972/73 as a control date, suggested because of legislation in that time period. It was felt that the very small sample size obtained from the U.S.A. would not give meaningful results. The test was applied to results obtained from the questions given below. The results of these questions are shown in tables 1 and 2.

NOTES ON TABLES 5.4.1. AND 5.4.2

SECTION 1

The following company information was used.

3. Number of employees i.e. company or organisation size

4. Membership of organisation or association? i.e. professional.

5. How useful is membership in terms of running your business or organisation?

6. What kind of contact is there within the profession?

7. Is there much interchange of information?

9. How much personal discretion is allowed in design (or approval)?

NOTE Question 8 on company structure:

Answers to this question proved ambiguous. It was not used in the search for statistical significance.

SECTION 2

Interviewee information used.

3. Age

4. Membership of any organisation or association? (Professional)

5. How useful is membership in terms of doing your job?

6. Do you personally have much contact with other members of profession?

10. What training have you had?

11. Have you had any specific training in smoke ventilation?

SECTION 3

Awareness of Smoke Ventilation

1. When did you first become aware of smoke ventilation?

   Company

   Individual

3. Have you been involved with smoke ventilation? When was this?

11. Does the company have a systematic way of updating information?

12. Do you have a personal updating system?

APPENDIX X - TABLE 1

DESIGN ENGINEERS U.K.

ORGANISATION																		
Organisation size	12	16	18	20	22	30	30	30	35	40	45	50	60	65	140	350		1000
Structure/No of Tiers	3	3	4	3	4	4	3	3	3	4	4	3	3	3		4/5		5
Discretion in Design or Approval	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes		no
No of Org M'ship	1	1	1	1	1	1	1		1	2	1		1	1	0	1		2
Usefulness of M'ship	use	use	use	use	use	use	some		use	use	some		use	use		use		use
Contact within the Prof.	some		some	none	some	some	some		some	often	some		often	often		often		often
Interchange of Info	none	some	none	some	some	none	some		some	yes	some		yes	yes		yes		yes
Infosystem	no	yes	no	no	yes	yes	no	no	no	no	no	yes	yes	yes	yes	yes	no	yes
Knowledge							1980					1980	1950			1948		
Adoption Date	1981	1981	1975	1975	1980	1987	1986	1983	1987	1974	1982	1987	1950	1970	1966	1972	1972	1985
INDIVIDUAL																		
Age	38	29	39	38	39	26	31	37	37	45	24	32	55	42	40	32	52	32
No of Org Membership	1	1	1	1	1	1	1	1	2		1		1	1		2		2
Usefulness of M'ship	some	use	none	some	use		none	some	none	none	use		use	use		some		use
Contact within the Prof.	often	often	some	often	often	some	none	some	often	often	some	often	often	often		some	flen	often
Interchange of Info	some	some	yes	some	some	none	none	some	yes	yes	some	some	often	often		some	some	often
Education	tech	tech	degree	tech	degree	tech	tech	tech	degree	tech	tech	tech	tech	degree	tech	tech	tech	degree
S/V Training	min	no	no	no	no	no	no	no	no	no	no	no	no		no	no	no	no
Info System	yes	no	no	yes	no	yes	no	no	no	no	no	no	no	no	no	yes	yes	no
Knowledge	1981	1981	1973	1975	1975	1985	1980	1983	1987	1970	1982	1982		1970	1966	1972	1972	1981
Adoption Date	1981	1981	1975	1975	1980	1987	1986	1983	1987	1974	1982	1987	1950	1970	1966	1972	1972	1985

APPENDIX X - TABLE 2

F.P.O's U.K.

RGANISATION																				
rganisation size	20	320	320	350	418	460	496	500	600	650	700	700	800	1100	1505	2000	2600			
tructure/No of Tiers	4	4	6	4	5	3	5	5					5/6	5/6						
iscretion In Design r Approval	yes	yes	yes	no	yes	yes								yes	no	no			yes	
o of Org M'ship	3	4	4	3	2	1	2	1	2	3	1		1	4	3		2		4	1
sefulness of M'ship	use	use	use	use	use	use	use	use	use	use	use		none	some	use		use		use	use
ontact within the Prof.	often	often	often	often	often	often	often	often	often	often	often	often	often	often	often		often	often	often	ofte
terchange of Info	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes		yes	yes	yes		yes	yes	yes	non
fosystem	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes		yes	yes	yes	yes
doption Date	1978	1972	1982	1975		1977		1968	1975	1975	1969	1966	1975	1985	1985	1986	1987		1975	197
nowledge	1968	1972	1972	1970		1977		1968	1975	1962	1969	1948	1972	1975	1948	1948	1983		1972	197
NDIVIDUAL																				
ge	47	51	39	43	47	47	41	50	48	54	47	47	47	45	37	59	38	43	40	42
o of Org Membership	1	2	1	2	1		1	2	2	2	2	1	1		2	2	2	1	1	1
sefulness of M'ship	use	use	use	some	some		some	use	use	use	use	some	none		use	use	use	use	use	use
ontact within the Prof.	often	often	often	often	often		often	often	often	often	often	often	often	often	often	often	often	often	often	ofte
ystem of Info	yes	no	no	no	no	no	no	no	no	no	no	yes		yes	yes		yes	no	no	yes
terchange of Info	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
ducation	FSC	FSC	FSC	FSC	Degree	FSC	FSC	FSC	FSC	Degree	FSC	FSC	Degree	Degree	FSC	FSC	FSC	FSC	FSC	
/V Training	yes				yes	yes	min	min	yes	min	yes	min	min	yes	yes	min	yes	yes	yes	yes
doption Date	1978	1972	1982	1975		1977		1968	1975	1975	1969	1966	1975	1985	1985	1986	1987		1975	1979
nowledge	1968	1972	1970	1970		1977		1968	1965	1962	1963	1966	1972	1975	1965	1948	1983		1972	1979

APPENDIX (xi)

Summary of Research Findings

1. **THE U.S.A.**

1. Influencing organisations were identified.

2. From this the structure of the industry was established (see Chapter 5)

3. Opinion leaders were identified.

4. Innovativeness on the part of either the company or the individual proved difficult to determine. A statistical analysis was not conducted because of the small sample. There was only on indication of innovation playing a part in the adoption process, this was the case of one individual with a strong, personal information network who adopted the concept 5 years earlier than other interviewees.

5. All engineers interviewed had a high level of professional qualification.

6. Most interviewees saw smoke ventilation as an important fire protection method.

7. None had any formal academic training in smoke control design.

8. All thought life protection the major function of smoke control.

9. All were aware of different smoke control design methods, but often mentioned was are change rate as a design method (this method does not account for fire size and smoke mass development). Many of the fire marshals mentioned cutting holes in the roof as a preferred method, although a large percentage did prefer autoventing. Various professional networks were identified at both company and individual level, such as the American Society of Heating and Air Conditioning Engineers (ASHRAE) and the American Society of Consulting Engineers (ASCE).

11. Publications were the main source of information on smoke ventilation.

12. The date of adoption was established as being between 1965 to 1980, the median being 1970.

13. The main reason for the rejection of smoke control proposals was established as cost.

14. Mechanical (powered ventilation) was the main method of smoke ventilation.

2. THE U.K.

1. Influencing bodies, organisations and factors were identified, including educational influences.

2. From this, a structure of the industry was constructed.

3. Opinion leaders were identified.

4. Statistical analysis of earlier adopters in relation to later adopters found that companies who were earlier adopters -

   (a) Had a high degree of contact within the profession;

   (b) Exchanged more information within the profession;

   (c) Had a systematic way of updating information.

   Both company and individuals who were earlier adopters -

   (a) Belonged to a higher number of professional organisations;

   (b) Viewed this membership as useful professionally.

   The results do point out the high influence of legislation in 1972 (The Home Office Town Centre Redevelopment Guide No. 1) in that the majority of Engineers and F.P.O's adopted after that date. In general F.P.O's were aware before engineers and the F.S.C. had influence in this.

5. All engineers and F.P.O's interviewed had academic and technical training.

6. Most of the engineers had no academic training in smoke control design (94%), whilst only 25% of the F.P.O's had no training.

7. Both engineers and F.P.O's gave a similar rating (6.2/6.0) to the relative importance of smoke ventilation compared with other fire protection methods.

8. All regarded life protection as a function of smoke ventilation. 44% of the engineers thought life and property, 35% of the F.P.O's life and property. 60% gave warning of fire fighting assistance.

9. All were familiar to some extent with the terms natural or powered smoke ventilation. Engineers identified numerous buildings smoke vented and the questionnaire came up with a smoke temperature range of 74 deg C to 350 deg C. Shopping centres, atria, warehousing, factories and various others were mentioned. F.P.O's had an awareness of changes in design in shopping malls and atria and the interaction of sprinklers and smoke vent. The showed reluctance in imparting project information quoting Section 21 of the Fire Protection Act, 1971.

10. Various professional networks were identified, e.g. Engineers; Chartered Institute of Building Service Engineers (C.I.B.S.E.), and the Association of Consulting Engineers (A.C.E.), the Institute of Fire Engineers, Fire Protection Association, Chief and Assistants Fire Officers Association for Fire Officers etc.

11. The source of awareness for Engineers was spread between F.R.S. 17%, literature and trade magazines 22%, manufacturers and project involvement 22%. For F.P.O's it was highest in two areas: BRE reports (F.R.S.) 20%, and the Fire Service College 20%, whilst trade journals scored 15%, manufacturers 15%, project involvement 15%.

12. Unlike consultancy companies, over half of F.P.O. organisations were aware of the concept before 1975. Even more of the individual F.P.O's (13) were aware before that date. The majority of the F.P.Os, both as organisations or as individuals (12 from 20), were involved with smoke ventilation before 1979 whilst the majority of the engineers (10 from 18) were involved from 1980 onwards. This earlier adoption by the F.P.O's is understandable considering their direct links with the F.R.S. Some criticism of the engineers is justified for their late adoption.

13. Major factors involved in successful implementation of systems for Engineers and F.P.O's were similar. Fire Prevention Agencies 61%/60%, Government Regulations 39%/30%, Building Type/Specification 25%/40%. For Engineers, manufacturers scored high in source of information for successful implementation 50%, matching the F.R.S. For F.P.O's the source was BRE/FRS 45%, with the Fire Service College being second, 25%, manufacturers third, 20%, trade literature 20%.

14. For Engineers, 39% took design methods direct from F.R.S. and 45% from manufacturers. For the F.P.O's BRE/FRS rated 20%, whilst manufacturers rated 10%.

90% of Engineers had little knowledge of design changes whilst many of the F.P.O's were aware of atria and sprinkler design controversy.

16. Most Engineers were aware of natural and powered vents. The F.P.O's did not distinguish as such but seemed to compare manufacturers.

17. Colt figures heavily on the question of which manufacturers are in the market with Nuaire coming second. However, F.P.O's did regard some engineering consultants as being in the market alongside Colt, Nuaire, Gradwood.

18. Educational influences were found at Edinburgh University. The Fire Service College and South Bank Polytechnic.