

Development of a Finishing Framework for the Irish Furniture Industry

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Declaration

I hereby declare that the work undertaken in this thesis is entirely my own.

Signed: _____

DAMIEN WALLACE

Date: _____

Abstract

Author: Damien Wallace

Thesis Title: *Development of a Finishing Framework for the Irish Furniture Industry*

This thesis originated from the desire of the author to develop a tool to assist Irish furniture manufacturers in meeting the requirements set out in the volatile organic compounds (voc) directive. The introduction of this directive has resulted in Irish furniture companies seeking advice and assistance in order to comply with the pertaining rules and regulations. There is a need for the development of a support mechanism for these companies to deal with the challenges that the legislation poses. The overall objective of the thesis is to provide a framework for these companies within the Irish furniture industry who are affected by the legislation.

This body of work initially takes an in-depth look into the Irish furniture industry, the VOC directive and also the theory of finishing. Once a greater understanding of the industry is developed the focus of the thesis moves onto examining how the legislation is affecting companies within the industry. This occurs through the use of case study analysis. Eleven case companies are used to develop a greater appreciation of the level of awareness of the directive in the industry and how each company is proposing to deal with the situation. This gives the author the ability to develop a set of requirements that need to be addressed in the generation of a framework. Once these requirements are identified, solutions are proposed and the framework developed. In order to test the validity of the framework, it is necessary to test and verify the elements of the framework. This is achieved by mapping the framework against 3 further case companies. By applying a set of predefined validation criteria the framework is validated.

The developed framework is both a practical and functional tool and will assist companies in complying with the legislation thus being very beneficial to the industry.

Publications

Conference Paper

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Table of Contents

<i>Acknowledgements</i>	i
<i>Declaration</i>	iii
<i>Abstract</i>	iv
<i>Publications</i>	v
<i>Table of Contents</i>	vi
<i>Table of Figures</i>	ix
<i>Table of Tables</i>	x
<i>List of Abbreviations</i>	xi
Chapter 1 Introduction	1
1. Introduction	1
1.1 Statement of Thesis	1
1.2 Background.....	2
1.3 Research Objectives	5
1.4 Research Scope.....	6
1.5 Research Methodology.....	7
1.6 Thesis Structure	8
Chapter 2 Finishing in the Furniture Industry.....	10
2.1 Introduction	10
2.2 Legislation Related to Finishing.....	10
2.3 Finishing – A Brief Overview	12
2.4 Types of Finishes.....	12
2.4.1 Wax and Oil.....	12
2.4.2 French Polish.....	13
2.4.3 Solvent Based Lacquers	13
2.4.4 Waterbased Finishing	14
2.4.5 Powder Coating	15
2.5 The Finishing Process of Waterbased Finishing & Solvent Based Lacquers	15
2.6 The Finishing Process of Powder Coating	16
2.7 Comparison of the Finishes	18
2.8 Other Solutions.....	22
2.9 Conclusion.....	24
Chapter 3 Case Study Analysis of Current Finishing Practices	25

3.1 Introduction	25
3.2 Data Collection Methodology	25
3.2.1 Profile of Case Companies	33
3.3 Case Findings and Analysis.....	35
3.3.1 The Finishing Material Being Used	35
3.3.2 Practices and Procedures	36
3.3.3. The Suppliers.....	42
3.3.4 Levels of Current Solvent Usage.....	43
3.3.5 Awareness of Legislation	44
3.3.6 Awareness of Alternatives to Solvent Based Finishing	45
3.4 Identification of Requirements	47
3.5 Conclusion.....	48
Chapter 4 The Irish Furniture Industry Finishing (IFIF) Framework.....	50
4.1 Introduction	50
4.2 Justification for Framework	50
4.3 The Irish Furniture Industry Finishing Framework.....	52
4.4 Conduct Feasibility Study	54
4.4.1 Evaluation of the current spraying practices and procedures of the company	55
4.4.2 Analyse the financial situation	57
4.4.3 Determine the company’s strategy for development.....	59
4.5 Framework Solutions.....	62
4.5.1 Change to Waterbased Finishing.....	62
4.5.1.1 Implement Best Practices.	63
4.5.1.2 Implementation Guidelines.....	65
4.5.2 Reduce Solvent.....	65
4.5.2.1 Implement Best Practices	65
4.5.2.2 Working with Suppliers.....	69
4.5.3 Outsource Finishing.....	70
4.5.3.1 Implementing Finishing Outsourcing.....	70
4.4 Conclusion.....	73
Chapter 5 Validation of the IFIF Framework.....	74
5.1 Introduction	74
5.2 Case Study Analysis	74
5.2.1 Validation Methodology.....	74
5.2.2 Data Collection Methods.....	75
5.2.3 Validation Criteria	77
5.3 Validating the Finishing Framework.....	78
5.3.1 Implementing the Framework	78
5.3.2 The Implementation of the Feasibility Study	78

5.3.2.1 Evaluation of Current Practices & Procedures	79
5.3.2.2 Analysing the Financial Situation	80
5.3.2.3 Determine the Company’s Strategy for Development	80
5.3.2.4 Feasibility Study Findings	82
5.3.3 Implementing the Elements	83
5.4 Verification of Framework using Validation Criteria	86
5.5 Conclusion	89
Chapter 6 Conclusions & Recommendations	91
6.1 Introduction	91
6.2 Thesis Summary	91
6.3 Overall Conclusion	94
6.4 Recommendations	95
<i>References</i>	97

Table of Figures

Figure 1.1 Generic Furniture Production Stages	6
Figure 1.2 Research Methodology	7
Figure 1.3 Thesis Structure.....	8
Figure 2.1 Spraying Sequence	15
Figure 2.2 Powder Coating Process.....	17
Figure 3.1 Research Methodology	25
Figure 3.2 Data Collection Methods for Case Study Development	26
Figure 3.3 Questionnaire	30
Figure 4.1 Research Methodology (Framework Development).....	50
Figure 4.2 Legend of symbols used in Framework Diagram	52
Figure 4.3 The IFIF Framework.....	53
Figure 4.4 Example of a Good Layout	67
Figure 5.1 Research Methodology (Validation).....	74
Figure 5.2 Sequence of Automated Spraying Line.....	76

Table of Tables

Table 1.1 The Irish Furniture Industry	3
Table 2.1 Comparison of Finishes.....	19
Table 3.1 Case Study Profile	35
Table 3.2 Type of Finish used by Case Studies.....	36
Table 3.3 Drying Room/ Area	37
Table 3.4 Sprayroom	37
Table 3.5 Main Finishing Suppliers	42
Table 3.6 Current Solvent Usage.....	43
Table 3.7 Legislation Awareness.....	45
Table 3.8 Case Studies Reasons For and Against Changing to WB Finishing	46
Table 5.1 Criteria Used for Validation of Finishing Framework (Cormican 2005).....	77
Table 5.2 Spraying Practices & Procedures	79
Table 5.3 Strategy for Development.....	80
Table 5.4 Tested Criteria	87

List of Abbreviations

AC:	Acid Catalyst
AIC:	Accredited Inspection Contractor
CNC:	Computer Numeric Control
E.P.A.:	Environmental Protection Agency
E.U.:	European Union
HVLP:	High Volume Low Pressure
I.F.I.F:	Irish Furniture Industry Finishing
IPPC:	Integrated Pollution Prevention and Control
MDF:	Medium Density Fibreboard
PC:	Pre-Catalyst
PU:	Polyurethane
VOC:	Volatile Organic Compounds
WB:	Waterbased Finishing
W.I.P:	Work in Progress

Chapter 1 Introduction

1. Introduction

This chapter will detail the following;

Statement of Thesis

Background

Research Objectives

Research Scope

Research Methodology

Thesis Structure

1.1 Statement of Thesis

There is growing concern across Europe and indeed the world that there is a need to protect the environment as a way of ensuring a better quality of life for current and future generations. The challenge is to combine the protection of our environment with continuing economic growth in a way which is sustainable over the long term. It is, therefore up to the relevant governing bodies to provide us with laws and regulations which will aid the protection of our environment. In 1999 an EU directive, commonly referred to as the VOC directive, was launched, aimed at reducing the amount of toxic emissions that were being emitted into the atmosphere. In particular, the amount of Volatile Organic Compounds (VOC's) used in industries, including the Irish furniture industry, must be lowered (Council of the EU, 1999). Companies who do not adhere to the new laws and regulations pertaining to this directive will find themselves in breach of the law and thus face sanctioning. This means that these companies have to reduce the quantity of solvents they are using. This could result in major changes in the operation of the company however there is no support mechanism currently available to assist companies with ways to reduce their solvent usage. Therefore the overall objective of the thesis is to provide a framework for those companies within the Irish furniture industry who are affected by the legislation. The framework will provide companies with a method of selecting an appropriate solution to assist in meeting the requirements of legislation.

1.2 Background

The Council Directive on Volatile Organic Compounds (VOCs) concerns the reduction of VOC emissions caused by the use of organic solvent in certain activities and installations, including finishing activities and finishing of wooden surfaces (Council of the EU, 1999). The decision to implement this legislation was taken to protect both public health and the environment. VOC's are gases emitted to atmosphere in certain solids or liquids. VOC's can be found in a number of products including paints, lacquers, glues, adhesives and cleaning supplies (Roux, 2004). Paints and lacquers are used for finishing in the automotive, printing, pharmaceutical and furniture industry. For the purpose of this thesis focus is placed on the Irish furniture manufacturers and the impact of the legislation on their industry. The legislation set out threshold limits, which companies must adhere to. The threshold limit set out for all furniture companies within the European Union is 15 tonnes of solvent usage per annum where 15 tonnes of solvent equates to approximately 22500 litres of pre-catalysed lacquer (G Rayner 2007, pers. comm., 13 November). If companies are found in breach of the legislation they will incur penalties from the local governing bodies. The severity of these penalties will depend on how much the offending company will be above the threshold limit. Companies who are in breach of the 15 tonne per annum usage threshold limit set out by the legislation must alter their spraying processes in order to meet the terms of the legislation. All companies involved in finishing need to understand and comply with the regulations of the legislation.

While there is limited information regarding finishing specifically in the furniture industry a lot can be deduced and learned from the automotive industry, which are major users of solvents (Winder et Stacy, 2002). The automotive industry accounts for approximately 8% of European total manufacturing and is heavily regulated in respect of the environment (Europa, 2007). It is in respect of this stringent regulation that developments in terms of the reduction of solvents in finishing materials have become available. These will in-time filter down to the smaller industries such as the furniture industry. In conjunction with developments of the finishing material, other practices used in the automotive industry can be examined and might be used in the Irish furniture industry as a way to approach the reduction of solvent. Outsourcing is prevalent in the automotive industry (Harrison, 2004) and its benefit to reducing levels of solvent usage cannot go unnoticed. By outsourcing full production and

finishing of components there is an opportunity to reduce solvent usage levels. This factor may be beneficial to certain companies within the Irish furniture industry. Automotive industry practice such as automating certain elements of the finishing process may also provide the opportunity to reduce the amount of solvent wasted or used. This experience of the automotive industry can assist in making Irish furniture manufacturing companies more compliant with legislation.

The Irish furniture industry consists of approximately 400 companies employing approximately 6,600 people (Intertrade Ireland, 2004). The industry consists mainly of small enterprises. In the context of the furniture industry it is important to note that a 'large furniture company' would typically employ up to 50 people. A 'medium sized furniture company' would employ between 10-20 people, while 'small furniture companies' employ 1-10 people. Large furniture companies account for approximately 30% of the industry, medium furniture companies account for approximately 23%, while small furniture companies account for approximately 47 % (Enterprise Ireland, 2008). The industry is broken down into two sectors: the domestic sector and the contracts sector. The domestic market mainly consists of small enterprises manufacturing bespoke products and accounts for approximately 40% of the market. The contracts sector consists of medium to large enterprises manufacturing mainly standard products. These would include mainly large kitchen, hotel, office, corporate and industrial furniture manufacturers. The contracts sector has approximately 60% of the market (Intertrade Ireland, 2004). The following table 1.1 illustrates the Irish furniture industry. The table has been developed from data extracted from the Enterprise Ireland website (Enterprise Ireland, 2008).

Table 1.1 The Irish Furniture Industry

Size	Number of employees	Number of companies	Percentage market share	Type of products produced
Large	21- 50	120	60%	Large scale kitchen, office, corporate & industrial furniture. High volume joineries.
Medium	11-24	90		Bedroom, living room, dinning room & occasional furniture. Batch production.
Small	1-10	190	40%	One off pieces of furniture, bespoke.

Due to the limited literature available for the industry it is rather difficult to put an exact figure on exactly how many companies within the industry are affected by the legislation. However, one indicator of how many companies will be affected is to see how many companies within the industry hold an IPPC licence. Companies who are using in excess of 10 tonnes of solvent per annum are required to hold this licence. Presently there are 50 companies in the Irish furniture industry who hold a licence (EPA, 2007). This would indicate that the new regulations could affect up to 12% of the industry. While this is a relatively good gauge as to the number of companies who maybe affected, it is also fair to say that there may well be more companies who will be in breach of the new legislation. From undertaking this research the author gained first hand experience that while some companies would be using in excess of the 10 tonne usage of solvent per annum, not all of them held an IPPC licence. This would indicate that more than 12% will be affected by the legislation. As well as the introduction of the VOC directive in 1999, the European Union have followed this up with another piece of legislation to reduce the amount of pollution in the air. An amendment to the Council Directive 1999/13/EC is the Directive 2004/42/CE known as 'The Deco Paints Directive', which came into force in January 2007. The amended directive is focused more toward the paint manufactures. The directive will essentially limit the amount of VOC content in products such as paints and primers.

With the European Union becoming more stringent in terms of implementing legislation aimed at reducing solvent usage it is likely that further lower threshold limits will be enforced in the future. If this happens then the author is of the firm belief that the number of furniture companies affected would increase significantly. From the authors experience furniture companies traditionally tend to be run by production orientated managers, who would have started the company themselves and would have little or no formal managerial training. Due to this fact companies tend to be run in a very ad-hoc fashion with no systematic way of dealing with operations. For companies needing to focus on changing or altering such an integral part of the manufacturing process as finishing, specific tools and techniques are essential.

In order for Irish furniture manufacturers to comply with the legislation, they may need to implement new finishing systems, work with suppliers, use outsourcing contacts, or alter

current practices and procedures. This will place extra financial burdens on companies, so they must try to become more cost effective, while still remaining competitive and maintaining a good quality finish. Therefore, it is important that companies have structured guidance so that they can achieve compliance with the legislation. The absence of a relevant support mechanism makes it difficult for companies to meet these requirements. The framework developed as part of this thesis will direct companies to look at all aspects of their finishing, including the finishing material they use, their spraying facilities and their current spraying practices and procedures. This will allow them to identify the most appropriate solution that suits their specific needs.

1.3 Research Objectives

The principal objective of the research undertaken is to provide an effective tool that will assist Irish furniture manufacturers in meeting the requirements of the VOC directive. This tool will take the form of a framework, which will specifically aid furniture companies in availing of, accessing and comprehending the relevant information needed to select the most appropriate solution. The framework will be developed following a review of the Irish furniture industry, and an analysis of case studies in the industry to be carried out by the author. Further case studies will be used to validate the framework. In order to achieve the overall thesis objective the following steps will be taken:

- A literature review of the Irish furniture industry, the VOC legislation, and the theory of finishing
- An in-depth study of current finishing practices and procedures in the Irish furniture industry using eleven case studies
- The identification of problems and requirements faced by the industry.
- The development of a framework to assist companies who are in breach on the legislation.
- The testing and validation of the framework, using industrial based case studies.

It is the intention of the author through this work to add to knowledge about the Irish furniture industry, provide practical guidance to companies in breach of the legislation, and to stimulate further research in the area.

1.4 Research Scope

The VOC directive is the main policy instrument for the reduction of the industrial emissions of volatile organic compounds (VOC's) in the European Union (Council Directive, 1999). It covers a wide variety of solvent using activities including printing, automotive and pharmaceuticals. The legislation also encompasses the furniture industry, and while it may not be as large a contributor to emission as some other industries it is none the less important. This thesis will focus its research on the Irish furniture industry. It will concentrate on providing appropriate solutions to companies in the industry who are in breach or in danger of breaching the threshold limits of the directive.

While furniture manufacturing can be diverse, the basic principles of production apply. Below a diagram indicates the stages of production all furniture products are subjected to.

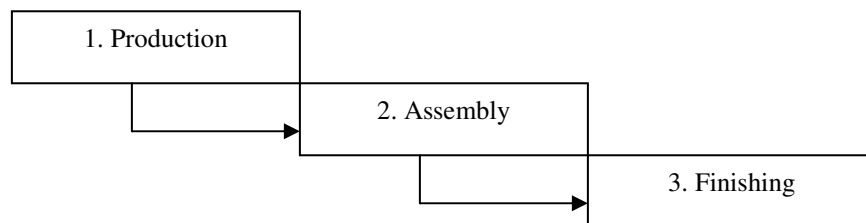


Figure 1.1 Generic Furniture Production Stages

What can be seen from Fig. 1.1 is that finishing plays an integral role in the production of furniture. Without finishing the production would be incomplete. All sizes and type of furniture companies use these stages of production, therefore legislation regarding finishing must be understood by all companies within the industry. The emphasis of the thesis will focus specifically on the finishing element of production within the Irish furniture industry.

1.5 Research Methodology

There are many forms of research methodology available to a researcher (Creswell, 2003). Selecting the most appropriate methodology depends greatly on the type of research being undertaken. Due to the lack of sufficient literature available to the author in relation to the furniture industry in Ireland, and in particular the lack of information regarding the current finishing practices and procedure of the industry, it was deemed necessary to base the majority of the study on case or field based research. The case study approach allowed for greater analysis of the industry to be undertaken. This method employed the use of a questionnaire, which was supported by a structured interview and also observations of the spraying facilities, practices and procedures of eleven Irish furniture companies. Twenty five companies were asked to participate in the research, eighteen replied favourably. Eleven were chosen because they provided a fair reflection of the industry in terms of size and product and could work within the timescale available. The case study methodology and the literature review plus the author's intuition and experience were essential in the formation of this framework.

The research methodology used in this research study is depicted in Fig 1.2. There are three distinct steps in the progression of the thesis.

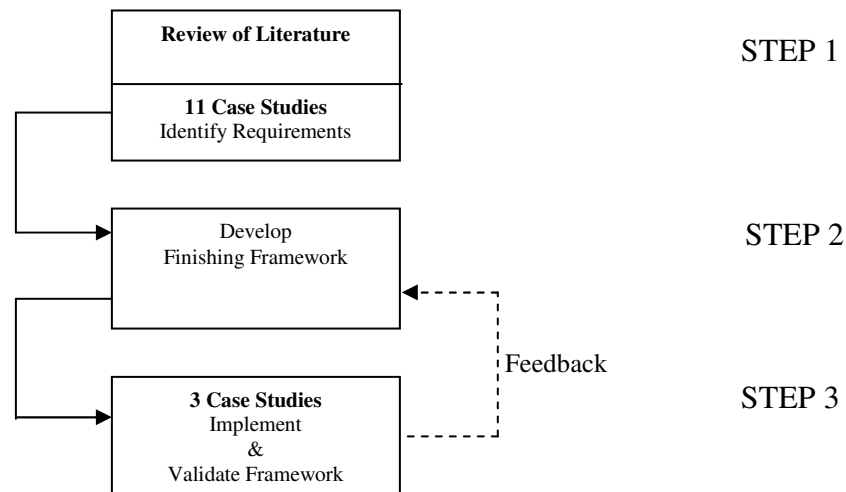


Figure 1.2 Research Methodology

The three steps are:

- Step 1: A literature review and eleven case studies were conducted. This was used to identify the requirements needed to address the problems.
- Step 2: A framework was developed to meet the requirements identified in step 1.
- Step 3: The developed framework was tested and validated using four case studies in order to prove its usefulness. Results of the validation were fed back into step 2 in order to further improve the framework.

1.6 Thesis Structure

The structure of the thesis is depicted in Fig 1.3.

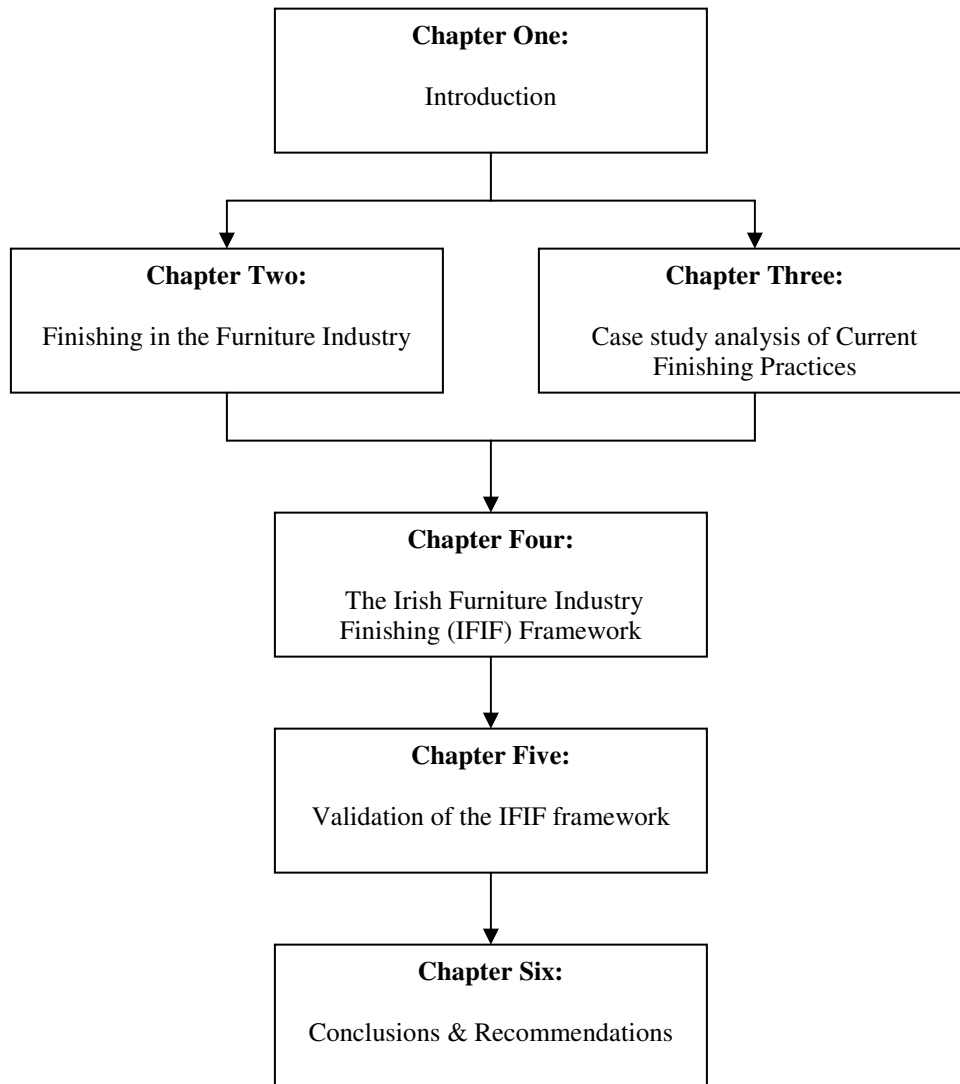


Figure 1.3 Thesis Structure

Chapter two examines the relevant research in relation to finishing in general. An overview of wood finishing, the different types of coating used within the industry, and the equipment used is described. A comparison of each of the finishes is illustrated. Emphasis is also placed on the legislation, and its impact on the Irish furniture industry. The chapter also focuses on the future of the furniture industry.

Chapter three focuses on current finishing practices used in the industry at present. Due to the limited literature available in relation to finishing practices and procedures within the Irish furniture industry it was necessary to use case companies from the industry to gather the information required. This information was achieved by using questionnaires, interviews and observations. The eleven case companies are profiled, the findings are analysed and evaluated. Requirements for companies within the industry who are affected by the new laws and regulations pertaining to finishing are identified.

Chapter four presents a framework for use by companies that are in breach of the legislation: They can use this to analyse their current position, and help them find the most suitable solution.

Chapter five applies the principles of the framework to case companies as a mean of testing its usefulness.

Chapter six summarises the thesis and gives the overall conclusion of the author. It also makes recommendations for future research.

Chapter 2 Finishing in the Furniture Industry

2.1 Introduction

This chapter will look at finishing in general. It will give an overview of the history of wood finishing, the different types of coating used, and the equipment employed. The chapter will also focus on the environment, and how finishes are affected by changing environmental laws and regulations. A synopsis from the view point of the Irish furniture industry will highlight the challenges from these environmental regulations. Particular attention will be paid to two finishes that are meeting the requirements of new legislation, and how they would suit the Irish furniture industry.

2.2 Legislation Related to Finishing

On the 11th of March 1999 the EU published the 'COUNCIL DIRECTIVE 1999/13/EC' on the limitation of emissions of volatile organic compounds (VOC) due to the use of organic solvents in certain activities and installations. It is commonly referred to as the VOC solvents directive, and is the main instrument for the reduction of VOC emissions within the boundaries of the European Union (Fonseca, 2004). The Directive was drawn up due to the damaging effects of solvents on human health and the environment. These damaging effects include nausea, irritation to skin, nose, lungs and throat. More long term damage can be associated to problems such as hearing loss, depression, mental illness, and damage to the kidneys and liver (Goossens, 2006). Harmful organic compound chemicals found within solvents used in industry lead to the outlined damaging effects on human health. These organic compounds include naphtha, xylene, toluene and keytones including acetone. These are harmful to human health if inhaled or ingested (Nanetti, 2006).

The driving factor for the development of the VOC solvent directive came from the European Union's aim to implement legislation to reduce air pollution. The European Union (EU) focused on many sources of air pollutions and devised many directives to limit the amount of pollutions being emitted to the atmosphere (Goossens, 2006). The VOC solvent directive came directly from a meeting of members of the European Parliament Plenary in January 1998 (Solutions, 1998). The members of that parliament voted to implement and developed a

directive, which would reduce the amount of solvent used by industries the 'COUNCIL DIRECTIVE 1999/13/EC'.

Member states including Ireland are required either to implement the set of emission limit values calculated by the directive, or to design and implement a National Plan to achieve the same reduction. The Irish National Plan is headed by the Environmental Protection Agency (EPA) who have set up a technical plan and guidance document for all companies that will be affected by the directive. All new and existing installations and equipment had to comply fully with the directive by October 2007 (Council of the EU, 1999). The directive sets emission limit values (expressed in terms of the maximum solvent concentration in waste gases), and fugitive emission values (expressed as a percentage of solvent input). At present the threshold limits for coating of wood surfaces is less than 15 tonnes per year. The EPA is encouraging companies to be proactive in relation to the environmental regulations (Dodd, D, 2006, pers. Comm., 10 May). The EPA, states that all companies both new and existing whose activities come under the regulations must hold a license. There are two forms of licensing systems, the Accredited Inspection Contractor (AIC), and the Integrated Pollution Prevention and Control (IPPC). A company that is involved in coating wooden surfaces must hold an IPPC license. A company wishing to obtain an IPPC license can do so through the EPA, or directly from their local authority (EPA 2002).

As stated in chapter 1 it is clearly evident that laws and regulations are becoming more stringent in relation to solvents and their effect on the environment. It is, therefore probable that the laws will further decrease the threshold limits for the coating of wood surfaces in the coming years. The onus is still on the user companies to try to reduce the levels of solvent use. Companies who find themselves constrained by this directive must choose the most cost-effective way to achieve the required reductions, either by the use of abatement technology, which means to use alternative methods to reduce the amount of solvent used, or by replacing high-solvent products by low-solvent or solvent-free products.

2.3 Finishing – A Brief Overview

Wood finishing can be defined as the process of enhancing and protecting the surface of wooden objects (Velikanje, 2006). The purpose of wood finishing is to both protect the wood by providing a durable finish and enrich the natural beauty and appearance of the wood. A finish can increase the stability of the wood by creating a resistance barrier against harmful penetrative substances such as chemicals, heat or liquid spills (Stokke, 2005). It will also accentuate the beauty of the timber and bring out its characteristic by highlighting the grain pattern. There are two general types of wood finishes, penetrating finishes and surface finishes (Halstead, 2000). Penetrating finishes are absorbed into the wood, whereas surface finishes build up layers on the surface of the timber.

Wood finishing can be traced back centuries to the time of the Pharaohs. It is believed that people first used oils such as poppy, nut and linseed to polish timber (Peters, 1987). Gums and resins were also used as a wax to polish the timber. It was not until the 1800's that more common methods were used, with French polish being introduced in 1820 (Peters, 1987). The development of the finishing environment progressed onto using resins and chemicals to produce more user friendly and quicker processing finishes, such as lacquers.

2.4 Types of Finishes

To gain a clearer understanding of the types of finishes available and the development and progression of the finishes over the years, a number of different types of finishing methods will be examined in this section namely, wax and oil; French polish; solvent based lacquers; waterbased finishing and powder coating.

2.4.1 Wax and Oil

Traditionalists tend to use wax or oil as their choice of finish. A common wax that is used combines a formulation of beeswax and turpentine that can be hardened by using additives such as pure copal varnish or carnauba wax. An advantage of using wax is the ease with which the finish can be renewed. Other formulations of waxes are available for finishing over thin base coats of cellulose or synthetic lacquers. These waxes are usually composed of a soft paraffin-wax with a synthetic micro-wax (Hawks, 1995). Oil finishing is similar to wax

polishing in that it can be renewed frequently to maintain the desired finish. Linseed oil is used on timber, however, as it can take up to 12 coats to acquire the finish needed it does not live up to modern day requirements as it is too time consuming. Typically a maximum of 3-4 coats would be the requirement of industry today. Development in oil finishing has seen newer oils on the market, which speed up the finishing process. This is achieved by adding rapid oxidizing agents to the oil mixture, providing capabilities of attaining a satisfactory build-up in as little as two coats. Wax and oil are still used today, but not usually for production due to the intensive labour required to apply the finish. The main areas where they are still used are on traditional pieces of furniture or one-off pieces. Wax and oil are still applied to flooring due to its ease of application and reparability. Wax and oil do not contain VOC gases and, therefore do not fall within the scope of the EU directive.

2.4.2 French Polish

It is a technique used for wooden furniture that generates a very high gloss, deep colour and tough surface. It is achieved by applying many thin coats of shellac using a rubbing pad, which is made of wadding inside a square piece of cotton. Shellac is a natural polymer that comes from the lac insect 'Coccus Lacca'. When the natural shellac is mixed with alcohol (typically containing ethanol and methanol) it produces a hard, durable finish that can be applied to wood (Le Coz C-J., et al, 2000). The process is very laborious and requires a high amount of skill on the behalf of the finisher. It was used on high quality furniture until the introduction of spray finishing in the 1930's. It is still used today, but mainly for restoration work. French polish does not contain VOC gases and, therefore is outside the scope of the EU directive.

2.4.3 Solvent Based Lacquers

Lacquer is a clear or coloured coating that dries by solvent evaporation producing a hard durable finish. The lacquer consists of a resin dissolved in a fast drying solvent. The earliest known lacquers were made in China around 7000 BC. They were made from the resin of the 'Rhus Vernicifula' tree and possessed a very hard, durable finish. It was very resistant to water and/or abrasion, however, it was not as tolerant of ultraviolet light (Nanetti, 2006).

In the 1920's nitrocellulose lacquers were developed (Jackson, 2004). It contains a resin acquired from the nitration of cotton and other cellulosic materials. It produces a highly transparent and even flow finish. As technology evolved the formulation of lacquers were altered to improve its characteristics. Synthetic lacquers are the umbrella name for these types of altered lacquers. They have increased heat, water and spirit resistance, have a tough film and can achieve a high gloss sheen. They include acid catalyst, pre-catalysed and polyurethane lacquers.

- Acid Catalyst lacquers are formed with urea formaldehyde, melamine and epoxy resins with alkyd plasticizers (Jewitt, 2004). In order for this lacquer to cure properly it must be mixed with an acid catalyst usually hydrochloric acid prior to its application. This acid triggers a polymerization of the lacquer. As a result the mixed lacquer has a limited pot life.
- Pre-catalysed lacquers already contain the catalyst when purchased. This is known as an all-in-one solution. The advantage of the pre-catalysed lacquer over the acid catalyst lacquer is the extended pot-life. However, the acid catalyst lacquer is a much more durable finish.
- Polyurethane lacquers also offer an exceptional hard durable finish with a resistance to water and chemicals. A high gloss sheen is more easily attainable.

The chemicals present in synthetic lacquers produce high levels of VOC gases when evaporating, and therefore lacquers come within the scope the EU directive.

2.4.4 Waterbased Finishing

In waterbased paints, the majority of chemical solvent has been replaced by water. Typically the ratio of water to VOC is typically 4:1(Heaney, 2002). Very recently a few zero VOC paints have become commercially available, but their performance has not been proven and is not considered here. Almost all types of resins can be formulated as water-based paints. Due

to the low ratio of VOC's present in this finish material, it can be considered to have a less harmful effect on the environment.

2.4.5 Powder Coating

Powder coating began in Europe in the mid 50s and filtered its way into North America in the late 60s (Palmer, 1999). Powder coating is a dry finishing process, using finely ground particles of pigment and resin, which are electrostatically charged and sprayed onto a part to be coated (Contrasting powder coating, 2006). This differs to most of the conventional methods of applying a finish to wood products, which are in liquid form and therefore, known as a wet finishing process. Powder coating is now the fastest growing finishing technology in the US representing over 10% of the total industrial finishing market (Palmer, 1999).

The finishing processes for Wax, Oil and French polish will not be discussed as they are not typically used for industrial scale production.

2.5 The Finishing Process of Waterbased Finishing & Solvent Based Lacquers

Applying waterbased finish or solvent based lacquer to timber can be done using the same techniques and equipment. It is vitally important that the surface of the substrate is prepared sufficiently to achieve a high quality finish, regardless of whether it is for waterbased or solvent based finishing.

The application is as follows.

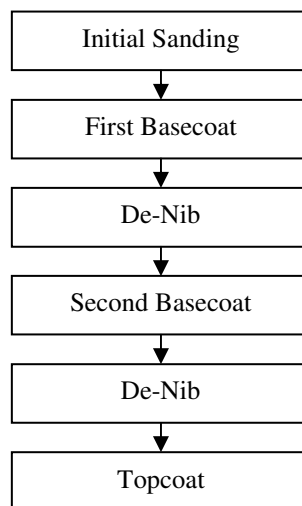


Figure 2.1 Spraying Sequence

In order to gain a smooth finish the surface of the substrate needs to be sanded. Surface preparation basically entails sanding the surface to be coated to remove any imperfections or defects acquired during its manufacture that could influence the quality of finish. These could include stains, uneven surfaces or marks. The sanded surface of the panel should be smooth, but still have sufficient grip for the finishing coat to adhere to.

As outlined in Fig 2.1 the first coat of finish applied to the substrate is commonly referred to as a basecoat. The basecoat acts as a protective film over the substrate. By spraying another coat of basecoat or a finishing coat of lacquer to the substrate a more durable finish will be achieved. After the initial coat the fibres in the grain will rise and cause a rough feel to the surface. De-nibbing is the process used to smoothen out the fibres raised as a result of spraying. The excess dust must be removed before spraying the next coat. This can be done by either using a cloth or an air line. It is totally up to the discretion of the operator as to how many coats to give the substrate. The final coat is termed a topcoat.

The ideal drying conditions for a waterbased finish is in a drying room where there is constant air movement at 30° C and a humidity of 30° (P Testa, 2006, pers. comm., 24 November). However a coated panel will cure if left to dry naturally but drying time will increase. In ideal drying conditions, drying times can be as little as 15 minutes (P Testa, 2006, pers. comm., 24 November). These conditions can also be applied to the drying of solvent based lacquers however, it is not as vital to achieving a quality finish.

2.6 The Finishing Process of Powder Coating

The coating process can be done manually or automatically with a wide variety of equipment available. The parts to be coated are electrically grounded so that the charged powder particles projected at them adhere to the parts and are held there until melted and fused into a smooth coating in the curing oven (Kreeger, 2000). Powder coating is only applicable to MDF and not solid timber. In order for the powder to adhere to a substrate there needs to be sufficient conductivity between the charged particles of the powder and the substrate itself. The moisture present within wood is used as the conductor to allow adhesion of the powder particles. The

process requires the wood based substrate to be heated to bring the moisture to the surface for coating. As MDF is a man made product its properties are uniform throughout a piece therefore, its behavior is predictable and controllable whereas solid wood does not have uniform properties. While MDF will react to heat in a certain way, solid timber is much less predictable and undependable. Therefore solid timber is unsuitable to the process.

The following diagram is of the powder coating process.

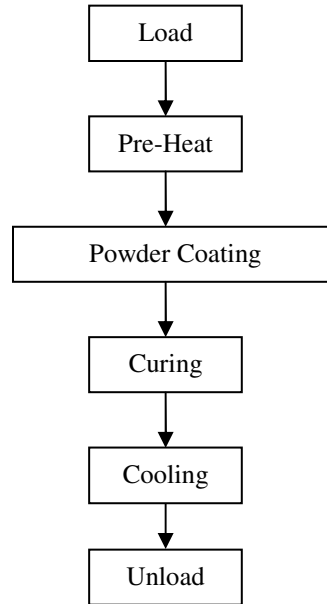


Figure 2.2 Powder Coating Process

Parts to be coated are initially loaded onto a conveyor. The substrate must have sufficient and even moisture content to provide conductivity, which is required by the powder to fuse to the substrate part (Hughes, 1997). This is achieved by preheating the part in an oven. The temperature of the MDF product needs to reach approximately 94°C to 108°C in order to remove excess moisture (Heathcote, 2001). The result will produce a substrate condition that is conducive to attracting and holding powder. The powder is then applied using an electrostatic spray gun. The charge is applied to the powder through either induced friction, known as Tribo charging, or a corona field, called Corona charging (Landgraf, 2002). Once the powder is applied to the preheated MDF it will begin to flow. The melting and flowing of the powder is referred to as gelling and the gelled powder is called the molten film (Heathcote, 2001). The coated object is then sent to an oven to cure the powder. There are two typical

processes for curing powder coated MDF, which are i) UV process, and ii) Thermoset process. Both are very similar with the only real difference being the curing section. For the UV process an ultra violet radiation light source is used to cure the powder. The ultra violet light emitted reacts with the specially formulated UV powder to dry the substrate rapidly. The thermoset process however, relies solely on the heat from the curing oven. The heat from the oven bakes the powder to form a durable film. The most commonly used heating source employed in thermoset process is from convection heat. The UV process is quicker but more expensive. This is due to the cost of the specialised powder and the heating source, which is more expensive than that employed by the thermoset process. Depending on the board thickness, the cure stage can take anywhere from five to seven minutes (sometimes as much as 20 minutes, depending on the powder formulation) at approximately 375°F (Binder, 2004). Finally, the boards advance through a cooling tunnel where they are then unloaded.

2.7 Comparison of the Finishes

Table 2.1 compares solvent based lacquers, waterbased finishing and powder coating in terms of VOC Emissions; Set-Up Costs; Process Characteristics; Quality of Finish; and Range of Applications.

Table 2.1 Comparison of Finishes

	<i>Solvent Based Lacquer</i>	<i>Waterbased Finishing</i>	<i>Powder Coating</i>
<i>VOC Emissions</i>	<ul style="list-style-type: none"> • High 	<ul style="list-style-type: none"> • Low 	<ul style="list-style-type: none"> • None
<i>Set Up Costs</i>	<ul style="list-style-type: none"> • Low 	<ul style="list-style-type: none"> • Medium 	<ul style="list-style-type: none"> • High
<i>Process Characteristics</i>	<ul style="list-style-type: none"> • Requires Numerous Applications • Low Drying Time • Limited Pot Life 	<ul style="list-style-type: none"> • Requires Numerous Applications • Drying Times longer than Solvent • Requires Excellent Spraying Environment • Thinning by Water • Cleaning Very Easy 	<ul style="list-style-type: none"> • One coat application • Powder is Recyclable • Fast Processing Time • Up to 98% Transfer Efficient • High Volume Required • Large Space Required • Careful Cleaning Required
<i>Quality of Finish</i>	<ul style="list-style-type: none"> • Durable Finish Attainable • Good Quality of Finish Attainable 	<ul style="list-style-type: none"> • Durable Finish Attainable • Good Quality of Finish Attainable 	<ul style="list-style-type: none"> • Durable Finish Attainable • Good Quality of Finish Attainable
<i>Range of Applications</i>	<ul style="list-style-type: none"> • Easy to Apply • Variety of Colour Available 	<ul style="list-style-type: none"> • Easy to Apply • Variety of Colour Available 	<ul style="list-style-type: none"> • Can only be used on MDF • Variety of Colours Available

VOC Emissions:

- Solvent based lacquers contain high levels of solvent, which emit toxic VOC gases that are harmful to the environment.
- Waterbased finishing contains significantly lower VOC levels than solvent based lacquers, making the finish environmentally friendly.
- Powder coating contains no solvents and therefore, emits no polluting VOC's in to the atmosphere.

Set Up Costs:

- Solvent based finishing material is the most inexpensive of the three types of finish. It is cheap to set up as it requires the least amount of atmospheric conditions present to achieve a sufficient finish. The required spraying equipment is relatively inexpensive and readily available
- Waterbased finishing material is more expensive than solvent based finish. It requires a greater initial investment and to achieve a good quality finish certain atmospheric variable conditions are needed. The spraying equipment needed is the same as that need for solvent based finishing.
- Powder coating is the most expensive. It requires a vast investment for setting up. It also requires a sizeable amount of space as it is a one coat process and necessitates the need for a lot of equipment.

Process Characteristics:

- Solvent Based Lacquers:
 - Solvent based lacquer requires numerous applications of material to achieve the desired finish.
 - Short drying time is required for this type of finish.
 - Due to the nature of some particular varieties of solvent based finishes such as acid catalyst (AC) the pot life of the finish can be limited. This means that once the material is mixed with a mixing agent it has to be used in a specific period of time.
- Waterbased Finishing:
 - Similar to solvent based lacquer numerous applications are required to achieve a quality finish.
 - Waterbased finish requires longer drying times than that of solvent based finish.
 - Drying equipment can significantly reduce the drying times, however, this requires investment.

- To ensure a good quality of finish the surrounding environment i.e. the airflow and the extraction need to be correct.
- Unlike solvent based material, waterbased finishing can be thinned out by using water.
- Powder Coating:
 - Powder coating is a one coat process.
 - Powder coatings main advantage over the other two finishes is that it is a one coat process. Powder coating can be 98% transfer efficient and the powder is recyclable resulting in resourceful finishing system.
 - There would need to be sufficient high volume of product to justify implementing a powder coating finishing system.
 - Due to the nature of processing in powder coating a large space is required to house the painting line. This is not the case with the two other finishes.
 - A thorough level of cleaning is required to make sure cross contamination does not occur during colour changing with powder coating. The powder coating application unit must be thoroughly cleaned out to ensure that colours will not get mixed up.

Quality of Finish:

- All three finishing methods offer good quality durable finishes.

Range of Application:

- Solvent based lacquer and waterbased finishing are both easy to apply and are available in a wide variety of colours.
- Powder coating is also available in a variety of colours. It can only be used on medium density fibreboard (MDF) presently. The technology is not available to use powder coating on solid timbers.

Having looked at the relevant information regarding the different types of finishes that are used in the furniture industry it seems clear that powder coating is not a suitable alternative to solvent based finishes. While powder coating does meet the requirement for an

environmentally friendly finish the fact that it can only be applied to MDF does not help its cause. A finishing system that is unable to be used on solid timber would not suit the greater need of the Irish furniture industry. Another negative point is that it is very expensive to implement. Furthermore powder coating is suited to high volume production, which is not the trend of the industry. On the other hand waterbased finishing has many advantages, which are suited to the Irish furniture industry. It is an environmentally friendly finish, which would meet the requirement of the legislation. It uses a simpler processing technique than powder coating. It is possible to use the same equipment for waterbased finishing as the ones used for solvent based finishing provided that the equipment is non corrosive. This would mean that a company who changed from solvent based finishing to waterbased finishing could use the same equipment, thus saving money. At this stage it is believed that powder coating is not the solution to meeting the requirements of the legislation.

2.8 Other Solutions

Apart from the VOC directive there are other challenges facing the Irish furniture industry. As Ireland continues to grow in economic terms, it has become increasingly more difficult to manufacture all components in-house, therefore, as is apparent from the Intertrade Ireland report on the Irish Furniture Industry 2004 (InterTradeIreland 2004) more companies are buying in their components from countries where production and labour costs are significantly cheaper. This is termed outsourcing, which is defined as the process of subcontracting a process, such as product design or manufacturing to a third party company (Banerjee, 2005, p. 272). The main reason for outsourcing is that it has become increasingly more difficult to produce components in-house at low cost. At the furniture design and market trends forecast 2006 conference, furniture designer Steve Armitage said that it is becoming increasingly more common for furniture companies to import their products from eastern European countries. He continued to say that the facilities are “top class” and that their technology is developing quickly. He also made the point of cheap labour being a factor in the changing attitude to importation. Another contributor at the conference, Sean Hassett of Mopan Ltd actually has based his factory in the Ukraine where the average monthly salary is approximately €100. This information signifies the advantage of outsourcing and would suggest an explanation as to the growth of outsourcing within the Irish furniture industry. According to the consumer group

sector report 2004, outsourcing by furniture companies increased by 35% since 1999. This is putting increased pressure on the industry to be more competitive.

By outsourcing finishing it means a company would not be in breach of any threshold limits. However, it must be remembered that due to the nature of the Irish furniture industry that outsourcing would not be considered the most appropriate route for many furniture manufactures. The Irish furniture industry consists of many types of furniture manufacturers. Among these are architectural joineries, cabinet makers, kitchen door manufactures, standard joineries, bedroom furniture manufactures and office furniture manufactures. Not all of these types of manufacturers would lend themselves to outsourcing. In order for outsourcing to be beneficial and cost effective, large batches and high order levels would be required. This simply would not be the case for most of the companies within the Irish furniture industry. The Irish furniture industry is characterised by small and medium enterprises (Sexton, 2004) producing small batch sizes rendering outsourcing unsuitable. Another drawback of outsourcing is that by having to sub contract the work out to cheaper processing countries it is harder to control the quality of the product. It is due to this that many furniture companies will only buy in components rather than finished items as they can control the finishing/ assembly of the products.

To try and avoid losing furniture manufacturing to foreign countries with cheaper labour costs, it is up to the companies to embrace new technologies, new innovations and up skill the workforce in an attempt to reduce the dependency on imports to stay in business (Intertrade Ireland, 2004). It is clear, from the authors experience that one of the major reasons why the industry is so reliant on imports is the lack of advancements in trying to reduce operation and running costs. Were the industries to address these issues, then it maybe able to reduce the amount of imports. Finishing areas need to become more efficient in order to deal with the increasing pressure of being able to adjust to changing product requirements. Therefore, a possible solution would be to use operation management techniques. Applying some basic operation management techniques could assist companies in becoming more resourceful. Many of the furniture companies in Ireland are family based and are also predominately manufacturing/ production orientated and have a reluctance to employ people with the relevant

management experience to develop the business (Intertrade Ireland, 2004). It is understandable that they might not possess the knowledge of how best to use certain management techniques and tools to benefit their operation. Focusing on issues such as the layout of the finishing facility and the training of operatives can increase efficiency. This will therefore, make companies more productive and can eliminate waste, which is also a cost factor (Slack et al 1995, p. 524). Another way to increase efficiency is to eliminate human error. In relation to finishing, one way to remove human error would be to use some form of automation. Slack et al explain that the benefits of automation are that it reduces direct labour costs and also variations in operations. This can result in less work in progress (WIP) and less rework.

2.9 Conclusion

This chapter has given a brief synopsis of the legislation and its impact on the Irish furniture industry. From this it emerged that laws and regulations are becoming more stringent and that there is a need for the industry to be reactive in terms of meeting the requirements of the legislation. A general overview of finishing methods was presented followed by a description of the finishing processes of solvent based lacquers, waterbased finishing and powder coating. A comparison between the above three methods was made with waterbased finishing emerging as the suitable to replace solvent based finish. In addition to waterbased finishing, outsourcing, automation or operation management techniques were identified as alternative ways of complying with the legislation.

There is a need to take a comprehensive look at the industry and examine the current practices and procedures in use. The following chapter will look closely at eleven case companies from the industry.

Chapter 3 Case Study Analysis of Current Finishing Practices

3.1 Introduction

With the arrival of the EU solvent directive and its impact on the Irish furniture industry the author felt there was a need to investigate current furniture manufacturer's practices in relation to finishing. The purpose of this chapter is to analyse these practices within the Irish furniture industry. A number of case studies were examined and research was carried out on their current finishing practices, setup and attitudes to change. This research was conducted through the use of a questionnaire and interviews with the companies. These results were evaluated and requirements for companies within the industry who were affected by the new laws and regulations pertaining to finishing were identified. This part of the study relates to the identification element of the research methodology diagram that was depicted in chapter 1. The highlighted segment in Fig 3.1 below indicates the process.

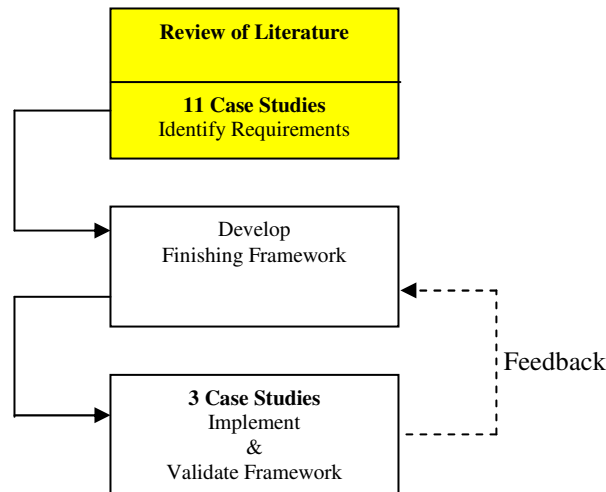


Figure 3.1 Research Methodology

3.2 Data Collection Methodology

Creswell (2003) states that case research employs varied ranges of data collection techniques. Data collection methods can be both qualitative and quantitative. Examples of the methods used in this study are (i) questionnaires, (ii) interviews, and (iii) observations. The strengths and weaknesses of each of the collection methods are depicted in Fig 3.2.

METHOD	STRENGTHS	WEAKNESSES
<i>Questionnaire</i>	Precise and consistent Easier to evaluate	Little room for elaboration Questions can be misinterpreted
<i>Interview</i>	Focuses directly on the case study topic Provides interviewee with the chance to elaborate on certain questions	Interview questions must be systematically developed Inaccuracy due to poor recall
<i>Observations</i>	First hand evidence of events Practices & procedures	Time consuming Hard to gain access

Figure 3.2 Data Collection Methods for Case Study Development (Creswell, 2003)

In order to gain a valuable insight into the current finishing practices of the Irish furniture industry and their attitudes to the EU legislation regarding solvent usage, eleven case studies were carried out. These case studies are representative of Irish furniture manufactures. The industry comprises of a number of different types of manufacturers including kitchen, bedding, contract and architectural joinery (Intertrade Ireland, 2004). The types of furniture companies used varied in terms of size, number of employees, and type of end product produced. The companies selected ranged from architectural joineries to kitchen door manufactures, however the similarity between all the companies was that they were involved in spray finishing. The main reason for selecting different companies was to provide an accurate reflection on the entire industry.

From carrying out a literature review of case study methodologies, the author decided that the best way to obtain the information required was to use a questionnaire and a time study. The author designed a questionnaire and a method to collect the time study data. The time study was a way to examine existing finishing processes and procedures by taking time recordings of how long it took operatives to spray items and how long it took those items to dry. In order to check the effectiveness of the questionnaire and time study the author tested both on a test company. The testing of the data gathering systems proved to be very beneficial as it showed the shortfalls of both the questionnaire and the time study. The decision was taken to drop the use of a time study. The reason for this was that the time study was only an indicator of how

efficient a company was at their individual finishing process rather than their overall procedures. The testing of the questionnaire showed that some of the questions needed to be refined and some needed to be eliminated. The testing stage also showed that the questionnaire needed additional support as well as refinement. It was therefore decided that in order to get the best out of the questionnaire it would need to be supported by an interview. By adding the dimension of the interview it meant that there was now a chance to gather information regarding alternative finishing methods and practices and procedures used in industry, which was not present in literature reviews. By combining the questionnaire and interview the shortcomings of the previously selected methods were overcome. From testing the questionnaire and the time study the author also found that there was a need to view and observe first hand the spraying environment and the practices put in place by each company in relation to spraying. By observing different spraying operatives in different companies, both similarities and improvement would be more easily recognised.

The Questionnaire

With the purpose of obtaining an understanding of the finishing environment in the Irish furniture industry a questionnaire was designed. The aim of the questionnaire was to find out all aspects of finishing within a selected number of companies, which would provide a realistic and reliable estimation of the industry on a whole. There were many questions that needed to be asked, ranging from the type of finishing systems currently in use to the understanding of legislation.

From researching into how to design a professional and high-quality survey, it transpired that both the structure and the style of the questions are important (Gillham, 2000). It is apparent that a much higher success rate can be achieved using multiple choice style questions, which are known as closed ended questions (Burgess, 2001). This style of question has a two fold benefit. Firstly, the benefit to the interviewee is that it is simpler to answer a multiple choice type question. Due to the time pressures of business many companies would not be able to spend time writing down all the answers and therefore a simple tick in the appropriate box suits them best. It is quicker to complete and because the questionnaire had been well researched beforehand it is more user friendly. As well as being practical for the user it also

has added benefits for the researcher by making the analysis easier. It is vitally important that the flow and sequence of a questionnaire is correct. By having a survey that moves progressively in a logical manner, the interviewee is more likely to answer the survey in a positive frame of mind (Burgess, 2001).

By applying the design criteria as identified from the literature, a questionnaire was developed to extract the necessary information from the interviewees. The majority of the questions were multiple choice type questions. However, the author was conscious of not restricting the companies in answering questions and provided 'other' boxes in the multiple choice sections which could be ticked. This provided the companies with an option to describe additional information if they felt it was appropriate. As stated previously the questionnaire was devised to gather information about current practices and procedures as well as awareness of the environmental laws and regulations.

Fig 3.3 is a copy of the questionnaire that was used on the case companies. As there was a mixture of the case companies who were using solvent based finishing and waterbased finishing, the questionnaire was altered to suit. The copy presented is a questionnaire for solvent based companies. The copy that was used for waterbased companies is in appendix A. The difference between the two questionnaires was that companies who had already installed waterbased finishing systems were asked some extra questions to detail the problems encountered when implementing the new system. It also gave the author the ability to understand their reasons for changing to waterbased finishing.

Chapter 3 Case Study Analysis of Current Finishing Practices

1. What type of finish do you currently use?				
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Acid Catalyst	Pre-Catalyst	Polyurethane	Water-Based	Other
If other please specify:				
2. How many spray guns do you have/ use?				
3. What type of spray guns do you use?				
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Suction Feed	Gravity Feed	Pressure Feed	Air Assisted Airless	Other
4. Do you use Conventional Air Spray or High Volume Low Pressure (HVLP) guns?				
<input type="text"/>	<input type="text"/>			
Conventional Air Spray	HVLP			
5. What types of spraying do you do?				
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
Lacquer (Natural/Clear)	Stain	Colours/ Paints	Other	
If other please specify:				
6. Have you got separate spraying guns for basecoat and lacquers?				
Yes				No
<input type="text"/>				<input type="text"/>
7. Have you a separate gun for paints?				
Yes				No
<input type="text"/>				<input type="text"/>
8. Have you a separate gun for stains?				
Yes				No
<input type="text"/>				<input type="text"/>
9. Do you use the same gun for more than one type of finish? (E.g. lacquers and paints)				
Yes				No
<input type="text"/>				<input type="text"/>
10. How often do you clean out you guns?				
Once a day			Once a week	Other
<input type="text"/>			<input type="text"/>	<input type="text"/>
11. How do you clean your spraying equipment?				
Spray gun washer			Manually	Other
<input type="text"/>			<input type="text"/>	<input type="text"/>
12. How often do you service your guns? (I.E. take gun apart to thoroughly clean, change filters etc...)				
Fortnightly	<input type="text"/>	Monthly	<input type="text"/>	Bimonthly
<input type="text"/>		<input type="text"/>		<input type="text"/>
13. Who are your main suppliers of finishing material?				
14. Do you have a separate drying room?				
Yes				No
<input type="text"/>				<input type="text"/>
15. Is the drying room heated?				
Yes				No
<input type="text"/>				<input type="text"/>
16. Is there a separate airflow in the drying room?				
Yes				No
<input type="text"/>				<input type="text"/>
17. How long does it take for a typical panel to dry before it can be de-nibbed or packed for assembly?				

Chapter 3 Case Study Analysis of Current Finishing Practices

18. What type of extraction system do you use?			
Water Flow <input type="checkbox"/>	Filters <input type="checkbox"/>	Other <input type="checkbox"/>	
19. Do you have a separate airflow coming into your spray booth?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
20. Is the spray booth heated?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
If yes please state how?			
21. How long does it take to change from one type of finish to the other (e.g. from basecoat to lacquer)?			
>5 minutes <input type="checkbox"/>	>=10 minutes <input type="checkbox"/>	>=15 minutes <input type="checkbox"/>	<15 minutes <input type="checkbox"/>
If <15 minutes please specify:			
22. How long does it take to switch between paints and lacquers?			
>5 minutes <input type="checkbox"/>	>=10 minutes <input type="checkbox"/>	>=15 minutes <input type="checkbox"/>	<15 minutes <input type="checkbox"/>
If <15 minutes please specify:			
23. How do you dispose of your spraying waste?			
Waste Contractor <input type="checkbox"/>	Other <input type="checkbox"/>		
24. There is a new EU Solvent directive that comes into forces in October 2007, which may have an effect on the amount of solvent that you can use. Are you aware of this legislation?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
25. In the legislation, limits are used to determine whether a company is in breach of the rules. The limits are expressed in the amount of organic solvent used per year. The limits are <5 tonnes, <10 tonnes, and <15 tonnes. Which category is your company in?			
<5 Tonnes <input type="checkbox"/>	<10 Tonnes <input type="checkbox"/>	<15 Tonnes <input type="checkbox"/>	Far below limits <input type="checkbox"/>
26. Are you aware that you must hold a license if using 10 tonnes of solvent?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
27. Have you considered changing your current spraying methods to comply with the legislation?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
28. Are you aware of waterbased finishing?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
29. Are you aware of its advantages (uses water instead of solvent for thinning purposes, reduced solvent emissions, lower fire risk, can use the same spraying equipment as used with solvent based material)			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		
30. Would you be willing to switch from your current situation to waterbased finishing?			
Yes <input type="checkbox"/>	No <input type="checkbox"/>		

Figure 3.3 Questionnaire

The breakdown of the questionnaire is as follows;

- The Finishing Material & Equipment Being Used

This information was required to get an understanding of the type of finishing material and the type of spraying equipment Irish furniture companies are currently using. Questions 1-5 are specially designed to gather this information.

- Practices and Procedures

Questions 6-12 were used to find out how efficiently companies use their equipment as well as the type of and frequency of maintenance used for this spraying equipment. Questions 14-23 also gave the author an indication of the practices used by companies in relation to drying area's and extraction. This assists the author in establishing whether or not companies would be ready to change to an alternative to solvent based finishing. It also helps identify the areas where improvement can take place.

- The Suppliers

Question 13 solely looked at who the main suppliers of finishing material to the industry are.

- Levels of Current Solvent Usage and Awareness of Legislation

An understanding of the level of solvent usage was a critical part of the questionnaire. It showed which of the case companies were in breach of the threshold limits and as a result it gave the author an opportunity to see how these companies were trying to comply with the regulations.

The author also wanted to get an understanding of the level of awareness of the companies in relation to the legislation. Questions 24-27 were structured to gain this information.

- Awareness of Alternatives to Solvent Based Finishing

Questions 28-30 extracted information pertaining to the level of awareness to alternative finishes to solvent based finishes. This gave the author the ability to test the knowledge of the companies with regard to alternatives to solvent based finishes. It also posed the question on how aware companies are in relation to waterbased finishing. The answers to these questions also gave the author the

ability to judge the willingness of those within the industry to embrace change to waterbased finishing. As outlined previously in this chapter there was a slight difference in some of the questions depending on whether or not the company was using waterbased or solvent based finishing. While the solvent based companies were asked about their attitudes and understanding towards waterbased finishing, the type of questions posed to companies using waterbased finishing had a different angle. To the companies using waterbased finishing, questions were posed to gain an appreciation of the difficulties experienced by the companies during the changeover period, and also to gain an understanding of their reasons for switching to waterbased finishing (Appendix A).

The Interview

While interviewing the companies it was clear that the companies wanted to elaborate on certain questions in the questionnaire. The questionnaire was designed specifically with the intention to extract the most relevant information but did not allow for the opinions of the companies on their approaches to spraying to be taken into account. This was the primary reason behind supporting the questionnaire with an interview. As well as elaborating on questions it also gave the companies the opportunity to discuss areas which were not in the questionnaire. This was very helpful as it gave the author a clearer understanding of the reasoning and rationale used by the companies in making decisions concerning spraying. The interview also gave the author the opportunity to discuss in greater detail the major concerns companies have in relation to waterbased finishing. It also assisted in establishing an understanding of the difficulties most likely to be experienced by companies who are considering change to waterbased finishing as an alternative to solvent based finishing. The overwhelming benefit of the interview is that it improved the accuracy of the questionnaire thus increasing the validity of the results obtained.

Observations

The pilot testing of the questionnaire and time study showed the flaws of the time study and identified the areas for improvement in the questionnaire format. It also highlighted the need

for observations of spraying practices and procedures to take place. To gain a further insight into how each individual company approaches the practices and procedures of finishing, the author spent time observing the spraying operatives, and also observed the differing styles of spraying facilities currently in operation in the Irish furniture industry. This gave a clearer understanding of the level of development in regards to the finishing sector in the Irish furniture industry. By observing the facilities, procedures and equipment the author was able to identify areas for improvement. Another significant advantage of observing the spraying facility, the operators, the practices and the procedures is that it backed up the answers supplied in the questionnaire.

3.2.1 Profile of Case Companies

A letter was written to twenty five furniture manufacturers in Ireland detailing the scope of the research being undertaken by the author. The letter gave details on the role that the case companies would play in assisting the research of the author in developing a solution to the problem of the legislation. The letters were followed up by telephone conversations to establish the number of companies that were interested in partaking in the research. Out of the twenty five companies contacted, eighteen companies gave positive feedback. Of these eighteen companies eleven were chosen. The reason why the other seven companies did not feature in the research was due mainly to time constraints. The eleven companies chosen were selected as they represented a fair cross section of the Irish furniture industry. The selected companies reflected a broad range of companies from medium enterprises to larger furniture manufactures. Likewise the type of production they were engaged in was varied with some involved in one-off specialised furniture and others involved in batch production and high volume production. As the Irish furniture industry is very diverse it was decided that in order for the study to accurately reflect the industry all type of furniture manufacturing companies needed to be chosen. While products, scale of production and numbers employed all varied the one constant with all the companies contacted was that they were involved in finishing. It was not until each company was interviewed, that the author was able to establish whether or not they were above, below or on the borderline of the threshold limits.

While taking this into consideration, it is highly unlikely that any small furniture companies as defined in chapter 1 will be affected by the legislation. Graham Rayner of Becker Acroma, one of the leading solvent based suppliers to the Irish furniture industry, indicated that in order to be encroaching on the threshold limits of 15 tonnes of solvent usage per annum, a furniture company would need to be using in excess of 21-24 thousand litres of pre-catalysed lacquer and in excess of 26-37 thousand litres of acid-catalysed per year (G Rayner 2007, pers. comm., 13 November). These figures are based on standard pre-catalysed and acid-catalysed lacquers. To give a clearer perspective of how much coverage this amount of finishing material would equate to, we can take a standard interior door as an example. A typical door measures 1980mm x 760mm. A litre of solvent finishing material is estimated to yield 7 square metres of coverage. If the door is coated three times on both sides, that would require just over 9 square metres of lacquer

$$1980\text{m} \times 760\text{mm} = 1.5048\text{m}^2$$

$$1.5048\text{m}^2 \times 2 \text{ sides} = 3.0096\text{m}^2$$

$$3.0096 \times 3 \text{ coats} = 9.0288\text{m}^2$$

1ltr of Solvent yields 7m² Coverage

$$9.0288\text{m} \div 7\text{m}^2 = 1.3\text{ltrs}$$

Given that a company would have to be using at least 21000 litres of pre-catalysed solvent per annum to reach the 15 tonnes solvent usage level, a furniture company would need to produce 62 doors per day to be anywhere near the threshold limits of the regulations.

$$21000 \div 1.3 = 16153.85$$

$$16153.85 \div 260 \text{ working days (52 weeks} \times 5 \text{ days a week)} = 62 \text{ doors a day}$$

It is highly unlikely that a company employing less than 10 people would be able to produce this quantity of product. This coupled with the fact that the majority of small companies produce one-off or unique products would almost certainly rule out small furniture companies being concerned by the new legislation. However, it is less clear as to how many of the medium size companies as defined in chapter 1 will be capable of producing this amount of

product. Therefore, all of the selected case studies are in the medium to large sized furniture company categories.

The following Table 3.1 presents a profile of each of the chosen case studies companies. The Table indicates the type of business that each case study is involved in. It also illustrates the number of employees employed by each case study and displays the type of finishing material currently used by each of the cases.

Table 3.1 Case Study Profile

<i>Case Study No</i>	<i>Type of Business</i>	<i>No. Employed</i>	<i>Solvent/ Waterbased</i>
A	Architectural Joinery	25	Solvent
B	Architectural Joinery	30	Solvent/Waterbased
C	Architectural Joinery	22	Solvent
D	Cabinet Makers	40	Solvent
E	Cabinet Makers	35	Waterbased
F	Bedroom/ Living Room Furniture	13	Solvent
G	Kitchen Door Supplier	30	Solvent
H	Occasional Furniture	15	Solvent
I	Bedroom Furniture	28	Solvent/Waterbased
K	Architectural Joinery	20	Solvent
L	Hotel Furniture	25	Waterbased

3.3 Case Findings and Analysis

The following section presents the findings and analysis of the case studies under the following headings;

- The finishing material being used
- Practices and procedures
- The suppliers
- Levels of current solvent usage and awareness of legislation
- Awareness of alternatives to solvent based finishing

3.3.1 The Finishing Material Being Used

63% of the case studies researched currently use solvent based finishing as their primary finishing material. The following table indicates the specific types of finishing material each case study uses.

Table 3.2 Type of Finish used by Case Studies

<i>Case Study No</i>	<i>Pre-Catalyst</i>	<i>Acid Catalyst</i>	<i>Polyurethane</i>	<i>Waterbased</i>
A	√	√	√	
B			√	(√)
C	√	√		
D	√	√		
E				√
F	√	√		
G			√	
H	√	√	√	
I	√			(√)
J		√	√	
K				√

The table indicates that the most commonly used finishing material used by the case study companies is Acid Catalyst (AC), at 63%, closely followed by Pre-Catalyst (PC) at 54%, Polyurethane (PU) at 45% while waterbased finished is used solely by 18%. The (√) symbol that is placed in the waterbased column indicates companies who are in the process of changing over to waterbased finishing. Using these case companies as a reflection of the Irish furniture industry, it can be deduced from this table that the majority of companies in the industry currently use solvent based finishing material. AC, PC and PU are all forms of solvent based finishing material. This indicates that the majority of the companies within the industry would need to be aware of the legislation, and to understand both the threshold limits and their current annual solvent usage.

3.3.2 Practices and Procedures

Table 3.3 relays information with regard to the drying room/areas of the case companies interviewed.

Table 3.2 Drying Room/ Area

<i>Case Study No</i>	<i>Separate Drying Room/ Area</i>	<i>Drying Room Heated</i>	<i>Separate Airflow</i>
A	√		
B	√	√	√
C	√	√	
D			
E	√*	√*	√*
F	√	√	√
G	√	√	√
H			
I	√*	√*	√*
J	√	√	
K	√*	√*	√*

All but two of the case studies have separate drying facilities. These range from specially designed heated drying ovens with additional airflow and extraction to vacant warehouse space adjacent to the spraying area where products are left to dry naturally. The √* symbol indicates the use of automated finishing lines which incorporate a controlled drying process. Those of the case studies who have heated drying ovens hold a distinct advantage over the other companies as they can control the drying conditions which lowers the process cycle time. This greatly enhances the possibility to improve on processing efficiency.

Table 3.3 Sprayroom

Case Study No	Extraction System Waterflow/ Dry Filtered	Separate Airflow	Sprayroom Heated
A	Dry Filtered		√
B	Dry Filtered		√
C	Dry Filtered		√
D	Waterflow		√
E	Waterflow	√	√
F	Dry Filtered	√	√
G	Waterflow	√	√
H	Dry Filtered		
I	Dry Filtered	√	√
J	Dry Filtered		
K	Waterflow	√	√

As indicated in Table 3.4 above, nine of the case study companies have heated spraying rooms. The majority of the case companies use heat from wood burners used to dispose of wood waste. Only six out of the nine have the ability to control the heat that is blown into the spraying area. The companies that can control the heat being vented into the spraying area

have the benefit of having a controlled tempered spraying area which can improve the quality of spraying. By controlling the air movement and air temperature it can significantly improve on the quality of finish acquired and also reduce the danger of imperfections in the spraying finish due to atmospheric conditions during application.

From analysing the data shown in both table 3.3 and 3.4, personally interviewing the companies and also observing the operators and the spraying process, it is interesting to notice that while some companies have installed a controlled spraying environment, they do not seem to be taking full advantage of the situation. The spraying environment factors such as the air supply, the air movement, the extraction, and the drying area all play a major role in the efficiency of spraying. Below is a list of the problems identified in the spraying facilities viewed.

- Excess Manual Handling

A great deal of human intervention with moving components between drying racks and spraying table was witnessed in many of the companies visited. This amount of human interaction can lead to a danger of damage to the component. This in turn results in the component requiring rework, which increases the amount of finishing material being used. This adds extra costs to the production. A way to counteract the amount of manual handling is to use portable trolleys that the component can be placed on once, and wheeled around to and from the spraying and drying area therefore lowering the risk of human error. Company C use portable racks for components to be sprayed. The benefit of the portable racks is that the item to be sprayed can be left in place on the rack and moved around comfortably without having to handle the item.

- No Set Spraying Procedures

Many of the companies analysed had very poor spraying procedures. In order for a consistent finish to be achieved the surrounding atmospheric conditions (i.e. the air movement within the spraying area) need to be maintained as stringently as possible. This entails keeping all doors leading into the spraying area firmly closed during spraying. Simple ways to ensure all operators know

when spraying is taking place is to install a go/ no go light outside the spraying area, and/ or to have vision panels on the doors so that workers can see if it is safe to enter the spraying area. By ensuring these conditions are maintained it can assure a quality finish is achieved. Keeping the door closed also benefits the extraction system. In order to maximise the usage of the extraction system the air flow within the spraying area must remain constant, a break in the air flow such as that caused by doors opening will reduce the extractions effectiveness. An inefficient extraction system will lead to overspray not being removed quickly enough from the spraying area and this overspray can land on the component resulting in a poor finish, which will require rework. Company F is an example of a company who has excellent spraying facilities. They are able to control their spraying environment, which in turn benefits the method of extraction and ensures levels of finishing defects are kept to a minimum.

- Poor Spraying Techniques

This is solely down to the skill levels of the spraying operatives. An operator who has not received adequate training will not be able to efficiently spray components. It can result in poor finishing of products which will result in rework. An untrained spraying operative will not have the required skills and understanding needed to identify problems with the spraying equipment of finishing material. In conjunction with this the operative will also lack the ability to solve any of these maintenance problems which can result in poor finishing and the need for rework. Company E fully train all of their finishing staff to both spray efficiently, and to be able to identify and rectify any defaults with the spraying material or equipment.

- Insufficient Drying Equipment

Many of the companies examined had very poor drying equipment. Whilst many had separate areas for drying the actual drying equipment was poor. Having drying equipment can speed up the spraying process. It can also insure a consistent quality finish as each component will be subjected to the same

drying conditions. Fluctuations in the drying temperatures can lead to defects such as blooming, orange peel or blistering which will result in components requiring rework. Company F have installed two drying ovens, which lowers processing time and also ensures all components are subjected to the same drying conditions. This results in a standard finish being obtained.

- Poor Spraying Equipment

Poorly maintained spraying equipment can result in poor application of the finishing material, which will produce a poor quality finish that will require rework. Regular maintenance and a daily cleaning procedure can lengthen the lifespan of the spraying equipment. Company H has a set procedure in place for cleaning and maintaining the equipment. This sort of care ensures the longevity of the equipment.

- Efficiency

Some of the case companies were producing large scale batches of similar products, which could easily be automated. Manual systems are simple and relatively cheap to use, however, using automated spraying machines can increase productivity and lead to an increase on savings of finishing material as there is an opportunity to reclaim unused or extra finishing material. Company K use an automated spraying line, which is highly efficient. The line is fitted with a recycling unit, which collects unused finishing material. As a result the manufacturers insist that the spraying line is 98% efficient. This is calculated on the amount of finishing material that adheres to the substrate compared to the amount of finishing material applied expressed as a percentage (ABC's 2001).

From observing the case studies practices and procedures, it is clear that best practices are not always fully understood, implemented properly or maintained.

Company C is a prime example of such a situation where best practices are not implemented and as a result the quality of finish suffers. Their spraying facility incorporated a large floor area where products were moved around on trolleys. If the weather outside was good the main doors at the back of the building were opened to allow a breeze into the area, thus acting as an extra air-flow to decrease the drying time. However, if the weather changes suddenly this can cause quality issues with the finish, whereby the finish starts to 'bloom' (bloom is a whitish cloud-like formation that appears on the surface of the finished panel, it is the result of too much moisture in the surrounding air when the panel is drying out). On these occasions the operators turn on the oil heater to dry out the air within the spraying area. This is not controlled and can cause other problems to the finish such as blisters or bubbles whereby finished panels are drying too quickly. Company C is not the only company that was interviewed to have this situation: therefore, it can be deduced that this is common across the industry.

However, there are companies who have implemented best practices by controlling their spraying environment and are reaping the benefits. Company F is a case in point. They have a separate controlled heated air-flow that is blown into the spray room. This means that the temperature within the room remains constant providing an excellent environment to spray the finish. Inside the spraying area are two separate heating tunnels or heated drying rooms. Each heated drying room is controlled thus providing the correct conditions for drying. By implementing such a controlled environment the company can guarantee a standard processing time for products. It also eradicates the conditions that lend themselves to finishing defects such as blooming and blisters experienced by businesses such as company C. By removing the conditions that lead to finishing faults/defects it reduces the amount of re-work. This results in better utilisation of the finishing material and reduces the amount of finishing product required.

Through discussion and observations it is clear that there is a lack of guidance in the form of how to utilise the spraying equipment properly. The companies are lacking a best practice guide to assist in maximising their spraying facility efficiency. They need to be made aware of

how to use best practices and given simple and effective procedures which will help improve their spaying process.

3.3.3. The Suppliers

Table 3.5 illustrates the different finishing material suppliers to the case companies.

Table 3.4 Main Finishing Suppliers

Case Study No	Finishing Material Suppliers
A	Becker Acroma
B	ICA
C	Becker Acroma
D	Becker Acroma
E	ICA
F	Morrells
G	Arch Sayerlack
H	Morrells
I	Arch Sayerlack
J	Becker Acroma
K	Becker Acroma

Becker Acroma supply 45% of the case companies, while ICA, Morrells and Arch Sayerlack all supply 18%. This indicates that the main suppliers to the industry are Becker Acroma. While discussing the role of suppliers with the case companies some interesting aspects of the type of relationship between the suppliers and case companies arose. Company H explained to the author that they had been using in excess of 12 tonne of solvent per annum. They managed to reduce the solvent significantly to less than 4 tonne per annum by working with their suppliers who offered the company a new formulation of basecoat and lacquer which had a lower solvent content. Another company who used their suppliers in a similar fashion was company F. The company has built up a relationship with their finishing supplier whereby the supplier monitors its tonnage usage. If the company comes close to exceeding the 10 tonne IPPC limit the supplier will provide a solvent based formulation finishing material to the company. Based on these conversations the author decided to contact the suppliers to try to understand if this is common place for suppliers to interact in such ways with their customers.

Graham Rayner of Becker Acroma, one of the leading suppliers to the Irish furniture industry informed the author that they would initially offer different products within the same range with higher solid content to their customers. However, if this still did not work they would

then work with the supplier to reformulate the product. Mr. Rayner did stress however that this would be the last resort as to reformulate a specific product would require a great deal of testing especially with regard to sustaining a specific type of finish and performance (G Rayner 2007, pers. comm., 16 November).

By analysing how beneficial it is and has been for some of the case companies to work with their finishing suppliers it is clear that this is an avenue which is clearly open to all furniture companies. There is an opportunity for companies to approach their supplier and ask for assistance in trying to alter solvent based formulations to make the furniture company more compliant with legislation. A knock on effect of having such an open relationship with the supplier is that, if there are any misgivings about certain quality issues pertaining to the finishing material, the furniture companies can feel more at ease to question the suppliers. Likewise by having a two way communication network the suppliers can feel free to make suggestions as to how to improve certain spraying applications of the company. This can tie in with the implementation of best practices which can lead to a very efficient and competent workforce and a very professional spraying process.

3.3.4 Levels of Current Solvent Usage

Table 3.6 indicates that only two of the eleven case studies are currently over the threshold limit of 15 tonnes per annum. All but one of the case studies are aware of their solvent usage tonnage.

Table 3.5 Current Solvent Usage

<i>Case Study No</i>	<i>Current Solvent Usage Tonnage</i>	<i>Previous Solvent Usage</i>	<i>Reason for Change</i>
A	<5 Tonne	No Change	N/A
B	>15 Tonne	No Change	N/A
C	<10 Tonne	No Change	N/A
D	<10 Tonne	>40 Tonne	Outsourcing
E	<3 Tonne	>20 Tonne	Switching to Waterbased
F	<10 Tonne	>15 Tonne	Working with Suppliers
G	7.2 Tonne	>35 Tonne	Outsourcing
H	4 Tonne	>12 Tonne	Working with Suppliers
I	>15 Tonne	No Change	N/A
J	Unaware	No Change	N/A
K	>5	No Change	N/A

However, from information gathered through the interview, a further 4 companies were in excess of the threshold limits before selecting an alternative method of finishing to comply with the legislation. Through a number of different methods those four companies were able to reduce their solvent usage and achieve compliance with the legislation. Both case study D and G used outsourcing of the finishing thus lowering their usage. Case study E switched to using waterbased finishing, which lowered their solvent usage levels dramatically. As previously mentioned case study F has worked with its suppliers to change the formulation of its solvent material so that it would fall below the limits.

The primary outcome of this table is that there are a number of companies who are or have been above the limits of the threshold that need to make and are making decisions to reduce their solvent usage. From interviewing all of the case companies there seems to be three main options or that are open to companies in these situations. These options are i) switching to waterbased finishing, ii) outsourcing the finishing, and iii) working with suppliers. While these options are being used by companies who have already complied with legislation the process of selection of the appropriate solution is unclear and in many cases was not planned out properly. From interviewing the companies it is clear that there is a distinct lack of guidance or information on which is the best and most appropriate course of action a company should follow. Therefore, by analysing the situation it is clearly visible that a structured approach in assisting the companies on how to choose the most suitable option for changeover is missing. There is a definite need for a framework type solution that will enable companies to identify a number of different solutions and give advice on how to select the most appropriate one.

3.3.5 Awareness of Legislation

Table 3.7 shows that all of the Case Study companies are aware of the legislation under the 'COUNCIL DIRECTIVE 1999/13/EC'.

Table 3.6 Legislation Awareness

Case Study No	Awareness of EU Solvent Directive
A	√
B	√
C	√
D	√
E	√
F	√
G	√
H	√
I	√
J	√
K	√

Upon discussing this matter further with each company in the interviews the author was able to see that the majority of the companies were made aware of the legislation through their suppliers. This once again highlights the importance and necessary role the relationship between the supplier and customer. Furniture companies need to be kept abreast of any changes pertaining to spray finishing that may affect the company, and also need to be able to use the supplier's knowledge to assist them with solutions to comply with legislation.

3.3.6 Awareness of Alternatives to Solvent Based Finishing

Table 3.8 deals with companies awareness of alternative finishing material to solvent based finishing material.

Table 3.7 Case Studies Reasons For and Against Changing to WB Finishing

<i>Case Study No</i>	Consider(ed) Change	Awareness of WB Finish	Willingness to Change to WB Finishing	Companies Changing to WB Finishing	Reasons for NOT changing to WB	Reason For Changing to WB
A	√	√	Undecided			
B	√	√	Yes	√		Compliance with Legislation
C	√	√	Undecided			
D		√	No		Quality Issues	
E			Already Changed			Compliance with Legislation, Environmental concerns
F	√	√	No		Quality Issues	
G	√	√	No		Too Expensive	
H	√	√	No		Too Expensive, Quality Issues	
I	√	√	Yes	√		Compliance with Legislation
J			Undecided			
K	√	√	Already Changed			Increased Production Speed, Environmental Concerns

The reason for selecting waterbased finishing as the only alternative to solvent based finish is a direct result from the literature review carried out in chapter 2. Table 3.8 looks at the willingness of the companies to change to using waterbased finishing. It is noteworthy that 72% of the case companies have previously considered or are currently considering changing their practices to comply with the legislation. 100% of the case study companies showed an awareness of waterbased finish. Two of the case companies, namely E and K have already changed to waterbased finishing. Case company B and I show a willingness to change to waterbased finishing. Case companies D, F, G and H have chosen not to change from their current finishing systems to waterbased finishing citing reasons such as cost and quality issues. Case companies C and J are undecided on whether or not to change to waterbased

finishing. It is noticeable that one of the main reasons why companies are reluctant to change to waterbased finishing is on the basis of quality. It must be remembered that to achieve a quality finish using waterbased finishing the spraying conditions must be suitable. This indicates that there is a lack of understanding about the requirements for achieving a good quality finish using waterbased finishing material. It once again highlights the importance and necessity of having guidance for best practice in relation to spraying. To ensure that the spraying environment is adequate for achieving a quality finish, best practices need to be observed and enforced.

3.4 Identification of Requirements

There are three main requirements that have arisen from carrying out this case study. They are the need for;

- Information regarding the different options/ solutions available to companies

Some companies are simply not aware of the options and solutions that are open to them. They need to be made aware of these options and the importance of choosing the correct solution to suit their needs. Some of the companies visited did not realise that they could use the expertise of their suppliers to try to meet the requirements of the legislation. Companies need to be informed of their options and made aware of the different approaches open to them.

- A framework, which can assist companies in selecting an appropriate solution to suit their requirements.

It is clearly visible from carrying out the case studies that there are no set procedures in place to assist companies in choosing an appropriate solution that is specific to their requirements. Companies must have some sort of support structure in place so that they can make a decision confidently, and be able to understand the implications of choosing such a solution. If a company takes the wrong solution they may suffer financial loss, drop in quality of finishing, and will not comply with legislation. There are many options open to companies

however the best solutions are dependant on the requirements of the company itself. There is currently no independent advice available for companies who are seeking direction on the most appropriate course of action. The only source of assistance is from the suppliers of the finishing material and it is fair to say that the advice could be biased.

- A guideline for implementing best practices

The practices and procedures witnessed during the course of the case studies observations highlighted the need for guidance in terms of carrying out best practices. The areas that need to be addressed have already been outlined earlier in section 3.3 of this chapter. To recap on the areas for improvement;

- Excess Manual Handling
- No Set Spraying Procedures
- Poor Spraying Techniques
- Insufficient Drying Equipment
- Poor Spraying Equipment
- Efficiency

Unless companies are given direction on how best to alleviate and eradicate these problem areas, the standard and quality of finishing will remain poor. Having good practices in place can improve quality and efficiency as less time and materials will be lost to rework.

3.5 Conclusion

In this chapter the finishing practices of the Irish furniture industry were analysed through the use of case study companies. Each of the chosen case companies were examined with the intention of establishing an understanding of current finishing practices. The attitudes of the case companies towards change in order to comply with legislation were also noted. The examination was conducted through the use of a questionnaire designed to extract the relevant information. The questionnaire was supported by an interview with each case company. The

author also availed of the opportunity to observe the spraying procedures of each case company which greatly assisted in building an appreciation of current spraying standards.

All the data was gathered, studied and analysed. The resulting data shows there are three main solutions to tackle the problem of complying with legislation, i) using waterbased finishing, ii) reducing solvent, and iii) outsourcing the finishing. The overwhelming conclusion that can be drawn from this analysis is that there is a need for;

- Information regarding the different options/ solutions available to companies
- A framework, which can assist companies in selecting an appropriate solution to suit their requirements.
- A guideline for implementing best practices

The following chapter will focus on developing a framework to assist companies in selecting the most appropriate solution to comply with the legislation.

Chapter 4 The Irish Furniture Industry Finishing (IFIF) Framework

4.1 Introduction

This chapter introduces a framework devised by the author to assist Irish furniture companies who are affected by the impending legislation regarding the use of solvents in Industry. Fig 4.1 illustrates the element of the research methodology with which this chapter deals with. The framework allows a furniture company to identify a number of different solutions and gives advice on how to select the most appropriate one. In the previous chapter, three options were identified where Irish furniture companies could alter or adjust their processing to comply with the legislation. These three main areas were i) using waterbased finishing, ii) reducing solvent, and iii) outsourcing the finishing. In order for an Irish furniture company to select the appropriate action for them, the author has developed a framework, which will assist in making that choice. The framework details the different aspects associated with the selection of each of the actions. The main objective of the framework is to both guide and assist an Irish furniture company in selecting the most suitable action for their individual need.

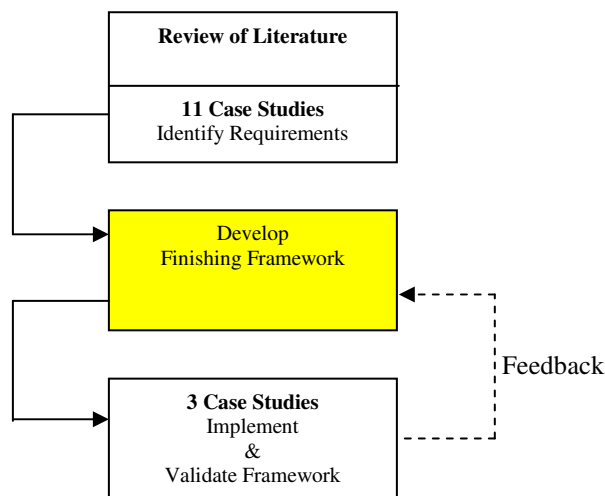


Figure 4.1 Research Methodology (Framework Development)

4.2 Justification for Framework

In chapter three it was recommended that a framework be devised for companies within the Irish furniture industry, to deal with the current and impending legislation on the use of solvents in industry. Case studies were examined and evaluated by the author in the previous

chapter. It was evident that not all of the companies are similar and therefore, not all companies could apply the same solution to the issue of solvent reduction. For some of the companies examined, simply working with their suppliers to reduce the amount of solvent content in their finishing material was sufficient in meeting the requirements of the legislation. However, other companies found it necessary to outsource the finishing, while further companies decided to change to waterbased finishing as a way of eliminating the threat of solvent usage. No strategic or structured approach was used by any of the case companies to select their solution. It is therefore, fair to suggest that a framework, which can assist companies in selecting an appropriate solution to suit their requirements is necessary. The fact that these companies did not use systematic approaches to selecting a solution is evidence of points raised in chapter 1 regarding the lack of managerial expertise in top level management in Irish furniture manufacturing companies. This shows that there is a need for tools and techniques to aid the furniture industry and specifically a framework to aid in the selection of solutions to address the legislation. There is also the requirement to provide a guideline for implementing best practices that will benefit companies in implementing a chosen solution.

From undertaking literature reviews and carrying out interviews with companies in the Irish furniture industry it emerged that there is very little advice available to Irish furniture companies at present. There is no framework currently available in which Irish furniture companies have the opportunity to see the options that are open to them, and no formatted selection process to choose from. As evident in chapter three, the main source of information regarding how to deal with impending legislation is through the suppliers of the finishing material. The finishing material suppliers have biased views and would be unable to offer an impartial judgment to the furniture company. Therefore, it is imperative that Irish furniture companies be provided with information regarding the different options/ solutions available to companies in an objective manner. In chapter two details were given on the VOC directive, which sets out a predetermined solvent usage level of less than fifteen tonnes of solvent usage a year. Failure to comply with the legislation will result in sanctions imposed by the government and environment agencies. Therefore, a framework based on the findings of chapter 2 and 3 plus the authors experience is presented in the following section. This

framework offers a method of assessing and evaluating a company's situation and selecting the most appropriate solution for that individual company.

4.3 The Irish Furniture Industry Finishing Framework

In order to meet the requirements outlined above the framework proposed is as illustrated in Figure 4.3. The framework is called the Irish Furniture Industry Finishing (IFIF) Framework. The diagram is based on a process flow chart method, which allows the user the opportunity to quickly identify the route which is most appropriate for their own requirements (Slack et al, 2004) (Render & Heizer, 1994). The process flow chart is a tool that assists in gaining an understanding in the steps of the process and the relationship between each of the steps. To fully understand the framework diagram it may first be necessary to familiarise oneself with the legend in Fig 4.2

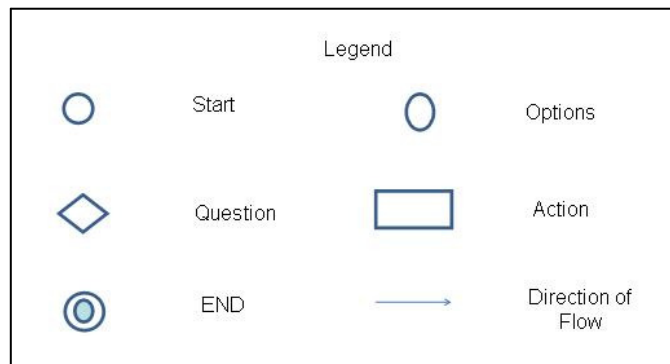


Figure 4.2 Legend of symbols used in Framework Diagram

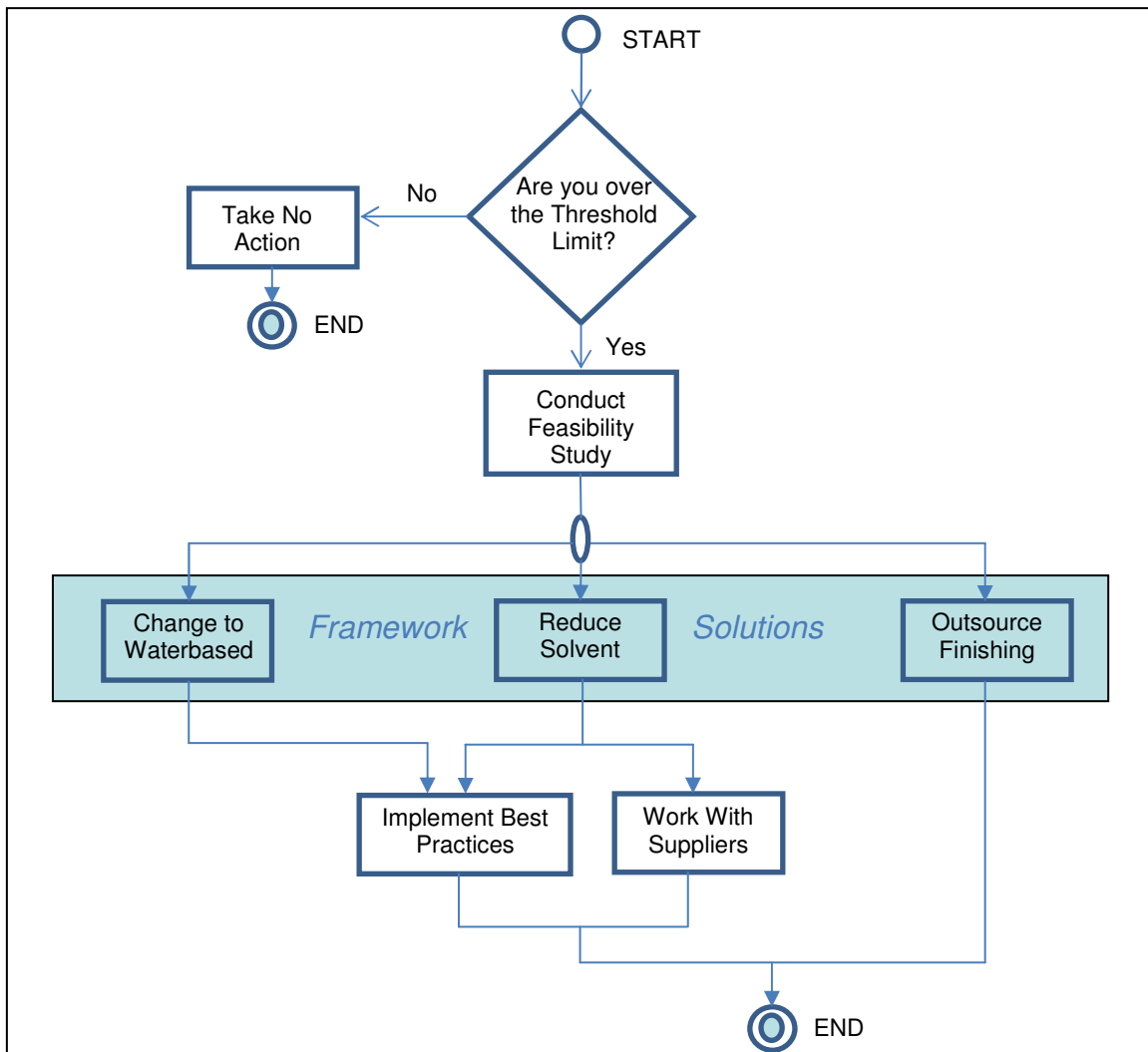


Figure 4.3 The IFIF Framework

Fig 4.3 shows the Irish Furniture Industry Finishing (IFIF) framework, which it is suggested can be used by Irish furniture companies in establishing the best way to comply with legislation. As can be seen from the diagram, the initial question posed to the user is whether or not they are over the threshold limits set out by the directive. If the answer is ‘No’, the company will not have to take any action as they are already complying with the legislation. However, if the company answer ‘Yes’ to the question then they have three choices, change the finishing system to waterbased finishing, reduce the amount of solvent they are using currently, or outsource the finishing. Before the company decide which of the three solutions they should choose, they must first conduct a feasibility study to determine which would be

most beneficial to them. Following the undertaking of the feasibility study the company will chose one of the solutions and be able to apply the guidelines provided. The following section will deal in greater detail with the elements of the framework.

4.4 Conduct Feasibility Study

A feasibility study is an analytical tool that should be utilised in the decision making process when determining whether or not a particular situation is suitable or not (Thompson, 2005). The premise of this feasibility study is that one can determine, which of the three solutions is more suitable. It is based on looking objectively at all the aspects of the company in order to identify the most appropriate decision. During the undertaking of a feasibility study both opportunities and problems will be identified, objectives clarified and assessment on the cost benefit analysis of each solution generated. The essential outcome of selecting and implementing this solution must be that the company will meet the requirements of the legislation.

To carry out the feasibility study, each company needs to describe their current practices and procedures, their future vision of the company and their financial situation in dealing with the problem. Therefore, the feasibility study of the company's selection will be based around three main steps, which must be meticulously analysed. These three main steps are;

- Evaluation of the current spraying practices and procedure of the company
- Analysis of the financial situation
- Analysis of the company's strategy for development

By focusing on these three steps the company will be able to find the best solution that can adequately meet the requirements of the legislation. Each of these three steps will now be discussed in greater detail. A set of questions is also provided to enable the company in carrying out this feasibility study.

4.4.1 Evaluation of the current spraying practices and procedures of the company

The company needs to look at their current spraying facility. They need to ask themselves if they are gaining the maximum efficiency from their facility. This will include analysing all their spraying equipment, evaluating whether or not the equipment is performing to its maximum capacity. The company must also evaluate whether or not the equipment would be suited to waterbased finishing. If a company decides to change to waterbased finishing their spraying equipment would need to be resistant to water to avoid corrosion and rust.

<i>Spraying Facilities</i>	<i>Yes</i>	<i>No</i>
<ul style="list-style-type: none"> • Do you have an adequate supply of spraying guns? • Are spraying guns used for more than one type of finishing material? • Is the equipment water resistant meaning that it could be used for Waterbased finishing? • Do you have a spray gun washer? • Are the turn tables manoeuvrable/ adjustable to deal with different products? 		

It will also require the company to focus not only on the efficiency of the equipment but also on the competence and effectiveness of the spraying operatives. By examining closely the operatives, the company will be able to ascertain if the operatives require more training to make them more efficient. Having untrained or incompetent spraying operatives leads to greater inefficiency. This can culminate in the waste of finishing material due to products needing rework due to human error. This increases the amount of solvent being used, which makes compliance much more difficult.

<i>Spraying Operatives</i>	<i>Yes</i>	<i>No</i>
<ul style="list-style-type: none"> • Do they receive training? • Are they made aware of how to identify problems/ defects with the finishing material? • Can they identify and solve quickly problems with the spaying equipment? • Do they know how to carry out maintenance on the equipment to ensure quality of finish is maintained? • Can rework products be attributed to operator error? 		

The company also need to focus on their spraying procedure. The company must determine if they are spraying their product in the correct manner to maximise their efficiency, which would reduce their waste and solvent usage. They need to focus on the layout of their spraying facility to establish if they are utilising the space to its full potential. Utilisation and efficiency are directly related to design layout and output (Slack et all, 2004). This means that the layout of the spraying facility can directly impact on the efficiency of the production. By having a good layout reduction in material waste is achieved, which can lead to lower solvent usage and compliance is made easier.

<i>Spraying Layout</i>	<i>Yes</i>	<i>No</i>
<ul style="list-style-type: none"> • Is there a process flow for products being sprayed? • Is the current layout of equipment easily accessible? • Do products need to be moved around during the allotted drying period due to space constraints? • Does all spraying equipment have a specific location? • Are all equipment locations easily identifiable? • Are there adequate holding racks for products? 		

The final consideration in this section of the feasibility is to establish whether or not the actual spraying area is sufficient. This requires the company to look at the extraction of the spraying area to determine if the extraction is taking away all the overspray quickly enough. Failure in doing so results in overspray landing on finished products and spoiling the finish. This results in refinishing, thus wasting more material and increasing solvent usage. If the company is considering changing to waterbased finishing they must understand that to ensure a good quality finish they require a spraying facility that has good air movement coupled with good extraction. There is also the necessity to have some sort of a drying facility to assist lowering the drying times.

<i>Spraying Area</i>	<i>Yes</i>	<i>No</i>
<ul style="list-style-type: none"> • Is the current extraction system strong enough to remove all overspray quickly? • Is there a separate air in-take for the spraying area? • Is the air in the spraying area heated? • Is there a separate drying area? • Is the drying area heated? • Is the air extracted recycled into the spraying area? 		

4.4.2 Analyse the financial situation

One of the key factors in the decision making in any company will be the financial implications as a result of selecting one particular solution over another. It is evident that out of the two key solutions put forward in the framework the lowering of solvent usage would be a cheaper option. By changing over to waterbased finishing the company will possibly have to upgrade their spraying facility to a purpose-built unit that will give the optimum spraying conditions required for waterbased finishing. The company may also have to invest in waterbased finishing spraying equipment as their old equipment may not be adequate for use with waterbased finishing. If the company do decide to go ahead in changing over to waterbased finishing then there will be a period of downtime while changeover occurs. When the system is implemented there may be an intervening period where there will be a lot of trial

runs to establish the operating sequence and eliminate teething problems. This will result in lower productivity initially which will have financial implications.

However, while there are obvious financial implications by selecting waterbased finishing it should not be taken for granted that reducing solvent usage will not require a financial effort. While reducing solvent may not seem as dramatic as changing to waterbased finishing, there is still a tremendous effort required. Depending on what route the company decide to take as a result of selecting to reduce the solvent they will either need to work closely with their suppliers as well as implementing best practice, or use their current outsourcing contacts to finish the products off site. If they chose to work with suppliers and implement best practices they will have to invest in training for operatives and upgrading of facility to ensure maximum efficiency. They will have to spend time working with the suppliers to formulate lower solvent content finishing material, which will need to be tested to ensure the same quality of finish. This may lead to downtime and cost the company money as a result. If the company is large enough and are using outsourcing already for production, they could then try and build up a relationship with their outsourcing firm to finish the products as well as produce them. This reduces the solvent usage significantly, but there is the need to spend time and money in developing a trusting relationship with the outsourcing company to ensure the quality of product is maintained. All of these issues need to be taken into consideration. Below is a set of questions that maybe useful for companies in assisting them with analysing their financial situation.

Financial

- How much will it cost to upgrade the current facility to make it adequate for Waterbased finishing?
- How much will it cost to purchase new spraying equipment if required?
- How much will downtime cost the company?
- How much would training operatives cost the company?
- How much will new finishing formulations cost the company?
- What are the costs associated with using current outsourcing contacts to finish the products?

4.4.3 Determine the company's strategy for development

The last major focal point that the company will need to assess in the feasibility study is the company's strategy for development. There are four key elements that are relevant to look at when discussing strategy in the context of selecting a solution to the impending legislation.

Those four key elements are;

- Outsourcing
- Size of the company
- The market
- The product

Each of the four elements are critical in the decision making process. Looking firstly at outsourcing, the company must look at their current standing in relation to this. Are they currently outsourcing? Will they continue to outsource or begin to outsource in the future? What are the implications with outsourcing? Will it remain a viable option in the future? These are the type of questions that each individual company must ask themselves. If they are currently outsourcing their production, then maybe a way of reducing their solvent usage is to get the outsourcing company to finish all the products. This will mean that the company meets the requirements of the legislation, however it will require a lot of planning, and also it means that the company would be relinquishing control of one of the primary elements of the product, which is the finishing. While one element of outsourcing is the contact with the outsourcing company and the trusting relationship that must be built up, the company must also be aware of ever changing economic trends. They must be able to understand the consequences of rising inflation rates, the price of the euro against other nation's currencies and also be aware of the continuing rise of the price of oil. Transportation costs are a significant cost in outsourcing and any sudden increase in transportation cost can have dramatic effect on profit margins.

Outsourcing

- Is the company currently outsourcing production of its products?
- If so, do they believe they will continue to outsource in the future?
- What are the current implications of outsourcing?
- Can they maintain the quality of the finish if they outsource?
- Will language be a barrier to insuring quality is maintained?
- How will rising transportation cost affect the company's outsourcing plans?

The second element in determining the strategy for future development is the size of the company. The company must be fully aware of its size and ability to grow. They must ask themselves are they happy with their current size? Are there any plans to develop and become a bigger company? What size will the company be in five or ten year's time? Will they increase or decrease in size in the future? While all these questions may be difficult to answer and require a lot of speculation, they play a vital role in the decision making process. If a company is 'medium sized' and has no plans to develop any larger, and they are currently just over the threshold limits of the legislation, they may take the decision to reduce their solvent by using best practices and working with suppliers. However, if the company has plans to grow and develop into a large company producing products in-house then they may take the decision to install a waterbased finishing line.

Size of the Company

- Are there plans for the company to expand?
- Will these plans affect compliance with legislation?

The market, which is the third element in the determination of strategy for the future plays an important role in the decision making process. The company must assess the market place. They must be able to speculate whether the market in which they are currently producing is viable for future development. Does this current market offer longevity? Will the company need to explore new markets to survive and develop? Is the current market strong? Can they depend on repeat orders from the current market place? If a company can assure itself that their current market is strong enough to support them into the future, then they can use this element as a key contributor to selecting a suitable solution. If their market will grow, then it

is fair to estimate that they will grow in terms of size and, therefore, their solutions will need to reflect this projection. However, if the company is unsure as to whether or not their future lies in the current market it would be unwise to base a decision heavily weighted under this element of the feasibility study.

Size of the Market

- Does this current market offer longevity?
- Will the company need to explore new markets to survive and develop?
- Is the current market strong?
- Can they depend on repeat orders from the current market place?

The final element in this section is to do with product. In much the same way as the market plays a fundamental role in the decision making process, the type of product the company produces is key to selection. If a company is assured that they are going to be continuing to produce a similar type product for the foreseeable future then they should use this information when selecting a solution. If a company is thinking of implementing best practices to reduce the solvent, then one aspect could be to automate or semi automate the finishing line to improve efficiencies and throughput time. This will only be possible if the product and/or component remains standard. However, if the company is unsure about its future product lines, it would be very difficult to implement such aspects such as automation. They may need to apply other elements of best practices to ensuring solvent reduction.

Type of Product

- Will the company continue to produce the same type of product into the future?
- Is it possible to modularise products for ease of manufacture and finishing?
- If so could automated/semi automated finishing improve production time?

On completion of the feasibility study the company will then make the decision on which option is best suited to their needs and requirements. In the following section each option will be dealt with in detail.

4.5 Framework Solutions

The next element of the framework is to use the results of the feasibility study to choose one of the three options.

- Change to waterbased finishing
- Reduce solvent
- Outsource finishing

4.5.1 Change to Waterbased Finishing

One way to lower the amount of solvent usage is to replace solvent finishing with an environmentally sound alternative. Waterbased finishing is an excellent alternative to solvent based finishing. As previously mentioned throughout the thesis, the threshold usage limit of 15 tonne of solvent is the level under which every Irish furniture manufacture must comply. In chapter three the author showed that 63% of the case studies interviewed used solvent based finish, therefore it is fair to say that the majority of the furniture companies in Ireland are using solvent based finishing material. For all companies who are using in excess of the threshold limit of solvent, they must change their current spraying methods. If the company is way above the limit, then simply reducing solvent may not be sufficient in meeting the requirements. They must then look at the two alternative methods, which are outsourcing finishing and using waterbased finishing. If the company does not have outsourcing links already set up then they must look at using an alternative to solvent based finishing. As has already been shown, waterbased finishing is a suitable alternative to solvent finishing. It offers similar quality finish to that of solvent based finishing material, but is environmentally friendly, which may be used as a marketing strategy to further enhance the image of the company to prospective clients.

4.5.1.1 Implement Best Practices.

As can be clearly seen from the Fig 4.3, if a company decided to change to a waterbased finish as a method of complying with the legislation then they should implement best practices. It can require a significant amount of money to change over successfully to a waterbased finishing system, therefore it is vitally important that the basic practices and procedures are identified and implemented correctly to try and eliminate any waste. This will assist in recouping some of the initial investment costs. From analysing the Irish furniture industry through the use of the questionnaire, observations and company interviews the author has identified a list of common problems that concern all furniture companies involved in spraying. These problems can be seen in chapter 3 section 3.3. The problems need to be addressed by a company involved in spraying to achieve a standard of better practice. When changing over to waterbased finishing the company will need to take into consideration the following advise in ensuring a quality finish is achieved using waterbased finishing.

- ***Temperature Control***

To achieve a good quality finish using waterbased finishing material it is imperative that the temperature in the spraying area is controlled. There must be an optimum level of 20°C present in the spraying application area. Heated air should be blown into the spraying area to maintain the required temperature. This air can be recycled and re-circulated which makes it more efficient. From observing the case companies a number of companies have burners which are used to burn wood waste and also heat the factory. These burners can be used to heat the air needed for the spraying area.

- ***Air-Flow Control***

There also needs to be sufficient air movement present which will aid in the application and drying of the material. The air movement is required to assist the extraction of the overspray, which can cause defects with the finishing of components.

- ***Extraction***

The quality of the extraction also needs to be monitored. It is vitally important that the overspray is removed as quickly as possible to avoid any imperfections in the finish which may lead to rework. The extraction assists the air movement, which is required to achieve a quality finish, and also aids in the drying of the finish. Companies should enlist the help of qualified professionals in establishing the correct type and force of extraction that will be required to meet their individual requirements.

- ***Drying Times***

As well as having the surrounding environment acceptable for ensuring a quality application of the material, the drying area needs to be looked at also. The company needs to look at its drying facilities to ensure the optimum drying times are achieved. The optimum drying temperature for waterbased finishing material depending on the supplier is approximately 30°C. To achieve this it may be necessary to install heated air tunnels, which can be set automatically to the required temperature and force air movement around the drying products to reduce drying times.

- ***Non-Corrosive Spraying Equipment***

Initially the company must assess their current facility to distinguish whether or not they are suitable for converting to waterbased finishing. They need to look at their equipment and see whether or not the equipment is non-corrosive. This is required as the waterbased finishing material can cause equipment to rust and corrode, whereas solvent based finishing material does not have the same effect on equipment.

- ***Procedures***

The company will need to observe their current spraying procedures, identify a process flow that each component is subjected to and develop a spraying procedure to reflect this.

4.5.1.2 Implementation Guidelines.

Below are some guidelines that all companies considering waterbased finishing material should employ;

- Carry out research into different suppliers of waterbased finishing material as different suppliers offer different qualities of finish.
- Do some trial runs with waterbased finishing products in house to test the quality of the product but also to see how the facility copes with waterbased finishing.
- Try to view other companies who have already changed to waterbased finishing material to gain an understanding of the pitfalls that are associated with converting to waterbased finishing.
- Consult with spraybooth manufactures to establish the degree of change required with the current spraying facility to bring it up to standard for use with waterbased finishing material.

By following some of these guideline companies can establish a greater understanding of the level of effort that would be required to convert to waterbased finishing.

4.5.2 Reduce Solvent

For companies that are just above the threshold limit and not anticipating to be significantly above the limit in the near future it may not be necessary to completely change their current finishing systems. They can apply simple techniques such as implementing best practices, and/or working with suppliers, which have the desired affect of reducing their solvent usage.

4.5.2.1 Implement Best Practices

Implementing best practices has already been discussed in the previous section 4.5.1.1. While the factors outlined in that section are critical to achieving a good quality finish with waterbased finishing they are less crucial to solvent based finishing. However by combining elements of operations management together with the steps outlined already this can result in reducing solvent usage. Applying some operations management techniques to improve the efficiency of the production, will in turn reduce the amount of waste of finishing material

resulting in the lowering of solvent usage. Two of the key fundamental techniques of operation management have been chosen to assist furniture companies in reducing their solvent usage, namely layout and automation.

- **Layout**

The type of layout that is most suited to Irish furniture companies would be the process flow layout. The essence of this type of layout is to minimise the flow of the product being worked on (Kolli, 2000) (Krajewski et al, 2002). All products that are sprayed go through a similar process where by they receive numerous coats of finish, in between which drying and de-nibbing occurs. It is best to set up a layout, which will allow for the maximum of work to be done on a product at any one time, without much movement. By having a good layout processing times can increase resulting in less waste of finishing material. A good layout will also make the process more manageable and areas for improvement can be identified more easily. Fig 4.4 is an example of a good layout of a spraying facility. It should be noted that the spraying area and the drying area are located side by side. This is because the most movement of products is between the spraying area and the drying area. The sanding area is where all the de-nibbing takes place. It is best to keep this area away from the spraying area to avoid contamination. The products should follow the directional arrows which show that there should be no going back from one section to another. This will eliminate the risk of damage and the possible increase in rework.

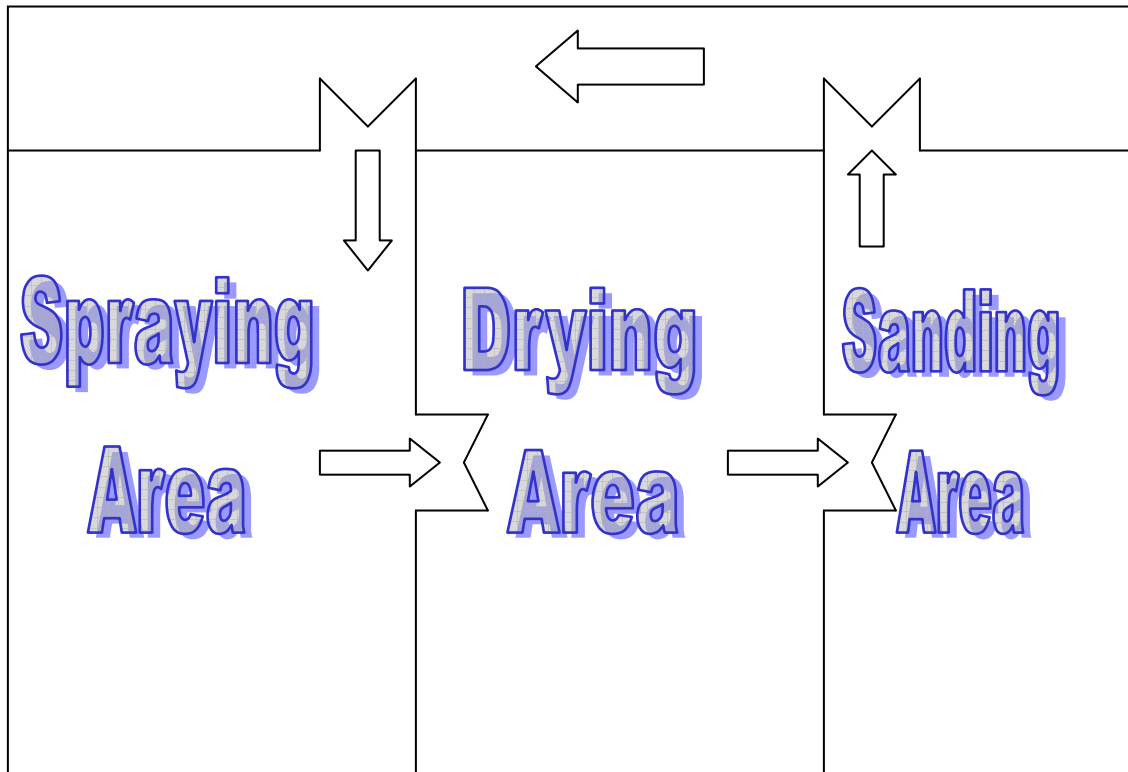


Figure 4.4 Example of a Good Layout

- **Automation**

While reducing solvent usage is very much dependant on improving efficiencies and reducing waste, depending on the size a company and the type of production they are involved in, automation may be of benefit to that company. Automation lends itself to improving efficiencies by automating process, which cut down on human error (Barnett, 1996). In relation to the spraying area and where automation could be used to reduce solvent usage, there are two types of automation that are applicable. The two types of automation are semi and fully automated.

It must be noted that not all companies are suited to automation. It very much depends on the type of products being produced and the scale of the production. Using the questions posed in the feasibility study in section 4.4, will decide if its viable or not.

- Semi Automated

An example of where semi automation could be used is by installing a carousel system that could be used to transport the products around the spraying area. It would reduce the amount of manual handling on the products, resulting in fewer reworks and work in progress. By having an automated carousel it means that the product being sprayed is always moving and is not taking up space. It also means that operators can stay in place to spray the products. The design of the carousel can be done to suit the layout of the existing spraying area. As the carousel is travelling at such a low speed it gives the spraying operator time to spray the entire product without having to rush. If the carousel is housed with heated air movement being forced through it can act like a heating tunnel, which will increase the drying times.

- Fully Automated

If the company are mass producers of a product then the company may have the opportunity to install a fully automated spraying line. In order to fully automate the spraying area, the products themselves must match the automation scenario. A common scenario in the furniture industry is the spraying of flat components. It would be necessary to have an automated spraying line that could carry out the application, drying and de-nibbing of a part. This form of automated spraying is not suitable for every company, as not every company would have flat components (e.g. spindle post manufacturers for stairs) but can be a viable option for some. It increases production and increases efficiencies, while reducing waste which can lower solvent usage. It would be best to enlist the support of an automation expert in order to provide and develop the most appropriate solution for the company.

The advantages of automation are that it can increase production and efficiencies (Groover, 1987). It can lower the amount of manual handling, which reduces the amount of human error resulting in less rework and work in progress. With efficiencies increased and waste decreased the outcome is a reduction in solvent usage. Another

advantage of automation is the consistency and quality of finish that can be obtained especially if using a full automated line.

The disadvantage of automation is it requires a huge investment. While there are significant savings to be made with automation it must be remembered that automation should be seen as the final stage when trying to reduce waste and improve efficiencies. Without the implementation of best practices at the basic levels, automation will not work effectively.

Both layout and automation will greatly help to reduce solvent usage but they can also be applied to companies using waterbased finishing systems.

4.5.2.2 Working with Suppliers

The second element in reducing solvent is to work with suppliers. For companies who are on the cusp of the threshold limit or who are just over the limit, working with their finishing suppliers is really the key element in trying to comply with the legislation. The suppliers are experts on their finishing material, and can assist furniture companies in meeting the terms of the legislation. It is possible for suppliers to change the formulation of their products so that it does not interfere with the quality of the finish, but reduces the amount of solvent that is required, therefore reducing the amount of solvent usage. Furniture companies who choose to go the route of lowering their solvent must contact their supplier and explain their situation. They can then use the expertise of their suppliers to test and develop new formulations of solvent based finishing material that will allow them to continue using solvent based material, but will also see them comply with legislation. For this to work adequately there must be an open and trusting relationship between supplier and customer, as any break down in communications could result in a poor quality finishing product. There are standard solid/solvent combinations of solvent finishing material that can be offered to the furniture manufacturers. However, changes in solid and/or solvent content of material can affect the quality of finish achieved. Application of two types of similar product using the same processing techniques but with differing solid/solvent content could result in different finishing qualities being achieved. A furniture company may well have a certain standard of

finish that they want to obtain and may only be able to achieve that standard of finish with one particular standard combination. If the solvent content of that particular combination results in the company exceeding the threshold limits, they will then need to work with their supplier to try and develop a suitable alternative.

4.5.3 Outsource Finishing

Another alternative to complying with legislation is to outsource the finishing to other countries. This would effectively eliminate the problem of how to comply with the legislation. By outsourcing the products the company is automatically complying with the legislation as they have eradicated their solvent usage levels. There are a number of criteria a company must adhere to before they can consider outsourcing as an option. If a company is not already outsourcing its production it is not likely to be a viable option to outsource the finishing as the cost alone would render it impractical. It must be pointed out that the majority of furniture companies in Ireland will not be able to choose this as a viable option. From the feasibility study in section 4.3 a company will be able to assess whether or not it is suitable for outsourcing.

4.5.3.1 Implementing Finishing Outsourcing

A company must initially have a trusted relationship with their supplier. The supplier must have a good track record. It is a necessity to have a trusted supplier who will not let the company down and who can meet the deadlines which the company set out. If all of this is already in place the next step is to meet with the supplier and discuss the actual practicalities of carrying out the finishing process. The contract between the furniture company and its outsourcing supplier will have to be expanded and agreed on. The company must make the supplier aware of the level of quality that will be acceptable. For the venture to work appropriately the furniture company will need to invest time and energy in building up the venture before finally allowing it to go ahead. Below is a checklist of factors that should be considered by companies who have chosen to outsource their finishing. The checklist details elements which should be followed to ensure the quality of finish is maintained. It also gives companies an understanding of the level of commitment required, and the pitfalls and hidden costs, which need to be taken into consideration.

Checklist

- Sending people over to the supplier to develop a procedure for finishing of products.

This will ensure that there are specific processes and procedures in place so that the suppliers will have a definite procedure to follow when finishing the company's products.

- Setting specifications

The company should develop a specification for each type of finish so that the suppliers can use these specifications to achieve the desired finish. One method of doing this is to have colour check charts so that the operators in the outsourcing plant can match their finish to that of the specified chart.

- Quality Checks

The company must put in place procedures to enable quality checks to become part of the finishing process. Therefore, they must train or put in place someone to train the operators in the outsourcing company to identify faults and defects that can occur during finishing. They must train or put in place someone to train the operators to fault find with equipment and material. Any defects that go undetected in the outsourcing company and are allowed to be shipped over to the furniture company will cost the furniture company money on excess packaging and shipping costs, as well as the cost to rework the component once the defect is found.

- Training

The furniture company should get the operatives trained in the necessary skills required to achieve the quality of the finish desired. This may result in the company sending over skilled workers to the outsourcing company to educate them on the techniques required to produce good quality finishing.

- Transport

Transport costs are a huge part of the cost involved in outsourcing. Whilst the company will already be transporting unfinished components, they will now have to take into consideration the fact that the components are finished and will require extra protection. This will require extra packaging which not only adds cost but will also make the components more bulky resulting in greater space being required to transport the products.

- Implications

There are many implications that may arise from outsourcing. There are the inevitable difficulties with the language barrier if the outsourcing company is from a place where English is not the first language. With every venture there will be some initial problems which will only arise after the initiative begins properly. The issue of quality control and the trusting nature of the two parties will be tested stringently throughout the venture. The issue of transport will also be a factor. Products which are damaged in transit will also bring implications. In order for the outsourcing solution to work it may be necessary for the furniture company to go to the outsourcing supplier on an ongoing period to discuss progress, further developments, issues concerning quality and any other issues. This must be also taken into consideration.

If the companies who are selecting the outsourcing finishing solution pay attention to the items listed in the checklist then they will have an advantage in being aware of the pitfalls and the drawbacks which can occur with outsourcing. The solution without question offers significant savings. However, to reap the rewards of outsourcing a lot of work must be done to ensure that trust is present for the venture to run smoothly.

4.4 Conclusion

This chapter has dealt with the development of a framework, which will assist furniture companies in selecting an appropriate solution to meet the requirements of the impending legislation regarding solvent usage. The framework was presented, discussed and explained to give the reader the ability to see its potential for the Irish furniture industry. The selection of a solution can only happen after the company carry out a feasibility study, which will direct them to selecting the most appropriate solution for their own requirements. It must be remembered that the framework and all the elements within the framework act only as a guide to furniture companies and the final decision can only rest with the company itself. The three solutions, i) changing to waterbased, ii) reducing solvent, and iii) outsourcing finishing were presented in a way as to guide the furniture companies in the implementation of the chosen solution. It details practical aspects of how to achieve the goals set out in selecting the appropriate alternative solution.

The following chapter will test one of the chosen solutions, by using the elements of the solutions on case companies to validate the solution.

Chapter 5 Validation of the IFIF Framework

5.1 Introduction

This chapter deals with the validation of the framework developed in chapter four in an industrial setting. It has been suggested that there is a greater need for field based research methods to propose and develop adequate solutions to problems in industry (Horton, 2003). Taking this into consideration case studies were utilised to validate the development of the finishing framework. The key findings and results of the case study analysis are presented in this chapter.

5.2 Case Study Analysis

A case study is a form of qualitative descriptive research. It focuses on collecting, examining, and displaying detailed information on a particular area of research (Sechrest et al, 1996). In this particular section of the thesis, case study analysis is used to test the validity of the framework. This section looks at (i) the validation methodology, (ii) the data collection methods and, (iii) the criteria to validate the framework.

5.2.1 Validation Methodology

As highlighted in Fig 5.1 below, the final part of the research methodology is to validate the framework. This was achieved by implementing the processes and procedures of the framework into 3 case studies.

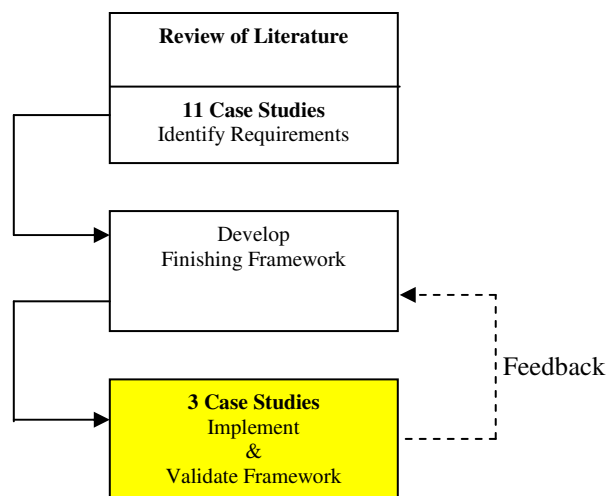


Figure 5.1 Research Methodology (Validation)

The framework was developed with the assistance of an initial eleven case study companies together with information ascertained through the use of a detailed literature review. Details on the case study companies used can be reviewed in chapter 3 of the thesis. As can be identified in Fig 5.1 the initial stage was to identify the requirements and develop solutions based on these requirements.

It was decided to select a further three furniture manufacturing companies to test the developed framework. This was to be achieved by mapping the framework against the test companies to test its usefulness. Each of the three companies chosen to test the framework had diverse manufacturing capabilities, which gave a fairer reflection on the Irish furniture industry. All three companies had been over the threshold limit but, had already selected and implemented an alternative finishing method prior to testing. None of the companies had used the framework as a guide to selecting the most appropriate alternative finishing method. By mapping the framework against these companies the elements would be tested, checked and therefore validated. The results of the test are provided in section 5.3.2.

5.2.2 Data Collection Methods

The data from the three companies was collected in two forms (i) how they were prior to changing, and (ii) how they are now. Each of the companies is profiled in the following section as to how they were prior to changing. The data collection method employed in this study utilised various sources of evidence such as (i) questionnaires, (ii) interviews and (iii) observations. It is the opinion of the author that by using a variety of collection methods that the strengths of one method compensates for the weakness of the other. Furthermore, by utilising an assortment of data collection methods a more complete picture of the situation is obtained.

Profile of Companies Analysed

Company X is a large bedroom furniture manufacturer. They produce mainly painted furniture but also produce hardwood bedroom furniture such as pine and oak. Prior to changing they had an automated finishing line. They used Pre-Catalyst finish. Their main supplier of finishing material was Sayerlack. The line incorporated a sanding station, a blowing off

station, four automated spraying guns and controllable heated air tunnels as illustrated in Fig 5.2.

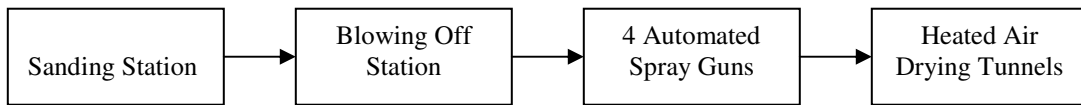


Figure 5.2 Sequence of Automated Spraying Line

A camera relayed the position and size of the component being sprayed back to the computer, which controlled the spray guns, resulting in a very efficient line. The excess material that lay on the bed of the conveyor was scraped off and returned to the spray gun. The components once sprayed travelled through the controllable heated tunnels, which dried the components. By using the heat source the drying time was significantly reduced and fibre swelling/ grain raising was lowered. Finishing defects such as bubbling and film cracking were avoided due to the application of the infra-red heat. The line was 98% transfer efficient and had very little wastage. Transfer efficiency is the amount of spraying material that adheres to a substrate compared to the amount of spraying material applied, expressed as a percentage (ABC's, 2001). The spray waste was disposed of by waste contractors. Company X were aware of the impending legislation. They were using over 18 tonnes of solvent per annum, and held an IPPC license.

Company Y is a furniture manufacturer dealing mainly in chair frames. They used solvent based finishing material, namely Pre-Catalyst, Acid Catalyst and Polyurethane. They had 2 HVLP spray guns. Their main supplier of finishing material was Morrells. Spraying and drying were conducted in the same room. The spray room was heated by the use of a blow heater, which was turned on when required. The heat was non controllable. There was one spray booth. They had an extractor fan fixed to the wall covered by a dry filter. Once products were sprayed they were left in the spray room to dry. If the weather was warm and dry the doors were opened to allow in air. Due to space constraints the floor could become very congested with products, which are left to dry. The spraying waste was disposed of by waste contractors. The company was aware of the impending legislation, and that they were just on the threshold usage limit of 15 tonnes annually. They were also conscious that legislation may become more stringent in the future.

Company Z is one of Ireland's leading kitchen door suppliers with more than 25 years of experience offering over 20 ranges of kitchen doors. They were outsourcing the majority of the door manufacturing to China and the Far East. They manufactured a small percentage of doors at their production plant. The company was buying in the doors and spraying them themselves, using a state of the art automated finishing line. The company was using in excess of 35 tonnes of solvent per annum. The company was aware of the impending legislation.

5.2.3 Validation Criteria

The validation of frameworks and methodologies is complex and difficult (Sharfritz, 1998). It is due to this that alternative research validation methods must be used. There is currently no identified and accepted validation for frameworks and methodologies (Mulligan, 2007). Cormican (2005) reviewed a large number of sources of validation criteria and compiled a list that can be used in order to validate frameworks. Table 5.1 compiles the most appropriate validation criteria taken from Cormican's list of criteria. It incorporates key questions needed to assess each facet of a framework.

Table 5.1 Criteria Used for Validation of Finishing Framework (Cormican 2005)

Criteria	Description
Effective	<ul style="list-style-type: none"> • Does the methodology work? • Does it solve the problems for which it was intended? • Do projects that follow the methodology turn out successfully?
Efficient	<ul style="list-style-type: none"> • Are the tasks & activities prescribed by the methodology strictly necessary? • Is there any redundant effort?
Universally Applicable Comprehensive	<ul style="list-style-type: none"> • Does the methodology work across the whole domain? • Does the methodology work in any organisation size, or culture?
Simple & easy to learn and use to participants	<ul style="list-style-type: none"> • Is the methodology targeted at a well-defined population? • Is the methodology based on a coherent set of concepts and techniques? • Is it easy to motivate people to adhere to the methodology?
Manageable	<ul style="list-style-type: none"> • Does the methodology provide guidelines for the management?
Visible Comprehensive	<ul style="list-style-type: none"> • Does the methodology make its reasoning clear and visible to the participants, so that they can intelligently judge the relevance and completeness of each piece of work?

5.3 Validating the Finishing Framework

The finishing framework has been presented in chapter 4. The framework was divided into two main elements, the feasibility study elements, and the solution elements. These elements were derived from an in-depth analysis of industry practices. The elements of the framework were validated, by (i) converting the feasibility study into a set of guiding questions for each of the companies to ask themselves, and (ii) by setting out detailed guidelines for each of the three actions elements. By implementing the framework into a selected number of companies the validity of the framework was tested in terms of both its effectiveness, and its practicality. The rest of this section demonstrates how the framework is implemented and highlights the findings from the validation process.

5.3.1 Implementing the Framework

The methodology to implement the finishing framework was described in chapter 4. The main aim of this methodology is for a furniture company to select the most appropriate solution by following the framework map. The framework is devised so as to allow the user to select a solution by focusing their mindset on three main areas. Those areas are namely; (i) evaluation of current practices & procedures; (ii) analysing their financial situation; and (iii) reflection on strategic development. Following the list of questions that are provided with each element of the feasibility study a company will be more confident in choosing the correct solution. The three case companies were all over the threshold limit. Following the framework map, feasibility studies were carried out for the case companies in order to determine the solution best suited for their needs.

5.3.2 The Implementation of the Feasibility Study

For the purpose of demonstration the data presented is only to give an indication of some of the reasoning that takes place in using the framework. It is highly recommended that future users of the framework will carry out a full and detailed feasibility study. The results of each part of the feasibility study are depicted in this section.

5.3.2.1 Evaluation of Practices & Procedures

Table 5.2 depicts the evaluation of practices and procedure for the three case companies prior to making any change.

Table 5.2 Spraying Practices & Procedures

Elements	Case X	Case Y	Case Z
Spraying Facilities	Adequate	Inadequate	Adequate
Spraying Operatives	Inadequate	Adequate	Adequate
Spraying Layout	Adequate	Inadequate	Adequate
Spraying Area	Adequate	Inadequate	Adequate

Case Company X with the exception of their spraying operatives had sufficient spraying facilities, layout and area to suggest that they had appropriate practices and procedures. The operatives did not receive any formal training in how to identify problems/ defects with the finishing material. This often led to rework, which could be attributed to inadequacy in operatives. The efficiency of the automated finishing line was being compromised by the lack of operator efficiency. The framework immediately highlighted this as an area for improvement for the company.

Case Company Y had well trained operatives, however their facility, layout and spraying area were insufficient for their needs. There were an insufficient number of spray guns, which resulted in operatives having to use many different types of finishing material in the same spray gun. This resulted in a lot of downtime. There was no spray gun washer therefore everything was cleaned manually resulting in lost time. The spraying area was small, which resulted in poor spraying layout as products were placed in an ad-hoc fashion in an effort to compensate for the lack of space. There were insufficient racks for holding products/components. The spraying area was also devoid of a proper extraction system, and had no proper form of heating, apart from a blow heater. This heater, a small portable device was fuelled by paraffin oil and emitted a very high tempered heat which was uncontrollable. The framework has identified areas that needed immediate attention.

Case Company Z employed a highly maintained finishing line, with suitably trained operatives. The attitude of the company assisted in maintaining a high standard of competence

in operators and resulted in a quality finish being attained with little rework needing to be performed.

5.3.2.2 Analysing the Financial Situation

Case Company X estimated that the cost of changing to a waterbased system would be approximately €8,000. The finishing system that the company employed was suitably designed to work in unison with waterbased finishing material. They estimated that the majority of this money would be on downtime and the cost of training operatives. No new equipment would be required; however they did estimate that there would be an increase in the cost of finishing material.

Case Company Y found that it would cost the company approximately €60,000 to convert to a waterbased finishing system. The majority of this money would be needed to upgrade the facility to the required specification for achieving a quality finish. It would require revamping the entire facility and providing all new equipment as the majority of the spraying equipment would not be compatible for use with waterbased finishing material.

Case Company Z estimated that the cost of switching to waterbased finishing would cost the company approximately €120,000 for the first year only. This expense would be made up primarily of the estimation of how much extra the cost of the waterbased finishing material would be. Company Z would use significantly higher amounts of finishing material than either of the other two companies. The figure also incorporates the cost of the new equipment that would be required for the waterbased finishing material, as the current equipment would not be sufficient.

5.3.2.3 Determine the Company’s Strategy for Development

Table 5.3 details the Case Company’s strategy for development.

Table 5.3 Strategy for Development

Elements	Case X	Case Y	Case Z
Outsourcing	No	No	Yes
Size of Company	Expanding	Not Expanding	Not Expanding
The Market	Stable	Unsure	Stable
The Product	Product Stability	Unsure	Product Stability

Case Company X did not have any existing outsourcing links nor did it intend to develop such relationship. The company both prided themselves and marketed themselves as producing fully Irish manufactured products. The company had plans for expansion in order to produce greater quantities of product. Together with the expansion of their facility the company were also investing in greater machining technology to produce higher quality products more efficiently. This would include more automated machinery such as CNC (computer numeric controlled) machines, as well as upgrading of existing machinery. This would greatly increase the efficiency of production. They had undertaken market research, which indicated that the market in which they were operating was strong and would continue to remain so for the foreseeable future. The products that were being produced had a loyal customer base, and the company were confident that there was longevity in the product.

Company Y did not have or intend to build any outsourcing relationships. The company did not have any strategy to expand, and develop into large production. They had no plans to invest heavily in technology or new machinery. They were unsure as to the stability of their market. They relied heavily on one contract, which attributed to over 60% of their production. They had no procedure in place if they were to lose that contract. The product that they produced was under threat from import from cheaper manufacturing countries, and therefore, it was viewed as unwise to suggest that their product provided longevity.

Company Z were outsourcing 95% of their production. They had a well established relationship developed with their suppliers, and had excellent procedures in place to ensure the quality of the product was of a high standard. The company did not envisage expanding their current status, as they believed that they were sufficiently developed to cope with demand. Company Z had also undertaken market research and estimated that their market was very stable. With the stability that the market offered, it had a knock on effect on the stability of the product being produced. They were confident that their product was streamlined sufficiently to maximise production.

5.3.2.4 Feasibility Study Findings

By using the feasibility study as a guide in selecting the most appropriate method for changing to a more environmentally friendly finish, it has indicated the following for each of the Case Companies.

Company X: - The feasibility study suggested that the most appropriate solution for the company to take was to introduce waterbased finishing. The study found that the company already had an automated system in place, which could be converted to waterbased finishing quite simply. As the company had plans to increase production and expand, they could also look at implementing another finishing line as part of their plans for expansion. They needed to increase the level of training being offered to maximise efficiency. This was an element of implementing best practices, associated with implementing waterbased finishing.

Company Y: - The feasibility study showed that this company were producing furniture in a non stable market. This uncertainty in market stability coupled with the size and scale of production led to the conclusion that the most appropriate action for the company to follow was to reduce their solvent. This was the most cost effective method open to the company and it was the correct course of action they needed to take. By working with the suppliers and implementing best practices such as training and developing a better finishing area layout, the reward greatly outweighed the investment. As the company did not need to dramatically reduce their solvent usage, the simple steps suggested would allow the company to meet the requirements of the legislation without investing a huge amount of money.

Company Z: - The feasibility study indicates that this company was greatly in need of changing dramatically to comply with legislation. It was obvious that converting to a waterbased finishing plant was going to cost a significant amount of money. With the trusted and developed relationship that the company had built up with its outsourcing suppliers there was a great incentive for the company to outsource its finishing also. It was a case of contrasting the cost of implementing a waterbased finishing system against the value of keeping the finishing process in their plant. Based on the nature of their relationship with their

manufacturing outsourcing supplier, the cost of developing that further to incorporate the finishing of the products was selected to be the most appropriate solution.

Now that the most appropriate solution has been identified for each company, the following section will illustrate how the elements of the framework were implemented and carried out.

5.3.3 Implementing the Elements

As previously stated in this chapter the validation of the finishing framework uses case studies that had already successfully altered their finishing process to deal with the legislation. The feasibility study was carried out using company information as input to select a suitable solution. It was not possible to implement the different solution elements that were reached as a result of the feasibility study and therefore, it cannot be accurately estimated as to how much the solvent usage of each company would have been reduced by. For the benefit of validation the author will present how each company should have implemented the solutions identified as a result of the feasibility study and according to the finishing framework. At the end of each section, the author presents what the companies had actually done in reality. This allows the reader to see the validity of the finishing framework.

Case Company X: - The result of the feasibility study indicated that Case Company X was a prime candidate for implementing waterbased finishing. From the feasibility study it became apparent that the company had all the features required to implement waterbased finishing successfully. They had a fully automated spraying line, which had the ability to be regulated and controlled. That meant that the variables described in chapter 4.5.1.1 of *temperature control, air-flow control, extraction, and drying times* were already in place and could be managed easily. With a controlled environment in which to operate waterbased finishing the next key variable feature that had to be achieved was to ensure that all the spraying equipment was non-corrosive. The spraying equipment in the automated finishing line was all from stainless steel resulting in the company not having to significantly change its equipment. The company did however need to change the fluid tips on the spraying guns so as to allow for the more viscous waterbased material. The next stage of implementing waterbased finishing according to the framework should be to carry out research into different waterbased suppliers

and to run trial runs with the material to find the optimum operation process at which the highest quality finish was attainable. The framework suggested that they should seek advice from other companies using waterbased finishing to assist them in their changeover from solvent to waterbased finishing. By following these simple guidelines company X would be able to reduce their solvent usage significantly.

In reality, company X did change to waterbased finishing system. They researched into waterbased finishing suppliers and materials. This is similar to the advice given in the finishing framework. This lead the company to understand that they had the correct environment present in which to carry out waterbased finishing. They changed the fluid tips on all spray guns and ran trial runs to find the best optimum operational process that gave the highest quality finish. When the company read the guidelines for implementing waterbased finish they felt that the suggestion to visit and consult other companies who had implemented waterbased finishing was an excellent suggestion. They did not do this and felt that they suffered in terms of prolonged downtime when changing over to waterbased finishing. The company had fallen to below 6 tonnes of solvent per annum.

Case Company Y: - The outcome of the feasibility study suggested that company Y needed to reduce their solvent. The first step identified was to dramatically change their spraying layout. Their layout needed to function better. This involves the company redesigning the layout of the spraying area so that there was less cluttering of products. This should include the introduction of moveable racks. This would give the spraying operator greater flexibility to work in a more structured manner. The operative would be able to spray to a number of components, place them on the racks and move them to an area of the facility dedicated for drying. Another area that needed attention was the lack of quality extraction. A stronger extraction system should be installed to assist in removing the overspray from the spraying area more efficiently. The next implementation criterion that should be looked at is to input some form of adequate heating. There was no capital available to purchase heated air tunnels, however heating panels should be installed on the walls of the spraying area adjacent to the drying area. Each heating panel should reach a certain temperature that should remain constant. With a proper process flow layout and a proper extraction and heating system in

place, the company would be able to reduce the risk of manual handling errors, thus lowering the amount of rework and work in progress. This should lower the amount of solvent usage to below the current threshold limits, however the fact that the company were concerned that the legislation would become more stringent, further alterations are necessary. Abiding by the framework the company should work with their suppliers to adjust the levels of solvent used in their finishing. By doing so it will result in the company falling well below the threshold limits.

In reality, company Y had in fact approached their suppliers with their problems. Working together the company received a lower content solvent finishing material that did not affect the quality of finish. In addition to working with their suppliers company Y had installed some fixed racks on the walls to help with space constraints. By working with their suppliers they fell from 15 tonnes per annum usage to under 8 tonnes per annum. After studying the framework and guidelines company Y believed it would be of great benefit to them if they installed heaters in the drying area as apposed to their paraffin oil blow heater they currently use. They also were of the opinion that a moveable rack was a great proposal for their situation. They also were in agreement with the extra powered extraction and coincidentally were in the process of ordering a new system at the time of validation.

Company Z

Company Z as a result of the feasibility study are directed to take the outsourcing solution to meet the requirements of the legislation. Following the implementation procedure the first issue would be to ensure that there was a trusted outsourcing relationship. This would involve checking to see if the outsourcing company had a good track record. The outsourcing company must also be willing to increase their contract to include the finishing of products. The next stage should be to travel to the outsourcing company and develop a procedure for finishing. This highlights the need for the outsourcing company to receive training to emulate the procedures that were being carried out in company Z facility. Once this is implemented the outsourcing company should be issued with finishing specification that needed to be adhered to. Quality checks must also be implemented as part of the setting up procedure to ensure no defect products were sent to the company. Other external factors such as the cost of

transportation and any laws/ regulations in the outsourcing company's country must also be taken into consideration. By investing the time and effort into outsourcing the company should be in a position to reduce its solvent usage dramatically.

In reality, company Z did opt to outsource its finishing. They initially trained the operators in the skills required to finish the products. To ensure that the quality of the finishing would match what they had been achieving at their own plant, they got their finishing suppliers to ship over the exact finishing material as they had been using. As quality was a major issue they developed a simple system whereby they put colour match charts for the operatives in the outsourcing plant. These charts allowed the operators to see what the acceptable finish is for each of the different colours that it was supplying. It was agreed that these charts were changed every 6 months to ensure quality did not decline. The company decided to travel every 2 months to oversee operations and discuss any problems being experienced. The steps that were taken are similar to those outlined in the framework. By outsourcing the finishing the company reduced their solvent usage to less than 5 tonnes per annum.

5.4 Verification of Framework using Validation Criteria

To illustrate the validity of the framework using Cormican's (2005) criteria, the following chart is presented. Each criterion is discussed after the chart is presented.

Table 5.4 Tested Criteria

Criteria	Description	Yes	No
Effective	<ul style="list-style-type: none"> • Does the methodology work? • Does it solve the problems for which it was intended? • Do projects that follow the methodology turn out successfully? 	√	
Efficient	<ul style="list-style-type: none"> • Are the tasks & activities prescribed by the methodology strictly necessary? • Is there any redundant effort? 	√	√
Universally Applicable/ Comprehensive	<ul style="list-style-type: none"> • Does the methodology work across the whole domain? • Does the methodology work in any organisation size? 		√
Simple & easy to learn and use by participants	<ul style="list-style-type: none"> • Is the methodology targeted at a well-defined population? • Is the methodology based on a coherent set of concepts and techniques? 	√	√
Manageable	Does the methodology provide detailed guidelines for the management?		√
Visibly Comprehensive	<ul style="list-style-type: none"> • Does the methodology make its reasoning clear and visible to the participants, so that they can intelligently judge the relevance and completeness of each piece of work? 	√	

Effective

- The finishing framework was found to be effective as the methodology worked. This is evident from the case studies it was carried out on. All three of the case companies used solutions matching solutions generated by the framework.

Efficient

- Not all tasks and activities that are listed in the framework need to be adhered to, to ensure threshold limits are reached. For example, if a company decide to reduce their solvent usage, simply implementing best practices may lower their usage enough to comply with legislation. If so they may not need to work with suppliers or vice versa. However, it must be remembered that the framework was developed for the generic industry and therefore, companies must choose and adapt the guidelines to suit their

situation. Depending of the situation the value of using an expert whilst implementing a solution can improve the efficiency of the framework.

Universally Applicable/ Comprehensive

- The methodology was developed generically and therefore cannot account for some diverse operations that exist in the industry. However the internal structure of the feasibility study together with the guidelines for implementation of the solutions can be applied to any situation. It is up to the individual organisation itself to select a combination of solutions to assist itself. This is a possible area for improvement in the framework.

Simple & easy to learn and use by participants

- The framework is designed to assist the majority of organisations within the industry. It is also based on accepted techniques from operations management as well as industrial experience. The frameworks simplicity ensures that companies can follow the roadmap outlined to achieving the goal of compliance with legislation.

Manageable

- The framework provides a clear set of guidelines for management to follow. However, it must be pointed out that in order to maximise the potential of the framework that companies may need to enlist the assistance of experts. These experts could assist the companies in achieving the guideline outcomes of the framework in a more efficient manner. This will depend on the capabilities of the company. Certain companies may possess all the knowledge required internally to implement the solutions correctly whereas other companies may need assistance.

Visibly Comprehensive

- The framework is clear and concise. It shows a clear roadmap of the steps involved from the beginning to end of the process. A company can simply follow the framework from identification and classification, to implementation of the chosen solution.

By applying this set of validation criteria, it is clearly evident that the initial objective of providing a framework that assists Irish furniture manufacturing companies in selecting an appropriate solution to comply with the legislation has been achieved. The framework provides the capability for companies to strategically look at their practices and procedures together with their potential for development, and based on this ascertain what the most appropriate solution to suit their needs is. It must be remembered that while the framework is based at a particular industry it is still a generic application. The Irish furniture industry is diverse and therefore, to be able to create a framework that would suit the individual needs of every company would be impossible. The framework has been generated with the intention of assisting as many companies within the industry as possible.

It gives clear steps and guidelines on how to implement the chosen solutions. However, depending on the capabilities within each company, the guidelines that are set out may need the assistance of an expert to fully maximise the effectiveness of the implementation guidelines. Companies can apply the framework and select the chosen solution and use their own expertise to implement the solution. On the other hand a company may decide to apply the framework to find the solution, but enlist the assistance of someone with more experience to improve the effectiveness and efficiency of the implementation. The author is aware that minimising disruption and downtime would be crucial factors for companies and that by companies using experts to assist implementation these factors could be lessened. It is also evident that while the framework has been tested against three case companies, there is the need to further test the validity of the framework. However, the author is confident that the framework has met the objectives set out.

5.5 Conclusion

This chapter focused on the validation of the finishing framework. Each of the key elements of the framework namely the (i) feasibility study and (ii) the implementation of the solutions were evaluated against a predefined set of criteria. To facilitate this process the framework was mapped against three case companies. Each of the case companies had previously altered their finishing system to comply with legislation with successful outcomes. None of the

companies had used the framework as a guide to selecting the most appropriate alternative finishing method. It was felt that by testing the framework against successful companies who had already changed it would highlight the validity of the framework. The validation proved that the framework was effective, easy to use and efficient. However the validation did show that as the framework is based on generic companies across the industry it does not and cannot fit each situation. Diverse organisation may need to be selective with elements of the framework solutions to suit their requirements. The framework without question provides companies with the ability to select an appropriate solution to comply with legislation. It also sets out steps and guidelines for implementing a chosen solution. This implementation procedure may or may not be assisted by an expert if the company do not possess the necessary competence. Finally although the framework has yet to be implemented in a real life situation, it nevertheless provides useful and easy to use guidelines for selecting an appropriate alternative to solvent based finishing.

Chapter 6 Conclusions & Recommendations

6.1 Introduction

This chapter reviews and presents the main findings of this research. Conclusions are drawn and other areas for future work are identified.

6.2 Thesis Summary

The primary objective of the research undertaken was to develop a tool to assist Irish furniture manufacturers in meeting the requirements set out in the VOC directive. This was achieved through the formulation of the 'Irish Furniture Industry Finishing (IFIF) Framework'. The IFIF Framework was developed with the requirement of the legislation in mind: it employs only known and tested methods from the industry. The framework was designed not only to highlight the most appropriate solutions to comply with legislation, but it should also lead Irish furniture companies to select the correct solution to suit their needs. Development of this framework was accomplished using a feasibility study. This feasibility study assessed the best solution to meet the requirements by centring the company's attention on ascertaining an understanding of their current practices and procedures, their future in terms of growth and development, and also looking at their financial situation in dealing with the problem.

Once the logic is applied through the feasibility study it will lead the company to one of three solutions namely; changing to waterbased finishing, working with suppliers or finally outsourcing finishing. These are explained in more detail below:

- **Changing to Waterbased Finishing:** Through the research undertaken at the literature review stage, it was clearly evident that one of the prime candidates as an environmentally friendly finishing material was waterbased finishing. It possesses many of the attributes that can be associated with solvent based finishing material such as giving a tough durable finish, as well as being easy to work with. Its major advantage is that it is almost 100% solvent free. As always there are disadvantages, with the main one being that all the spraying equipment used for waterbased finishing

must be corrosive free. Using waterbased finishing the user must ensure that the spraying facilities are suitable: appropriate extraction, heating and air flow are required. This is crucial in gaining a good quality finish.

- **Reducing Solvent:** Another solution to meeting the requirements of the legislation is to reduce the amount of solvent currently being used in a company. To achieve this, a company must follow a further two sub elements; implementing best practices and/ or working with suppliers. If we first focus on implementing best practices, the framework suggests that a company should use trusted and known methods from operations management techniques with a view to enabling these techniques to assist in reducing solvent usage. The framework guides the company to initially look at their layout. It describes what the characteristics are of a good layout and the importance of good layout in reducing solvent usage. Another part (within the context of reducing solvent using operation management techniques) directs the company to look at their product type and scale of production with a view to automation in a finishing context. Were it possible to semi automate or fully automate the finishing process it should increase production and efficiencies. It would also result in less manual handling and therefore should lead to reduced rework and work in progress. It would also increase the quality and consistency of the finishing.

The second sub element of reducing solvent revolves around working with suppliers and is a key fundamental for any company who may be just verging on or just over the limits of the threshold. The framework describes how valuable the suppliers of the solvent based material are in terms of their ability to reformulate the solvent based material which will reduce the solvent content but not infringe on the quality of finish.

- **Outsourcing Finishing:** The final solution that the framework suggests is to outsource finishing. By outsourcing the finishing a company can completely eliminate the risk of not complying with legislation. The main justification required by a company to consider this solution as an option would necessitate the company

already having a trusting relationship in place with an outsourcing contact. A company would have to be of a significant size and turnover to consider this, but if they are candidates then the option is a viable one.

Once a company has used the feasibility study to select their chosen solution, the framework provides the implementation methodology through which organisations can co-ordinate and successfully implement their new process.

- **Implementing Waterbased Finishing:** Companies will have to ensure that their spraying facility is adequately equipped for waterbased finishing. Implementing best practice factors will result in a quality finish being achieved. The best practice factors are; temperature control, air-flow control, extraction, drying times, use of non-corrosive spraying equipment and procedures.
- **Reducing Solvent:** Companies choosing the reducing solvent solution will have to implement best practices similar to the best practices outlined for implementing waterbased finishing. In conjunction with implementing best practices organisations will also have to improve their efficiency. Two significant techniques identified during the course of this project to aid Irish furniture companies to improve efficiency were layout and automation. Coupled with implementing best practices to improve efficiency, another element of reducing solvent is to work with suppliers.
- **Outsourcing:** The final alternative for Irish furniture companies is to outsource their finishing. In order to effectively outsource the framework provides a checklist that will assist companies to ensure that all aspects have been thought about. The checklist includes areas such as; developing finishing procedures, setting specifications, quality checks, training, transport and implications.

The framework is devised to highlight the solutions that are available, as well as give guidance as how to select and implement a chosen method.

6.3 Overall Conclusion

At the beginning of this project the objectives were set out and the process of meeting those objectives commenced. It was apparent from the outset that there was a significant necessity for establishing a framework whereby an Irish furniture company could select an alternative finishing method to meet the requirements set out by the VOC directive. In the absence of detailed literature available on the industry, it became necessary to gather the information by carrying out primary research. It is the belief of the author that because the framework was developed primarily through the use of the primary research it is of greater benefit to the industry in question.

The framework provides organisations with a structured approach to selecting an alternative finishing solution to meet the requirements outlined in the Council Directive 1999. It systematically directs organisations through a scheme of questions and reflections that will lead the company to choosing the correct solution for their particular needs. Upon selecting a chosen solution the framework identifies the implementation method required to successfully execute the solution.

The framework is formulated to assist all companies that are in breach of the legislation. It takes into consideration all the diversities of manufacturing within the industry, both in terms of size and scale of organisations, and the type of products they produce.

The framework not only provides the companies with a structured method for selection of an alternative method, but it also outlines the advantages and disadvantages that are associated with each solution. The framework makes sure each company is aware of all aspects of the solution and makes sure that all information is available to the user.

The framework has been validated to test its usefulness in industry. The IFIF framework does meet the requirements it was set out to achieve. It gives a clear roadmap that companies can follow to select a solution that will assist them in complying with legislation. However, from the validation section it indicated that to maximise the effectiveness of the implementation of the solutions, certain companies may need to use external experience to assist with this.

Taking everything into account, the framework will provide both a practical and functional tool for the Irish furniture industry. While the main objective of this research was to develop a framework to assist companies in selecting an appropriate solution to comply with legislation, the author has also added knowledge and information to literature related to the furniture industry. The work undertaken in this study can be used to assist other researchers as it provides a further study into an area where there is little information available.

6.4 Recommendations

A number of issues were raised throughout the duration of the thesis that were not possible to investigate or develop fully, but which merit further research. These are presented below:

- Further research is required into expanding on the effectiveness of the implementation of the solutions generated in the IFIF framework. This will include greater testing of the IFIF framework in ‘real life’ situations where its results can be more closely scrutinised.
- One of the key findings of this study centred on the use of best practices as a way of improving efficiency. Many of the companies studied employed best practices in manufacturing, but did not follow it through to the finishing process. This raises a key question as to why best practices are not implemented in every process of the product life cycle. Further research could investigate this matter further to see if there are forms of neglect in areas apart from manufacturing.
- There seems to be a significant investment into automated machinery at present in the industry but little comprehension and understanding as how to best utilise the new equipment. Significant amounts of money are being spent on machinery, even though the company may not fully understand the capabilities of the machine. An understanding of the levels of research and development at management levels need to be further investigated.

- A perception that seems to exist in the industry at present is that outsourcing is the direction which should be aimed for. There is very little literature available that explores this phenomenon in terms of its advantages and indeed its disadvantages to this particular sector of the industry. Research to explore the relevance of outsourcing for Irish furniture manufactures is needed.

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Appendix A

Appendix A: The Waterbased Questionnaire

1. What type of finish do you currently use?				
Acid Catalyst	Pre-Catalyst	Polyurethane	Water-Based	Other
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
If other please specify:				
2. How many spray guns do you have/ use?				
3. What type of spray guns do you use?				
Suction Feed	Gravity Feed	Pressure Feed	Air Assisted Airless	Other
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Do you use Conventional Air Spray or High Volume Low Pressure (HVLP) guns?				
Conventional Air Spray		HVLP		
<input type="checkbox"/>		<input type="checkbox"/>		
5. What types of spraying do you do?				
Lacquer	Stain	Colours/ Paints	Other	
(Natural/Clear)				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
If other please specify:				
6. Have you got separate spraying guns for basecoat and lacquers?				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
7. Have you a separate gun for paints?				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
8. Have you a separate gun for stains?				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
9. Do you use the same gun for more than one type of finish? (E.g. lacquers and paints)				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
10. How often do you clean out you guns?				
Once a day	Once a week		Other	
<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	
11. How do you clean your spraying equipment?				
Spray gun washer	Manually		Other	
<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	
12. How often do you service your guns? (I.E. take gun apart to thoroughly clean, change filters etc...)				
Fortnightly	Monthly	Bimonthly	Other	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
13. Who are your main suppliers of finishing material?				
14. Do you have a separate drying room?				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
15. Is the drying room heated?				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
16. Is there a separate airflow in the drying room?				
Yes	No			
<input type="checkbox"/>	<input type="checkbox"/>			
17. How long does it take for a typical panel to dry before it can be de-nibbed or packed for assembly?				

18. What type of extraction system do you use?
 Water Flow Filters Other

19. Do you have a separate airflow coming into your spray booth?
 Yes No

20. Is the spray booth heated?
 Yes No

If yes please state how?

21. How long does it take to change from one type of finish to the other (e.g. from basecoat to lacquer)?
 >5 minutes >=10 minutes >=15 minutes <15 minutes

If <15 minutes please specify:

22. How long does it take to switch between paints and lacquer
 >5 minutes >=10 minutes >=15 minutes <15 minutes

If <15 minutes please specify:

23. How do you dispose of your spraying waste?
 Waste Contractor Other

24. There is a new EU Solvent directive that comes into forces in October 2007, which may have an effect on the amount of solvent that you can use. Are you aware of this legislation?
 Yes No

25. In the legislation, limits are used to determine whether a company is in breach of the rules. The limits are expressed in the amount of organic solvent used per year. The limits are <5 tonnes, <10 tonnes, and <15 tonnes. Which category is your company in?
 <5 Tonnes <10 Tonnes <15 Tonnes Far below limits

26. Are you aware that you must hold a license if using 10 tonnes of solvent?
 Yes No

27. Why have you chosen to use waterbased finishing?
 Environmental Concern E.U. Legislation Quality of Finish Other

If other please specify:

28. Are you satisfied with the quality of finish you are achieving with waterbased finish?
 Yes No

If No please specify:

29. What were the main challenges that had to be overcome when changing to waterbased?
 Drying Times Increased Air Flow Process/ Technique Alterations Other

If other please specify:

30. Have you seen an increase in lowering insurance costs as a result of using waterbased finish?
 Yes No

31. Would you recommend other manufactures to switch to waterbased finishing?
 Yes No