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Sustainability Evaluation of the Use of Solvent-based vs Water-based Trim Paint

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Abstract.

Paint for buildings has changed due to reductions of volatile organic compounds (VOC). The European VOC in paint legislation 2004/42/EC was driven by an ambition to reduce ground level ozone. As a result, the trend towards replacing solvent-based trim paints with water-based was resurrected by paint manufacturers, it having failed to be accepted in the 1980's. Both solvent-based and water-based trim paints are subject to legislative VOC limits. Further VOC reductions have just been announced in BREEAM 2018 UK non-domestic construction manual. It is now more important than ever to prevent a reoccurrence of the unintended consequences of the legislation. The sustainability evaluation of the use of solvent-based versus water-based trim paint began with a questionnaire to stakeholders involved with paint. Decorators views were of particular interest because little was found from their perspective in literature reviews. 4 medium sized decorating contract case studies were followed by interviews with professional stakeholders. The reductions of VOC in paint for buildings have produced some unintended consequences. The shifts of sustainability impacts could have a greater sustainability impact than the original VOC problem. This study examined the shifted impacts and aims to help make these paints more sustainable in use. This study recommends that all stakeholders have a role to play in making a difference to the sustainability of the use of trim paint.

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List of Abbreviations and Acronyms.

BCF	British Coatings Federation.
BRE	Building Research Establishment Ltd.
BREEAM	Building Research Establishment Environmental Assessment Method.
CEPE	European Coatings Trade Association.
CIOB	Chartered Institute of Building.
CIS	Construction Information Service.
CITB	Construction Industry Training Board.
CO	Carbon Monoxide.
DEFRA	Department of the Environment, Food and Rural Affairs.
DIY	Do it Yourself.
EPD	Environmental Product Declaration.
EU	European Union.
HMSO	Her Majesties Stationary Office.
IWBI	International Well Building Institute (aka WELL)
LCA	Life Cycle Assessment.
LCI	Life Cycle Inventory.
NAEI	National Atmospheric Emissions Inventory.
NBS	National Building Specification.
PEF	Product Environmental Footprint.
PEFCR	Product Environmental Footprint Criteria Rules.

R&D	Research and Development.
RDC	Richardson Decorating Contractors Limited.
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SI	Statutory Instrument.
UCEM	University College of Estate Management.
TVOC	Total Volatile Organic Compounds.
UD	Authors 2016 Undergraduate Dissertation.
UK	United Kingdom.
UV	Ultra Violet.
VOC	Volatile Organic Compounds.
WCoC	Worshipful Company of Constructors.

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Glossary of Terms and Common Synonyms.

For the purpose of this study the following meanings apply:

Compliant paint (currently 2012)

Solvent-based or water-based paint which complies with the current VOC in paint legislation.

Contractor

Principal contractor or other construction professional other than a decorating contractor.

Decorator

Painters, decorators, paint applicators, decorating contractors and any representative or agent involved with a paint application business.

Designer

Any Architect or specifier of paint coating other than paint manufacturers specifier.

Manufacturer

Paint manufacturers in general, their branded suppliers, their representatives and agents unless specifically named, (AkzoNobel for example).

Solvent-based Paint

Any paint where water is NOT the solvent constituent, usually for buildings the solvent is White Spirit. See Compliant and Traditional solvent-based paints. Common synonyms: Alkyd, Gloss, Oil based, Solvent Paint and Spirit Based.

Surveyor

Clerks of works, the client or any representative or agent of the client involved with inspection.

Traditional Solvent-based Paint

Solvent-based alkyd resin trim paint manufactured before the reduction of VOC in paint legislation.

Trim Paint

Paint for application to timber or composite interior trim, such as skirting, architrave, dado and picture rails, door linings, doors, window boards and the like.

Water-based Trim Paint

Any trim paint where water is the solvent constituent.

Common synonyms: Acrylic, Aqueous, Emulsion, Latex, Quick or Fast drying.

White Spirit

Solvent and diluent for both traditional and compliant solvent-based trim paints.

Common synonyms: Mineral Spirit, Solvent, Solvent Naptha, Stoddard Solvent and Turpentine Substitute (Turps).

Sustainability Evaluation of the Use of Solvent-based vs Water-based Trim Paint.

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Chapter 1. Introduction.

1.1 Scope of Chapter.

A brief synopsis setting out the aim and objectives posing the question; How has sustainability legislation affected those using paint professionally? There are around 129,000 professional decorators in the UK, BCF (2015). These are craftsmen who know about using paint. Their practical experience means their opinions are well-founded and should be valued.

1.2 Study Synopsis.

There is a UK trend towards replacing solvent-based paint for trim, (architrave, skirting etc.) with water-based paint. This appears to be a direct result of European legislative reductions of volatile organic compounds (VOC). Mainstream construction paint manufacture in the UK is dominated by AkzoNobel, (formerly Imperial Chemical Industries plc. (ICI)), Crown Paints Ltd. and PPG industries (UK) Ltd. (PPG), IBIS (2017). AkzoNobel have an ambition that 50% of trim paint will be water based by 2020, Dulux (2017). Crown Paints (2017) support a (legislatively), smooth transition to lower VOC. PPG say water based trim paint means decorators don't have to worry about destroying the planet when they are decorating, Johnstone (2017). Are they right?

AkzoNobel, who own the Dulux brand, were enthusiastic when this study commenced. Other manufacturers have since shown interest but because Richardson Decorating Contractors Limited (RDC) are Dulux Contract Partners and AkzoNobel have adopted such a proactive sustainability stance, it was a commercial decision to work solely with AkzoNobel for this study.

This study challenges the sustainability of the trend. It is important to note that this study is not about the healthiness of either solvent-based or water-based trim paints. Health cannot be ignored as it is a significant driver for the change.

This study is not about seeking a reversal back to “traditional” solvent-based paint which itself must not be confused with “compliant” solvent-based trim paint. It is important that the distinction is understood, see figure 1.1, excerpt from the glossary of terms of this study.

Traditional Solvent-based Paint

Solvent-based alkyd resin trim paint manufactured before the reduction of VOC in paint legislation.

Compliant paint (currently 2012)

Solvent-based or water-based paint which complies with the current VOC in paint legislation.

Figure 1.1, Excerpt from Glossary of Terms.

The solvent-based trim paint evaluated in this study is all 2012 compliant and is distinctly different from traditional solvent-based trim paint. The water-based trim paints evaluated have been developed as a result of the legislation and have no distinction from pre-legislation mainstream water-based trim paints. The legislative VOC content maximum limit values apply to both solvent-based and water-based trim paints, table 1.1.

In chapter 4, a synopsis of 4 of the authors 2016 undergraduate dissertation (UD) case studies, 3 with water-based and 1 with solvent-based trim paint are reported.

Maximum VOC content limit values for paint	Type of paint	VOC grammes per litre (g/l) of ready to use product
Interior/exterior trim and cladding paints for wood and metal	Water-based	130
	Solvent-based	300

Table 1.1 taken from Statutory Instrument 2012 No.1715, HMSO.

This study is about finding ways to optimise the sustainability of the use of current compliant trim paints. Use is a key word which distinguishes this study from the sustainability of the paint itself.

Water-based paints have some very positive attributes. Not least of which, is the resistance to the surface spread of fire and total inflammability in transport and in storage. In the wake of the Grenfell Tower disaster it is almost inevitable that the flammability of paint coatings, along with many other construction materials, will come under scrutiny.

The UD investigated the sustainability of reducing VOC in paint. The three leading UK paint manufacturers were questioned along with other stakeholders, UD questionnaire appendix A. The findings raised questions about the sustainability of VOC reductions.

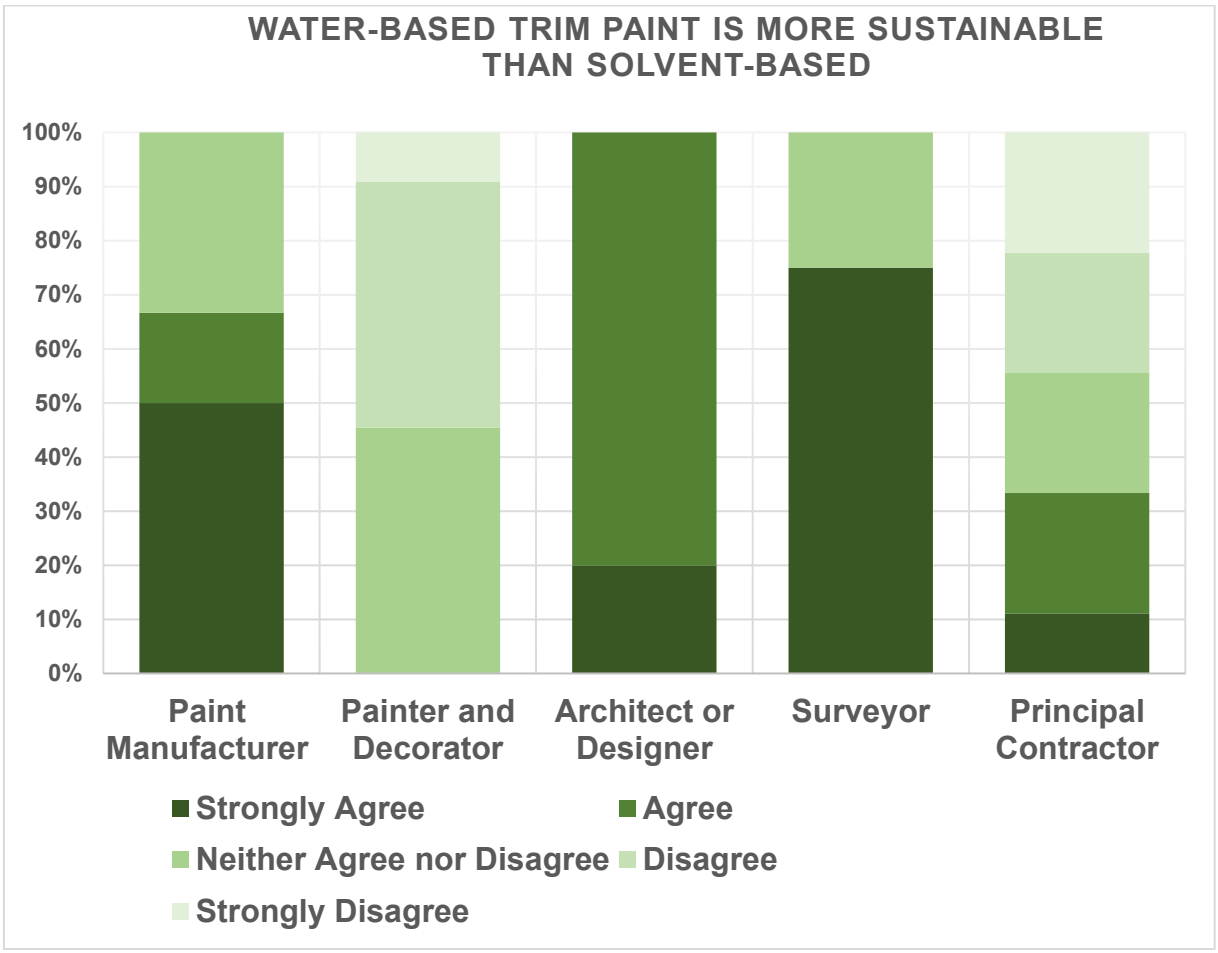


Figure 1.2, UD 5.4, Statement B4 Response Graph.

Paint manufacturers reactively formulated trim paint for compliance with EU Directive 2004/42/EC, (the VOC in paint directive). This study is a follow-on from the UD exploring ways of reducing decorating contractors resource wastes and to overcome the shifted environmental impacts. Water-based trim paint was perceived more sustainable by all stakeholders questioned for UD, except decorators themselves and the mixed messages appear to have added confusion to principal contractors, figure 1.2.

1.3 Aim.

To evaluate the sustainability of the use of water-based paints compared to that of solvent-based trim paints in the UK.

1.4 Objectives.

1. To identify and explain the constituents of solvent-based and water-based trim paints that impact most on their sustainability.

2. To identify the current information concerning sustainability of the whole life cycle of solvent-based and water-based trim paint.

3. To identify and explain the issues concerning the use of these trim paints that impact on their sustainability.

4. To evaluate the sustainability of the use of solvent-based and water-based trim paints.

1.5 Paint Sustainability.

There are many definitions of sustainability, for the purpose of this study the Cambridge Business English Dictionary, (2017) definition is used.

The Cambridge definition encompasses the environmental ethos of the VOC legislation and the subsequent changes by manufacturers to paint for compliance. The definition has the idea that goods and services should be produced in ways that do not use resources that cannot be replaced and do not damage the environment. The negative damage to the environment caused by the reworking of finishes due to unrealistic expectations fit this definition. The second part of the definition which is the ability to continue at a particular level for a period of time, concerns the economic sphere of sustainability and epitomises manufacturers striving to produce paint more sustainably. The definition encompasses the unsustainability of wasted resources by decorating contractors. The three spheres of sustainability, sometimes called the triple bottom line are, environmental, economic and social which, ideally, should balance. Vanderbilt University model, figure 1.3, depicts the balance of the spheres. The environmental sphere demonstrates the natural use of resources, for example; by paint manufacturers. Pollution of air, water, land and, for example; the waste associated with paint use. Similarly, the economic sphere depicts cost savings and R&D. Education is identified in the social sphere of Vanderbilt. An adaption of the Vanderbilt Venn entitled ‘The three spheres of paint sustainability’, figure 7.1 is used to help visualise the conclusions of this study.

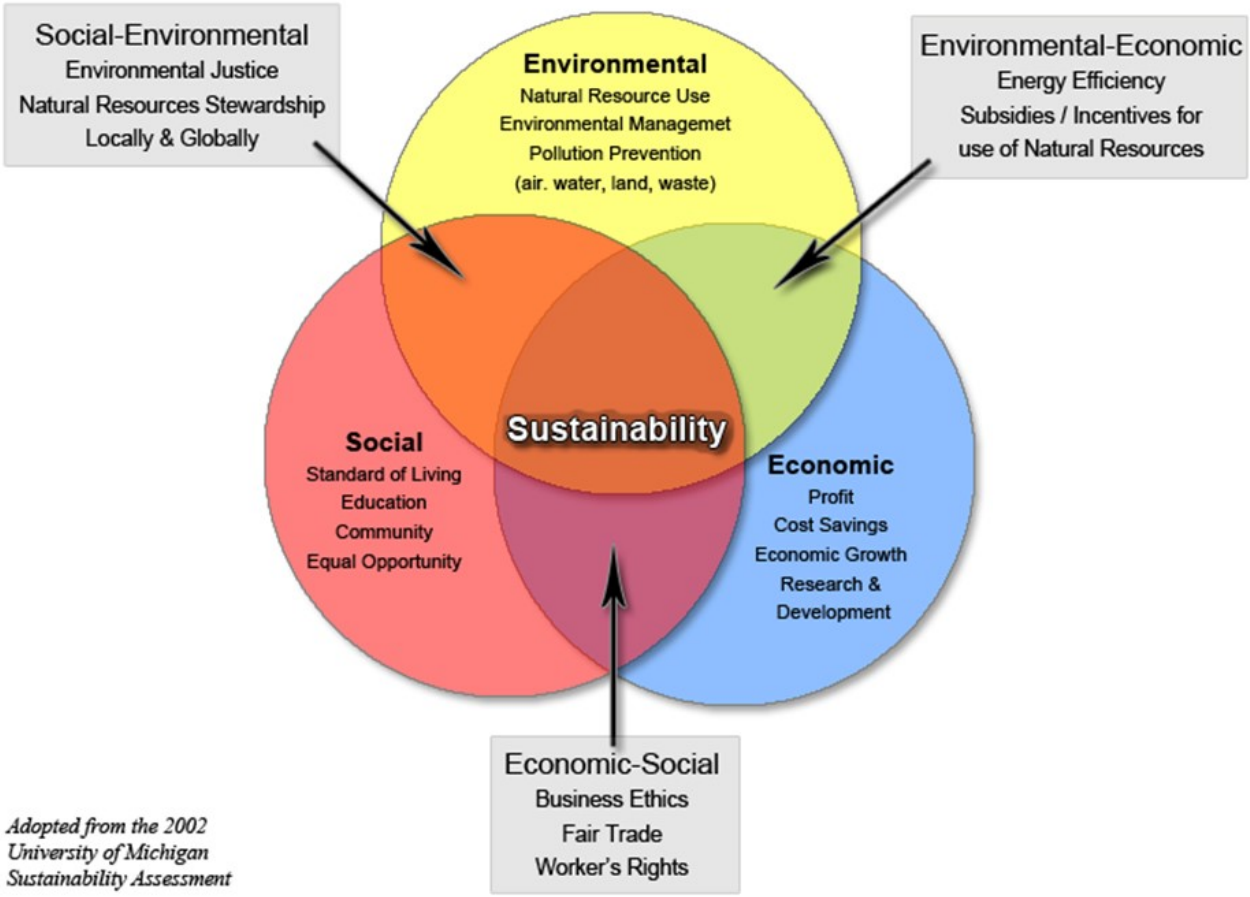


Figure 1.3, The Three Spheres of Sustainability, Image from Vanderbilt University, (2016).

1.6 Rationale.

The complex composition and use of paint must be balanced between the sustainability of use and the impact of not protecting construction materials. The clients' expectation of a tactile and aesthetically pleasing surface must also be considered.

Paint adds colour to our lives, there is probably paint within reach of any reader of this paper. Touch it, look at it critically. If it has been applied by hand within the last decade it will almost certainly have brush marks and/or orange peel, (slight stipple, caused by lack of flow), figure 1.4. Paint has changed. Some people resist change, having the natural assumption that the future will be the same as the past.

No evidence of end user consultation could be found in the literature regarding the changes in paint due to VOC legislation.

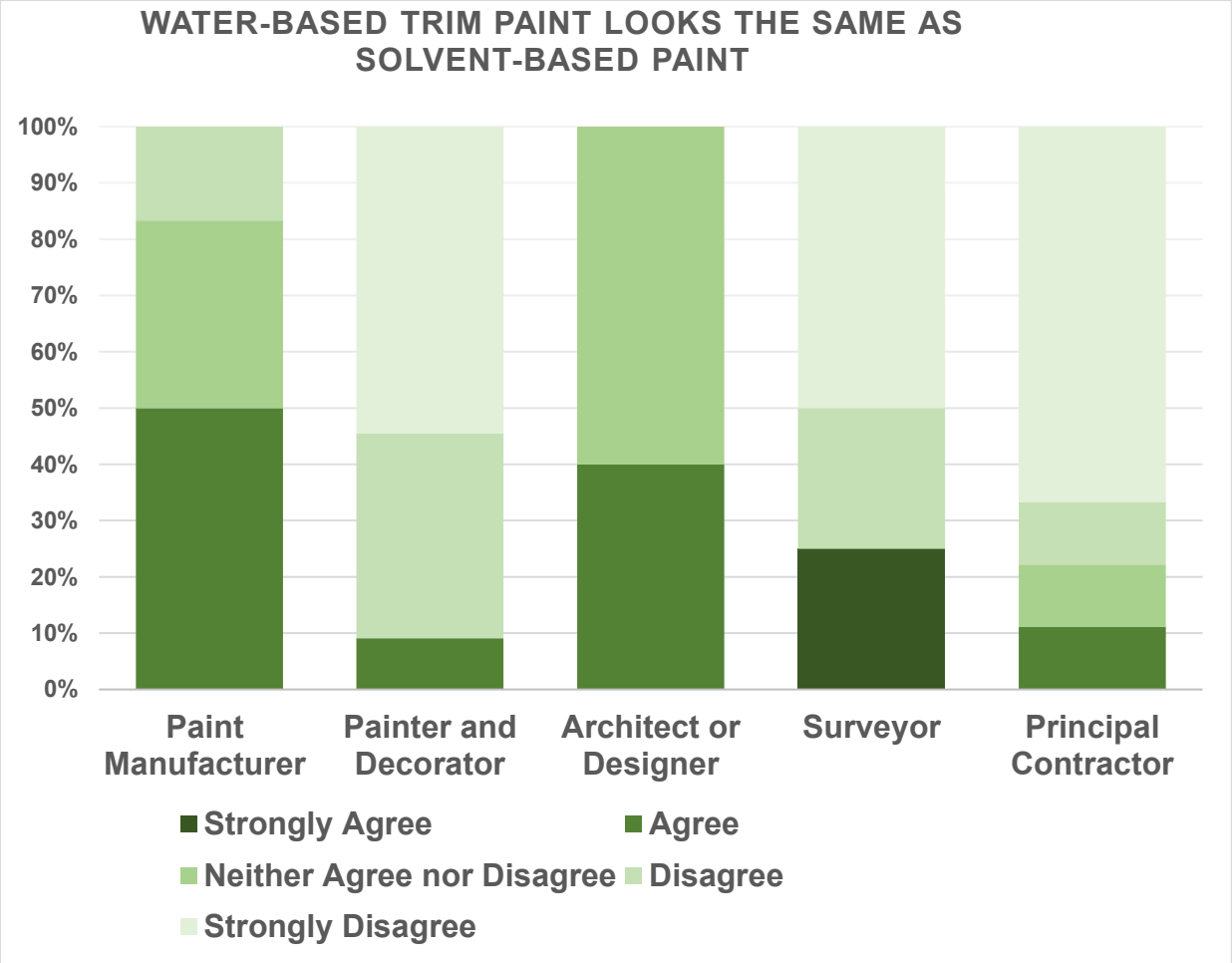


Figure 1.4, UD 5.14, Statement F1 Response Graph.

1.7 Change.

It is considered that paint should be manufactured and used in a sustainable manner. Developments in paint manufacture and use which advance sustainability ought to be embraced. Robson (1997), Finlay (2000), Haberberg & Rieple (2001) and Race (2013), all agree that change has human impediments.

In 2017 the UK Secretary of State was obliged to review the reduction of VOC in paint regulations, SI 2012/1715 (2012), this did not happen, which could be due in part to the current political uncertainties surrounding Brexit.

1.8 Building Research Establishment Environmental Assessment Method. (BREEAM).

BREEAM introduces itself as the world's first and leading sustainability assessment and certification scheme for the built environment. It is an international standard that is locally adapted, operated and applied through a network of scheme operators, assessors and industry professionals. Through its application, BREEAM recognises and reflects the value in higher performing assets and aims to inspire and empower change by rewarding and motivating sustainability across the life cycle of master-planning projects, infrastructure and buildings. Launched in 1990, to date, BREEAM has been used to certify over 590,000 assessments of buildings across the building life cycle and is being applied in over 78 countries, BREEAM (2018). BREEAM is assessed during the construction phase. At the time of the case studies it made no allowance for building use or end of life.

Legislative VOC limits for all trim paint have been reduced further by BREEAM from 130g/l to 90g/l without the inclusion of a solvent-based option, currently 300g/l. BREEAM 2018 UK non-domestic construction manual was implemented 07/03/2018, figure 1.5. Thus, implying that BREEAM will not certificate any projects that utilise solvent-based trim paints. It is therefore more important than ever that a repeat of the unintended consequences of the legislative reductions is avoided.

Product category	Free TVOC content of ready-to-use product (g/l)	Testing requirements (see CN7.4)
Interior matt walls and ceilings (Gloss <25@60°)	10	ISO 11890-2 or ISO 17895 or Calculation based on the ingredients and raw materials
Interior glossy walls and ceilings (Gloss >25@60°)	40	
Interior trim and cladding paints for wood and metal	90	
Interior trim varnishes and wood stains, including opaque wood stains	65	
Interior minimal build wood stains	50	
Primers	15	
Binding primers	15	
One-pack performance coatings	100	
Two-pack reactive performance coatings for specific end use such as floors	80	
Multi-coloured coatings	80	
Decorative effect coatings	80	

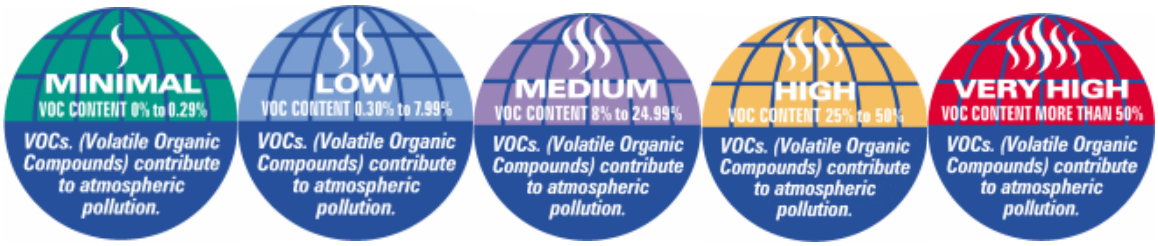
Table 1.2, BREEAM, (2017), Draft 2018 UK Non-Dom New Construction Manual. (adopted 07/03/2018)

Paint for buildings has changed in the name of sustainability and it appears that it will continue to do so. Resistance to this change by stakeholders and their unwillingness to accept that these changed paints are aesthetically different will be discussed.

1.9 Considered Exclusions.

The shift to water-based alternatives for do-it-yourself (DIY), paints, spearheaded by the British Coatings Federation, (BCF), and UKs largest paint product retailer, B&Q, are excluded from this study.

The difference in quality expectation between DIY painters and professional decorators is the rationale for the exclusion. B&Qs legacy is VOC globe labelling, figure 1.6, which has been adopted by the UK paint coatings industry, BCF (2015).



Minimal	**Low**	**Medium**	**High**	**Very High**
0% to 0.29%,	0.3% to 7.99%,	8% to 24.99%,	25% to 50%,	more than 50%

Figure 1.5, UK VOC Globe labelling, BCF (2015).

Figure 1.7. shows the most up to date sales figures for UK at the time of writing and are for the year ending November 2017. Numbers are in 1,000's of litres:

Decorative Paints	286,892
Retail	135,729
Trade	151,163
Solvent Based	48,305
Water Based	238,587
Woodcare	51,405
Retail	44,229
Trade	7,176
Industrial Coatings	80,738
All other industrial	55,420
High performance	18,181
Marine	7,137
Total UK Sales	419,035
Export Sales	152,837
Decorative paint	14,471
Industrial	138,366
Grand Total Sales	571,872

DIY is not insignificant in impact, Britain now has about 30 million DIY painters and the coatings industry sold over 135 million litres of paint last year to the retail market.

Figure 1.6, BCF UK Paint sales, AkzoNobel (2018).

Chapter 2. Literature Review.

2.1 Scope of Chapter.

To review literature surrounding the environmental impacts and the economic sustainability of the movement towards replacing solvent-based trim paint with water-based. Starting with a laymans explanation of what paint is, the basic constituents and their sustainable impact in use.

2.2 Objective 1, To identify and explain the constituents of solvent-based and water-based trim paints that impact most on their sustainability.

2.2.1 What is Paint?

The actual composition of paint can be complex, Chudley (2014). In laymans terms paint is a liquid applied compound which through solvent evaporation forms a dry surface coating. It is widely agreed that paint is primarily a protective coating, (preservation), Fulcher, *et al* (1983), Butterfield (2011) and Chudley *et al* (2012). Other objectives of paint application are, to make the substrate washable, (sanitation), to colour the substrate, (decoration) and to distinguish the substrate, (identification). AkzoNobel believe decoration is the primary reason for painting, BCF, figure 1.7, categorised almost 50% of annual sales as decorative paints. It could be that more pre-finished materials are now used in buildings, but, that is another subject. The UK exports more Industrial paint than it sells decorative paint to the domestic retail market and exports only a fraction of decorative paint. Paint has four base constituents, binder, pigment, solvent and drier.

2.2.2 The Solvent Constituent.

In solvent-based paint for buildings it is the solvent which constitutes the greatest VOC content. Solvents are liquids or mixtures of liquids that dissolve resin and carry pigments and other paint components. Without solvent, which extends drying time, paint dries too quickly during application and becomes too thick and stringy to facilitate good surface finish, (Dulux, 2014). White Spirit is the organic solvent for most solvent-based paint used in UK buildings. Organic solvent is replaced with water for water-based paints. The VOC content in water-based paint is smaller and is in the other constituent parts.

2.2.3 Solvent Evaporation.

All solvent-based paint, whether natural or synthetic, contains VOC. Solvents are used to keep the binder and pigment in suspension until applied. After application, in laymans terms, the solvent evaporates and leaves a dry paint film on the surface. Solvent evaporation is said to contribute to the formation of ground-level ozone and smog which can contribute to global warming, Turner (2015). The EU Directives aim is to substantially reduce those solvent emissions which contribute to the generation of harmful ground-level ozone, Prieto, (2010). The Solvent Industry Association (SIA) disagree, they say that emissions of organic solvents into the air degrade typically within a couple of days, after which they break down into carbon dioxide (CO^2) and water, SIA (2015). AkzoNobel say that not all organic solvents are capable of breaking down to form CO^2 and many will persist way beyond a few days.

2.3 Solvent, Paint and the Environment.

Over the last decade, decorative coatings have been subject to European legislation aimed at reducing the VOC content. The main impacts from VOC arise from its part in forming ground-level ozone. VOC reacts with oxides of nitrogen in the presence of sunlight, DEFRA (2012). Ozone is the stated trigger for the regulations. This means that the paint content volume of solvents such as White Spirit, have been reduced in order to comply. Manufacturers and trade decorators' merchants still sell unrestricted quantities of White Spirit separate from 2012 compliant solvent-based paint which requires thinning to aid aesthetic flow. DEFRAs 2009 statement is still valid for the current regulations, SI 2012/1715.

> *"Neither the paints directive nor the implementing regulations directly restrict usage, the only offence is to market paints which exceed the allowed VOC content", (DEFRA, 2009).*

2.4 Paint Aesthetics.

The BCF, according to Turner, (2015) agree that solvent-based gloss paints will be glossier and more resistant to wear and tear than lower VOC acrylic gloss paints. Non-acrylic natural paints based on chalk for example, may have even poorer aesthetics. Solvent-based paint has a better flow and appearance, AkzoNobel (2015). Solvent-based paints can compensate better for climatic variations in application and drying. Traditional paint based on alkyd resin was preferred by many decorators because it had more open time and was easier to work with, Prieto (2010). The period in which irregularities in a freshly applied coating can be repaired without resulting in brush marks is referred to as the open time, McCreight *et al* (2011).

2.5 Water, Paint and the Environment.

Construction Design and Management regulations (CDM), (2015), state that designers should eliminate hazardous materials from their designs or specify the least hazardous products which perform satisfactorily.

For environmental paints to have credibility they have to meet acceptable usability standards. Adding chemicals to water-based paint is described as a balance between usability and fitness for purpose, McWilliam (2004). The production of water-based gloss paint is said to involve an energy intensive production process which requires a complex mixture of neutralising agents, auxiliary diluents and preservatives, Turner (2015), although, only traces of these should remain in the finished product. Water-based paint brushes which are washed by painters under a tap could be contaminating an estimated 25-150 litres of water each time, Siegle (2010).

2.6 Objective 2, To identify the current information concerning sustainability of the whole life cycle of solvent-based and water-based paint.

2.6.1 Environmental Debate in Europe.

It can be identified that 40% of the environmental footprint of paint is downstream from the factory gate, Mash (2015) although, some industry sources believe the figure could be different. EU recognises the issue and is sponsoring a research programme to develop a method for making objective comparisons between competing products and systems in terms of life cycle sustainability, Mash (2014). Through its Product Environmental Footprint (PEF) project, a number of industry pilot studies have been identified, the decorative sector of the coatings industry has been selected to be one of the first. At the time of writing, the EU PEF are in the

process of agreeing the criteria rules (PEFCR), and how to determine the definition of LCA. Where paint is concerned, the Technical Secretariat are awaiting the approval of the PEFCR before any further progress can be made. It is uncertain whether this will be adopted in UK post Brexit.

2.6.2 Life Cycle Thinking.

In 2010, the EU Sustainability Taskforce took the decision to stimulate a shift towards 'Life Cycle Thinking', van Maurik (2013). European coatings trade association, (CEPE), developed a Life Cycle Inventory (LCI) database covering both raw material and coating manufacturing. The scope of this project was cradle-to-gate. Life Cycle Assessment (LCA) uses the cradle phrases invented by Walter R. Stahel in the 1970s, Braungart and McDonough (2002). From the extraction of raw materials (cradle) to disposal (grave), cradle-to-gate implies raw material extraction through manufacture to the point of sale, which from the decorators' perspective, as Mash describes, is upstream. Nahmens (2012), van Maurik (2013), Mash (2015), and Toxopeus *et al*, (2015), all agree that the effect of legislation upon the built environment should be addressed on a life-cycle basis. LCI data for raw materials enables member companies to identify, analyse and evaluate environmental effects of their products over the products full life cycle, van Maurik (2013). It is this data on which paint manufacturers environmental product declarations (EPD) are based. Downstream from the gate (point of sale), involves sustainability impacts from transport of the manufactured paint, labour resources, the plant associated with paint application, the process of application itself and disposals (gate-to-grave).

2.7 Sustainable Partnerships.

Sustainability is a selling point in the global paints and coatings markets, Oestreich **(**2009). Some sustainable improvement has been driven by legislation, Mash (2015). Mash also suggests that the coatings industry has made a good start but has further to go on its path of sustainable development and recommends the creation of partnerships up and downstream.

2.8 Paint Application Techniques.

Opacity is often less in low VOC (water-based) paints than with traditional paints because of the amount of water required to keep water-based trim paint in suspension and to inhibit the speed of drying, Brimo-Cox (2006). Because low VOC paints dry faster they have less flow and levelling, Brimo-Cox believes it is important that decorators are aware of the limitations these products have and adjust their techniques accordingly. Mash (2015), agrees with Brimo-Cox adding that it is the paint manufacturers who must understand downstream requirements of paints and their application methods.

"Anyone familiar with art could tell an acrylic from an oil painting. Why do paint manufacturers think they can claim the new paints have the same finishes and perform as well as the old ones? The fact is they are different and painted surfaces are never going to look the same again", Clover (2010).

The specialty chemical sector is now helping the coatings industry address sustainable development by the provision of new, more sustainable constituents. The coatings industry needs to help its downstream industries address their own sustainability targets, Mash (2015). This raised the question; what is industry doing about downstream awareness of changed application techniques? A synopsis of this is contained in chapter 5.

Chapter 3, Research Methodology.

3.1 Scope of Chapter.

The reviewed literature along with the UD case studies, appendix B, and UD questionnaire findings, appendix A, formed the basis of this research. 80% of UD questionnaire respondents agreed that there needs to be an increased awareness of the whole paint process from extraction of raw materials to disposal, figure 3.1. An interview and discussion technique has been used to gather qualitative attitudinal opinions from sustainability motivated stakeholders.

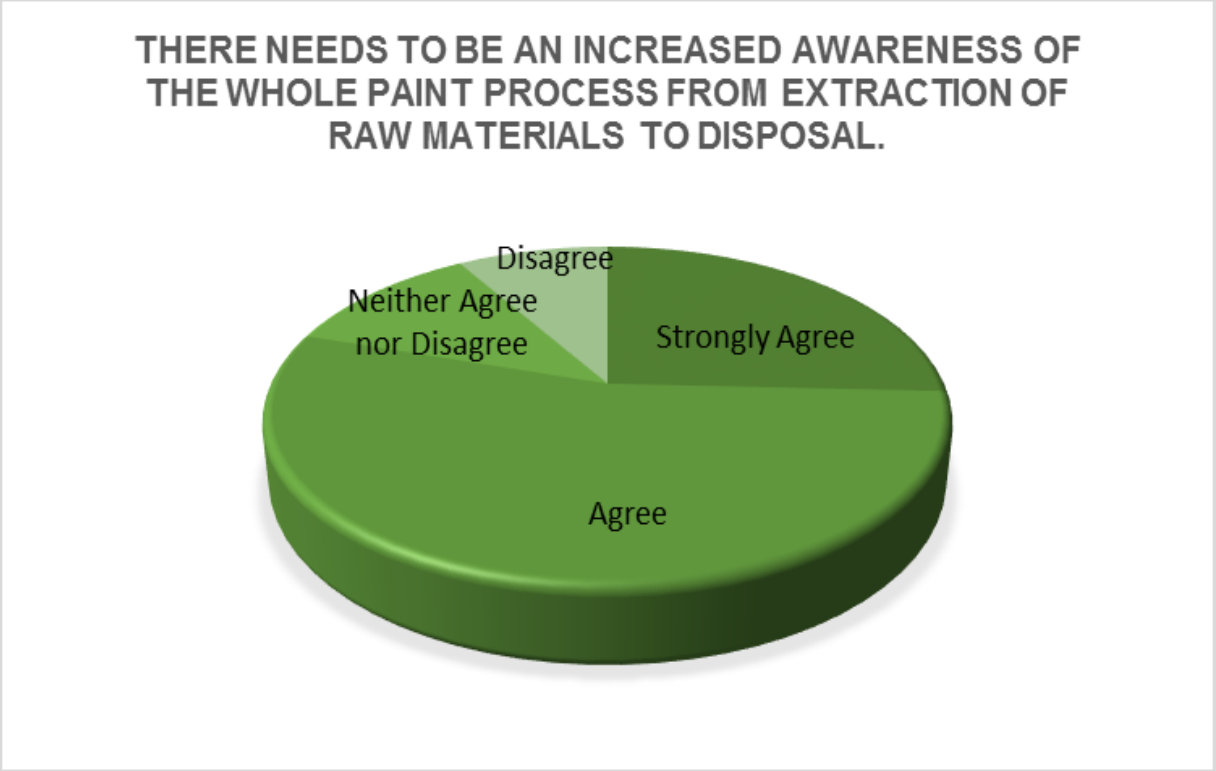


Figure 3.1, UD Statement C1 Response Pie Chart.

3.2 UD Questionnaire.

Detailed analysis of UD questionnaire '*The Sustainability of the Reductions of VOC in Decorative Paint Coatings for Buildings in the UK'* can be found in appendix A. The results are depicted using appropriate chart or graphical representation to accentuate similarities and differences between stakeholder groups.

The number of responses returned are shown in table 3.1, the total number of responses is approximately 12% of the 300+ petitioned. 75% of the responses were from those involved with the on-site practicalities of paint application, (decorators and principal contractors). However, due to the arbitrary distribution processes this is deemed a representative response for the industry.

Which of the following best describes your role in the painting industry?	Responses
Paint Manufacturer or Supplier	6
Painter and Decorator	11
Architect or Designer	5
Surveyor, Client or Client Representative	4
Principal Contractor or other Construction Professional	9
Total number of responses	35

Table 3.2, The Number of UD Questionnaire Responses Returned.

3.2 Decorators.

RDC take sustainability very seriously and are continually looking at ways to improve their environmental impact. A collaborative approach involving all stakeholders was chosen. The UD questionnaire included anonymous non RDC decorators. The opinions of the UD questioned decorators and principal contractors often opposed that of manufacturers and designers, figure 3.3.

It was considered that further research of these stakeholders not directly involved with paint application conditions on site was required.

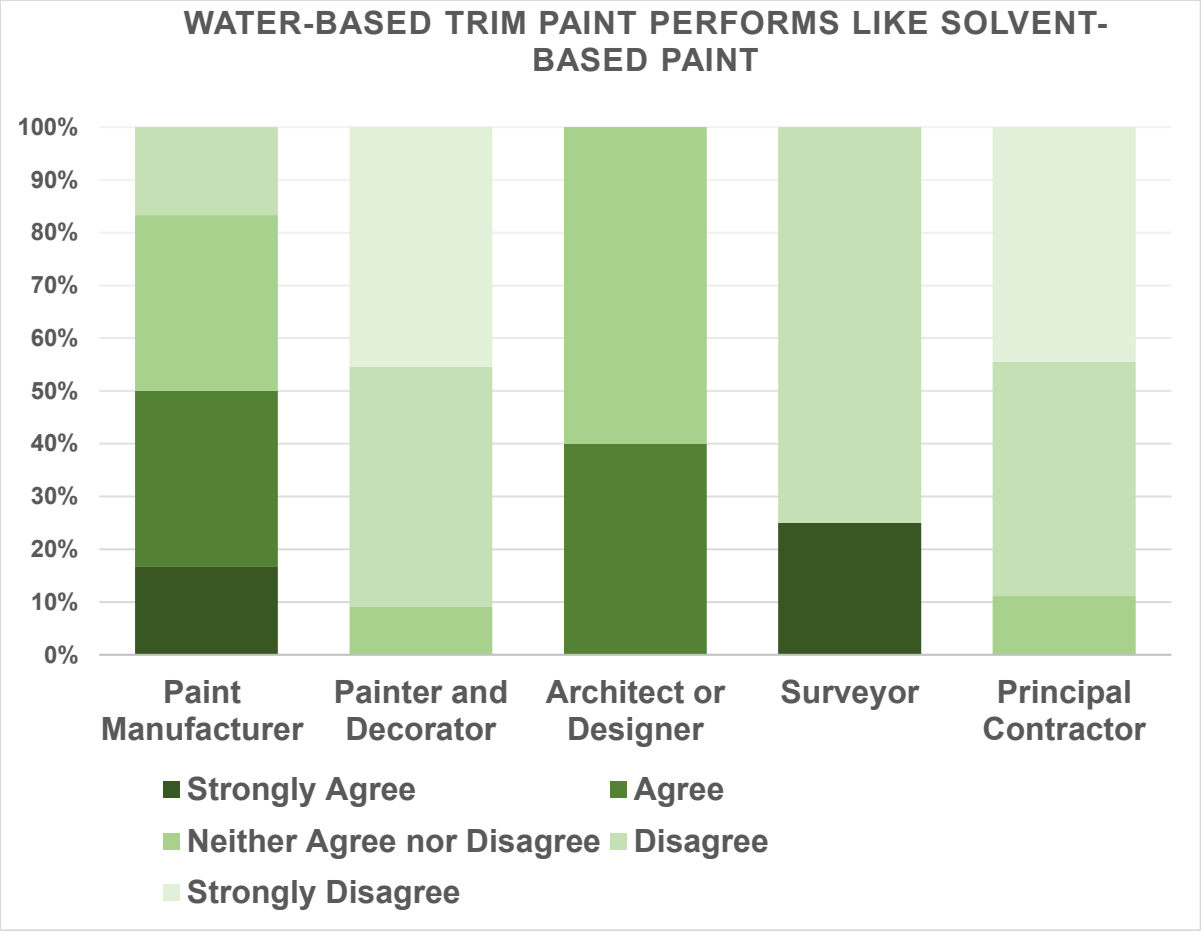


Figure 3.3, UD 5.11, Statement E1 Response Graph.

3.3 Paint Manufacturers.

Mainstream UK paint manufacturers were invited and engaged in a UD paint sustainability dialogue. The majority of those questioned believed that the industry was right to switch from solvent-based to water-based trim paint, figure 3.4. Practical demonstrations and hands on training were encouraged where possible. AkzoNobel were involved in UD case studies and most interviews for this study.

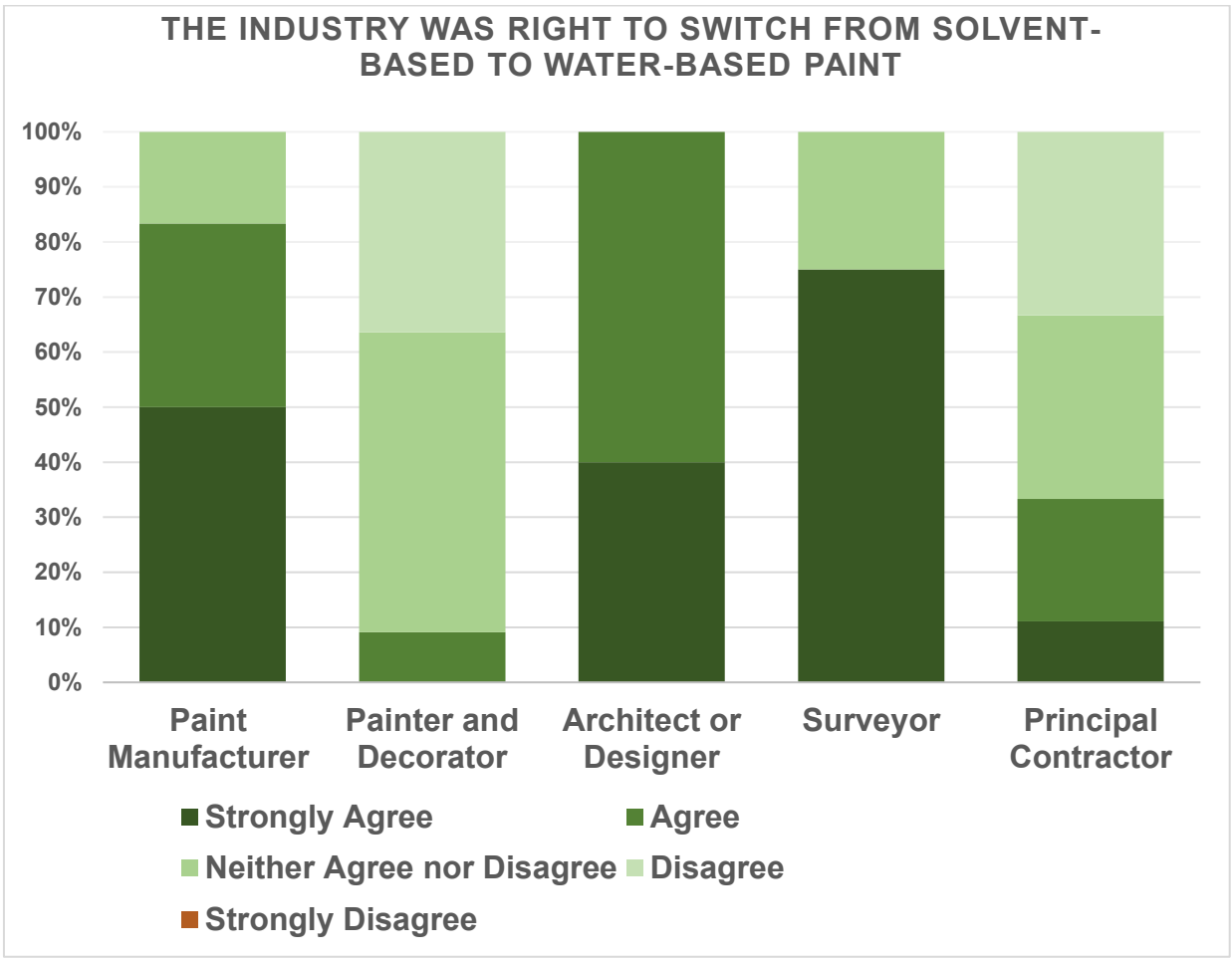


Figure 3.4, UD 5.8, Statement D1 Response Graph.

3.4 Clients and Designers.

Clients and designers were interviewed, where possible, with the inclusion of their specified paint manufacturer. This was limited due to the contractual barrier that principal contractors have on any given project. The UD figures 1.1, 1.4, 3.3 and 3.4 all depicted a similarity of opinion between manufacturers, clients and designers which is significantly opposed by stakeholders who are actually involved with application or inspection of paint on site.

3.5 Principal Contractors.

Principal contractors were invited to facilitate and attend interviews between RDC, the designer and the specified paint manufacturer for the respective projects. There was resistance by some principal contractors to enable access to the designer. It is contractually expedient to use principal contractors as a conduit to the designer.

Chapter 4, Synopsis of Case Studies.

4.1 Scope of Chapter.

A brief overview, maintaining principal contractor confidentiality, of four case study sites with paint sustainability issues. All of the case studies were sub-contracted to RDC for decoration but not all by the same principal contractor.

4.2 Case Study 1, Theatre Refurbishment and New Extension.

4.2.1 Shifting Liability.

Water-based trim paint specified for the internal doors and frames had not fully cured up to eight weeks after application. The paint manufacturer was asked to assess why, and identified two possible reasons why the paint was not fully curing. The first shifted the liability to the cleaners who may or may not have used an alcohol based cleaning solution. The second possible reason was plasticiser migration from the rubber smoke seals to the water-based trim paint.

4.2.2 Increased Water Use.

The formulation of the water based trim paint clogged the synthetic paintbrush bristles at the ferrule during application making the working volume of the paintbrush decrease during the course of the day. Decorators had to wash their brushes during, as well as at the end of their shifts.

4.2.3 Sustainability Awards.

The paint was specified in order to achieve BREEAM Excellent, mainstream paint manufacturers' state that all of their paint for buildings, including solvent based, meet the BREEAM criterion. The designer claimed six regional conservation and sustainability awards for the project. The decorating contractors investigative and re-work was detrimental to the environment because of unnecessary additional resource wastes and transportation. Once the defects period was concluded the theatre facilities management team repainted the doors with solvent based products. In the course of this case study a similar situation was highlighted at a hospital concerning the same principal contractor, RDC and paint manufacturer. Insufficient data was available for the hospital so a live student accommodation project was substituted.

4.3 Case Study 2, Student Halls of Residence.

4.3.1 Manufacturer Demonstration.

Being a live site it was possible to try and prevent a recurrence of the previous issues. Once an appropriate paint specification was chosen for approximately 1,000 flush internal doors, the manufacturer was invited to demonstrate the product to one painter from each team working on the site. Eight decorators participated in this hands-on demonstration, appendix C. The manufacturers' demonstrator, who openly admitted he was not a decorator, had issues with the product, notably runs in the water based undercoat and visible scratch marks from the inter-coat de-nib through the top coat. Despite these setbacks some of the decorators were able to adapt their application techniques and get a solid looking undercoat. Subsequent topcoats looked translucent and patchy, most of the doors ended up with three to five topcoats and still did not look like they had more than one. Sustainability issues also arose at two schools related to the opacity and flow of 2012 compliant paint.

4.4 Case Study 3, School Refurbishment and New Extension.

4.4.1 Additional Material, Labour and Road Transport Wastes.

At school A, a solvent-based 2012 compliant product was specified and used, but the finish was rejected on over a hundred doors by the clerk of works because the paint failed to flow. A report by the paint manufacturer to the decorating contractor was submitted and the findings rejected by the clerk of works. After re-visits at each school holiday over several months at an environmental cost of additional material, labour and road transport the report was accepted by the principal contractor and the design team overruling the clerk of works.

Additional road transport could have a significant environmental impact. The average UK construction worker commutes 272 miles per week, UK Construction (2015). Road transport in UK was responsible for 8,500 times more greenhouse gas in 2014 than the entire paint industry, NAEI (2014).

4.5 Case Study 4, New Build Special Needs School.

4.5.1 Poor Opacity of 2012 Compliant Paint.

At school B, the strong trim colours which were specified required additional coats for opacity. The decorating contractor insisted that the paint manufacturer was involved in product specification. Subsequently the designer and client accepted that the opacity of the colours and product specified, required additional coats. Additional coats have an adverse impact on the environment, mostly through transporting extra resource.

Chapter 5, Synopsis of Interviews and Discussions.

5.1 Scope of Chapter.

A synopsis of the interviews and discussion around the questions raised through literature review, UD questionnaire and the case studies. The questions were primarily directed at paint manufacturers with some input from designers, clients and principal contractors.

5.2 What was the driver for switching from solvent-based to water-based paint for trim?

AkzoNobel said the first water based gloss products were industry/manufacturer driven and there was very little interest from either consumers and certainly not decorators. In the 1980's and 1990's there was a forming long term view that just as wall paints had moved from solvent-based to water-based, so solvent-based paints for trim would go the same way. There was also a view that solvent-based products would come under legislative pressure as discussions on EU VOC legislation began circa 2000.

Water-based gloss was seen by AkzoNobel as real innovation in the 1980's and 90's if the benefits of solvent based high gloss, flow, toughness etc. could be combined with the quick drying (QD) ease of use of single pack benefits of water-based wall paints and a total solution was seen as a big technical challenge. However, at that time there was no customer demand for QD trim products because the traditional solvent-based trim paint was perfectly satisfactory.

Water-based gloss and trim paint products were seen by manufacturers as a way to improve their environmental foot print (specifically VOC) by moving away from solvent-based products.

Over time environmental concerns, VOC levels, climate change have all played a part in moving the market but AkzoNobel suggest this was very much driven by the manufacturer.

The 2010 EU VOC levels had an impact in moving the market with all the attendant issues with compliant solvent-based paint, yellowing etc. Yellowing is particular to trim paints because external compliant solvent-based paint is exposed to ultra violet (UV) light which bleaches and counteracts the process. AkzoNobel say that this created a degree of demand for water-based gloss from decorators, specifiers and consumers. AkzoNobel have a short list of ideal outcomes through switching from solvent-based to water-based trim paint. These are to maintain/improve product quality and affordability, to help customers see the benefits of making the transition and to be recognised as driving positive industry change.

The reasons AkzoNobel stated for switching include the post VOC reduction yellowing of solvent-based paint, benefits concerning air quality, speed and ease of application, improving lives and demonstrating commercial and sustainability leadership.

Using water wisely at the AkzoNobel Prudhoe plant through rainwater harvesting was estimated to save 1.7 million litres of water for new paint production. That plant is now closed, a similar system has been installed at the new Ashington plant. AkzoNobel believe the state of the art facility at Ashington is the worlds most the most advanced and sustainable mainstream paint factory, AkzoNobel (2017). An AkzoNobel solution to helping customers save water is to install Clear Wash units which recycle the water used to clean brushes. AkzoNobel state that Clear Wash uses about 30 litres of recycled water to clean a paint brush which falls just within 25-150 litres, Siegle (2010). A current AkzoNobel study which is not yet completed, into wastes associated with painting may show the amount of water used for brush washing could be less.

5.3 What are paint manufacturers doing about downstream awareness of changed paint application techniques?

AkzoNobel stated a sustainability commitment, not only to their own portfolio of businesses, but to their suppliers and customers too. Aiming to win and secure the business of sustainability focused customers by anticipating how emerging sustainability concerns will impact future customer and consumer needs.

The Dulux Academy in Slough had just completed its first year of training when RDC toured and had seen about 1,900 candidates on various courses based around four main principles:

- Product application and innovation.
- Sustainability.
- Colour and design.
- Business management.

Dulux have a flexible training ratio of 6 candidates to 1 instructor because they believe quality is more important than commercialism, Dulux (2015). They can also cater for bespoke courses and on the day of RDC visit there were candidates from a well-known building contractor being given a course on snagging paintwork and a large chain of decorators merchants learning about Dulux product specification. Of particular interest to this study are the “sustainable solutions” and “water-borne application” courses which can be booked as $^1/_2$ day stand-alone courses or as part of the City and Guilds programme which is exclusive to Dulux at this time. The downside to the Academy is the lack of Construction Industry Training Board (CITB) recognition.

5.4 Are designers, principal contractors and clients actively made aware of what they are specifying and the limitations?

The designers, principal contractors and clients interviewed were unaware that the solvents removed by manufacturers for compliance with the EU Directive 2004/42/EC are reintroduced as white spirit by decorators to make the changed products user friendly in application. They were surprised to find that manufacturers and trade decorators' merchants still sell unrestricted quantities of White Spirit separate from 2012 compliant paint which still requires thinning to achieve an aesthetic finish. They were all unaware that the paints directive and the implementing regulations do not directly restrict usage of solvent VOC, and that the only offence is to market paints which exceed the allowed VOC content. Manufacturers specify in their National Building Specification (NBS) *"Thinning and intermixing of coatings: Not permitted unless recommended by manufacturer".*

A younger Architect interviewed, suggested that designers need to invest more up front and engage with decorating contractors and paint manufacturers. He believes younger Architects are more likely to think about collaborative engagement with appropriate sub-contractors and manufacturers. The Architectural profession is currently mostly engaged with sustainability through legislation.

On a new site this collaborative early engagement was employed so that a sustainable specification could be determined. The principal contractor was asked to facilitate and attend a meeting between the Architect, AkzoNobel and RDC.

The principal contractor was reluctant to host such a meeting until site work could not possibly proceed without the paint specification. A condition was stressed by the principal contractor that whatever the outcome of the meeting the specification must be cheaper or at worst cost neutral to that which has been priced.

The project had a slightly out-dated Dulux paint specification. AkzoNobel were able to assist with a more appropriate specification at the meeting. The designer was acquainted with a realistic expectation of the finish achievable on site with the specified water-based trim paint. It was explained that QD equals less flow and that these products can only be more sustainable if a realistic aesthetic benchmark is expected. A sample room was decorated for designer approval and accepted. At the time of writing this project is nearing completion and there have been no issues with the quality expectations of the water-based trim paint.

5.5 Should designers accept that paint which offers some protection of the environment may compromise aesthetics?

Protective paint coatings such as anti-corrosion and intumescent paints, are accepted by designers as primarily functional rather than aesthetic. When designers specify sustainable or environmental paints perhaps they should accept that some protection of the environment compromises aesthetics.

Designers were unaware that Water based trim paints have a minimum application temperature which has raised from 5ºc to 8ºc, it is also inherently fast drying. Decorators also endure accelerated paint drying in crashed programmes where they are trying to apply these products at the same time as new heating systems are being commissioned sometimes in temperatures up to 32ºc. Designers agreed that expensive revisits could cause more environmental harm through road use and more product use.

Chapter 6, Discussion of Results.

6.1 Scope of Chapter.

Combining the findings of the literature review, case studies and interview opinions. This discussion will create an evaluation of the sustainability of the use of solvent-based versus water-based trim paint

6.2. Solvent-based Paint and the Environment.

Solvent evaporation is said to contribute to the formation of ground-level ozone and smog which can contribute to global warming. It has been identified that the solvent constituent of solvent-based trim paint has the most impact on sustainability. Traditional solvent-based trim paint had some of the solvent removed in order to comply with the VOC in paints directive. Compliant solvent-based trim paint does not flow in quite the same way as the traditional paint it replaced.

An unintended consequence of the VOC legislation is a shifted environmental impact in solvent-based trim paint downstream. Manufacturers state that thinning and intermixing of coatings is not permitted unless they recommend it. However, to make the changed solvent-based paint user friendly in application, decorators are thinning compliant solvent-based trim paints with pure VOC white spirit. The designers, principal contractors and clients interviewed were unaware of this practice. They were surprised to find that manufacturers and trade decorators' merchants still sell unrestricted quantities of white spirit separate from 2012 compliant solvent-based trim paint. They were also unaware that the paints directive and the implementing regulations do not directly restrict usage of solvent VOC, or that the only offence is to market paints which exceed the allowed VOC content. Thinning aids flow but can also decrease opacity, the resulting re-visits are environmentally detrimental.

6.3 Solvent-based Paint Economics.

Solvent-based gloss paints are glossier and more resistant to wear and tear than lower VOC acrylic gloss paints. Traditional paint based on alkyd resin was preferred by many decorators because it had more open time and was easier to work with. Re-visits by decorating contractors, identified in UD, due to misguided expectations bring into question the environmental and economic validity of reducing VOC in paint for buildings. Furthermore, any health benefit from VOC reductions would be negated by the addition of white spirit to compliant solvent-based trim paint by decorators.

The UD theatre case study trim paint was specified in order to achieve BREEAM Excellent, AkzoNobel stated that all of their paint for buildings, including solvent-based, meet the BREEAM criterion. BREEAM is assessed during the construction phase and, at present, makes no allowance for building use or end of life. Once the defects period was concluded the theatre facilities management team repainted the doors with solvent-based products.

Compliant solvent-based trim paints have an inherent yellowing problem which is particular to trim because external paint is exposed to UV. AkzoNobel say that yellowing of solvent-based trim created the demand for water-based products.

6.4 Water-based Paint and the Environment.

Water-based trim paint has little or no solvent content which is a positive sustainability attribute for the manufacturer. Decorators view the sustainability of these trim paints differently because they flow out even less than compliant solvent-based trim paints. Decorators can often be faced with re-work due to the misguided expectations of other stakeholders. Just as with solvent-based re-visits are detrimental to the environment.

Fresh water is a renewable resource which is relatively abundant in the UK. Obtaining water is simple, storing it is more difficult. Rainwater harvesting is employed at the new Ashington plant to ease the volume of mains water used to manufacture AkzoNobel paints. The amount of water required to keep water-based trim paint in suspension and to inhibit the speed of drying can lead to poor opacity especially in strong colours. Water-based paint brushes are washed regularly under a tap by decorators. The formulation of the water-based trim paint for UD theatre case study, clogged the synthetic bristles at the ferrule during application. Decorators had to wash their brushes during, as well as at the end of their shifts. The run-off from brush washing using tap water in a basin could potentially contaminate sewerage ecosystems.

6.5 Water-based Paint Economics.

Designers were unaware that water-based trim paints have a minimum application temperature which has raised from 5ºc to 8ºc. There is an environmental impact associated with temporary heating on site over the winter months. Water-based trim paint is also inherently fast drying. Designers Agreed that expensive revisits due to lack of flow could cause more environmental harm through additional road use and more product use.

6.6 Manufacturer Demonstration.

Decorators need to be made aware of the limitations these products have and be shown how to adjust their techniques accordingly. At the UD student halls case study site the manufacturer was invited to demonstrate the product to eight decorators. Despite application setbacks, some of the decorators were able to adapt their application techniques and get a solid looking undercoat. Subsequent topcoats looked translucent and patchy, most of the doors ended up with three to five top-coats and still did not look like they had more than one.

6.7 Additional Material, Labour and Road Transport Wastes.

All additions have an associated cost for one or another of the stakeholders. Whether this is for materials, labour or plant there is a common theme for the construction industry; transport. Sooner or later all of the resources have to get to site. Additional road transport could be having a significant environmental impact. The average UK construction worker commutes 272 miles per week. Plant and materials have to be delivered and plant and wastes collected. Road transport in UK was responsible for 8,500 times more greenhouse gas in 2014 than the entire UK paint industry.

Paint aesthetics can have a significant impact on the sustainability of the entire life cycle. Paint manufacturers EPDs rely on generic LCI data which is unlikely to account for the wastes of resources post sale as no evidence of end user consultation could be found in the literature regarding the changes in paint due to VOC legislation. Downstream sustainability impacts from transport of paint, labour resources, plant associated with paint application and the process of application itself are not measured as part of the manufacturers carbon footprint. These are considered to be decorator emissions. Disposals, however, are considered in the EPD. AkzoNobel measure their environmental impact using carbon across the value chain (Cradle to Grave). 73% of their impact is upstream, 5% in operations and 22% downstream (made up of VOC 9% and end of life 13%).

6.8 Sustainable Partnerships.

Mash (2015) identified that 40% of the environmental footprint of paint is downstream from the factory gate. Paint manufacturers must understand the downstream requirements of their paints and application methods, helping downstream industries address their own sustainability.

There were recommendations of the creation of partnerships up and downstream from the factory gate in the literature. RDC are Dulux contact partners and AkzoNobel have been extremely supportive of this study.

6.9 What are paint manufacturers doing about downstream awareness of changed paint application techniques?

The sustainable solutions and water-borne application courses at the Dulux academy in Slough are a step in the right direction. There are other AkzoNobel training facilities, one at the new Ashington plant and several colleges providing regional cover across the UK. It is not just decorators that need to be made aware of the changes to paint. The bespoke courses such as snagging paintwork and Dulux product specification demonstrate an emerging awareness of other stakeholder involvement. This is a good start but, with a training ratio of 1 trainer for 6 candidates, 129,000 professional decorators are going to take a while. Add to this the other stakeholders and the variations of technique for each paint manufacturer and the scale of the problem can be seen.

6.10 Was the Industry Right to Switch from Solvent to Water-based Paint?

Paint manufacturers appear to have been forced by legislation to reformulate paint with reduced VOC. AkzoNobel maintain the view that water-based trim paint was industry lead. BREEAM 2018 has now been implemented with reductions which are more rigorous than the legislative limits for 2012 compliant trim paints.

Decorators adding unregulated pure VOC white spirit to compliant solvent-based trim paint, demonstrates the failure of the VOC in paint legislation where the use of solvent-based trim paint is concerned. The use of water-based trim paint eliminates the addition of VOC by decorators.

Little is said of usability of compliant paint in the literature although a move towards life cycle thinking could be positive. There still appears to be an ignorance of paint sustainability post sale. The reviewed literature demonstrates that the argument is not as simple as water is good and solvent is bad. VOC was extremely good for paint, maybe, not so good for the environment and certainly not renewable. The UD case studies and questionnaire highlight issues with both solvent-based and water-based compliant trim paints. Both solvent-based and water-based trim paints have had VOC reductions imposed on them through legislation.

The interviews revealed a desire for sustainable solutions by designers and clients. 80% of UD respondents agreed that there needs to be an increased awareness of the whole paint process from extraction of raw materials to disposal.

Chapter 7, Conclusions and Recommendations

7.1 Scope of Chapter.

To conclude by linking back to the objectives and the studies aim identified in chapter 1. Recommendations to the industry will be discussed followed by the limitations of the study. Future research potential will also be identified.

7.2 Sustainability Evaluation of the Use of Solvent-based vs Water-based Trim Paint.

Before linking back to the objectives, let us remember the title, above. Sustainability is widely agreed to sit at the centre of the three spheres or triple bottom line, which is environmental, economic and social. The following conclusions and recommendations are depicted and explained in conjunction with the diagram 'The three spheres of paint sustainability, figure 7.1.

The Three Spheres of Paint Sustainability

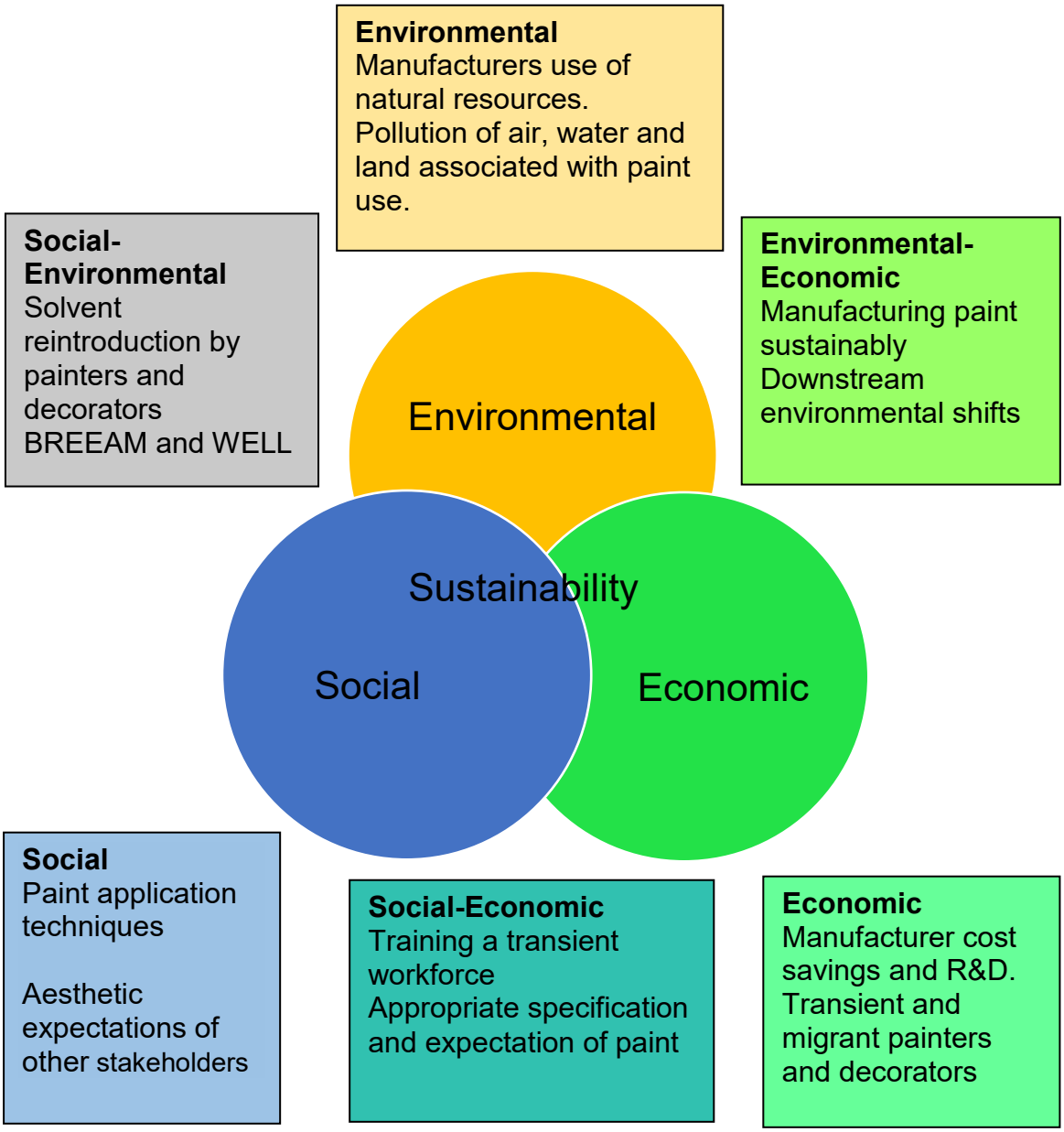


Figure 7.1, The Three Spheres of Paint Sustainability, Adapted from Vanderbilt University, (2016).

7.2 Objective 1, To identify and explain the constituents of solvent-based and water-based trim paints that impact most on their sustainability.

It has been identified that it is the solvent constituent of solvent-based trim paints that most impact on their sustainability. The lack of flow in compliant solvent-based trim paint and the addition of white spirit to aid flow demonstrates a failure of the VOC legislation where solvent-based paint is concerned. The reduction of solvent VOC is an environmental-economic positive for manufacturers, but it can be seen impacting on end users social-environmental credentials through the downstream shifts. Whilst exterior solvent-based paints have not been part of this study, it is possible that these are being treated the same by decorators. Water-based trim paints are inherently fast drying because the solvent which has been substituted with water, evaporates quickly and flows out even less than compliant solvent-based paint. This has a social impact associated with aesthetics and expectations.

7.3 Objective 2, To identify the current information concerning sustainability of the whole life cycle of solvent-based and water-based trim paint.

Paint aesthetics can have a significant impact on the sustainability of the entire life cycle. There still appears to be an ignorance of paint sustainability post sale. Downstream from the factory gate involves sustainability impacts from transport of paint, labour resources, the plant associated with paint application, the process of application itself and disposals. Manufacturers such as AkzoNobel measure the VOC release and disposals as their downstream environmental impacts.
The rest of the carbon footprint is considered by manufacturers to be that of the decorator. This means that VOC reduction is a positive move for manufacture in the whole life cycle. This can be seen in the environmental box of figure 7.1. The unintended consequence of a downstream shift of sustainability impacts has not been measured because manufacturers consider these as end user statistics.

7.4 Objective 3, To identify and explain the issues concerning the use of these trim paints that impact on their sustainability.

Resistance to change by some stakeholders and this unwillingness to accept that these changed paints are aesthetically different is an issue that impacts on trim paint sustainability. The client has an expectation of a tactile and aesthetically pleasing surface. When designers specify sustainable or environmental paints perhaps they should accept that some protection of the environment may compromise aesthetics. This is not a singular stakeholder issue. Paint manufacturers play an important role in educating stakeholders about the changes such as aesthetics and application techniques. Decorators also need to be less resistant to change and embrace the advice.

7.5 Objective 4, To evaluate the sustainability of the use of solvent-based and water-based trim paints.

The use of both solvent-based and water-based trim paints have been evaluated. Both had VOC reductions imposed on them through legislation. Decorators adding unregulated pure VOC white spirit to compliant paint is probably not good for the environment, certainly not for their environmental credentials. The adoption of water-based trim paint eliminates the addition of VOC by decorators. BREEAM 2018 has been implemented which means it is likely that there will be no solvent-based option on projects looking for accreditation. Water-based trim paints are not ideal, but, if all stakeholders 'buy in' and accept a little bit of tolerance to the changes they could, as per CDM (2015), be made to 'perform satisfactorily'.

7.6 Recommendations.

Making the new, more sustainably produced, water-based trim paints that we now have, sustainable in use, requires communication and education, social sphere, 7.1. There needs to be a buy-in from all stakeholders.

AkzoNobel are beginning to engage with decorators and other downstream stakeholders about sustainability. Resource wastes are costly in all three spheres of sustainability. A continued open communication between all of the above for individual projects including items such as programme and site conditions should be explored.

Paint manufacturers are changing paint formulations in order to keep ahead of regulation and for their own sustainability. There are an estimated 129,000 professional decorators in UK. These decorators need to be informed when manufacturers change application techniques. The on-site demonstrations conducted in the course of this study seem like a good starting point. Re-training decorators about sustainability and application techniques will help improve quality of finish. The finish achievable with water-based trim paint and site conditions is not the same as traditional solvent-based paint. Manufacturers should be making this clearer to downstream stakeholders as shown in the social-economic overlap. If clients, designers, principal contractors and surveyors were presented with a realistic expectation, decorators would have a better chance of getting it right first time. This would save needless wastes of resources in social, economic and environmental spheres of sustainability. Then these new water-based trim paints could be truly sustainable from cradle to grave.

7.4 Limitations.

The research sample was limited by the number of responses. Despite the small sets, a rich set of responses were obtained. Due to the arbitrary distribution processes these are deemed a representative response from the industry.

The literature available in relation to this study was lacking in decorators' perspective, possibly due to the group naturally leaning towards artistic rather than academic traits.

Geographically the primary data collection was limited to locations within the southern region of the UK.

7.5 Further Research Potential.

7.5.1 Carcinogenicity of Solvent Paint VOC.

It appears likely that the process of painting exposes decorators to an increased possibility of contracting cancers. It is unclear whether carcinogenicity is from the VOC in solvent based paint or from other construction materials, which entices further research.

7.5.2 Chemical in Water Based Paint.

Reactive paint manufacturing processes appear to encourage loading of some products with biocides, preservatives and embodying greater volumes of carbon as paint manufacturers struggle to stay ahead of legislative interference. What health hazards may await decorators from the accumulations of these chemicals in future years?

7.5.3 Chemical in Waste Water.

The chemicals in water based paint are being washed down drains every time a brush or roller is washed. Will this have an effect on sewerage treatment as demand for these paints increases?

7.5.4 Water Use.

The cleaning of brushes and rollers from water based paint use appears to have been overlooked. This study touched on the amount of water wasted through professional decorators' brush washing. This also concerns DIY paints which have deliberately not been discussed. Britain now has about 30 million DIY painters and the coatings industry sells about 165 million litres of water based paint a year for this market alone.

7.5.5 Investing in a Transient/migrant Workforce.

For a large proportion of decorators English is not their first language. These transient decorators are rarely directly employed. Training this element of decorators could be uneconomical for companies such as RDC. Ways of targeting these decorators need to be explored. Decorating companies employing migrant workers are now even less likely to train these individuals given the European political uncertainties.

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Appendix A Analysis of Questionnaire Results.

5.1 Scope of Chapter.

To analyse questionnaire results using appropriate chart or graphical representation to accentuate similarities and differences between groups. The quantitative raw data obtained via questionnaire responses can be found in appendix C.

5.2 Questionnaire Title.

The Sustainability of the Reductions of VOC in Decorative Paint Coatings for Buildings in the UK.

5.2.1 Question A Responses.

Which of the following best describes your role in the painting industry?

The number of responses returned are shown in table 5.1, the total number of responses is approximately 12% of the 300+ petitioned. However, due to the arbitrary distribution processes, described in methodology section 4.5.3, it is deemed a representative response for the industry.

Which of the following best describes your role in the painting industry?	Responses
Paint Manufacturer or Supplier	6
Painter and Decorator	11
Architect or Designer	5
Surveyor, Client or Client Representative	4
Principal Contractor or other Construction Professional	9
Total number of responses	35

Table 5.1, The Number of Questionnaire Responses Returned.

5.3 Question B.

To assess the sustainable advantages of reducing VOC in paint for buildings.

5.3.1 Statement B1 Rationale.

The primary object of paint coating is preservation of building materials.

Fulcher *et al*, (1983), Butterfield (2011) and Chudley[A] *et al*, (2012), agree that preservation is the primary reason for painting. Statement B1, aims to establish whether respondents know why paint is used. The literature review identified the argument that biodegradability of coatings may compromise the ability of future generations to recycle construction materials.

5.3.1.1 Statement B1 Responses.

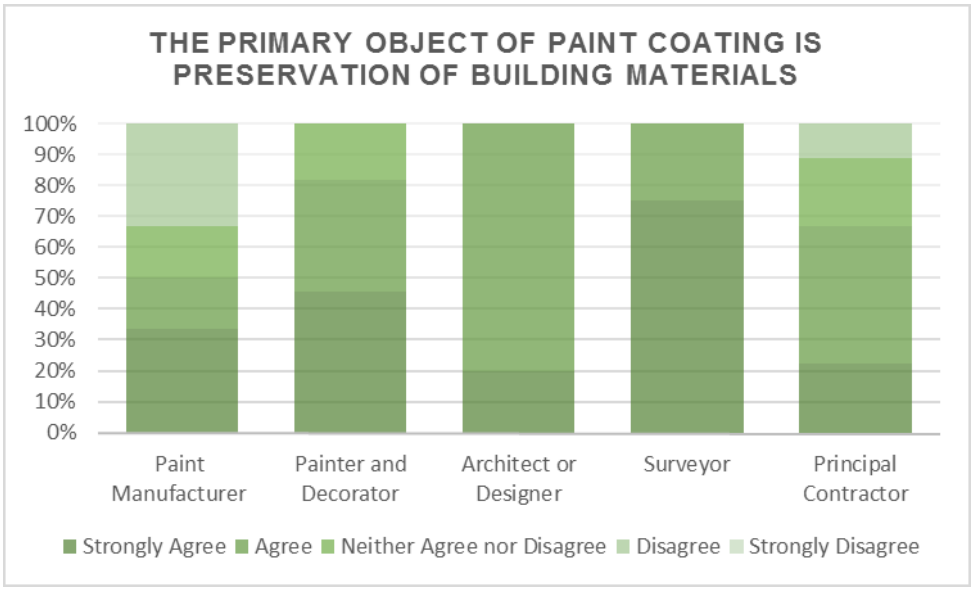

Figure 5.1, Statement B1 Response Graph.

77% of respondents agreed with the literature that paint performance is about protecting and preserving construction materials, figure 5.1.

5.3.2 Statement B2 Rationale.

Bio-degradability of paint is important for sustainability.

Environmentalists are concerned that petrochemical-based paints do not degrade, McWilliam, (2004). Statement B2 was included to assess whether respondents have considered the impracticalities of preservatives that readily degrade.

5.3.2.1 Statement B2 Responses.

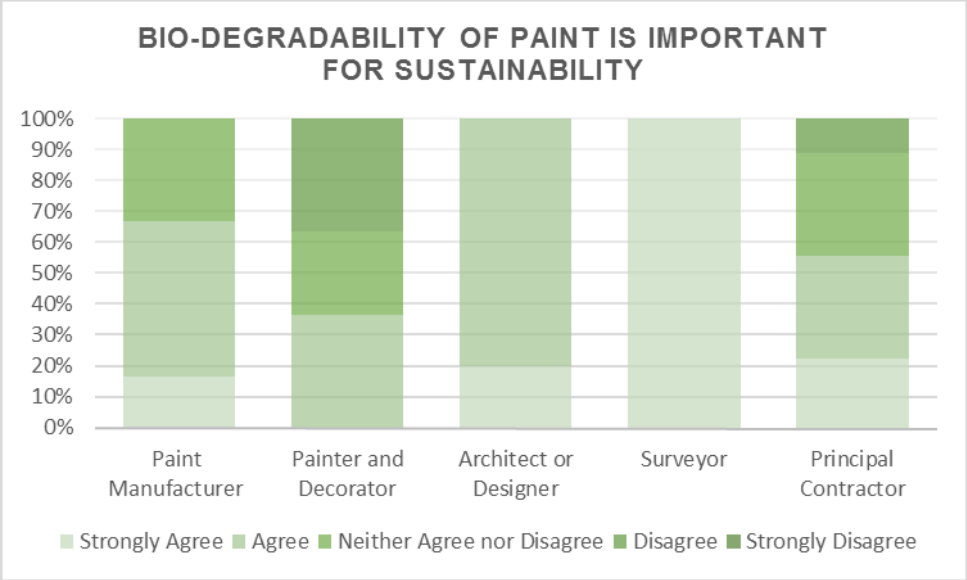

Figure 5.2, Statement B2 Response Graph.

63% of respondents agreed that bio-degradability of paint is important for sustainability, figure 5.2, this could be an ideological response especially 100% of surveyors.

5.3.3 Statement B3 Rationale.

VOC compliant solvent based paint still requires White Spirit for thinning.

The rationale for requesting opinions on this statement is to establish where the White Spirit may be utilised given the tacit observations within the case studies. This will become more apparent when aligned with environmental, statement C3, which evaluates opinions regarding the cleaning of solvent based paint brushes.

5.3.3.1 Statement B3 Responses.

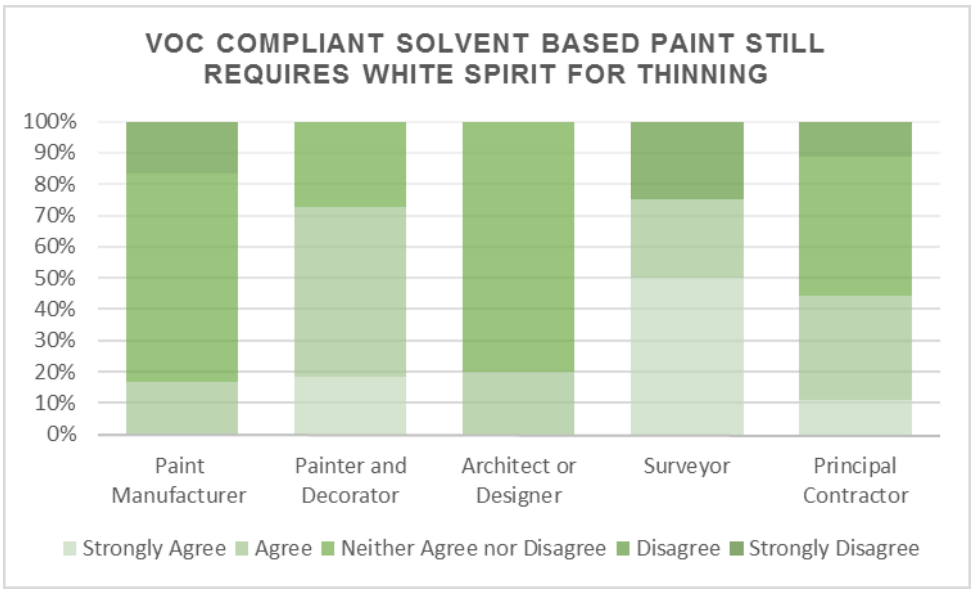

Figure 5.3, Statement B3 Response Graph.

The tacit observations within the case studies of painters adding White Spirit to compliant paint appear to be reinforced by painters' responses, figure 5.3. This could demonstrate that even if solvent VOC is contributory to indoor air quality, there is little health benefit for VOC reductions in solvent based paint.

5.3.4 Statement B4 Rationale.

Water based trim paint is more sustainable than solvent based.

No credible researched sources stated that water based paint is more sustainable than solvent based, merely that it contains less VOC. The literature review also raised the question of harmful chemicals in water based trim paint.

5.3.4.1 Statement B4 Responses.

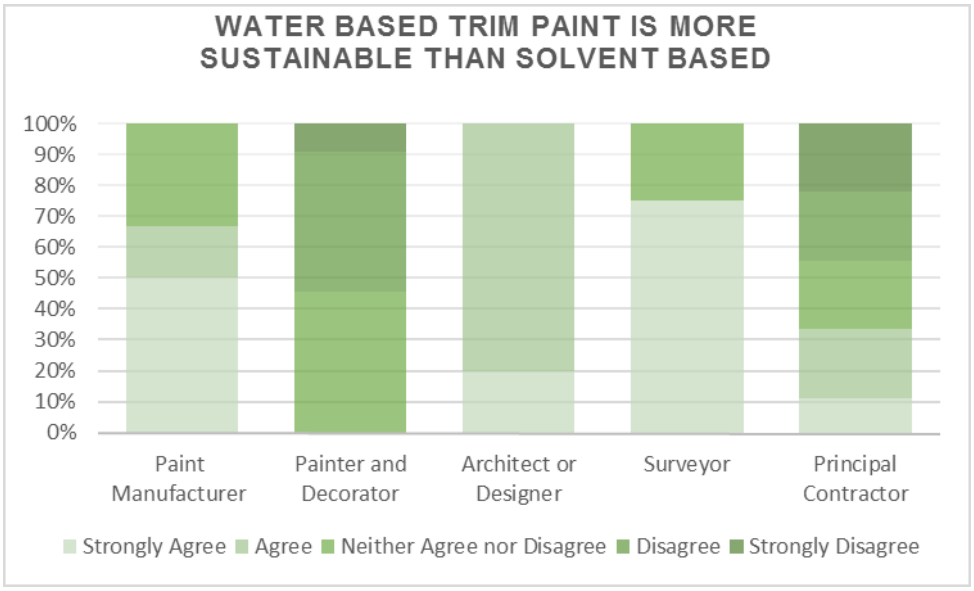

Figure 5.4, Statement B4 Response Graph.

42% of manufacturers, Architects and surveyors agreed and none disagreed that water based trim paint is more sustainable than solvent based, figure 5.4. 29% of painters and contractors disagreed, painters accounted for 60% of those who disagreed none of the painters agreed. Principal contractors had no majority opinion.

5.4 Question C.

Formed of three statements to evaluate the environmental credentials of compliant paint for buildings.

5.4.1 Statement C1 Rationale.

There needs to be an increased awareness of the whole paint process from extraction of raw materials to disposal.

This extract from Prieto (2010), epitomises the purpose of this study, although at present it appears European ideology. The purpose of inclusion is to provide an ideological bench mark, should one be required.

5.4.1.1 Statement C1 Responses.

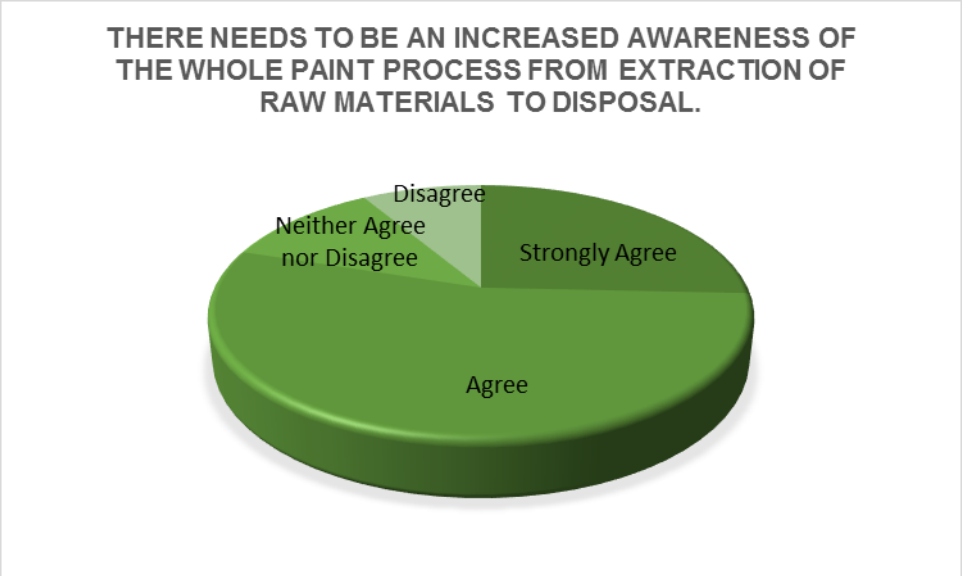

Figure 5.5, Statement C1 Response Pie Chart.

80% of respondents agreed that there needs to be an increased awareness of the whole paint process from extraction of raw materials to disposal, figure 5.5.

5.4.2 Statement C2 Rationale.

Water based paint brushes and rollers are frequently washed under a tap.

Disposal of paint is not a singular action, brush washing is an overlooked disposal. There should be an awareness of how many times in a buildings construction and use water based brushes and rollers are washed. Turner (2015), is concerned about harmful chemicals in water based paints which are washed into water treatment systems wasting millions of litres of clean drinking water.

5.4.2.1 Statement C2 Responses.

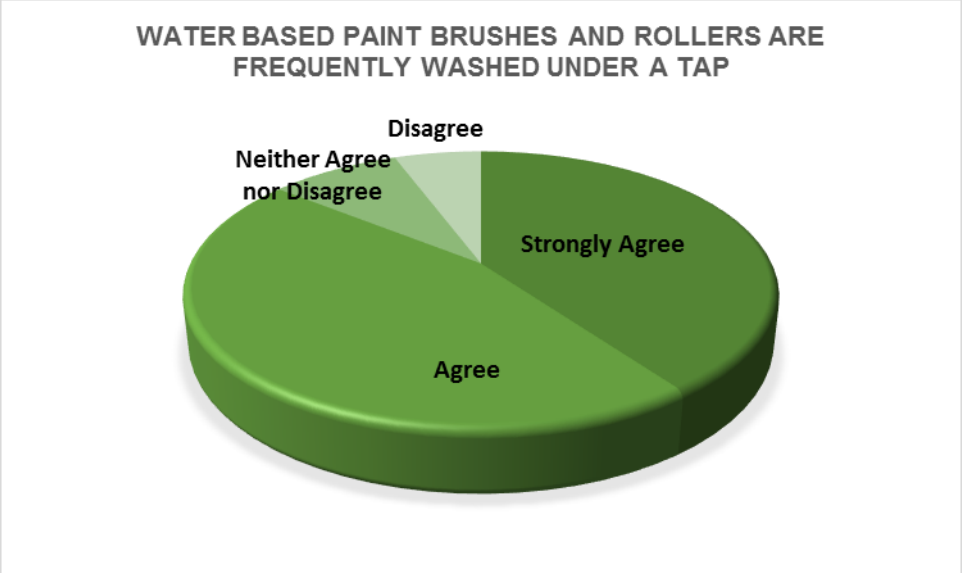

Figure 5.6, Statement C2 Response Pie Chart.

86% of respondents agreed that water based paint brushes and rollers are frequently washed under a tap, figure 5.6.

5.4.3 Statement C3 Rationale.

Solvent based brushes are kept in a brush mate or small pot of water and are infrequently washed.

There should be an awareness of how painters keep their solvent based brushes, figure 6.1. Brush Mate storage, appendix K, or water storage, prevent oxidisation of solvent paints and significantly reduces the need for cleaning. Change of colour shades being the main reason for cleaning means that brushes in white, black, clear or any colour used regularly usually wear out rather than ever be cleaned, figure 6.2. Statement B3 may better explain where the solvent, White Spirit, is being utilised.

5.4.3.1 Statement C3 Responses.

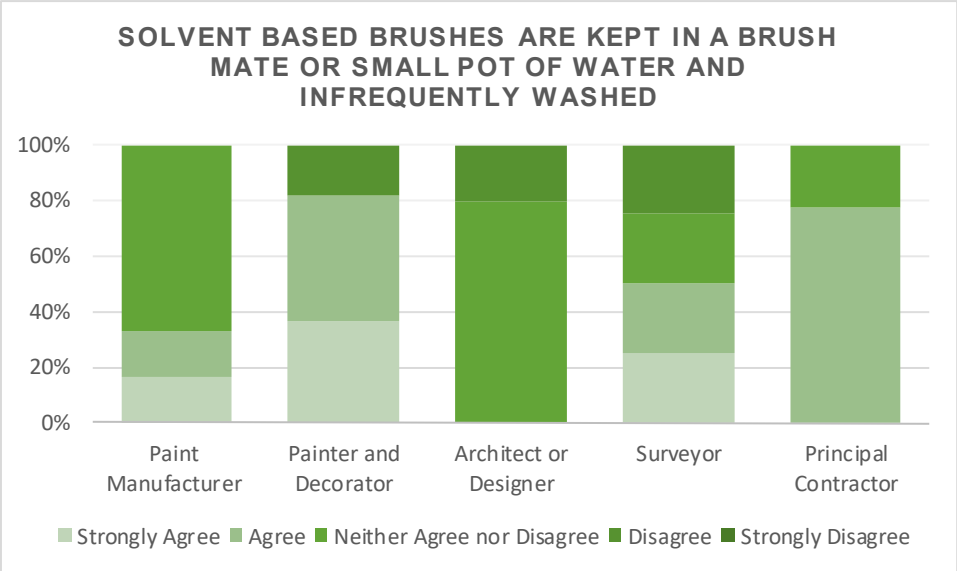

Figure 5.7, Statement C3 Response Graph.

Painters' responses to C3, figure 5.7, adds further weight to the argument that the majority of White Spirit sold to the trade could be thinning paint rather than cleaning brushes, figure 5.3. 57% of all groups except Architects, agreed that solvent based brushes are kept in a brush mate or small pot of water and are infrequently washed.

5.5 Question D.

To examine the health benefits of VOC compliant paint.

5.5.1 Statement D1 Rationale.

The industry was right to switch from solvent based to water based paint for trim.

Mash (2014) posed the question; was the industry right? As addressed in 4.4.4.2, accentuating the positive enables knowledgeable disagreement to be more accurately assessed.

5.5.1.1 Statement D1 Responses.

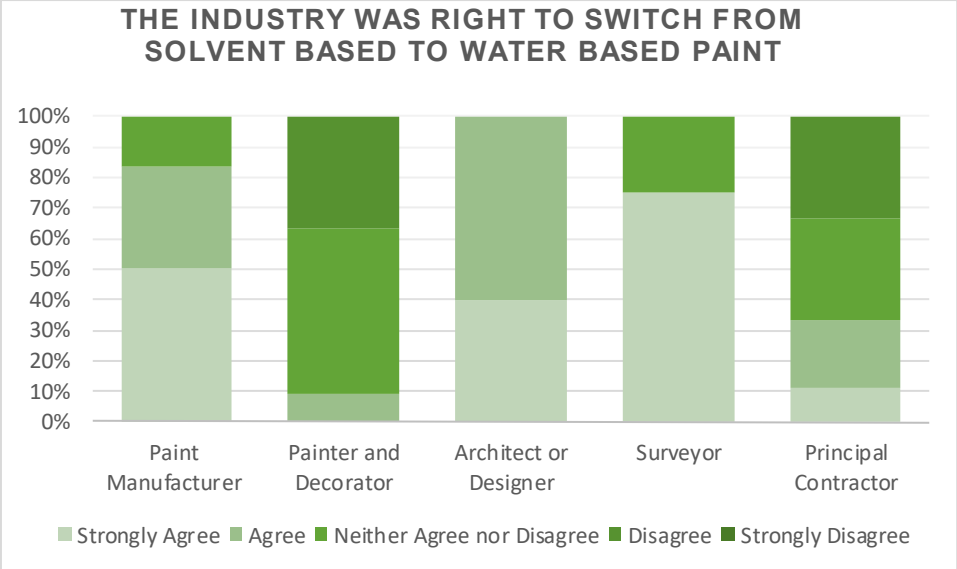

Figure 5.8, Statement D1 Response Graph.

49% of manufacturers, Architects and surveyors agreed that the industry was right to switch from solvent based to water based paint for trim, figure 5.8. 20% of painters and contractors disagreed and 31% of all groups except Architects did not know.

5.5.2 Statement D2 Rationale.

VOC reductions in paint have improved indoor air quality.

The literature review indicated that the VOC from painting dissipated within a short time and that it was possibly the storage of painting materials that is the cause of indoor air quality issues, Coward *et al*, (2001) and Turner, (2015). Sealing timber composites which emit the most common indoor VOC, formaldehyde, by painting them is identified as an improvement to indoor air quality.

5.5.2.1 Statement D2 Responses.

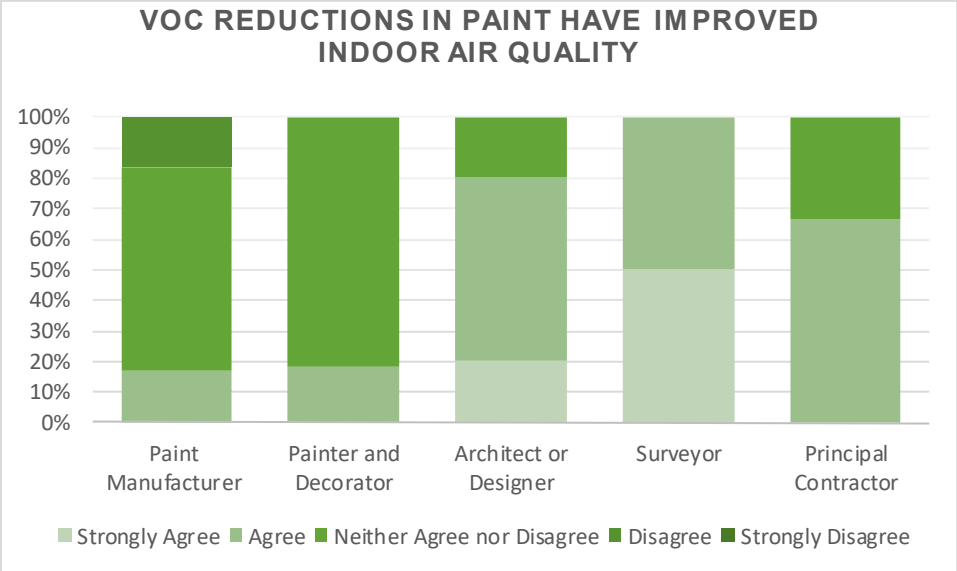

Figure 5.9, Statement D2 Response Graph.

97% were equally divided between agreeing and not knowing whether VOC reductions in paint have improved indoor air quality, figure 5.9. 100% of surveyors, 80% of Architects and 67% of principal contractors agreed. 67% of manufacturers and 81% of painters did not know whether indoor air quality has improved.

5.5.3 Statement D3 Rationale.

VOC reductions in paint have reduced occupational health hazards for painters and decorators.

VOC is said to be responsible for respiratory ailments amongst decorators. Tacit observations of painters adding unregulated volumes of White Spirit to compliant paint could demonstrate there is little health benefit in VOC reduction. Responses to statements B3 and C3 are designed to add weight to the tacit observations.

5.5.3.1 Statement D3 Responses.

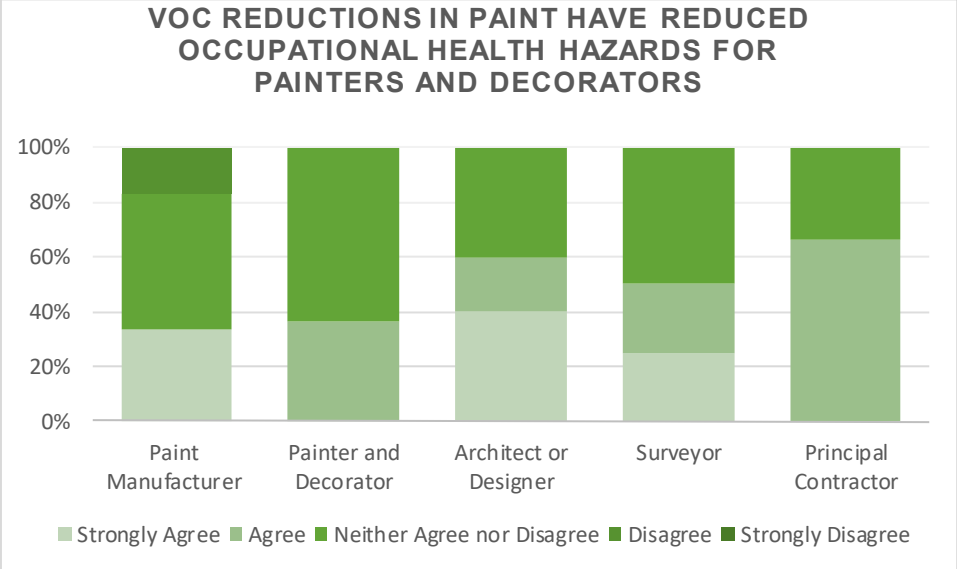

Figure 5.10, Statement D3 Response Graph.

97% were equally divided between agreeing and not knowing whether VOC reductions in paint have reduced occupational health hazards for painters, figure 5.10. 50% of surveyors agreed with the statement as did 60% of Architects, 64% of painters did not know. Most notably paint manufacturers are divided in their opinions which is disconcerting as paint manufacturers are responsible for the production of the MSDS upon which construction professionals base their specification and RAMS.

5.6 Question E.

To compare the quality of finish of compliant paint for buildings with client and designers' expectations.

5.6.1 Statement E1 Rationale.

Water based trim paint performs like solvent based paint.

This statement is intended to examine performance of application and quality. The case studies identified paint coatings which failed to cure and the literature, BCF[B] (2015), identified durability issues with Water based alternatives for trim.

5.6.1.1 Statement E1 Responses.

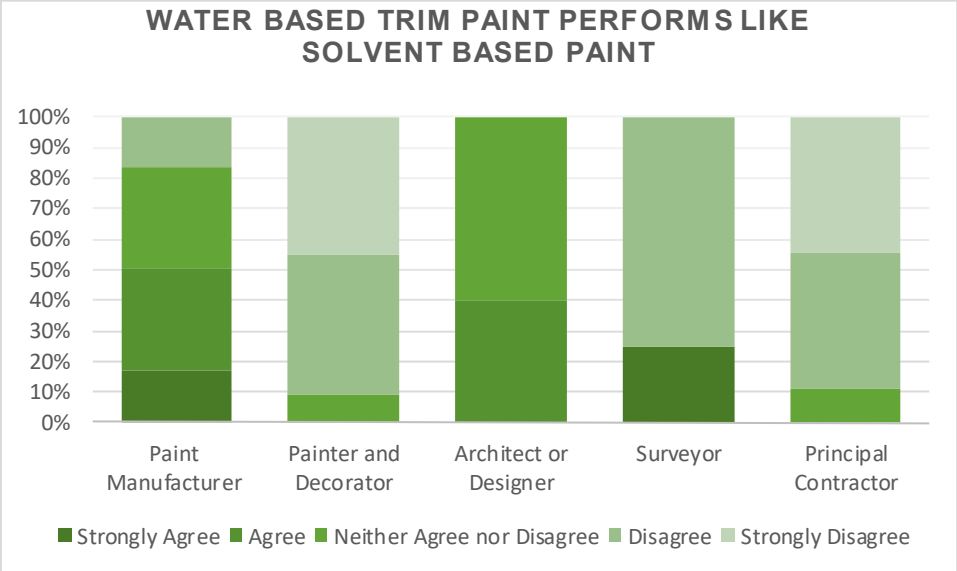

Figure 5.11, Statement E1 Response Graph.

63% of painters, surveyors and contractors disagreed that water based trim paint performs like solvent based paint, figure 5.11. 91% of painters disagreed and no painters agreed. The 17% who agreed comprised primarily of manufacturers and Architects, the remainder did not know.

5.6.2 Statement E2.

Orange peel, brush marks, flashing etc. no longer occur in 2012 compliant paint.

This statement is intended to examine quality of finish of 2012 compliant paint in terms of flow, Akzo Nobel (2015), admit solvent based paint is superior to water based in this respect.

5.6.2.1 Statement E2 Responses.

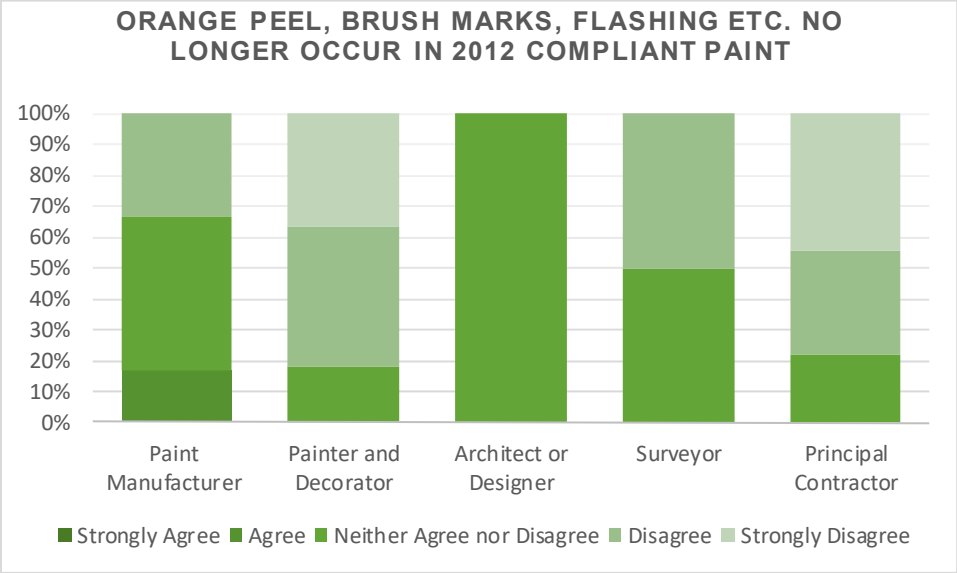

Figure 5.12, Statement E2 Response Graph.

82% of painters and 78% of contractors disagree that orange peel, brush marks, flashing etc. no longer occur in 2012 compliant paint, figure 5.12. Architects did not know, 50% of surveyors disagreed, and the remainder did not know either. 50% of manufacturers do not know, 17% agreed and the remainder of manufacturers disagreed.

5.6.3 Statement E3.

Designers and specifiers are aware of the limitations 2012 compliant paints have and adjust their specification accordingly.

Identified in economic evaluation 2.7.3, this statement is included to establish whether designers and specifiers are aware of the limitations and whether other respondents believe this awareness.

5.6.3.1 Statement E3 Responses.

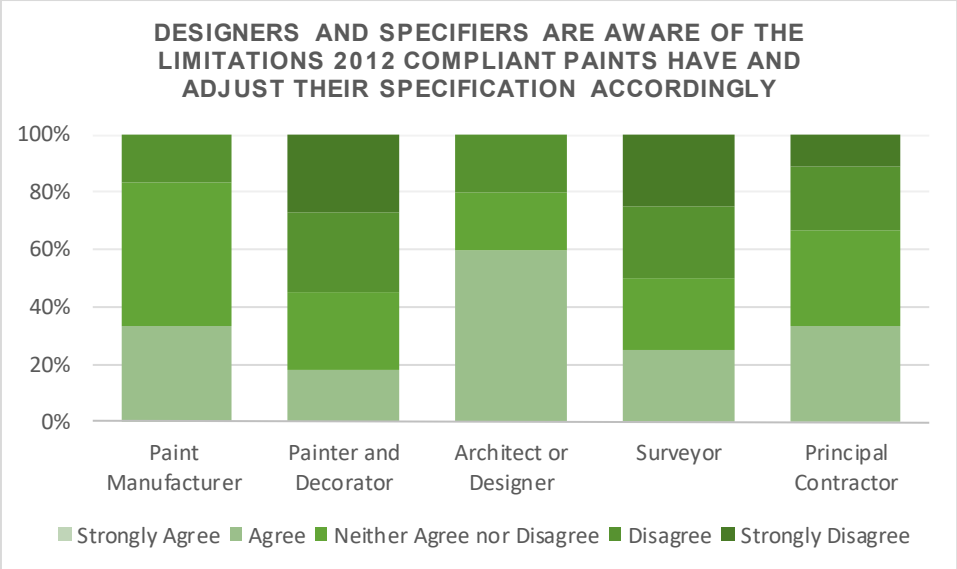

Figure 5.13, Statement E3 Response Graph.

No group could unanimously decide whether designers and specifiers are aware of the limitations 2012 compliant paints have and adjust their specifications accordingly, figure 5.13. None strongly agreed but 13% of painters, surveyors and contractors strongly disagreed.

5.7 Question F.

To determine the distribution of the economic burden of reducing VOC in paint for buildings.

5.7.1 Statement F1 Rationale.

Water based trim paint looks the same as solvent based paint.

In the case studies both painters and the paint manufacturers agreed this statement is not entirely true and the designers were forced to admit the same. The inclusion of this statement is to determine whether this is the case in the wider context.

5.7.1.1 Statement F1 Responses.

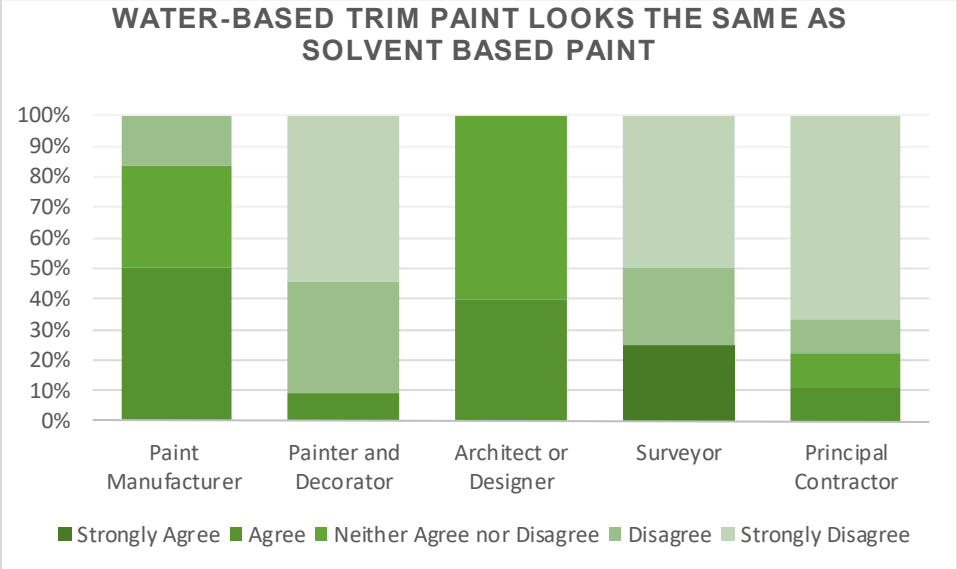

Figure 5.14, Statement F1 Response Graph.

91% of painters, 78% of principal contractors and 75% of surveyors disagree that water based trim paint looks the same as solvent based paint, figure 5.14. 83% of manufacturers and 100% of Architects either agree or do not know.

5.7.2 Statement F2 Rationale.

Principal Contractors and Clients are Aware of the Limitations of VOC Compliant Paints and Adjust Their Expectations Accordingly.

The case studies identified many unpaid re visits by the painting contractor involving thousands of vehicle miles mostly at what should be their most productive times, (school holidays for example). This statement aims to highlight unseen expense which often cannot be passed on to the client.

5.7.2.1 Statement F2 Responses.

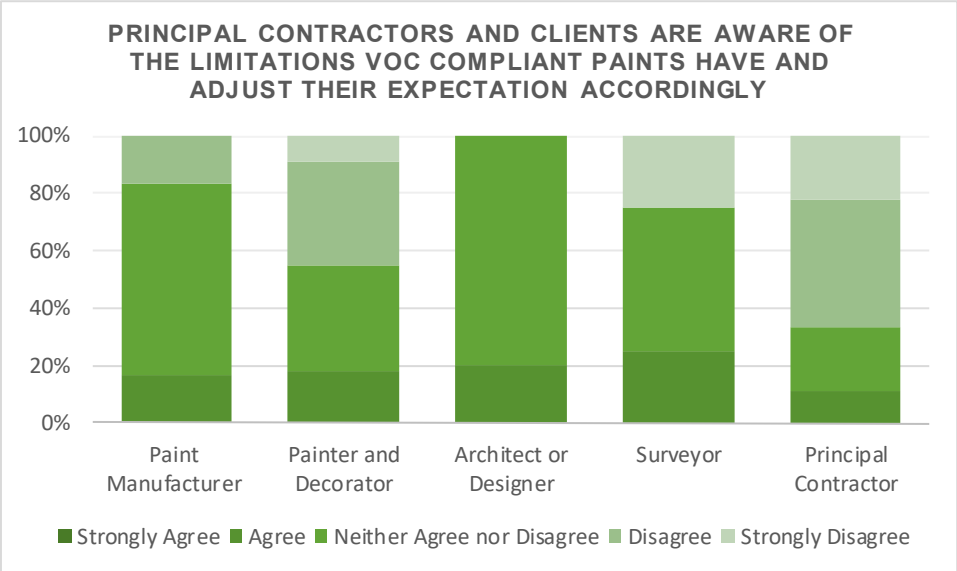

Figure 5.15, Statement F2 Response Graph.

67% of principal contractors disagreed that contractors and clients are aware of the limitations of VOC compliant paints and adjust their expectation accordingly, figure 5.15. 45% of painters also disagreed, a minority in every group except Architects agreed, but most respondents did not know.

5.7.3 *Statement F3 Rationale.*

Snags and re-visits are greatly reduced since the introduction of reduced VOC paints.

Expensive re-visits were not reduced in the case studies. This statement aims to highlight unseen expense which often cannot be passed back to the paint manufacturer.

5.7.3.1 Statement F3 Responses.

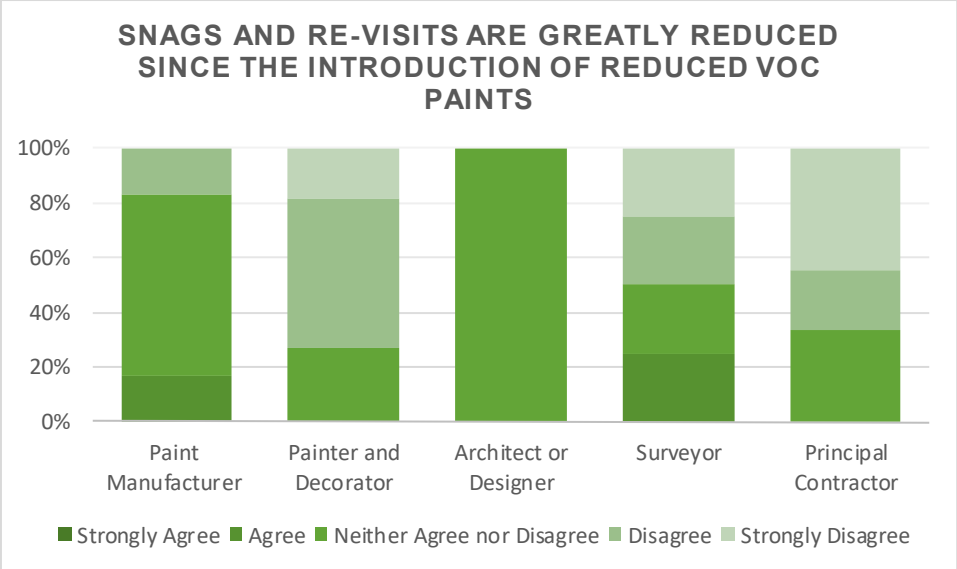

Figure 5.16, Statement F3 Response Graph.

73% of painters, 67% of contractors and 50% of surveyors disagree that snags and re-visits are greatly reduced since the introduction of reduced VOC paints, figure 5.16. Architects and paint manufacturers did not know.

Appendix B. Case Studies Overview.

3.1 Scope of Chapter.

A brief overview, maintaining contractor confidentiality, of four case study sites with paint sustainability issues. Three sites have been completed, one is live at the time of writing. All of the case studies are for the same painting contractor, a log of the sustainability issues, queries and resolutions, (if any), is available, appendix A.

3.2 Synopsis of Case Studies.

3.2.1 Shifting Liability.

At a theatre the water based paint specified for the internal doors and frames had not fully cured eight weeks after application. The paint manufacturer was asked to assess why, and produced a report for the decorating contractor. The report, appendix A, identified two possible reasons that the paint was not fully curing.

3.2.2 Increased Water Use.

The formulation of the water based trim paint clogged the synthetic bristles at the ferrule during application making the working volume of the paintbrush decrease during the course of the day. Painters had to wash their brushes during, as well as at the end of their shifts.

3.2.3 BREEAM.

The paint was allegedly specified in order to achieve BREEAM Excellent, at least two manufacturers' state that all of their paint for buildings, including solvent based, meet the BREEAM criterion, appendix F & G. BREEAM is assessed during the

construction phase and makes no allowance for building use or end of life. Once the defects period was concluded the theatre facilities management team repainted the doors with solvent based products.

3.2.4 Sustainability Awards.

The Architect claimed six regional conservation and sustainability awards for the project. The painting contractor was not paid for a large proportion of the investigative work, most notably the additional, non-environmental transport fuel use. In the course of this case study a similar situation was highlighted at a hospital concerning the same principal contractor, painting contractor and paint manufacturer. Insufficient data was available for the hospital so a current student accommodation project has been substituted.

3.2.5 Manufacturer Demonstration.

Being a live site it was possible to try and prevent a recurrence of the previous issues. Once an appropriate paint specification was chosen for approximately 1,000 flush internal doors, the manufacturer was invited to demonstrate the product in the presence of one painter from each team working on the site. Seven painters participated in this hands-on demonstration. The manufacturers' demonstrator, who admitted he was not a painter, had issues with the product, notably runs in the water based undercoat and visible scratch marks from the inter-coat de-nib through the top coat. Despite these setbacks some of the painters were able to adapt their application techniques, appendix H.

3.2.6 Additional Road Miles.

Sustainability issues also arose at two schools related to the opacity and flow of 2012 compliant paint. At school A, a solvent based 2012 compliant product was specified and used, but the finish was rejected on over a hundred doors by the

clerk of works because the paint failed to flow. A report by the paint manufacturer to the painting contractor was submitted and the findings rejected by the clerk of works. After re visits at each school holiday over several months at an environmental cost of additional material and over seven hundred miles travelled per week for the painting contractor the report was accepted by the main contractor and the design team overruling the clerk of works. The painting contractor received no payment for the additional labour, materials or transport.

(272 miles/5 days) x (300,000 x 0.43) = 7,017,600 miles.

The average CO^2 emissions rating is 138 g/km (grams of carbon dioxide per kilometre driven), Carpages (2016).

7,017,600 miles = 11,300,000 km x 138g = 1,559,400,000g

/1,000,000 = 1,559.4 tonnes of emissions per visit per UK painters.

EU Directive 2004/42/EC inception 2004 = 25,000 tonnes of paint application emissions, NAEI (2014), reduced to 13,000 tonnes 2012

25,000t – 13,000t = 12,000t/8 years = 1,500 tonnes reduction per year, 1,500 reductions – 1,559.4 per single re-visit = -59.4 tonnes of emissions per single site re-visit for UK painters.

Figure 3.1, Additional Annual Emissions.

The average construction worker commutes 272 miles per week, UK Construction (2015). Based on this figure and BCF (2015) industry statistics, figure 2.4, it can be demonstrated that a single additional site visit multiplied by the number of UK decorators could cost the environment over 7 million additional road miles, an

addition of almost 60 tonnes of emissions per year, figure 3.1, over the savings created by the VOC in paint legislation.

3.2.7 Poor Opacity of 2012 Compliant Paint.

At school B, after paint manufacturer intervention at the painting contractors insistence, the designer and client accepted that the opacity of the colours and product specified, required additional coats and the additional cost was recoverable by the painting contractor.

Appendix C. Manufacturer Demonstration.

On Site Training, 26/02/16

The painting contractors predicament is a water based paint specification for around 1,000 Leaderflush doors primed with an Ultra Violet, (UV), cured factory applied product which is extremely durable but has a high sheen. Surveys were invited and conducted by manufacturers and a system duly approved by the client. The questionnaire results identified differences of opinion between manufacturers and painters about the usability of 2012 compliant water based paints. The specifier for the manufacturer of the chosen paint system agreed to give on-site training for the application of the new product undercoat and finish. A door was wet rubbed with 180 grit paper, rinsed and damped with a sponge, the sheen and surface temperature were measured. Undercoat was applied ahead of the training to allow 16 hours cure time for full adhesion. The product was applied with a synthetic glosser 4” roller at about 80µm wet film thickness, (WFT), and laid off with a 2” synthetic brush. It was demonstrated that over brushing will result in brush marks in the finish, the brush was loaded prior to laying off which is opposite to solvent based application where the brush is ✓impressive, unfortunately there were some

curtains (runs) in the finish, the specifier admitted that he was not a painter and was nervous about showing painters how to paint.

Before on-site training commenced the specifier had rubbed out the runs and de-

nibbed the door with 180 grit paper. The painters were shown the importance of preparation, wet rubbing another door to be undercoated then wiping down with a sponge and clean water. The importance of stirring the product because solids fall to the bottom of the can was demonstrated. Under the specifiers supervision the primed door was coated with quick drying undercoat by roller and not laid off. The purpose was to see if it would flow or remain stippled. The previously undercoated door was coated with quick drying satin and laid off with a synthetic brush. A re-visit after an hour to inspect revealed a nice flow of the material, however the contractor condemned the finish because scratch marks were visible from the rubbing down through the finish. The specifier was asked to check specification for de-nibbing between coats. It is possible that the painters were not laying enough product on the substrate.