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CHEMICAL MODIFICATION OF TIMBER DECKING: LOOKING TO THE FUTURE

SHAUN KILLERBY
P.O.Box 47-063, Trentham, Upper Hutt, Wellington, New Zealand

FRANCES MAPLESDEN*
Trade and Economic Development Group, Scion,
Private Bag 3020, Rotorua, New Zealand

MICHAEL JACK
Sustainable Consumer Products, Scion,
Private Bag 3020, Rotorua, New Zealand

GAEL McDONALD
Business Ethics, Unitec New Zealand,
Private Bag 92 025, Auckland, New Zealand

and DEBORAH ROLLAND
School of Communications, Unitec New Zealand,
Private Bag 92 025, Auckland, New Zealand

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ABSTRACT

To help avoid conflict and even market rejection, the design and introduction of new technologies can be aided by consideration of the potential concerns of different stakeholder groups. An assessment of their desired goals for technological change may be useful for pre-empting changes in the parameters of acceptability for technologies. As part of a research programme evaluating the parameters of acceptability for bio-based technologies using life cycle assessment of products and an analysis of the perceptual frameworks of stakeholders, respondents from four stakeholder groups in New Zealand were interviewed about the desirable and undesirable trajectories for chemical modification technologies. Three examples of pine decking products derived using different amounts and types of chemical modification served to help explore the contemporary criteria and rationale for acceptability. The responses of the 70 respondents in those four groups indicated that new technologies need to be able to prove their worth with regard to both tangible and intangible qualities if they are to be accepted into the market in the place of either the existing product or an inorganic competitor.

Keywords: chemicals; wood; innovation; acceptability; industrial ecology.

* Corresponding author: frances.maplesden@scionresearch.com

INTRODUCTION

Recent advances in the biological sciences, combined with economic initiatives in certain regions, are helping to fuel an increasing world-wide focus on renewable and eco-efficient resources (Singh *et al.* 2003). At first glance this implies significant opportunities for growth in the global production and consumption of bio-based products. Yet a key requirement for the adoption of bio-based products continues to be that they are competitive with alternative products in terms of both cost and performance. Organic products such as wood are generally, by their nature, more susceptible to degradation and deterioration than inorganic products. They consequently often require some form of treatment to enhance attributes such as longevity, if this is a desired goal. Perceptions about the environmental or social impacts of such treatment may seriously jeopardise the acceptance and uptake of organic products.

The criteria for accepting or rejecting a technology extend far beyond the physical properties, functionality, and perceived benefits of the finished products. Concerns about the sustainability of the source materials, the environmental and social hazards pursuant to manufacture, use, and disposal of the products, and the consistency of all of these with social values, are part of the equation as well. People may, for example, reject a product which uses materials sourced from tropical rainforests or from genetically modified organisms (Marris 2001; Walter & Killerby 2004). People may also reject organic products which have been treated with chemicals such as arsenic, which has a reputation in popular culture as being highly poisonous, no matter how tightly such chemicals have been bound into the product. For this reason, a full deliberation about the acceptance and uptake of technologies should realistically consider not only the finished product but also the entire industrial ecology of the product. An industrial ecology perspective embraces the extended supply chain of the product, from the materials and processes used in manufacture through to disposal (Allenby 1994; Kleindorfer & Snir 2001). In considering the industrial ecology of the product, however, the emphasis should not be exclusively on the physical materials and processes. It is people's reactions to these materials and processes, both now and in the future, which will ultimately endorse or preclude a technology.

In order to evaluate how a full appraisal of the potential impacts of new technologies could feasibly be implemented, the New Zealand research organisation Scion, in conjunction with Unitec New Zealand, undertook research using chemically treated pine decking as an initial case study. This case study involved a comparison of three bio-based products made from exactly the same species for exactly the same end use, but differing in the type and amount of chemical modification used — copper-chrome-arsenate (CCA), acetylation, and thermal treatment. A life cycle assessment was undertaken for each decking product in order to provide a comparison of the potential environmental impacts relating to the manufacture, use, and disposal of the same quantity of each material (De Smet *et al.* 1996; Maplesden *et al.* 2004). Simultaneously, 114 respondents from six different stakeholder groups were asked to evaluate the three technologies, based on physical samples of the finished product and an overview of information relating to the industrial ecology of each product. Respondents in four of those groups (n = 70) were asked additional questions about the direction of technology development. The intention of the research was not to determine how many people in the population held certain opinions or preferences about particular technologies, but rather to ascertain how and why people in certain stakeholder groups may react differently to the same material and the same information.

One key aspect of this research programme was the issue of time. Respondents were asked to appraise the acceptability of different treatment technologies with respect to the life cycle of the resulting decking product. At the same time, it was assumed that the manner in which the concerns are appraised is dynamic. The parameters of acceptability for chemically modified bio-based products may be different in a decade from what they are now, given technological changes and stakeholder aspirations. As a consequence, the interviews with the professional participants in this research (n = 70) included a “strategic conversation” about desirable and undesirable technological change. This report summarises the preliminary findings of the research on the role of time in stakeholder appraisal of the technologies used for the case study. The results of the perceptual research are to be published separately (Killerby *et al.* in prep.).

Chemical Modification of Decking Products

The chemical modification technologies assessed in this case study were selected because of a contemporary dilemma within the timber construction industry. For the past 50 years or so, the primary chemical treatment for *Pinus radiata* D.Don grown in, and exported from, New Zealand has been CCA. This involves high-pressure saturation of the wood with an acidic aqueous solution of copper, chromium, and arsenic. When it dries, this solution is fixed into the wood (Smith & Shiau 1998). Such treatment has been commercially successful in terms of enhancing longevity and being cost-effective. In recent years, however, CCA-treated timber has been banned or phased out of all domestic uses in Europe, the United States, and Australia (Vlosky & Shupe 2002). This action has been prompted ostensibly by public concerns about the exposure of children to timber treated with arsenic, with particular emphasis on wooden surfaces such as decks and children’s play equipment (Vlosky & Shupe 2004b). A background issue is concern by regulatory authorities regarding the disposal of large quantities of CCA-treated timber, together with lack of knowledge about the actual wood treatment process or appropriate disposal. Burning of the timber releases arsene gas, and there are concerns that inappropriate burial of large quantities of discarded timber in landfills could result in the slow leaching of arsenic and chromium into the soil and groundwater (Sinclair & Smith 1990; Smith & Shiau 1998; Alderman *et al*. 2003; Jambeck *et al*. 2003; Donovan & Hesseln 2004; Vlosky & Shupe 2004a).

As concern has grown about the current regime for chemically modifying timber, there has been a move toward alternative products and new technologies. Lack of familiarity with alternative treatments inhibits their uptake, however, especially when problems arise. During the 1990s, for example, there was a rapid increase in the use of untreated kiln-dried timber in New Zealand. This was followed, within only a few years, by a public outcry when new timber-frame homes began leaking and rotting (Orsman & Trevett 2003). It was found that untreated kiln-dried pine had been selected and used as a structural material in houses with modern designs that allowed more water into the roof and wall but did not allow such water to escape (Yates 2003). Known colloquially as Leaky Building Syndrome, this situation has led to the situation where there is now probably as much concern in New Zealand (if not more) about lack of chemical treatment of timber as there is about chemical treatment (Gibson 2003).

The dilemma in the New Zealand timber industry is that new and novel products are marginalised through fear of toxicity from treatment on the one hand, and fear of a lack of performance through lack of treatment on the other. Many consumers probably continue to look for building materials which have low chemical input but also are seeking assurances about performance and so are opting for inorganic products. Regulators may be seeking assurances about the proven ability of treatments to meet new performance criteria. This situation raises the question as to what the parameters of acceptability are for new bio-based products with regard to chemical modification. How do we ascertain if and when different stakeholder groups are going to perceive problems with the treatment used?

RESEARCH PROCEDURES

Focus groups, stakeholder interviews, and workshops were used to gain a preliminary understanding of the current thresholds of acceptability for chemicals in outdoor decking in New Zealand. In order to stimulate discussion about issues relating to chemical treatment of wood, all the respondents were shown examples of three decking products with different amounts and types of chemical modification. One prompt was a physical sample of CCA-treated *P. radiata* decking, representing the existing base technology. The other two prompts were similar-sized pieces of *P. radiata* which had been treated with acetic anhydride (acetylated pine) and high-pressure steam (thermally treated pine).

Given that two of the timber treatments being considered were not yet on the market in New Zealand, all respondents (from focus groups, interviews, and workshops) were invited to handle and examine the samples. They were also all required to read a standardised card for each product outlining known and/or ***hypothetical*** benefits and problems associated with its manufacture, use, and disposal. These three cards (Appendix 1) provided fuller information than consumers would currently have access to. The rationale for this was that we were seeking to ascertain how people in different stakeholder groups may react to issues relating to the entire life cycle of the product should such issues come to their attention through the media and public debate. The two products that were not yet on the market were given hypothetical relative price differentials so that the three products could be compared as if they were actually on the market. All three products were described as being sourced from sustainably managed plantation forests. Almost all of New Zealand's domestic timber supply is sourced from plantation-grown exotic species, which has allowed the majority of the remaining indigenous forest estate to be reserved from harvesting (MAF 2006).

In order to scope the range of concerns that people currently had about chemical modification of decking, four focus groups (n = 38) were held in November 2004. Subsequently, after the data derived from these focus groups had been analysed, interviews were held with representatives from six stakeholder groups. A total of 114 people were interviewed between February and August 2005. The stakeholder groups represented included: chemistry, wood product, and environmental scientists involved in increasing the range of technologies available (n = 19); business people involved in developing and marketing the new technologies (n = 15); influencers, such as Government policy regulators and media, involved in filtering the options available (n = 17); selectors, such as architects and builders, potentially involved in specifying appropriate materials to homeowners (n = 19); consumers, who have to live with the new products (n = 30); and Maori consumers, potentially critiquing bio-based products from a unique indigenous cultural perspective. Of the 114 respondents, 70 were therefore interviewed in their professional capacity and 44 as consumers. The majority of respondents (64%) were male, with a particularly high bias toward men among the architects and builders (89%) and scientists (79%). In contrast, there was a higher representation of women (59%) among the influencers. The selection of both the consumers and the professional respondents was made using a snowball methodology, whereby four or five people who had decks or were employed in a desired profession were identified and contacted and then their friends or colleagues with similar credentials were contacted. Larger sample sizes, random selection, and quotas for gender were not deemed necessary for this phase of the research, which was looking at how and why various stakeholder groups were reacting to the same stimuli, rather than the representation of these perceptions across the population. Furthermore, some of the stakeholder groups, such as the producers/scientists, have a fairly small population in New Zealand.

Representatives from all six stakeholder groups were asked to complete a written questionnaire about the acceptability of different types and amounts of chemical modification in pine decking products. This questionnaire and subsequent workshops are the subject of another publication regarding the parameters of acceptability for bio-based products (Killerby *et al.* in prep.). In addition to this written questionnaire, the respondents from the four professional groups (n = 70) were asked questions (to which they responded verbally) regarding their desired trajectory for technological change, given that they could be instrumental in enhancing or constraining the availability and use of new technologies. The questions presented to them were based on those suggested in Kees van der Heijden's book "Scenarios: The Art of Strategic Conversation" (van der Heijden 2005) for the generation of alternative future scenarios. Firstly, respondents were asked to state what they would like the future to look like for the manufacture, use, and disposal of decking products in New Zealand. Secondly, they were asked to imagine and describe the worst-case scenario for the same. Thirdly, the respondents were asked to state what major decisions with long-term implications need to be made in order for the future to unfold as they would like it to be. Fourthly, they were asked what major constraints there were in implementing such decisions. Van der Heijden suggests a final question designed to get managers to think "outside the square", considering what they would like to achieve if there were no such constraints. For the purpose of this project we presented the respondents with a final teaser question — namely, how do they decide when the amount of chemical modification in decking products is too great and too little? Given that the answer is not as simple as too much and too little, almost all proceeded to elaborate upon what the true parameters of acceptability were in their perspective.

The strategic conversation methodology used in this study is the product of scenario generation research that began in the 1950s. Scenario generation proved a highly successful tool for companies such as the Royal Dutch/Shell group (van der Veer 2005), who used it to foresee and prepare for the oil shocks of the 1970s. Kees van der Heijden extended and refined the methodologies used by Royal Dutch/Shell, providing tools which are beneficial to companies and sectors facing market change. In recent years Scion has undertaken a number of scenario generation exercises, including one internal study of the organisation, one on the future of the Australasian built environment (Bates *et al.* 2001), and another on global changes which could affect bio-based technology development (Bates & Killerby 2002). The first two studies included use of structured questions about desirable and undesirable futures.

In addition to the questions about the trajectory of technological change, the representatives of the professional stakeholder groups were asked about their impressions of the benefits and problem areas with the three products used as prompts for the questionnaire. Their answers to these questions tied in with what they saw as the elements of a desirable and undesirable future. These interviews were administered between February and September 2005. The issue of chemical modification of timber was in the news throughout the time that the interviews were held, raising the profile of certain topics (NZ Herald 2005a). The media featured continuing editorials about the so-called Leaky Building Syndrome in New Zealand and changes to building requirements that were being introduced in response to this (NZ Herald 2005b; 2005c; 2005d). Other issues included soil contamination from CCA-treated posts buried on former horticultural land in the Marlborough and metropolitan Auckland regions. There was concern amongst home-owners in the affected Auckland area that the publication of information about such soil contamination would have a marked detrimental effect on their property values (NZ Herald 2005e).

After the interview results had been analysed, identifying any marked differences between the groups of respondents, two workshops (n = 20) were held in November 2005. Representatives from the scientists and architects (selectors) were invited to one, and representatives from the business community and regulatory authorities (influencers) were invited to the other. There they were presented with the findings regarding respondent reactions to the three technologies, together with a comparison of some environmental metrics for each derived using life cycle assessment methodologies (Maplesden *et al.* 2004). The workshops provided an opportunity for representatives from one stakeholder group to consider why the respondents from their group answered the way that they did, as well as why the other group represented held a significantly different view. The representatives then shared their deliberations, allowing them to see how the other group thought they were thinking, and how that other group were actually making their decisions. Finally, the workshops also provided an opportunity to see how robust their respective views were in response to the additional scientific data obtained through the life cycle assessment.

RESULTS

Perceptual Differences between the Stakeholder Groups

The purpose of this research was not to scientifically measure market preferences for CCA-treated pine and new treatment technologies. Rather, we were interested in evaluating how and why people in certain stakeholder groups may react differently to the same material and the same information. After examining the samples of three decking products made from *P. radiata* treated with CCA, acetic anhydride, and steam, together with the information cards for each, the interview respondents (n = 114) were initially asked to rate the overall acceptability of each product. A Likert scale was used where 1 indicated highly acceptable and 5 highly unacceptable. The respondents were subsequently asked to rate the acceptability of each product across each of 17 selection criteria. Specifically, these 17 criteria were, in no particular order of importance: low cost (initial outlay); low maintenance costs; durable; adequate stiffness and strength; no warp, twist, or bow; family health and safety; desirable appearance; natural; sustainably sourced raw material; minimal waste created in production; minimal waste created in disposal; recyclable; low energy input in production; low chemical input in production; low emission of gases from newly manufactured wood; proven technology; and trust in the manufacturer.

Overall, acetylated pine was deemed to be the most acceptable decking product of the three (mean = 1.86), even though the information sheet supplied asked the respondents to consider it to be hypothetically twice the price of CCA-treated pine decking. Similarly, thermally treated pine was the next most acceptable treatment (mean = 2.39), even though the respondents were asked to consider it as having half the life-expectancy of CCA-treated pine decking. This treatment was appealing on the basis of low chemical treatment and aesthetics. CCA-treated pine was ranked third overall (mean = 3.04) in terms of acceptability. Note that acceptability is not the same as willingness to consider purchasing the product. A high price or lack of performance may limit willingness to purchase, even where a product is seen as far more acceptable than an available alternative.

Looking at the responses of the different stakeholders, there is a clear disparity between the scientists and business people and the other groups (Table 1). While the scientists and business people perceived acetylated pine to be the most acceptable product considered, they preferred the CCA treatment over thermal treatment, whereas all of the other groups (especially the architects and consumers)

TABLE 1–Acceptability of sample technologies by stakeholder group

Stakeholder group	Acceptability (mean)			Total (n)
	CCA-treated pine	Acetylated pine	Thermally treated pine	
Scientists	2.47	1.63	2.79	19
Business	2.36	2.08	2.64	14
Influencers	3.06	1.88	2.29	17
Selectors	3.47	1.95	2.53	19
Maori	3.00	2.07	2.36	14
Consumers	3.47	1.73	2.00	30
TOTAL	3.04	1.86	2.39	113

ranked CCA treatment lowest. Analysis of the data about the acceptability of the products across the selection criteria revealed that the scientists and business people were placing a greater weighting on proven performance and trust in the manufacturers.

While a person may hold an academic preference for a particular product, this need not flow into their willingness to consider it for purchase, or their consequent purchasing behaviour. In order to examine this, the respondents were asked to rate how willing they would be to consider purchase given the hypothetical information on the three cards supplied (considering that they had feasible alternatives available). A rating of 1 indicated that they were definitely willing to consider purchase and 5 that they were definitely not willing.

The results revealed that there were a number of people who, even when unsure or uncertain about the acceptability of certain technologies (both the existing treatment and the hypothetical alternatives presented), were willing to consider purchase of that product. Overall, however, the distribution of preferences did not change. Acetylated pine decking was the preferred option, with scientists and business people placing CCA as their second choice and everyone else placing it third (Table 2).

TABLE 2–Willingness to consider purchase by stakeholder groups

Stakeholder group	Acceptability (mean)			Total (n)
	CCA-treated pine	Acetylated pine	Thermally treated pine	
Scientists	1.74	1.42	2.84	19
Business	2.20	1.93	2.47	15
Influencers	2.59	1.53	2.29	17
Selectors	3.26	1.68	2.58	19
Maori	2.64	1.71	2.36	14
Consumers	2.80	1.53	2.17	30
TOTAL	3.02	1.84	2.37	114

Discriminant function analysis and Hotelling's T^2 tests were used to determine if there were significant differences between the six sets of respondents, and which selection criteria had the most important impacts on this difference. A clear difference was found between the scientists, selectors, and consumers, with the influencers not differing much from any other group (overlapping all of them). The Hotelling's T^2 tests between each pair of stakeholder groups revealed that scientists and selectors were not as concerned about price as consumers and Maori were. Sustainably sourced raw materials were significantly more important to the selectors (architects) and scientists, while low waste in disposal was a greater concern for consumers and Maori. Comparing the scientists and selectors, it was found that the former were significantly more concerned about low waste in production, high durability, low maintenance costs, and trust in manufacturers. In contrast, the selectors (architects) interviewed were significantly more concerned about low chemical input in production and low emission of gases from newly manufactured wood products.

In examining the differences between the overall acceptability of the three decking products considered and the respondents' willingness to consider purchasing them, major divergences were noted. The respondents could be categorised into three distinct groups on the basis of their reaction to the base technology (Table 3). One group, who could be called the Traditionalists (n = 51, 46%), rated CCA-treated pine as acceptable or highly acceptable and were willing or definitely willing to consider its purchase. A second group, the Objectors, (n = 38, 33%), rated CCA-treated pine as unacceptable or highly unacceptable and were unwilling or definitely unwilling to consider purchase. The third group, the Pragmatists (n = 24, 21%), deemed CCA-treated pine to be unacceptable or were uncertain about its acceptability, yet they felt they would consider purchase or at least not rule it out as an option.

TABLE 3–Categorisation of respondents by reaction to CCA-treated pine decking

		Acceptability of CCA-treated pine decking					n
		Highly acceptable	Acceptable	Unsure	Unacceptable	Highly unacceptable	
Consider purchase	Definitely consider	10	25	1	3		39
	Possibly consider	1	13	5	7		26
	Unsure		2	2	6		10
	Possibly not consider			2	15	6	23
	Definitely not consider			1	4	10	15
n		11	40	11	35	16	113

Discriminant function analysis and Hotelling's T2 tests were used to determine the variables differentiating the three groups and their degree of separation. The groups displayed no statistically significant differences when it came to their appraisal of the importance of the 17 selection criteria; however, different criteria were used to score the three treatment types. Overall, Traditionalists tended to place greater importance on the strength and durability of the product. Objectors placed greater importance on low warp, twist, and bow, low chemical treatment, and being recyclable. Pragmatists placed greater emphasis on low cost and low energy in production.

The business people and scientists surveyed were predominantly Traditionalists (79% and 68% respectively) (Table 4). In contrast, the selectors (architects) were predominantly Objectors (53%) or Pragmatists (21%), finding CCA unacceptable or being uncertain about it. The consumers and influencers were also largely Objectors (37% and 35% respectively) or Pragmatists (38% and 24% respectively). We were very interested in finding out why there was such a vast difference in the reactions of these stakeholder groups to the base technology.

TABLE 4–Distribution of reactions to the base technology by stakeholder group

Stakeholder group	Traditionalists (%)	Pragmatists (%)	Objectors (%)	Total (n)
Scientists	68	16	16	19
Business	79	0	21	14
Influencers	41	24	35	17
Selectors	26	21	53	19
Maori	50	14	36	14
Consumers	27	37	37	30
TOTAL	46	20	34	113

With regard to the intrinsic and extrinsic properties of the decking products, statistical analysis of the questionnaire data revealed a clear difference between the scientists, selectors, and consumers, while the influencers were a rather broad group that did not exhibit much difference from any other group. Scientists and architects proved to be not as concerned about the price of the product as the end-users were, possibly due to being further removed from the purchasing decision. The scientists and selectors gave much greater weighting to selecting sustainably sourced raw materials than did the end users, while the consumers and Maori were more concerned about low waste in disposal than the scientists and selectors were. With regard to differences between the scientists and architects, the former considered low warping, high durability, low waste in production, trust in the manufacturer, and low maintenance costs to be more important, whereas the architects felt minimal chemical input and emissions were more important.

Given the notable variation in representation of Traditionalists and non-Traditionalists between the various stakeholder groups, two workshops were subsequently held. The purpose of these workshops was to explore the capacity for dialogue and understanding between divergent stakeholders. One workshop had five scientists and five architects in attendance. The second workshop had five business people and five influencers. Stakeholder representatives were selected on the basis of professional interest plus known ability to relate well in workshops.

In the workshops, the representatives of the two stakeholder groups were presented with the findings of the research to date, including the life cycle assessment data for the three products and the divergences in reactions from the respondents in the different groups. Separating the two groups, each was asked to consider why they felt that the respondents from their industry may have responded the way that they did. They were also asked to consider why the other stakeholder group may have had such a different reaction to the base technology. The two groups were then brought together again to report on their discussion, thus obtaining some insight into (a) the mindset of the other group and (b) the perception of the other group as to their own mindset. Such feedback provided a number of insights for both the researchers and participants.

When the results of each break-out session were reported back by the stakeholder group spokesperson, several key comments were noted by them as clarifying their group's position. The business representatives stated that the business respondents were probably largely Traditionalist given that they were immersed in the present market environment, lacking much opportunity to look into the future regarding new technologies. Their primary concern was to avoid short- to medium-term problems by selecting proven and familiar products. New technologies would be considered only if the existing technology was proved to be excessively harmful or new products had improved performance. In contrast, the scientists stated that the producer/scientist respondents were probably Traditionalist given that they had confidence in their community to come up with solutions in the future, either through reducing any problems associated with disposing of CCA-treated pine or in developing an alternative product. Given this faith in future scientific improvements, they saw no need to change from a product which they believed to be proven, familiar, and of lower risk than new technologies still in development.

The architects considered that the selector respondents had been largely non-Traditionalist given that their goal was not the mere creation of a structure but a healthy living environment. As such, they were willing to consider novel new technologies which could improve on the quality of the living environment in the medium term. In contrast, the influencers stated that they were largely non-Traditionalist given that they were watching overseas developments with an eye to ensuring market access and avoiding disposal problems and/or potential litigation problems in the longer-term.

Each of the responses reflected the different operating rationale and experiences of the stakeholder group, and each was a valid risk management strategy. Architects and business people looked to the short to medium term, and scientists and influencers were looking to the long term; however, architects and scientists were seeking to improve the living environment or product, while the business people and influencers were seeking to maintain sales and avoid problems (Table 5). In other words, the primary factors distinguishing the risk management of the four professional focus groups were the temporal focus (present or future) and the form of resolution (improving the product or avoiding problems). The conjunction of these factors altered the degree of emphasis that the respondents placed on proven and trusted products with existing chemical regimes as opposed to moving to new products with different amounts or types of chemical modification. Familiar products with a proven high performance accorded with the mindset of the business people and scientists, while products with what was perceived to be a safer chemical treatment were given greater consideration by the architects and influencers.

TABLE 5–Deduction of differing risk management strategies among four stakeholder groups

	Present focus	Future focus
Improvement focus	**Architects** 74% non-traditionalists Look to new, potentially more benign products, to improve health of living environment	**Scientists** 68% traditionalists Promote what is tried and true, with faith in improving technologies or improving disposal
Avoiding problems	**Business** 79% traditionalists Promote what is tried and true, seeking to maintain present sales and avoid problems	**Influencers** 59% non-traditionalists Look to new, potentially more benign products, to maintain market access and avoid problems

Given that the respondent groups were each immersed in their own rationale, they naturally had difficulty seeing how and why other groups were reacting differently to the same technologies and related information. For each of the four stakeholder groups, their priorities determined that theirs was the most appropriate and valid way of assessing the technology. Each had an operating rationale and risk management strategy that was valid, although each was derived from a different approach and ended with a different response. Such are the perceptual issues involved when considering the acceptability of technologies, whether new or existing.

Desired Trajectories of Technological Change

In addition to being asked to complete a written questionnaire during their interviews, the producers/scientists, business people, influencers, and selectors (n = 70), being actively involved in the production and dissemination of products, were also asked a series of questions about their aspirations for the future development of decking materials. It was assumed that awareness of these aspirations would also help clarify how and why different stakeholder groups were reacting to the case study technologies in different ways. This assumption was based on the idea that respondents are looking not only at how a technology matches their present service requirements but also at the degree to which it matches their values.

The professional respondents were first asked to imagine how they would like the future to look with regard to the manufacture, use, and disposal of decking products. They were then asked to describe their worst-case scenario for the same. Whilst a host of issues and themes (and combinations thereof) were forthcoming, an analysis of their written responses using sets of key words allowed the desirable futures to be categorised into six themes (Table 6). Between five and 10 key words described each theme. Those who mentioned the environment, for example, included one or more of the words "environmental", "environmentally", "sustainably", "renewable", "energy", "disposal", "toxic", "emissions", and "leach". Similarly, those who mentioned performance used one or more of words "durable", "durability", "lasting", "longevity", "strength", "hardness", "appearance", "looks", "twist", and "warp".

TABLE 6–Distribution of themes in the preferred future by stakeholder group

	Scientists (n=19)	Business (n=15)	Influencers (n=17)	Selectors (n=19)	Total (n=70)
Environmentally benign	18	7	14	15	54
High performance	12	7	10	14	43
Cost-effective	6	2	5	6	19
Healthy and safe	2	4	4	2	12
Locally produced	0	1	2	4	7
Socially responsible	1	1	3	2	7

The respondents were also asked to describe an undesirable future for treated decking. Two dominant worse-case scenarios emerged. Thirty-eight respondents (mainly environmental scientists, regulators, and selectors) feared a continuation of existing technologies and the status quo. Another 24 respondents (mainly wood scientists and business people) feared a rejection of existing technologies and their replacement with new products lacking proven physical and environmental performance. These divergent scenarios reflect the different reactions to the base technology held by the Traditionalists, Objectors, and Pragmatists. An analysis of the written responses revealed that the components of the worst-case scenarios were, however, the inverse of the six desired values (Table 7).

TABLE 7–Themes underlying desirable and undesirable futures for decking products

Desirable future	Undesirable future
Environmentally benign products	Environmentally harmful products
High-performance products	Poorly performing products
Healthy and safe products	Health and safety compromised
Cost-effective products	High costs and expensive products
Local (New Zealand) products	Imports and loss of New Zealand identity
Socially responsible products	Lack of social responsibility

Environmentally benign products

Most of the professional respondents (77%) described a desirable future as one where environmentally benign decking products were available, which had minimal environmental impact throughout their life cycle. There were differences, however, in the type and amount of chemical addition that was deemed to be acceptable in achieving a minimal environmental impact. Thirteen respondents (of whom eight were architects) stated that no chemical addition or enhancement to products was acceptable in an ideal future. Two environmental policy regulators also considered that zero environmental impact was the only acceptable outcome. At the other extreme, two respondents considered CCA-treated pine to be more environmentally acceptable than alternative products. A common preference, however, was that the resulting product should perform at least as well as CCA-treated pine with regard to strength and stability.

Sustainability was a recurrent theme in relation to desired environmental outcomes. In order to eliminate the need for chemicals, a few respondents suggested the establishment of naturally durable hardwood plantations. Another view was that treatment technologies which enabled plantation softwoods to perform "in all respects" were better than using unsustainably sourced tropical hardwoods. These treatments could include organic-based fungicides or acetylated and thermally treated pine.

Safe disposal was singled out by many of the scientists, business people, and environmental policy regulators as being critical to minimising the environmental impact of decking products. A number of methods were suggested for achieving this. One respondent proposed that "disposal costs [be] included in the life cycle costs [so that] the true costs of a product include the life cycle environmental costs of the product". The most common view was that products need to be made available which are both functional and safe to burn, such as hardwoods. Others suggested recycling as a means to minimise disposal problems. One chemist and one environmental policy regulator envisaged that technology solutions could be found for safe disposal of CCA-treated pine, both stakeholders suggesting clever chemistry to enable extraction of toxic chemicals from treated pine before disposal in landfill or by burning.

Disposal of CCA-treated pine by inadequate methods, leading to potential toxic emissions into the air and the leaching of chemicals into waterways, was identified as an undesirable future for many respondents. Another concern was that environmental efficacy may be discarded in favour of low-cost products, so that "only the cheapest but most environmentally harmful product is used". Responses differed, however, regarding which products were considered to be environmentally harmful, and the extent to which chemical use in decking products contributed to environmental harm. Some respondents regarded any chemical modification of products as wholly undesirable. For others, banning the production and use of CCA-treated timber in New Zealand was not considered to be a desirable solution. They were concerned about the uncertain environmental impacts of alternative products, particularly the use of oil-based chemicals (plastics) and the potential for using unsustainably sourced tropical hardwoods.

High-performance products

Most respondents (61%) wanted future decking products to be simultaneously high performing and fit for purpose, with enhanced performance properties relative to the raw material. Durability was the most important criterion for future decking products. Other important performance criteria identified were: low warping, twisting, or bowing; strength; low maintenance; colour retention; non-slip surfaces; requiring no special fasteners; and easy to work with. There were differences, however, in stakeholder expectations of the life of the product and the trade-offs required with parameters such as environmental integrity and low cost.

In terms of a worst-case scenario, the use of products which were poor-performing, not fit for purpose, and likely to fail in service was seen as most undesirable. CCA-treated pine was regarded as the benchmark for physical performance (particularly durability) by a number of respondents, being a known and proven technology. Fears were expressed that durability could be compromised in favour of products with low chemical content but with performance inferior to CCA-treated pine. Others considered hardwoods to have better physical performance in use. Growing naturally durable plantation species and importing sustainably grown tropical hardwoods were thus seen as solutions for achieving long-lasting wood-based products while sustaining environmental integrity. Growing naturally durable species, however, would take a considerable time to implement.

Cost-effective products

In terms of a desirable future, 27% of the professional respondents stated that decking products needed to be cheap, affordable, economical, or competitive.

Indeed, cost was identified as a key trade-off for enhanced physical performance and environmental efficacy. Fourteen respondents suggested that costs needed to be constrained so that products were affordable. Others stated that the cost should not merely reflect the raw materials used in production, but reflect "all aspects of its performance", including expected service-life and disposal. Recycling products was seen as a means to improve raw material costs, as well as removing issues relating to disposal in landfill and by burning.

The issue of high production costs or a lack of affordable products was mentioned by a few respondents when considering a worst-case scenario. There were concerns that low cost would be used as a trade-off for other performance attributes. There were also concerns that solid-wood products may be priced out of the market, with cheaper low-performing substitutes taking their place.

Healthy and safe products

Healthy and safe products were specifically described as an important feature of a desirable future by 17% of the professionals surveyed. This was driven mainly by two concerns: worker safety in manufacture and handling of products, and end-user health and safety, particularly with regard to children and pets. Some chemistry scientists expressed concern for workers in factories handling hazardous chemicals. Builder safety was a concern, particularly to architects, because they were felt to be often unaware of the health risks associated with the handling and disposal of CCA-treated pine. In a worst-case scenario, concerns were raised about both the continuation of the status quo and the use of new products whose health effects were unknown. Some chemists and business people expressed concerns for people's safety if CCA was banned and other inferior products, which were inappropriately tested, were made available on the market. One respondent suggested that a worst-case scenario was that knowledge about detrimental health effects of such products was available, but nothing was done about it. Similarly, another was concerned about a future in which healthier options were available but industry was unwilling to adopt them because it had a vested financial interest in continuing with the status quo.

Locally produced products

Having New Zealand-made products "in keeping with the New Zealand lifestyle and brand" was important enough for 10% of the professional respondents to be mentioned as an aspect of a desirable future. Wood products were seen as more in keeping with the New Zealand lifestyle, being enjoyable to walk and relax on as they were natural (not artificial). A bio-based future was also identified as being an important contributor to New Zealand's future economic welfare and environmental health. For some, a future in which New Zealand-grown materials were predominant was important so that there would be less reliance on imported tropical hardwoods, although architects considered that these also had to be at least cost-comparable. The importance of products being manufactured in New Zealand was also stressed due to the potential economic benefit to New Zealand and the need to ensure that products were suited to the New Zealand (climatic) situation.

A future which did not use New Zealand's wood product resources, but used substitutes such as plastics, was seen to be detrimental to New Zealand's future environmental welfare. Concerns were also expressed for the New Zealand outdoor lifestyle if CCA-treated pine was no longer accepted in the marketplace and there were no adequate alternatives available. It was felt that New Zealanders would lose some aspects of their lifestyle and culture.

Socially responsible products

In addition to the aforementioned values, 10% of the professional respondents expressed concern about social responsibility. A desirable future for them included New Zealand consumers using local resources rather than exploiting countries that produced unsustainably managed tropical hardwoods. A desired future was also one where manufacturers were concerned about disposal issues, consumers were provided with good and accurate information about products, and the products were used by qualified people who knew the limitations of the products and used them appropriately.

Questions were raised regarding where the responsibility lies for the environmental and health impacts of products. One undesirable future was where "Government and the public have to pick up the costs of cleaning sites after the manufacturer has pulled out", suggesting that manufacturers needed to be more responsible for their products. Others suggested that consumers were particularly accountable in terms of ensuring that they purchase sustainably sourced products. A number (mainly scientists and business people) suggested that, if CCA-treated pine were to become unavailable in New Zealand, a worst-case scenario would be the sale of poorly performing substitute products to an uninformed and unsuspecting public. An uninformed public was not an ideal future, specifically if "no information about environmental problems at production and disposal is given to the public". Marketing in which "unfair and unfounded claims are made regarding one product's benefits over another" would also be socially irresponsible from a public health viewpoint.

One science policy respondent suggested that a world in which we become closed to new ways of thinking and doing things was undesirable, technophobia affording fewer changes aimed at improving economic, environmental, and social outcomes. In other words, their worst-case scenario was an "unrealised future."

Necessary Decisions to Achieve a Desired Future

Having considered what both a desirable and an undesirable future would look like with regard to the manufacture, use, and disposal of decking products in New Zealand, the respondents were then asked what major decisions with long-term implications were needed in order to realise their desired future. Nine different means were stated for achieving a desirable future. These were: Government action; local authority action; new forestry planting; importing / not importing; industry action; economic and political reform; marketing; education; research and development. Three key questions appeared to underlie these responses: How do we make new products available? How do we restrict undesirable products? Who is responsible for each?

Government action, in the form of legislation, taxes, and incentives, was considered a key to achieving desirable environmental outcomes. It was suggested that there should be legislation for restricting the use of any toxic chemicals for treating timber, plus ensuring safe disposal of products from all new building work. Changes to national building codes and standards to deter the use of environmentally unsustainable timbers or treatments were also suggested, including the incorporation of sustainability indices using life cycle analyses for treatment processes. Government incentives were suggested to enable the manufacture and use of alternative, environmentally benign, decking products. Another means to achieve this was through tax relief to the timber industry and companies for research into and development of viable commercial alternatives to CCA treatment. Some respondents also called for environmental taxes and cost levies to enable the safe disposal of products.

At an industry level, it was suggested that companies take more entrepreneurial risk by investing in new technologies and making alternative products available to the public. Manufacturers were also requested to be more responsible for their product's environmental performance beyond the factory gate, self-regulation being suggested as a means for achieving this. Business respondents called for voluntary industry action to support the production of environmentally safe products. Various marketing initiatives, such as environmental costing of products and making environmentally benign products more available in the market, were also considered to be the responsibility of industry.

Many respondents considered research and development to be a crucial step for achieving a desirable future. The research initiatives suggested focused mainly on growing new species, or developing new products with superior sustainability credentials to CCA-treated pine. Other aspects of research and development that were suggested included market research to determine appropriate decking products for export markets, economic research to find the most affordable products, and product development to engineer a transition to alternative products. Wood product scientists suggested the re-engineering of the CCA treatment process to achieve a better environmental outcome.

All stakeholders were considered responsible for educating industry and consumers on sustainability issues relating to chemical treatment of wood products and alternatives to CCA-treated pine. No specific responsibility was assigned for the longer-term solution that New Zealand grows sustainable and naturally durable timber suitable for decking uses. At least one respondent considered that some responsibility for environmentally acceptable decking products lay beyond New Zealand's borders, stating that economic and political reform was required in countries supplying unsustainably sourced tropical hardwoods for New Zealand decks.

Constraints to Achieving a Desirable Future

The most commonly cited constraint to achieving a desirable future with regard to new treatment technologies was inertia of industry and Government. Manufacturers were perceived to have a vested interest in maintaining the status quo as their investment was in CCA treatment technologies. Government was perceived to lack the political will to put into effect the costly measures required to make alternatives to existing treatment options commercially acceptable. Lack of vision and long-term planning, plus lack of unity in the wood products industry, were also seen as significant obstacles to change.

As the acceptability of existing treatment regimes for *P. radiata* diminishes, one option suggested for change was to move to more durable species which do not require much in the way of artificial enhancement. It was realised that there are few such species available in New Zealand, however, given that the majority of the naturally durable indigenous species are not available for harvest and the focus of the forest industry for the past 90 years has been on the planting of *P. radiata* . Providing alternative, naturally durable, plantation-grown species locally is constrained by the time required to grow these products and unwillingness to invest in such long-term change. The alternative, in terms of naturally durable species, is to import tropical hardwoods, but this raises the problem of trade costs and the risk of supporting unsustainable timber harvest practices in developing countries. Restricting the supply of unsustainably sourced hardwood timbers is further constrained by political and economic issues in the countries where these hardwoods are sourced.

An interim solution is required to the lack of naturally durable species and this may be through alternative treatments. A common view among the interview respondents was that society must accept the higher costs of using environmentally benign decking products but that the high relative costs of alternative products are a major constraint to consumer acceptability. Some stated that this problem was exacerbated by a general lack of awareness of the issues, as well as by consumers being advised by unqualified people who supplied them with minimal information. It was suggested by some that consumer resistance could be countered only by a well-funded education programme. Performance of products needed to be proven before they could be accepted; however, a lack of Government and industry funding for research and development and for subsequent education was seen as a constraint on achieving such an end.

Parameters of Acceptability

The strategic conversation ended with a teaser question about how much is too much or too little chemical modification of pine decking products. The wording of this question prompted the respondents to explain what the true parameters of acceptability were in their opinion.

In relation to "how much is too little" chemical modification of decking, 32 respondents (46%) stated that the true bottom-line with regard to acceptability is the ability of the product to perform. The product must be fit-for-purpose and able to last. Related to this, but also having a bearing on health and safety, was product failure, mentioned by eight respondents. Together these were essentially the "non-negotiable" aspects for decking. Six of the stakeholder representatives stated that their benchmark was compliance with legal requirements and standards, while another three felt that the bottom-line was the willingness of consumers to buy the product. Other issues raised by three or fewer respondents were cost, function being compromised, and litigation.

When asked "how much is too much" with regard to chemical modification of decking, the two most frequently mentioned parameters of acceptability were the degree of potential environmental harm (n = 27, 39% of professionals) and potential adverse effects on health and safety (n = 24, 34% of professionals). The latter included the safety of manufacturers, builders, and people in the home. Five respondents stated that the upper benchmark was failure to comply with legal requirements and standards, while four stated that public opposition and unwillingness to purchase the product was the real benchmark. Two respondents stated that they were opposed to any chemicals in wood, while another three felt that there could not be too much.

The result of this question indicates that the zone of acceptability for chemical modification is defined first and foremost by the ability of the product to perform, being fit-for-purpose, and conforming to individual expectations about how long the product should last. So long as the cost is not prohibitive, then the merits of alternative products will be assessed according to the extra physical, environmental, and social benefits that may be realised for the extra cost. If the chemical modification is seen as excessively detrimental to human health or the environment, however, it will be rejected from consideration. Such was the perception of the respondents in this study who were classified as Objectors, finding CCA-treated pine unacceptable and stating that they were unwilling to buy it (if they had feasible alternatives). The environmental and health limits raised by the respondents were primarily the perceived toxicity of the chemicals in the decking material and their potential to be released back into the environment.

Perceived Benefits of the Case Study Technologies

In addition to the open questions about the desired trajectory of technological change in relation to the manufacture, use, and disposal of decking products, the stakeholders from the professional groups were also asked what they saw as being the benefits and perceived problems with each of the three products presented to them in this case study. Overall, the existing technology (CCA-treated pine) was seen as performing well in terms of physical parameters such as strength and durability, as well as being cost-effective and proven; however, there was concern about its safety. Acetylated pine was seen as also potentially performing well in terms of strength and durability, and it had the advantage of better appearance, lower toxicity, low environmental harm, and safer disposal. It was relatively weak, however, in the area of hypothetical cost-effectiveness and, naturally, had a lack of proven ability. Thermally treated pine was seen as particularly beneficial in terms of appearance, low chemical input, low environmental harm, and safe disposal, but was relatively weak in terms of physical performance, proven ability, and cost.

These results were corroborated by the quantitative data obtained through the written questionnaires. Interestingly, however, the responses to the open questions revealed that CCA-treated pine was seen as having the benefit of using locally and sustainably sourced raw materials, whereas this was not seen with the acetylated and thermally treated pine — despite the fact that the information cards provided stated that they were all produced from sustainably managed plantations of *P. radiata*. The difference would appear to come down to the fact that CCA-treated pine has become almost an iconic use of New Zealand's forests, whereas the new technologies do not have the same iconic appearance. Indeed, the thermally treated pine was seen as more reminiscent of cypress in terms of colour and smell, and also brought to mind the words "Scandinavian," "spa", and "sauna" for many respondents. While they liked its appearance, it just was not as "Kiwi" as CCA-treated pine.

CONCLUSION

The purpose of this report was not to critique either CCA-treated pine or the two alternative technologies considered as comparisons. Rather, these were prompts to help explore how different stakeholder groups determine the acceptability of new technologies with different amounts and types of chemical modification. The results of this case study suggest that the different stakeholder groups were evaluating the technologies based not only on physical properties and performance, but also with regard to wider issues such as trust in the product, iconic associations, and the history of the product in terms of manufacture and disposal, influenced by the different operating rationales of the particular stakeholder group. Some groups placed greater weighting on present performance, while others were looking more to future improvements or problems.

There were six main themes upon which the desirable futures of the technologies were compared. If there is a degree of parity between alternative products in terms of physical performance, then the relative merits of the different products will be evaluated according to trade-offs across the other five values: cost, health and safety, environmental impact, origin, and social responsibility. Respondents and stakeholder groups vary in their preferences for each of these values. The existing technology has an advantage, however, in that the performance value includes not only tangible aspects such as strength and longevity, but also the intangible aspects of proven ability, established trust or goodwill, plus branding and iconic associations. New technologies need to be able to prove their worth against these intangible qualities as well if they are to be accepted into the market in the place of either the existing product or an inorganic competitor.

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APPENDIX 1

STANDARDISED HYPOTHETICAL DESCRIPTIONS OF THE CASE STUDY TECHNOLOGIES

CCA-treated pine

CCA-treated pine is sourced from sustainably managed plantation forests. The wood is then pressure-treated with copper-chrome-arsenate solution, which is fixed into the wood.

This chemical treatment enables the wood to be used outside without protection for purposes such as decking. While untreated pine will last for only about 5 years, a treated pine deck will last at least 25 years before it starts to decay to the stage where it is considered unsafe.

Although the CCA solution is fixed into the wood, a very small quantity of arsenic will leach from the wood over time. The treated pine is also difficult to dispose of at the end of its productive life. Burning the wood produces arsene gas, and burying the wood in landfills can cause environmental problems due to leaching of chemicals. For these reasons, CCA-treated pine has been banned from all domestic uses, including decking, in the United States and Europe. Nevertheless, it is still used extensively in New Zealand.

Acetylated pine

Acetylated pine is manufactured from trees grown in sustainably managed plantations. The wood is kiln-dried and then treated with a chemical known as acetic anhydride. Although this chemical is an irritant and can be highly flammable, it changes during processing. The results are a wood product which is not toxic, and a solution of acetic acid (otherwise known as vinegar) which can be re-used. The wood consequently smells like vinegar — essentially, it is pickled.

At the end of its productive life the waste wood can be safely burned or disposed of, being non-toxic. As with any kiln-dried timber product, however, heating and drying during manufacture cause volatile chemicals (such as formaldehyde) to evaporate from the wood in small quantities for a limited period of time.

Given that the wood is kiln-dried in addition to being treated, the product is more expensive than CCA-treated pine. However, acetylated pine is more stable than treated pine in terms of warping or twisting, being heavier and harder. Decking made from acetylated pine is expected to have a life of about 30 years. It does not change colour with age and is easy to maintain. It is easy to paint and stain, and does not crack or splinter.

Thermally treated pine

Thermally treated pine is made from trees grown in sustainably managed plantations. The wood is heated through with steam to very high temperatures. but there are no chemicals added. Instead, the wood has essentially been cooked through.

At the end of its productive life (it lasts about 10–15 years as decking) the waste timber can be safely burned or disposed of, being non-toxic. Although there is no chemical treatment of the wood, heating and drying during manufacture cause volatile chemicals (such as formaldehyde) to evaporate from the material in small quantities for a limited period of time.

Because of the energy used in manufacture, the final product is more expensive than CCA-treated pine, though not as expensive as acetylated pine.

Thermally treated pine has been used in Scandinavia for decking and has proved to be more durable than untreated pine, but not as durable as CCA-treated pine. It is light but stable (not twisting, warping, or bowing) and will not move as much as treated pine. It has the same gluing, nailing, and painting properties as both untreated and treated pine, but it could be more prone to cracking, checking, and splintering. The colour of the wood also silvers over a period of time if exposed to sunlight.