

Opportunities for Wood/Natural Fiber-Plastic Composites in Residential and Industrial Applications

By Paul M. Smith and Michael P. Wolcott

Changing social and economic trends are increasing pressure on the forest products industry to improve performance of wood-based building products, implement environmentally appropriate technology, and keep pace with global demand for wood products. Since the 1950s, North America has experienced rapid growth in the use of both structural and nonstructural wood composites, substituting primarily for traditional solid wood products. In the 1990s, interest accelerated in developing wood-based composites that include a wide variety of materials such as gypsum, cement, and plastics.

Wood/natural fiber-plastic composites (WPCs) are a unique development in the wood products industry, an emerging renewable material class based on performance, process, and product design innovation. The emerging material class combines the favorable performance and cost attributes of wood (and non-wood agricultural fibers) with the processability of thermoplastic polymers. Historically, molded wood composites have been used extensively in North America for a wide range of products, including automobile parts, interior door skins, appliances, and furniture to name a few. It is only recently that *extruded* wood-plastic composites have entered the mainstream of the building materials industry.

As WPC production capacity increases, new products and markets are being developed. WPCs are now finding their way past decking and railing systems, into fenestration applications (e.g., window lineals, door stiles, and rails), mouldings, and exterior covering applications like siding and trim. Figures 1a and 1b show some of the developmental WPC products from Washington State University and Strandex Corporation. Figure 1c shows a prototype (capped) 4- by 12-inch industrial WPC deckboard. The photo on the cover of this issue shows a prototype 4- by 12-inch natural (uncapped) industrial WPC deckboard in the background and a 1- by 6-inch residential WPC deckboard in the foreground. The new WPC products are being designed for applications where long-term performance, consistent appearance, and dimensional stability are important. More recently, structural applications for WPCs in both low-rise buildings and industrial structures (e.g., docks, piers, and bridges) have captured the attention of the industry.

MARKET DRIVERS

Applications first captured by WPCs included land-

scape timbers, picnic tables, playground equipment, benches, fencing, and trash receptacles. These uses have relatively low structural requirements and are not regulated by building codes. In the early 1990s, Trex Company, Inc.¹ introduced a residential deckboard product that addressed a general dissatisfaction among many consumers regarding various treated lumber product attributes such as long-term maintenance, surface characteristics, and straightness. This application increased the structural requirements over previous uses and introduced the need to qualify the product with building code authorities.

The growth of WPC decking has been driven by four factors, the first of which is a favorable value proposition in terms of a life-cycle cost. Perceived customer value can be defined as the tradeoff between the quality (benefit) and price (sacrifice) to use a product in relation to the competitive offering and is a fundamental consideration when a wide variety of solutions exist (Walter et al. 2002). For decking, a superior value proposition throughout the useful product life has become a salient marketing point. Most WPC decking producers emphasize life-cycle costs by highlighting reduced maintenance in their product literature.

Countering the long-held tenet that building products are purchased solely on price rather than performance benefits, WPCs have succeeded in the market with a substantially higher initial material cost compared to the competition. In the spring of 2005, pressure-treated ACQ² decking (grade No. 2 & Better, 5/4 by 6 in) sold for approximately \$0.72 to \$1.02/lineal foot (average retail), whereas WPC

¹ Trex Company, Inc. was formed in August 1996 in a buyout of the Composite Products Division (est. April 1992) of Mobil Oil Corp.

² ACQ is the primary replacement chemical for CCA.



Figure 1a. — *Examples of prototype WPC products from Washington State University’s Wood Materials and Engineering Lab. From top: extruded sill plate; chock members being drilled for installation at Port Hueneme, California; installed chock members.*

substitute products retailed for approximately twice that price. In addition, synthetic decking purportedly requires similar labor costs, estimated at one-half the installed cost of a typical deck, and the same substructure requirements as the pressure-treated decking. But when comparing the completed WPC deck costs (with pressure-treated substructure), WPC selections are estimated to cost a mere 15 to 20 percent more (installed) versus a comparable deck constructed entirely of pressure-treated lumber. Since the WPC deck allegedly requires lower maintenance³ costs, the actual payback period for a deck constructed with higher cost WPC deckboards is estimated at 2 to 5 years compared to a deck constructed entirely of pressure-treated lumber products (Anon. 2004a-d).

A second important issue affecting WPC substitution for pressure-treated lumber products is the fate and

³ Maintenance is typically classified as periodic cleaning, sanding, staining, sealing, and/or painting.



Figure 1b. — *Prototype WPC products from Strandex Corporation, Madison, Wisconsin; top: window sill; bottom: low density fencing.*

impact of chemicals in the environment. The wise-use movement’s continued desire to improve wood utilization presents an interesting dichotomy to the forest products industry. On the one hand, the wood protection industry has effectively extended the life of wood products far beyond that of the natural durability of wood, thus minimizing the amount of forests harvested. On the other hand, this same industry has come under increased public and legal scrutiny regarding potential long-term health and safety issues of the chemicals used to preserve the wood. In the spring of 2001, a class-action lawsuit targeting retailers, chemical companies, and treaters was filed in Dade County, Florida, alleging that “leached CCA is potentially creating thousands of mini toxic waste sites in backyards and parks” (Anon. 2001). Chromated copper arsenate (CCA), the predominant waterborne wood preservative under scrutiny, has been in use since the 1940s. However, a voluntary transition to arsenic-free preservative-treated wood products for residential applications⁴ was implemented on January 1, 2004. This action has affected approximately 350 U.S. treating plants now in some stage of modifying their business practices, including the conversion to new wood preservative chemical treatments.

The U.S. Environmental Protection Agency (EPA) does not suggest that homeowners should tear down the estimated 75 billion lineal feet of existing CCA-treated wood structures currently in use nationwide. However, the agency does recommend that people, and in particular children, wash their hands after touching treated structures (Eisler 2003, Ricks 2004). The EPA released a Draft Preliminary Risk Assessment in November 2003 with initial

⁴ Industrial, commercial, and farm applications are currently exempt from the CCA voluntary withdrawal.



Figure 1c. — *Prototype 4 by 12-inch capped industrial WPC deckboard. This deckboard, and the deckboard on the cover of this issue, were extruded at Strandex Corporation’s research and development laboratory in Madison, Wisconsin. These industrial deckboards were developed under sponsored research from the Office for Naval Research (ONR) by Washington State University and Strandex Corporation and are being commercially produced by a Strandex licensee and distributed by McFarland Cascade Corporation. These products are being deployed in demonstration projects such as a trail bridge near Missoula, Montana (in cooperation with the USDA Forest Service Wood-In-Transportation Program) and a new pier at the U.S. Naval Academy in Annapolis, Maryland.*

findings indicating that children with prolonged exposure to CCA may have a slightly higher risk of developing cancer. However, following an independent review by the EPA-commissioned Scientific Advisory Panel, the EPA now states that it is still too early to draw definite conclusions from the findings (Anon. 2004e). Further, the EPA now agrees with the American Council on Science and Health that there is no conclusive evidence that CCA-treated wood causes harm or poses a threat to the public (Froome 2004, Martin 2004).

In the meantime, home improvement chains such as Lowe’s and Home Depot are offering pressure-treated ACQ (ammonia copper quarternary) and CBA (copper boron azole) lumber products as well as alternative naturally durable species and synthetics. However, the new preservative chemicals have been shown to be both more expensive and more corrosive to conventional fastening systems (Anon. 2004e, Froome 2004, Tomasulo 2004). Additional developments are sure to ensue on this rapidly evolving and highly controversial subject. This lesson suggests that few definitive solutions exist with regard to social perceptions of chemicals in the environment. It further emphasizes a need to proactively transition products prior to fatal litigation and/or regulation. New product developments, such as WPCs and alternative chemicals, represent potential technical solutions to this particular issue.

The third market driver facilitating the entry of WPC products into the U.S. marketplace is the general builder acceptance of new wood composite building material solu-

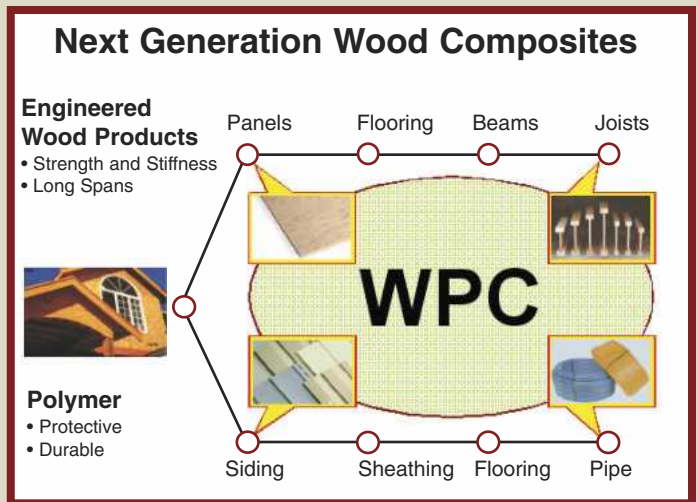


Figure 2a. — *Evolution of wood composites as building materials in the United States.*

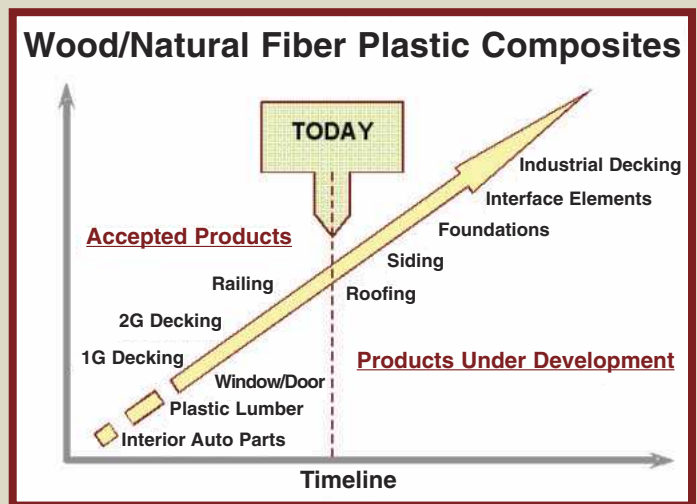


Figure 2b. — *Evolving applications for WPC materials in the United States.*

tions such as oriented strandboard (OSB) panels and laminated veneer lumber (LVL) products. Figure 2a illustrates how the wood composite and polymer industries have evolved separate building material solutions with different product applications. Traditionally, wood composites have emphasized strength, stiffness, and long spans in built-up members, whereas polymer products have featured durability and protection in weather-exposed applications. Today, hybrid WPCs are blurring these traditional lines to provide a superior value proposition that includes the best features of each material.

Over the past two decades, the successful adoption and diffusion of various wood composite products into U.S. timber construction markets has established the precedent for today’s new WPCs. For example, LVL and wood I-joist use by U.S. builders increased from approximately 2 percent for each product category in 1980 to 67 and 73 percent, respectively, in 1998 (Eastin et al. 2001). Similarly, OSB use increased from a 4 percent market share of North American structural sheathing in 1980 to

	Year							
	1997		2000		2004		2005 (est)	
	\$ (billion)	%	\$ (billion)	%	\$ (billion)	%	\$ (billion)	%
Lumber^a	2.784	96	2.848	89	2.963	79	2.925	75
WPC	0.058	2	0.256	8	0.563	15	0.702	18
Plastic	0.029	1	0.064	2	0.075	2	0.078	2
Imports	0.029	1	0.032	1	0.150	4	0.195	5
TOTAL	\$2.90	100	\$3.20	100	\$3.75	100	\$3.90	100

^a The 75 percent lumber in 2005 consists of approximately 66 percent pressure-treated lumber, 6 percent redwood, and 3 percent cedar.

approximately 58 percent in 2003 (Adair 2004). And the fiber-cement (FC) siding market share grew from 1 percent in 1994 to an estimated 13 percent of the 12.5 billion ft.² of siding, fascia, soffits, and trim products sold in North America during 2003 (Anon. 2004f). Figure 2b illustrates how improving material performance has impacted the evolving acceptance of WPC material solutions in residential, commercial, and industrial applications. A variety of WPC products (e.g., decking, railings, and window/door lineals) currently enjoy market acceptance whereas new generation WPCs with greater material performance requirements (i.e., siding, roofing, and industrial decking) are under development.

And finally, the highly effective combination of push-pull marketing communications employed by WPC manufacturers (and their distribution partners) has greatly facilitated the diffusion of these decking materials into the U.S. residential construction industry. The push promotion is aimed at the channel intermediary to persuade distributors to carry and/or stock a variety of stock keeping units (SKUs) of synthetic decking and railing products. Push tactics may include favorable credit terms, co-op advertising, sales contests, trade show assistance, training programs, and point-of-purchase (POP) displays. On the other hand, pull promotion targets the distributor's customer; that is, the builder and homeowner. These tactics are aimed at pulling customers into the store in search of their products through home and garden magazine ads, television home-improvement shows, trade/home shows, web-based information, NASCAR racing endorsements, and showcase product demonstration projects such as at Disney World, the Grand Canyon, and in the Everglades.

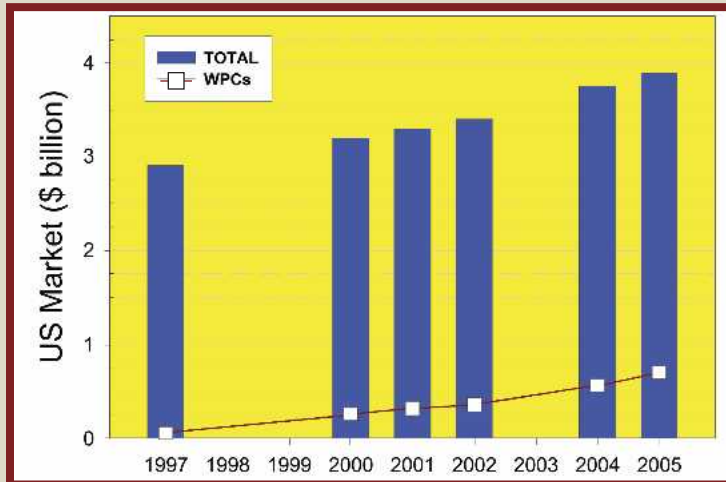


Figure 3. — U.S. WPC deckboard and railing market estimates and projections by product type and by value.

MARKET OVERVIEW

Over the past 20 years, use of composite materials has been transitioning from aerospace to civil structures. Nowhere is this transition more evident than in residential and light commercial timber construction where wood composites have substituted for structural component markets once dominated by solid wood. These wood-based composites have been successful in the marketplace primarily because they deliver a consistently appropriate

structural performance at a reasonable cost. Use of plastics in building and construction has also grown tremendously during this time, but for use in more protective and durable applications. With the growing need and interest in providing durable, environmentally sound alternatives to conventional building materials, hybrid materials like WPCs are emerging to fill the niche.

Commercial WPCs are produced with formulations composed of wood flour, synthetic thermoplastic resins, and additives (lubricants, inorganic fillers, coupling agents, stabilizers, and biocides) in various combinations. Among the thermoplastics used, virgin and recycled polyethylene is the most common with an estimated 83 percent market share followed by polyvinyl chloride (9%) and polypropylene (7%) (Morton et al. 2004). Many higher performance polymers such as nylons, ABS, SAN, and ASA have been used on a limited basis.

Residential decking and railings consumed nearly two-thirds of the \$1 billion (estimated retail) extruded WPC market in the United States in 2005, followed by window and door frames (11%), plus a wide variety of additional applications including but not limited to siding and accessories, fencing, boardwalks, docks, shingles, playground equipment, industrial infrastructure, and pallets (Morton et al. 2004; Smith and Wolcott 2005a, 2005b).

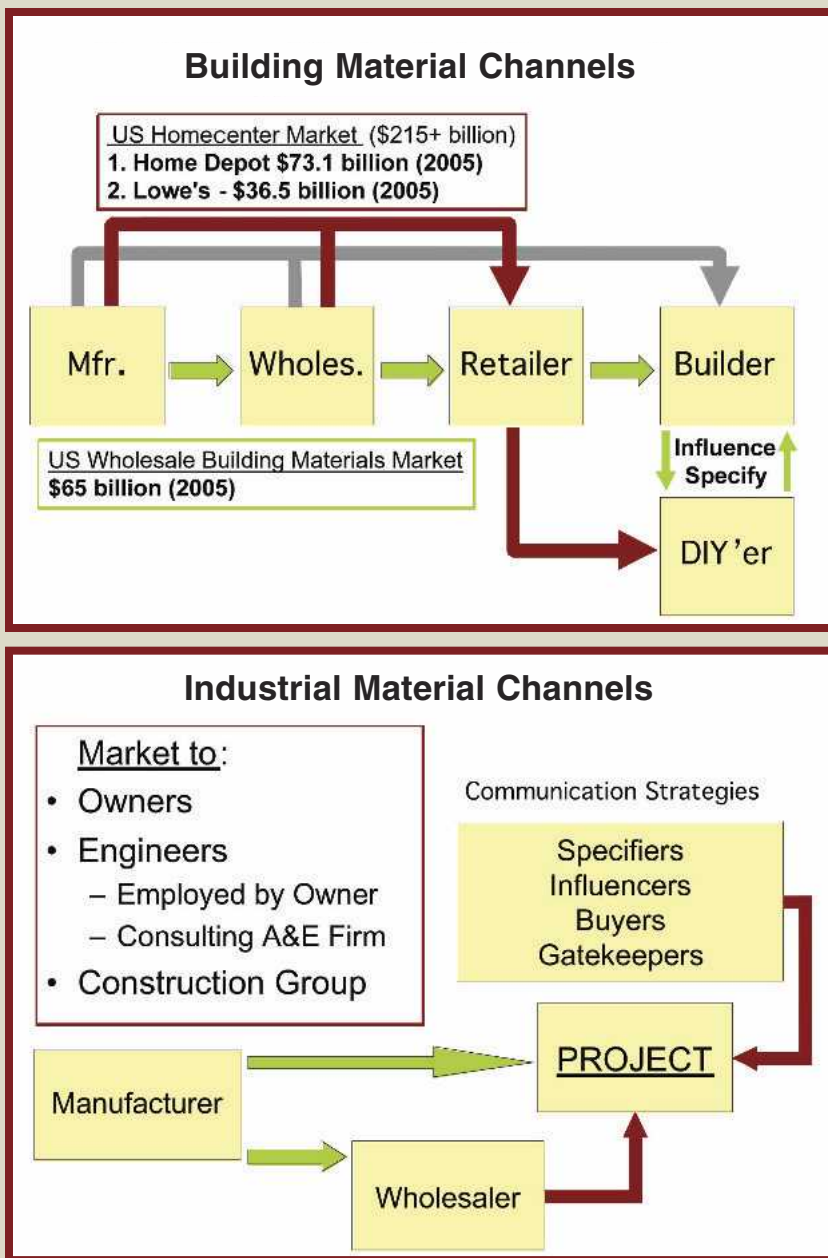


Figure 4. — Alternative channels for WPC products in the U.S. marketplace.

Decking and Railings

The greatest success of WPC products thus far has been in the \$3.9 billion (estimated for 2005) U.S. residential and industrial deckboards and railings market. Strong activities in new housing and repair/remodeling have resulted in the steady growth of the U.S. residential decking market. Over the past several years, pressure-treated wood has been losing market share to synthetics and imported products. Today, pressure-treated lumber is estimated to represent about 64 percent of the U.S. decking market followed by WPCs (18%), redwood (6%), imported wood species (5%), cedar (3%), and plastics (2%) (Fig. 3). Redwood and cedar are limited by production factors such as access to raw materials, and increasing limits to

old-growth forests, thus decreasing their potential for expanding market share. Imports of pine decking (both pressure-treated and untreated lumber destined for domestic treatment) from South America and Scandinavia are expanding and imported tropical hardwoods, such as Ipe, have increased market share in recent years.

The WPC share of the North American decking market has grown considerably, from about 2 percent in 1997 and 8 percent in 2000, to an estimated 18 percent in 2005, totaling \$700 million (Fig. 3). Those WPC decking and railing products were manufactured by about 30 firms that year.

WPC Perceptions in Decking Applications

Several pertinent market studies delineating buyer selection and perceptions of residential decking products have been conducted over the past decade. Shook and Eastin (2001) surveyed the decking material use of 320⁵ U.S. builders who indicated that long life, aesthetically pleasing appearance, and high durability were the 3 most important decking material attributes and that low material cost was the least important. This finding again dispels the notion that materials must be low cost to compete and supports the premise that a superior value proposition is the key to competitive advantage.

Smith and Carter (1999) examined WPC decking material perceptions from the largest 100 U.S. homecenter retailers and largest 100 U.S. builders in 1999. Retailers viewed WPC decking materials as more expensive than pressure-treated pine, redwood, and cedar, but also more resistant to decay and more environmentally friendly. Moreover, the largest 100 builders rated WPCs as more expensive than pressure-treated lumber, similar in price to cedar and plastic lumber, and less expensive than redwood. However, these builders rated WPCs as the most environmentally friendly material and the second most resistant to decay (after plastic lumber).

While studying U.S. homeowners in several New England states, Damery (2001) showed that 89 percent of respondents currently owned a deck made of pressure-treated lumber in the year 2000. However, only 62 percent of homeowners would choose pressure-treated lumber as their first choice in a replacement deck. Whereas only 2 percent of the homeowners surveyed owned a WPC deck, 15 percent said they would select WPCs as their first choice in a replacement deck. These findings underscore the strong dissatisfaction of many homeowners with pressure-treated decking.

⁵ A stratified sample of 2,400 firms (600 in each of 4 geographic regions of the United States) was selected from a database containing 100,000 single- and multi-family construction firms operating in the United States.

In a brand awareness study among builders, Trex® was the most familiar, followed by Certaineed®, TimberTech®, Nexwood®, LP WeatherBest®, and USPL® (Anon. 2003). In that same brand study, Trex® was viewed by builders as the highest quality brand of decking.

Distribution and Communication Strategies

Distribution channels and communication strategies for construction materials differ among product types and customers. For example, channels for industrial infrastructure materials rely heavily on project specifications that may, or may not, be influenced by in-house or independent architects, engineers, and owners (Fig. 4). This rather obscure process underscores the importance of understanding the appropriate mechanisms by which new industrial materials are communicated to the architectural and engineering community (both government and private). Demonstration projects, trade shows, and key trade journals and association newsletters are typically used to disseminate technical information to these technical audiences.

In contrast, distribution channels for residential and light commercial building materials may include wholesale and/or retail intermediaries who provide the goods and services direct to builders or Do-It-Yourself (DIY) buyers (Fig. 4). The U.S. home improvement market is comprised of approximately 41,600 independent hardware stores, homecenters, and lumberyards with total sales estimated at nearly \$245 billion in 2005 (Bucksot et al. 2004). Of this total, homecenters (\$149 billion) and lumberyards (\$66 billion) are estimated to account for approximately 88 percent (\$215 billion) with 2005 sales by the largest two homecenters, Home Depot (\$73 million in 2005) and Lowe's (\$36 million in 2005), representing about half of the total sales. In addition, approximately 5,500 lumber wholesalers operate in the United States, with a combined annual revenue of \$65 billion in 2005 (Anon. 2005). Most U.S. lumber wholesalers are privately-held companies with annual revenue of less than \$10 million.

Two key, and related, elements for successfully competing in U.S. building materials markets are 1) access to distribution channels; and 2) the ability to employ an effective communications program. A channel position is defined as the manufacturers' reputation among distributors for providing products, services, financial returns, quick response systems, and support and incentive programs vis-à-vis competitors. Competition for key building materials distributors is intense, barriers to entry are high, and channel positions are highly coveted for the significant competitive advantage they represent. An effective push-pull communication strategy is a key requisite for securing distribution contracts. The synchronization of the push-pull promotional efforts creates impressions and excitement regarding the products or brand and thus strengthens the manufacturers' channel position.

NEW PRODUCT AND MARKET DEVELOPMENT

New product development is high-risk, but necessary for business survival. Whereas 40 percent of new industrial products fail in the marketplace, up to one-third of profits for U.S. firms derive from new product introductions during the previous 5 years (Griffin 1997). In addition to increased profitability, new products serve to better satisfy changing customer needs and are essential to enhance a firm's image with customers, channel intermediaries,

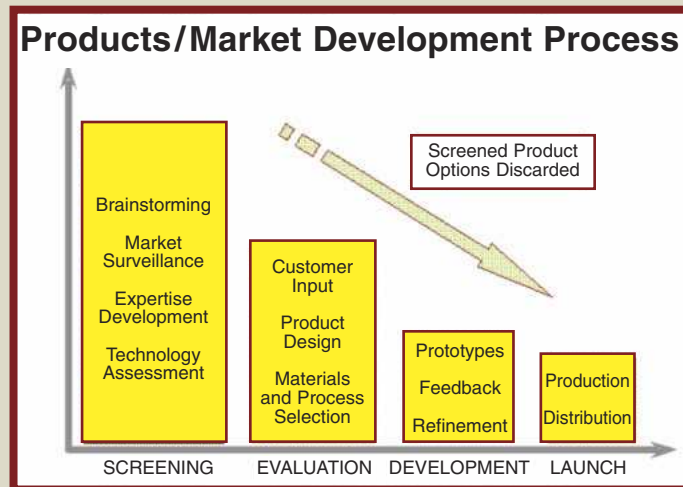


Figure 5. — Typical process for new development of new products and markets for U.S. industry.

and current/potential employees by positioning a company as innovative, creative, and cutting-edge.

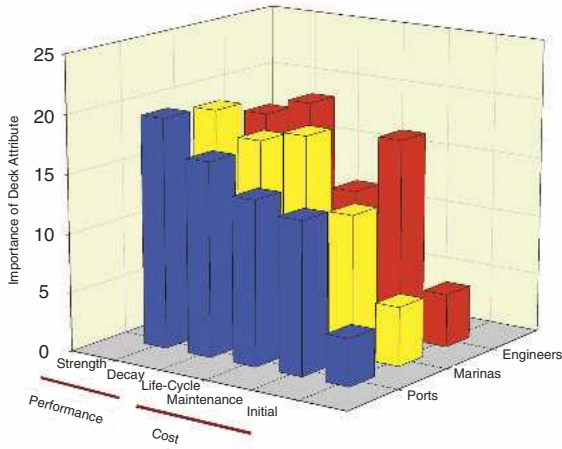
In many firms that service business-to-business markets, and particularly among forest products companies, new product development has traditionally been conducted by operations and engineering research and development (R&D) personnel. However, the growing trend is toward integrating the important role of business marketers into the process. Typically, new product development follows a process whereby ideas are initially generated and screened, then evaluated through various analytic techniques. The screened products are developed internally, tested internally and externally, and then launched.

As forest products firms' R&D budgets have stagnated, we are experiencing an increased demand on industry, government, and university partnerships to supply research that leads to new product development. The forest products industry has long been recognized as a leader in partnering with government and universities, but breakthrough technologies are now necessary to address environmental pressures, an aging production infrastructure, and increasing difficulty in attracting talented individuals (Showalter and Raymond 2004). Boehner (2004) has stated that the forest products industry is looking for well developed, easy to implement, close-to-market solutions, without large capital expenditures or significant disruption to operations. One challenge for future relationships is the industry trend toward increased secrecy and confidentiality. In contrast, academia has traditionally thrived on open sharing of knowledge. Finally, increasing competition is developing between ownership and control of intellectual property rights. These differences, although real, can be mitigated through effective communication between the academic community and senior level industry management.

Industrial Infrastructure Markets

Several of the more recent developments in WPC products and markets have emanated from research sponsored by the U.S. Navy and administered through Washington State University. This ongoing 7-year research program has developed and extended WPC technology and market know-how, while assisting in the development of additional structural and non-structural wood-based composite material solutions for indus-

Decking Attribute by Customer Group



Decking Perception for Material Type

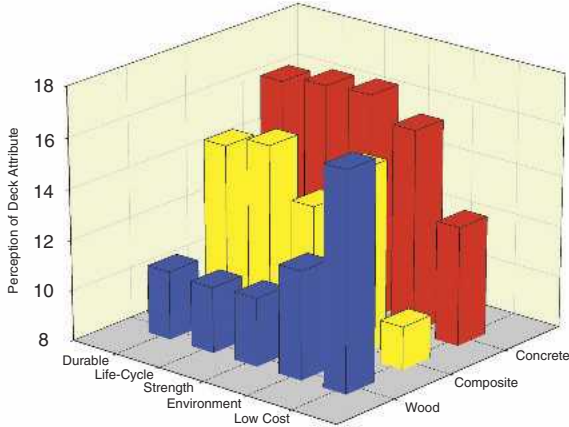


Figure 6. — Waterfront infrastructure decking material perceptions and comparisons by U.S. port authorities ($n = 165$), engineers ($n = 95$), and marina owners ($n = 11,045$) (Bright and Smith 2002, Smith and Bright 2002).

trial infrastructure applications around the world. The new product development process as applied by the U.S. Navy research team is illustrated in Figure 5. The brainstorming process serves as a screening mechanism of new product ideas. Additional product options are discarded as the new product/market development process continues in the identification of “low hanging fruit.” Ultimately, only a handful of prototype products are developed and fewer still make it into production.

A demand exists for strong, cost-effective, durable, and environmentally benign building materials for weather-exposed waterfront applications. Increasing marine borer populations, environmental concerns regarding the use and disposal of chemically treated wood in marine environments, and larger service load requirements are factors contributing to an interest in using new engineered materials for waterfront applications.

In 1999 and 2000, three nationwide surveys of decision makers at the nation’s 165 port authorities,⁶ 95 engineering consulting firms,⁷ and 11,045 marinas⁸ (Bright and Smith 2002; Smith and Bright 2002) indicated a need for waterfront materials and products with superior performance capabilities and a combination of “ideal” attributes that

may not be currently available in the marketplace. In particular, these industrial market studies showed that waterfront building materials and products are driven by performance features (strength, decay resistance, etc.) rather than initial cost and that life-cycle and maintenance costs were more important than initial material costs (Fig. 6).

These same three specifier groups for industrial infrastructure ranked wood lower on performance attributes (strength, long life, durability) and better on low cost (viewed as less expensive), when compared to concrete and composites (Fig. 6). These findings underscore the perilous position of treated wood materials and products that are currently used in waterfront infrastructure applications and lend credence to the viability of new composite products with superior value propositions for these markets.

Although much of the interest in engineered WPC materials arises from the U.S. Navy, other potentially high-volume residential and industrial infrastructure end-use applications exist within civilian construction markets. For example, the U.S. preservative-treated wood market totaled an estimated \$5.85 billion in 2004 and, at a projected 15 to 25 percent substitution rate, new product applications could represent a potential \$88 million to \$146 million opportunity for WPCs. The more favorable product/market opportunities for high-value, preservative-treated industrial lumber products include structural lumber, timbers, poles, ties, piling, landscape timbers, crossarms, and other products (Fig. 7) (Mickelwright 1998, Smith 2003). Expanding WPCs into these and other industrial infrastructure market applications will require targeted commercialization efforts building on research in product design, structural performance, durability, and customer acceptance.

SUMMARY AND CONCLUSIONS

The WPC market, although currently small, is rapidly growing. Penetration of WPCs into the decking market has attracted significant attention by both the forest products and plastics industries. Within the deckboard and railing market segment, WPC products will most likely be defined by branded offerings to specific target markets. In turn, these brands will be differentiated by design (profiles and hardware systems), material components, formulations, and a variety of environmental and service attributes. Essential market entry skills include access to distribution channels and the ability to implement an effective push-pull communications strategy. However, it is believed that decking and railing products are merely a first step in an expanding list of product offerings with the potential to enter other value-added and/or high-strength structural applications.

By incorporating continual new product development into a firm’s R&D process, the forest products industry can greatly benefit through increased profitability, improved customer and stakeholder perceptions, and reduced risk of litigation and regulation. Moreover, concurrent new product

⁶ Represents those U.S. Port Authorities listed in the American Association of Port Authorities (Mihaiu 1998).

⁷ Represents those U.S. engineering consulting firms listed in the American Association of Port Authorities (Mihaiu 1998) and involved in waterfront infrastructure projects in 1999.

⁸ Includes all U.S. marinas listed in the 1999 National Marina Directory published by the National Marine Manufacturers Association, Chicago, IL.

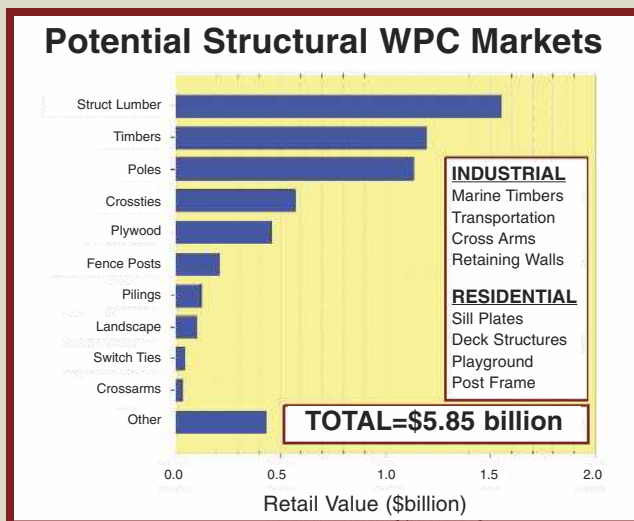


Figure 7. — Potential structural markets for WPCs based on the estimated value of preservative-treated wood produced in the United States. Retail value was determined by combining census volume data by Mickelwright (1998) and price data from Smith (2003) and Smith and Wolcott (2005).

and market development efforts, integrating customer needs back into the design and engineering of new products, will provide competitive advantage to WPC industry innovators.

Considerable R&D attention has recently been focused on reducing WPC product weight through commercial foaming processes and the design and production of structural elements with complex cross sections. These technologies hold tremendous promise for expanding market applications for these WPC materials. Increasing R&D expenditures and capital investments in WPC commercial ventures are anticipated. Opportunities also exist for the development of a WPC trade association to standardize products and help mitigate liability concerns.

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