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The U.S. non-wood, non-metal primary building materials sector in flux: A sectoral analysis and a proposed materials development and innovation framework

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Abstract

An examination of the building materials sector raised two critical questions: Why do more firms in the building materials sector not attempt to directly gauge end-users' preferences? And, why do many materials producers employ self-limiting definitions of building materials? The sector was analyzed using transaction cost economics and network theory. A framework was then developed for materials development and innovation. The role of a key actor in the framework, the researcher, was illustrated through a materials study performed in a developing country. In concluding, it is suggested the framework could be used to expand the study, expand markets for the producer and strengthen producer–researcher links.

Keywords: Building sector analysis; Building materials development; Organizational analysis; Technical materials research; Aesthetics and perceptual materials research

1. Introduction

The building materials sector is at a crossroads, given its decreasing share of the domestic market and the increasingly prominent role of imported building materials. A key reason for this decline is that the links between materials producers and end-users are fuzzy at best and non-existent at worst. Concerted efforts are needed to bridge this divide. Moreover, firms in the building materials sector also need to explore ways in which they can expand beyond their traditional markets to spur organizational and sectoral growth. Beyond that, this type of expansion would also provide a financial buffer for the building materials firms whose existence is contingent on the seasonal variability of national and sub-national economies. However, for this expansion to occur, building materials firms need to establish more systematic processes for gauging consumer preferences.

In this paper, the building materials sector is analyzed in order to gauge the current state of the sector. Following that, sectoral and individual actor analyses of the sector are performed using organizational theory, specifically transaction cost economics and network theory. After the analysis, a framework is proposed that would not only provide better links between materials producers and end-users, but that also charts the way for further innovation in the building materials sector. The framework also charts a path that materials producers could use in expanding to foreign markets. The role of one of the actors in the framework, the researcher, is illustrated through a materials research study performed in a developing county, Kenya. Additional discussion of the framework notes its flexibility; for instance, the framework could be modified to suit different regions or different types of building products.

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2. Current situation of building materials sector

An analysis of the overall state of the current construction sector would create the impression that the sector as a whole is rather robust; in fact, economic analysts have suggested that one of the main reasons the economy recovered from the recent recession was the bullish state of the homebuilding sector. However, when the construction sector is divided into services and materials sub-sectors, it becomes evident that while the engineering services and specialty construction sectors are well-positioned for future growth, the non-wood, non-metal primary building materials sector is on shakier economic footing.

Nowhere else is this more apparent than in the current state of the U.S. export market for building materials, and particularly non-wood and non-metal primary building materials, such as concrete. Table 2 shows data for 2002 on the average foreign sales of a Fortune 500 firms arranged by two-digit SIC code. The stone, clay, glass and concrete products group had foreign sales of 14.62% of total revenue. In contrast, the engineering services group had sales of 45.69%, the fabricated metal products group had sales of 32.683% and the lumber and wood products group had sales of 21.717%. Given that the homebuilding boom is predicted to slow in the next few years [1], it is only logical to question the future of the non-wood and non-metal primary building materials sector absent a viable strategy for expanding access to untapped markets. Many firms already understand this intuitively, having long taken advantage of "various U.S. regional economies to balance sales. If sales slumped in New England, sales could still climb in the Southwest" [2]. These firms now need to also target overseas markets, which would protect them "from a fluctuating U.S. economy" [2], while expanding opportunities in the domestic market.

I will cite three specific sources to point out some troubling trends in the building materials sector: data on average foreign sales for Fortune 500 firms; data on foreign trade in building materials; and selected market research reports.

Davis [1] compiled 2002 data on average foreign sales for Fortune 500 firms grouped by two-digit SIC code. This information is shown in Table 1. The groups with the lowest percentage of foreign sales were health services, agricultural services and the building materials..., and mobile home dealers group (all 0%). The groups with the highest level of foreign sales are: leather and leather products (56.451%); engineering, accounting, research ... and related services (45.690%); and electronic and other electrical..., except computer equipment (44.367%).

The construction and special trade contractors group (43.249%) also had significant proportion of its revenue from foreign sales. In contrast, building construction general contractors and operative builders (3.598%), heavy construction other than building construction contractors (14.304%), and stone, clay, glass and concrete products (14.610%) all had relatively low levels (less than the mean) of average foreign sales. Lumber and wood products, except furniture, had average foreign sales (21.717%) almost equal to the mean (21.753%). Two other construction materials-related groups had relatively significant average foreign sales: primary metal industries (27.014%) and fabricated metal products, except machinery and transportation equipment (32.683%).

Based on the above data, it is evident that the metal and wood materials groups, and the engineering services and specialty contractors groups all had above-average levels of foreign sales. Above-average foreign sales are essential for ensuring that establishments are buffered from the inevitable swings of the domestic economy, as this results in financial stability. On the other hand, all other construction-related groups either had average foreign sales that were about the mean or lower than the mean. In the case of the building materials dealers group, average foreign sales were non-existent. The stone, clay, glass and concrete products group had low levels of foreign sales, a feature that is characteristic of all concrete and masonry-related products.

The second source of data reports on foreign trade in construction materials published by the U.S. Department of Commerce, International Trade Administration [3–5]. From the years 1996 to 1998 (Table 2), the balance of trade for all SIC-coded non-wood building products groups [3] was positive in 1996 and 1997 ($ 391.3 million and $ 819.4 million, respectively) and negative in 1998 ($ −1.3361 billion).

Because the data from 1998 to 2003 is arranged by NAICS codes (Table 3), complete equivalency cannot be assumed between this data and that from the years 1996 to 1998. However, from 1998 to 2003, the negative trade balance for U.S. non-wood building products has increased every year. In fact, the negative trade balance's annual percentage increase ranged from 13.6% (1999–2000, 2000–2001) to 159.1% (1998–1999). The increasing reliance of the U.S. building materials sector on imports does not bode well for domestic producers.

The third set of data sources was select market research reports by the U.S. and Foreign Commercial Service (US&FCS) and U.S. Department of State [6,7]. Two markets of differing sizes, Japan and Israel, were selected to depict the heterogeneity of options that materials producers face when considering targeting foreign markets. Japan is a good representative of a large market for U.S. exports. Japan accounts for 7.19% of all U.S. exports and 25.2% of all U.S. exports to Asian countries (Table 4). According to Takabatake [6], "the total size of the Japanese building products market (both residential and commercial) is estimated at roughly 13.9 trillion yen (US$120 billion at 116 yen/dollar) in 2003. Although the building products market has been declining over the last several years due to weak economic conditions, the Japanese economy shows signs of recovery and it will likely resume its healthy growth rate over the medium to long term". Of interest to U.S.

Table 1
Average foreign sales, per cent (source: Ref. [1])

Average foreign sales for fortune 500 firms, 2002, two-digit SIC coding

	SIC group description	SIC	Average foreign sales (%)
1	Health services	80	0
2	Agricultural services	7	0
3	Building materials. . ., and mobile home dealers	52	0
4	General merchandise stores	53	1.939
5	Home furniture, furnishings, and equipment stores	57	2.365
6	Food stores	54	2.466
7	Railroad transportation	40	2.471
8	Automotive dealers and gasoline service stations	55	2.894
9	Depository institutions	60	3.554
10	Insurance Carriers	63	3.556
11	Building construction general contractors and operative builders	15	3.598
12	Communications	48	4.810
13	Electric, gas, and sanitary services	49	6.269
14	Wholesale trade—non-durable goods	51	8.010
15	Apparel and accessory stores	56	9.685
16	Miscellaneous retail	59	9.875
17	Hotels, rooming houses, camps, and other lodging places	70	10.850
18	Printing, publishing, and allied industries	27	11.705
19	Real estate	65	12.066
20	Heavy construction other than building construction contractors	16	14.304
21	Stone, clay, glass, and concrete products	32	14.611
22	Automotive repair, services, and parking	75	18.096
23	Forestry	8	18.306
24	Motor freight transportation and warehousing	42	19.462
25	Furniture and fixtures	25	20.977
26	Non-depository credit institutions	61	21.083
27	Lumber and wood products, except furniture	24	21.717
28	Wholesale trade—durable goods	50	22.915
29	Oil and gas extraction	13	25.113
30	Petroleum refining and related industries	29	25.375
31	Food and kindred products	20	25.394
32	Apparel and other finished products . . . and similar materials	23	25.420
33	Transportation by air	45	25.443
34	Tobacco products	21	26.521
35	Security and commodity brokers, dealers, . . ., and services	62	26.890
36	Primary metal industries	33	27.014
37	Paper and allied products	26	27.853
38	Eating and drinking places	58	32.428
39	Fabricated metal products, except machinery . . .	34	32.683
40	Transportation equipment	37	33.727
41	Measuring, analyzing. . . and optical goods; watches and clocks	38	35.030
42	Metal mining	10	37.212
43	Rubber and miscellaneous plastics products	30	39.169
44	Miscellaneous manufacturing industries	39	40.444
45	Insurance agents, brokers, and service	64	41.636
46	Textile mill products	22	41.709
47	Business services	73	41.714
48	Chemicals and allied products	28	41.909
49	Industrial and commercial machinery and computer equipment	35	42.900
50	Construction special trade contractors	17	43.249
51	Electronic and other electrical. . ., except computer equipment	36	44.367
52	Engineering, accounting, research, . . ., and related services	87	45.690
53	Leather and leather products	31	56.451
Mean average foreign sales for all 500 firms			21.753

building products manufacturers is the fact that Japanese "imports of both residential and commercial building products were 1.17 trillion yen (US$10.1 billion) on a CIF (cost plus insurance and freight) basis in 2003, including 112 billion yen (US$968 million) from the United States, representing an import market share of 9.6%" [6]. Out of this total, the import market size for residential building products was estimated at 45 billion yen (US$388 million), of which 16 billion yen (US$136 million) was from the U.S.; "it is also estimated that the United States and Canada are the two largest suppliers and each country has a market share of about 35%" [6].

Furthermore, globally, the Japanese housing market [6] is second only to that of the U.S.; in 2003, Japan had 1.16 million housing starts compared with 1.57 million housing starts for the U.S. The Japan US&FCS report notes that "the imported housing market is very receptive to U.S. residential building products and currently offers the greatest potential for U.S. building products" [6]. Moreover, "homebuyers' demand is a key factor in homebuilders' decisions to use imported building products. Major reasons for choosing to build with imported products include quality, design and cost" [6]. Takabatake notes that "a survey of builders and architects conducted by the JETRO Housing Materials Center in Osaka showed that consumer preference is a key factor in determining use of imported products in Japanese homebuilding" [6]. Interestingly, the predominant approach to marketing building materials (both in domestic and foreign markets) is to target architects and builders, rather than the end-users or consumers.

In most cases, invention or innovation in the building materials/products sector happens when architects or builders transmit second- or third-hand feedback to manufacturers. There are certain exceptions, such as when the Robinson Brick Company [8] targets end-users over the

Table 2
Non-wood, non-metal building materials trade data (source: Ref. [3])

U.S. non-wood building products exports, imports, and trade balances, 1996–1998 by two-digit SIC product groups (Census Basis; Foreign and Domestic Exports, F.a.s.; General Imports, Customs; Millions of Dollars)

	1996	1997	1998	1996–1998 change
Total exports for building materials	9924.8	11,182.6	10,793.8	869
Total imports for building materials	9533.5	10,363.2	12,129.9	2596.40
Total trade balances for building materials	391.3	819.4	−1336.1	−1727.4

Internet, or when Owens–Corning [9] pitches its pink insulation foam directly to end-users in television commercials. Why should this not be standard practice when, clearly, the "chief decision maker regarding use of [imported] building materials is most often the prospective homeowner" [6]?

In contrast to Japan, Israel is a relatively small market for U.S. exports. For the year 2003, Israel accounted for only 0.95% of all U.S. exports; however, Israel accounts for 35.52% of all U.S. exports to countries in the Middle East (Table 4). In 2002, the U.S. accounted for only 12% of all Israeli imports of construction and building materials. Wielunski notes that the "building materials market is a $2 billion sector that is heavily focused on home renovation" [7]. Of this figure, more than half was made up of imports in 2002, with $120 million being imported from the United States. In contrast to the large homebuilding market in Japan, there were only 28,000 housing starts – down 4175 units from 2002 – in Israel in 2003 [7].

The US&FCS Israel report notes that due to external pressures such as the Palestinian intifada, the construction sector has experienced declines in available labor and credit [7]. As such, the niche that American exporters can exploit is the introduction of "new, especially labor-saving, methods and technologies that will help to speed up the building process." There is also a demand for specialty American products such as "concrete stone with special finish or other unique properties such as being porous, acoustic or made of mixed granite stone" [7]. The major disadvantage facing American exporters is that the Israeli market has become very price competitive.

To remain competitive in the building materials market, American companies need to shift towards exporting building technology and services rather than traditional building materials. Over the past decade, the Israeli market has become very price competitive. American companies have been losing ground to Chinese imports of lower cost and improving quality. Additionally, U.S. companies are unable to compete with European exporters of raw building materials because of the high cost of shipping. To circumvent these disadvantages, American companies must focus on the licensing of technology and the establishment of joint ventures in order to produce their products in Israel. [7]

Licensing and joint ventures can only work successfully when the product in question is innovative and of good quality. U.S. producers possess the technological know-how to excel in exporting building technology and services.

While the U.S. construction materials sector has the technological know-how to make this type of innovation possible and commonplace, most firms in this sector take a more cautious and conservative approach. There appear to be two motivations for this conservative behavior. The first and primary reason is the nature of the feedback process between the producer and the end-user. In both domestic and foreign markets, this feedback is indirect and mediated by third parties, such as architects and builders; it would be unwise to posit that these third-parties have the neutrality necessary to act as objective arbiters of the information flow between producers and end-users.

The second reason for the conservativeness in the construction materials sector is the propensity by many in the industry to approach construction materials purely from the perspective of physical entities, as opposed to also seeing the potential for materials to be regarded as intellectual property. In the first conceptualization, materials (as 'physical entities') present the firm with transportation problems among others. For example, dimension stone has to be quarried, worked and transported from the primary site of operations to a major port from where it is shipped to the foreign market being targeted. Both intra- and inter-national transportation can add substantially to the costs of materials, especially when the materials in question are low-value. In

Table 3
Non-wood, non-metal building materials trade data (source: Refs. [4,5])

U.S. non-wood building products exports, imports, and trade balances, 1998–2003 by six-digit NAICS product groups (Census Basis; Foreign and Domestic Exports, F.a.s.; General Imports, Customs; Millions of Dollars)

	1998	1999	2000	2001	2002	2003	1998–2003 change
Total exports for building materials	12,656	13,021	15,024	14,118	12,789	12,797	145
Total imports for building materials	14,154	16,903	19,434	19,128	20,270	22,029	7875
Total trade balances for building materials	−1498	−3882	−4410	−5010	−7481	−9232	−7730

Table 4
U.S. export data (source: Ref. [10])

U.S. total exports to select regions and countries, 1997–2003 (Census Basis; Foreign and Domestic Exports, F.a.s.; Millions of Dollars)

Country/Region	1997	1998	1999	2000	2001	2002	2003	03–02 change ($)	03–02 change (%)
World	689,182	682,138	695,797	781,918	729,100	693,103	724,006	30,903	4.5
Asia	213,547	187,566	190,881	218,796	198,929	193,494	206,631	13,138	6.8
Japan	65,549	57,831	57,466	64,924	57,452	51,449	52,064	615	1.2
Middle East	20,928	23,661	20,885	19,015	19,278	18,930	19,365	435	2.3
Israel	5995	6983	7691	7746	7475	7027	6878	−148	−2.1

the second conceptualization, materials (as ‘intellectual entities’) do not have the same transportation limitations, meaning that they can be disseminated quickly and more easily. For example, a building materials firm can develop a new type of concrete-stone, develop the appropriate technology for producing the material and either establish joint ventures with firms in overseas markets or license the technology to foreign firms in return for royalty payments. In reality, an optimal approach would have to consider both aspects of construction materials.

Given the preceding discussion, I would pose two questions. First, why is it that more establishments in the building materials sector do not make the effort gauge more directly the preferences of their end-users? And secondly, why do many of these materials producers employ self-limiting conceptions of what building materials are? The answer(s) to these questions are rooted in structural problems in the building materials sector. To answer these questions, one must perform a multi-level analysis of the building materials sector; at the sectoral level, at the organizational level and at the level of the individual actors. Such a multi-level analysis would combine some or all of the levels I have described (or even more if there is any utility to such a process). In this paper, the building materials sector was analyzed using organizational theory. Given that organizational theories define individual, organizational and sectoral structure and processes, they lend themselves to the multi-level analysis necessary to answer the two questions posed.

3. Organizational perspective of building materials sector

I have already mentioned in the preceding chapter two of the main causes responsible for hindering U.S. establishments from better understanding end-user preferences, and hence hindering how effectively they can target foreign markets. I will now restate them in organizational theory terms. Since I intend to shed light on these questions by examining the entire sector as a single entity (although some may argue that looking at the sector as a single entity is too simplistic, I would aver that it lends clarity to my analysis), the issues will be framed by looking at organizational theories that permit analysis at both the level of the individual establishment and the sectoral level. More specifically, I will address these issues firstly by using transaction cost economics [11], and secondly by using network theory or perspective [12].

3.1. The first issue

In the construction sector, tasks and procedures that could be applied to improve the communication between end-users and producers are seldom internal to a firm. For conceptual clarity, these tasks and procedures can be described as ‘transactions’. I will define ‘transaction’ shortly.

Typically, the only internal structure set up for promoting a firm’s products is the marketing and/or sales department. This department is limited in efforts to better understand consumer preferences because the typical building materials producer thinks of architects and builders as the clients. In fact, a more nuance definition of ‘clients’ would have to include end-users. Consequently, the firm would have to target each of the different client groups differently. There have been various attempts by some firms to do this. The degree to which these attempts have been successful is yet to be determined; for example, while Owens–Corning executives recognized that “contractors, distributors, and builders are the gatekeepers in the building products business” [9], and that they had to “find a way to increase consumer influence,” it is unclear to what extent Owens–Corning’s efforts to market its products directly to the end-user have improved sales revenues. More importantly, Owens–Corning represents a small minority of firms in the construction products sector that are willing to explore non-traditional ways of selling and marketing their products. Such a non-traditional approach might include, for example, novel means of soliciting consumer preferences. Unfortunately, such structures are often external to establishments in the construction products sector if they exist at all. Moreover, building materials sector firms are often unaware of or are unwilling to utilize such structures given their conservative attitude to product development and marketing. For example, while researchers in various settings have explored the perceptual and aesthetic attributes of building materials, this body of work is seldom if ever used by building materials producers. Other parties, such as architects and developers, show more of an interest in this type of research than do buildings materials producers.

A 'transaction' is an exchange of goods or services between actors across boundaries of any sort. Williamson [11] suggests that the 'transaction' is the basic unit of economic analysis, an idea first advanced by Commons in 1934. Williamson's contribution to organizational theory is to state that the determination of the most efficient boundary of the firm is the decision variable in transaction cost economics (TCE). The boundary of the firm is the interface that separates the firm from the market. Functions that are non-specialized (not transaction-specific) are best left in the market, while transaction-specific functions are best internalized in the firm's structure. Basically, "only two organizational alternatives are considered: either a firm makes a component itself or it buys it from an autonomous supplier" [11].

In the case of the building materials sector, the transactions that would most help producers better gauge consumer preferences would include, for example, empirical research on end-user preferences for different properties of specific materials, such as color, texture, grain and mass. There are three critical dimensions for describing transactions: frequency with which transactions recur, uncertainty and asset specificity. Uncertainty and asset specificity are the two most critical dimensions of transactions. Of these two, "asset specificity is ... the most important dimension for describing transactions" [11]. Asset specificity takes three forms: site specificity, as when assets are co-located for the purposes of economizing on expenses, such as inventory and transportation; physical asset specificity, as where one asset is required for the production of another; and human asset specificity, which arises from learning-by-doing.

Non-specialized investments do not pose a hazard to either buyers or sellers in a market because alternatives exist [11]. However, if an investment is transaction-specific, once it is made, the buyer and seller operate in a bilateral exchange for a considerable period of time. It is therefore in the interest of the buyer and seller to design an exchange that has good continuity properties. Essentially, this is the relationship between producers (the 'buyers') and researchers (the 'sellers') where the commodity concerned is information on the end-user preferences for specific materials or certain qualities about these materials. But in this case, the relationship gets even more complicated because it is mediated by a class of third-parties, designers and builders.

A TCE-influenced response to the first question I posed would have to note that empirical research, for example, is currently a market 'transaction'. However, the friction caused by the presence of third parties would necessitate the firm expanding its boundary to include some functions of research on consumer preferences. Also, a TCE-influenced response to the second question would have to note that the third parties responsible for the 'weak ties' between the producer and the consumer and the designer and the builder, are also the ones for whom a definition of materials as 'intellectual entities' have no import. These third parties operate entirely in the realm of materials as 'physical entities'. As such, the materials firm would have to expand its boundary to capture some of the market research functions that would make it easier to deal with materials as intellectual property, and not merely 'physical entities'. Considering site specificity and human asset specificity, for example, a firm in the building materials sector could either 'internalize' the task of researching consumer preferences and materials' definition to the extent that it hires an in-house researcher, or it could wholly or partially fund empirical and market research by another local or regional organization primarily involved in this type of work, such as a university department or research institute. In so doing, the building materials producer would be assured access to research that directly examines consumer preferences or captures non-traditional conceptions of building materials.

3.2. The second issue

The second issue is related to the first. However, whereas the first issue addresses the problematic question I initially posed at the sectoral level, the second issue addresses the question at the level of individual actors.

It is inconceivable that the third parties who mediate the flow of information on consumer preferences between producers and end-users, and researchers and materials producers would encourage any changes that would dilute this advantage. By playing the role of mediator, these actors are able to leverage both producers and end-users to their own advantage. For example, if a builder told a brick producer that certain colors and textures were considered 'hot' by end-users, the producer would mostly have to unquestioningly accept the builder's assessment of consumer preference. In a like manner, while the end-user is nominally the most important determinant of building materials used in construction (especially residential construction), many architects are usually able to hold sway over their clients; in essence, architects can get clients to accept their judgment because they are better informed on availability of materials. A better informed consumer could conceivably stand their ground despite the architect's opinion, and in the process get materials more in tune with their preferences. Finally, in a situation where the designer has a good exposure to empirical research on consumer preferences of building materials, they can use whatever interpretation suits them best if they are fairly confident that the materials producer is largely unaware of this body of knowledge.

An organizational theory that lends itself to analysis of the ties and links between the various actors involved in the process of determining consumer preferences, and interpreting that information for the production of building materials (to suit these preferences) is the network perspective. A core construct of Burt's [12] discussion of networks as a form of social capital is 'structural holes'. Burt states that the most important characteristic of a good network is non-redundancy of contacts. "Contacts are redundant to the extent that they lead to the same people and so provide the same information... Non-redundant contacts are connected by a structural hole. A structural hole is a relationship of non-redundancy between two contacts" [12]. Burt's key insight is the argument he develops by combining the concept of structural holes with that of 'weak ties' developed in Granovetter in 1973. Essentially, the 'weak ties' proposition is that "people live in a cluster of others with whom they have strong relations. Information circulates at a high velocity within these clusters. Each person tends to know what the other people know. Therefore, and this is the insight of the argument, the spread of information on new ideas and opportunities must come through the weak ties that connect people in separate clusters. The weak ties so often ignored by social scientists are in fact a critical element of social structure" [12].

The actor who spans the structural hole between separate clusters (thus exploiting a weak tie) can accrue profit by gaining both information and control benefits made possible by the hole. Actors "with a network optimized for structural holes enjoy higher rates of return on investments because they know about, and have a hand in, more rewarding opportunities... The structural holes that generate information benefits also generate control benefits, giving certain players an advantage in negotiating their relationships" [12]. These actors are able to do this by assuming the role of the *tertius gaudens*, the third who benefits. This characterization of the *tertius gaudens* was first proposed by Simmel in 1923. Burt notes that there "are two *tertius* strategies: being the third between two or more players after the same relationship, and being the third between players in two or more relations with conflicting demands" [12]. The second strategy is a better description of the role architects and builders play in mediating information flow between end-users and producers.

While "information benefits of structural holes might come to a passive player ... control benefits require an active hand in the distribution of information" [12]; that is, the hand of an 'entrepreneur'. Entrepreneurs obtain control benefits by brokering 'tension' between other players; "the tension essential to the *tertius* is merely uncertainty" [12]. The *tertius'* "motivation is now an issue. The *tertius* plays conflicting demands and preferences against one another, building value from their disunion" [12]. Given the advantages the structural hole gives the *tertius*, it is to be expected that the *tertius* would vigorously oppose any attempts by the other players to bridge the structural hole in a manner that would weaken their control over the network of relations. For example, Owens–Corning dropped an idea to "establish kiosks in home-center stores that would allow consumers to contact Owens–Corning directly to serve as the general contractor for home improvement projects" [9] after running into opposition from local contractors. In hindsight, Owens–Corning might have overcome this spirited opposition and bridged that structural hole had they stayed the course, rather than acquiesce to the contractors' demands.

After having $5 billion in revenues during the 1990s, Owens–Corning's sales have stagnated in the last few years; for example, sales dropped from $4.9 billion in 2000 to $4.7 billion in 2001 [9]. Increasingly, Owens–Corning's executives have realized that the only way out of this slump is to increase more business-to-consumer links. All the firm did by capitulating to contractors on its kiosks idea was to delay the inevitable conflict that must occur for that structural hole to be bridged (or filled up!).

Generally, building materials producers face two structural holes (Fig. 1, top and bottom). The first hole is between them and empirical researchers of consumer preferences for building materials. The second hole is between them and the information borne out of the real-life feedback from the end-users of buildings materials. In both cases, the third parties straddling the holes are designers and/or builders.

4. Framework for building materials development

In this section, I will propose a framework that is in part a response to some questions I raised earlier. To reprise, the questions were: "Why is it that more establishments in the

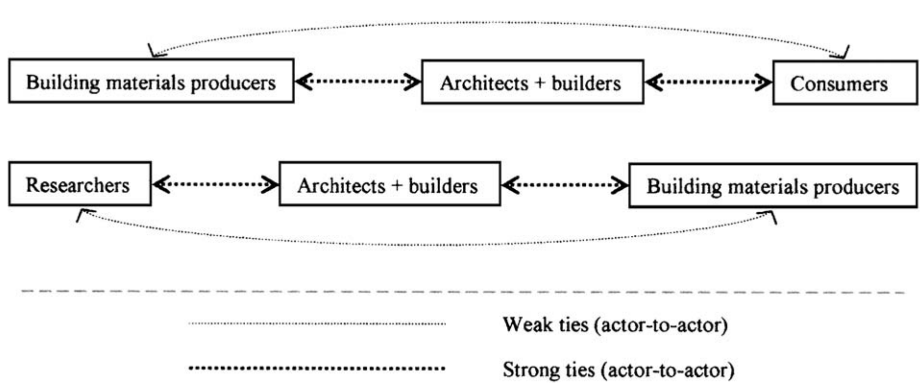

Fig. 1. Two types of weak ties that materials producers face.

building materials sector do not make the effort to more directly gauge the preferences of their end-users? Moreover, why do many of these materials producers employ self-limiting conceptions of what building materials are?"

Fig. 2 shows a framework that would not only help the building materials producer bridge the main structural holes he or she faces, but also establishes a means for initiating and sustaining innovation and the development of new building materials. Innovation could include those situations where new materials, the technology for producing them and the processes that optimize on their application are marketed as one product; material is considered an 'intellectual entity'. Also, any one of these steps just mentioned could also be marketed by itself as a stand-alone 'intellectual entity'. Moreover, the framework shows a potential path the producer can take in targeting new markets.

The paths and feedback loops in the framework are as follows:

- A1. The existing standards act a benchmark for any new products or innovations that the producer may generate.
- A2. The producer, in the process of generating new products and innovations, proposes new standards. Should the producer create these standards with a credible, independent third-party testing agency, the standards would have more legitimacy in the building materials sector.
- B1. The researcher appraises the producer on the most up-to-date materials technology, especially technology that is most suitable for immediate application. Researcher also communicates current research findings directly to the producer, especially findings that are most ready for the market.
- B2. The producer educates the researcher on the most pressing research needs, whether in materials development or production processes.
- C1. The producer acquires materials from other firms in the sector or from other sectors with an eye to evaluating their availability for use as building materials in a particular segment of the population.
- C2. The producer makes some exploratory building materials prototypes based on specific attributes deemed important to consumers, or that consumers might desire in a material once they are made aware of them.
- D1. Basic and applied research in materials may lead to the development of new standards.
- D2. Existing standards may provide the framework within which researchers conduct basic and applied materials research.
- E1. Basic and applied materials research would lead to the development of exploratory prototypes, that are not fully tested for the market and based on existing or new standards.
- E2. The researcher may test or evaluate exploratory prototypes, whether developed by researchers or by producers, and in the process better gauge the prototypes' strengths and weaknesses. This testing could be 'attribute-based' (perceptual and aesthetic) or 'performance-based' (technical factors).

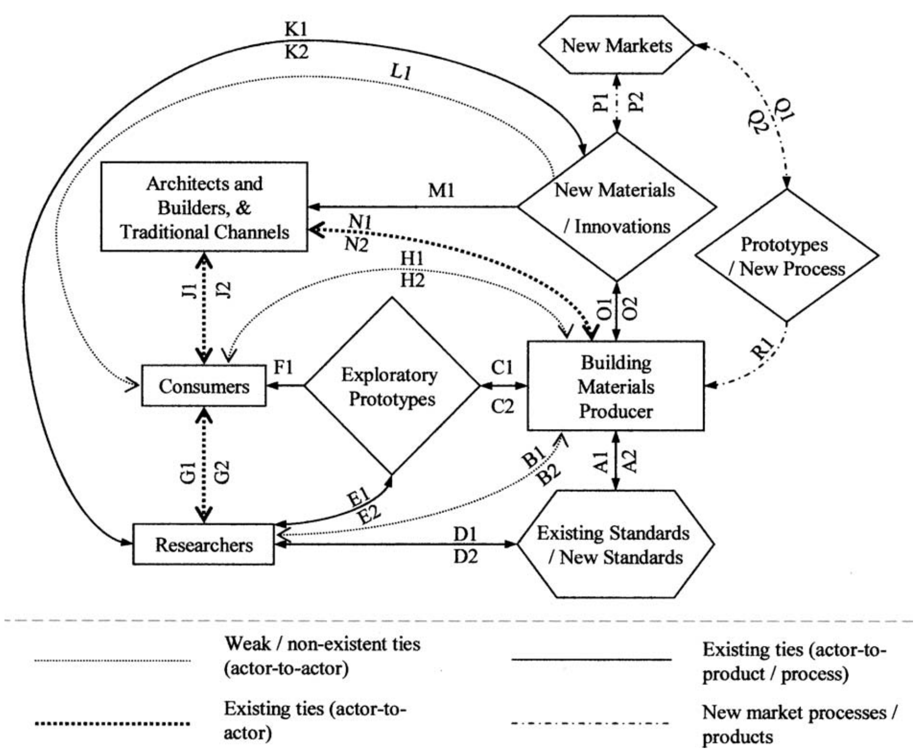

Fig. 2. Framework for building materials development and innovation.

F1. The consumer would be allowed to interact with exploratory prototypes before they have been fully tested as this might reveal hidden strengths and weaknesses that ought to be addressed before the product is prepared for the market.

G1. The researcher would provide the consumer with information on available technology, materials, and innovations, especially highlighting ways they may or may not be appropriate for certain situations or projects. The researcher would also conduct research on the consumer's preferences; this research would be of a mostly attributive nature.

G2. The consumer would reveal their preferences for materials, specific attributes of different materials or for particular processes and innovations.

H1. The consumer supplies feedback to the producer. This feedback is based on the consumer's real-life experience and use of particular materials and processes.

H2. The producer would inform the consumer on available choices; for example, on whether or not a particular material suits the consumer's needs and for a fair price, despite the builder not informing the consumer about this fact.

J1. The consumer would reveal his or her preferences to the architect and/or builder during the design and building process.

J2. The architect and/or builder can inform the consumer on the pros and cons of using a particular material for certain applications or in specific situations.

K1. The researcher would test or evaluate new materials and innovations, whether this is technical or attributive testing.

K2. Basic and applied research would lead to the production of new materials and innovations.

L1. The consumer would evaluate new materials and innovations either in a research setting or in a real-life setting, such as when the consumer is commissioning a new project. The producer should also make it possible for all consumers to evaluate new materials, within reason of course, as this would not only provide invaluable feedback, but may also expand the producer's revenue base by creating new customers.

M1. The architect and/or builder would evaluate new materials, particularly in the course of working on various projects.

N1. After evaluating the new materials or innovations, the architect and/or builder would then give this feedback to the producer. The producer should not only encourage feedback from the architect and the builder by instituting a relatively painless process for doing so, but the producer might also want to give the architect and builder an incentive for doing so. For example, the architect and builder would receive a commitment from the producer to receive information on certain products, be it negative or positive information, before such knowledge is widespread among other builders and producers.

N2. The producer provides the architect and builder with feedback on specific materials before such information is commonplace. The producer could also provide the architect and builder with the type of information that I have just described above.

O1. Based on what is known about exploratory prototypes, the producer can then make the necessary adjustments before finally releasing these prototypes as new materials. It might also be the case that producer will end up making innovations to the building process, such as materials as 'intellectual entities', whether these processes be related to the new materials or not.

O2. The producer could enter into an arrangement with another firm, be it of foreign or domestic origin, to either market ready-made new materials or enter into a licensing agreement to produce these new materials.

P1. The new materials and innovations made by the producer could be targeted at new markets, especially foreign markets. This process is usually simpler when the material in question innovates on a certain quality that is attractive to consumers in that market, for example, thermal or aesthetic qualities, etc.

P2. New materials and innovations from other markets can find their way to the domestic market and to the producer.

Q1. In the process of marketing new materials and innovations to the consumers in the new market, it might necessitate making some alterations and transformations that would eventually lead to exploratory prototypes. These prototypes would then initiate the cycle of innovation and materials development.

Q2. Once the cycle of innovation and materials development has been initiated, it is conceivable that even more markets, both internal to and external to the initial market, could be opened up by the new products.

R1. New ideas and products may diffuse back to the producer from the new market.

The framework outlines possible paths and roles for different actors in the process of materials development and innovation. For example, the researcher might contribute to the materials' development and innovation in three different ways: through a regular and frequent process of revising and updating the technical standards used in evaluating new materials; through conducting research on consumer preference for existing and new materials; and through the identification of unmet needs for building materials and the subsequent development of materials to meet this need. These three potential contributions of researchers to the materials' development process correspond to steps F1, G1, G2, E1, E2, D1, and D2.

Importantly, the framework creates a path for the researcher to communicate findings directly to the materials' producers, which would be B1 and B2 on Fig. 2. The producer can then use the new innovations devised by the researcher to target new markets that have a need for the building material; these markets could be either unexplored domestic markets or foreign markets. For the foreign markets, the materials' producer would have the choice of whether to target the market with materials as physical entities or as intellectual entities. I will briefly describe a study that might crystallize some of the potential contributions of the researcher outlined above. The study incorporates two of the three potential contributions of the researcher to the process of materials' development and innovation: identification of unmet building materials needs and development of new materials to meet this need, and research on consumers' preferences for the new materials developed. With regard to the framework in Fig. 2, the study covers paths F1, G1, G2, E1, and E2.

5. The materials research study

The study was conducted in two distinct phases. The first phase, conducted from October 2002 to April 2003, was research of a technical nature [14], in which all the relevant design parameters were performance-based. The second phase consisted of attributive materials research [16]. In this phase, potential low-income end-users were researched on their preferences for some of the different materials developed in the first phase. The second phase was conducted from July to September 2003.

5.1. Phase 1

Despite all the technological assets possessed by U.S. production firms, "the view of the developing world is that U.S. corporations are generally not making the needed marketing and research effort to adapt their products to the need, climate, maintenance regimes, and other conditions of the tropical countries" [17]. In the quarter century following World War II, "the United States was the world's most productive economy by virtually any measure" [18]. That is no longer the case, and U.S. production firms no longer have the uncontested access to the domestic economy they had in this era. Today, it is not unusual to find foreign firms dominating certain parts of the U.S. economy, such as specific segments of the automobile industry. U.S. firms can longer afford to ignore foreign markets with the expectation of dominating the domestic economy.

U.S. materials producers have the technological expertise that is needed in many parts of Africa, Asia and Latin America. The "bulk of technologies needed by developing countries from the United States are for . . . health and shelter in Africa, and for problems of urbanization and unemployment in Latin America" [17]. Moreover, "the sharing of this know-how . . . is not likely to create threats to trade and employment in the United States" [17].

5.1.1. Identification of an unmet need

For most developing countries, the most expensive component of housing is materials; reducing materials' costs would therefore make low-cost housing a reality. One can reduce materials' costs by re-discovering traditional materials. However, despite being cheaper than modern materials, traditional materials have been ignored in the construction of formal housing. This is surprising given that these materials have thermal and other properties that are superior for use in the tropics [13]. Moreover, some traditional materials, such as clayey soils, are usually discarded during construction. Incorporating them into housing construction would be a sustainable practice.

Concrete is a versatile building material, and suitable for use in low-cost housing for a number of reasons. First, concrete is cheaper than steel. Second, concrete is better suited for the low-skill construction labor force in Kenya. However, concrete is still relatively expensive, due mostly to the high price of cement. Cement production is expensive chiefly because of the energy involved in its production. The two cement clinker factories in Kenya rely on hydroelectric power. This is expensive and the supply is unstable, given the significant seasonal variations in reservoir levels due to unreliable precipitation. Substituting soil for cement in concrete would substantially lower the costs of housing, which would go a long way in providing low-cost housing.

5.1.2. Creation of new materials to meet untapped need

In the first phase, research was performed on the feasibility of substituting the cement content in concrete with varying levels of different types of soils. Cement "has been found to be effective in stabilizing . . . clays. . . Enough cement is added to produce a hardened material with the strength and durability necessary to serve as the primary structural base. . . The result is a moisture-resistant material that is highly durable" [23]. The main binding agent in soil is clay, and three soil types with different amounts of clay content were chosen. Also, clay's action in soils is similar to cement's in concrete since both are physical and chemical binders, and the content of either largely determines the properties and strength of the soil or concrete respectively. The Grand Rapids soil was a clayey loam (31% clay), the Ann Arbor soil was a sandy loam (14% clay), and Cleveland soil was 100% clay. Five different concrete mortar mixes were devised with clay and cement in varying proportions for each mix. The mixes had the following soil–cement ratios: mix I was 9:1; mix II was 7:3; mix III was 5:5; mix IV was 3:7; and mix V was 1:9. This gave a total of five different soil–cement concrete mortar types for each soil. The five different mixes are shown in Fig. 3, with the weight ratios based on a 1 kg mortar block [14]. To each material, except the Portland cement control sample, lime was added, constituting 3.367% of the material by weight. The lime improved the soil–cement mortars' strength, resistance to fracture, fatigue, and permanent deformation, resilient

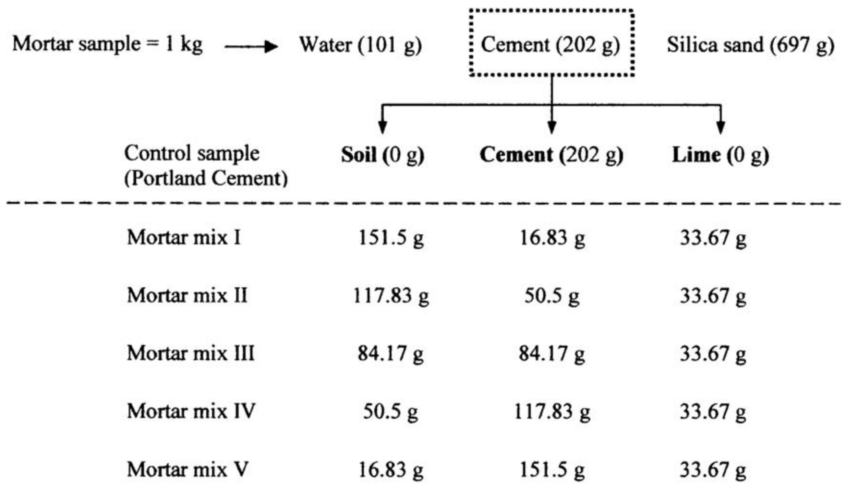

Fig. 3. Soil, cement, and lime ratios for the five mixes plus the control mix (source: Ref. [14]).

properties, and reduced swelling and resistance to the damaging effects of moisture [23].

A Portland Cement control mix (with no soil) was also made. Three samples were made for each concrete mortar type, giving a total of 48 samples. Each sample was a 2-in. (~5 cm) cube; there were transportability and handling advantages of making mortar samples rather than structural blocks. The soil–cement samples were tested for compression strength, and the results were favorable in comparison with other traditional mortars (Tables 5 and 6). Unconfined compressive testing for soil–cement materials can also substitute for durability tests. The advantage of using "strength tests is that they can be conducted more rapidly than the durability tests (7 days vs. 1 month) and require less laboratory equipment and technician training" [23]. Mortars with low E values tend to be less stiff and therefore more workable than those with higher E values [14]. While cement mortars have higher E values and therefore higher strength, they are usually stiffer and less permeable [14]. There was also a correspondence between higher soil–cement ratio and lower material density, and hence lightweight materials.

The study proved that up to 70% of the cement in concrete could be substituted with soil to make a mortar that met the performance requirements of various building codes. If used both for making mortar and structural blocks, these concrete alternatives could reduce the cost of low-cost housing by between 25% and 50%.

5.2. Phase 2

5.2.1. Consumer preferences research

Of the three samples of each material developed in phase 1, two samples were tested for compressive strength. The mix I's for all three soils were not used in phase 2 as their strength was too low. The remaining 13 materials, mixes II–

Table 5
Strength properties of soil–cement materials (source: Ref. [14])

Strengths and elastic moduli data of soil: cement materials+control material					
Soil type	Mix #	Compressive Strength		[E] Elastic Modulus	
		psi	kPa	ksi	MPa
Ann Arbor (14% clay)	I	2.53–2.98	17.44–20.55	.06–.12	.43–.81
	II	32.89–33.21	226.78–228.98	2.44–4.03	16.79–27.81
	III	108.29–116.28	746.66–801.75	10.24–14.33	70.61–98.83
	IV	182.60–218.14	1259.03–1504.08	15.28–15.81	105.36–109.02
	V	334.11–359.47	2303.69–2478.55	31.05–43.88	214.07–302.58
Grand Rapids (31% clay)	I	8.14–8.22	56.13–56.68	.44–.97	3.03–6.67
	II	28.52–37.26	196.65–256.91	4.63–5.37	31.93–37.03
	III	144.49–180.02	996.26–1241.24	15.23–19.78	104.98–136.38
	IV	277.09–300.44	1910.54–2071.53	28.21–33.21	194.47–228.96
	V	343.48–370.13	2368.29–2552.05	28.78–33.12	198.45–228.38
Cleveland (100% clay)	I	5.28–5.39	36.41–37.16	.04–.05	.25–.35
	II	29.05–32.15	200.30–221.68	2.18–3.58	15.04–24.70
	III	118.83–119.93	819.33–826.92	7.79–11.52	53.72–79.44
	IV	192.98–209.26	1330.60–1442.85	11.36–14.12	78.30–97.33
	V	348.42–355.64	2402.36–2452.14	28.79–33.40	198.53–230.27
Portland Cement (no soil)	–	437.68–462.83	3017.80–3191.21	31.61–32.49	217.93–224.00

Table 6
Strength properties of traditional materials and building elements (source: Ref. [15])

Strengths of lime mortars, and load-bearing+non-load-bearing walls		
Description	Compressive Strength	
	psi	kPa
Fat lime (pure, non-hydraulic) mortar	14.72–191.36	101.49–1319.43
Feebly (slightly) hydraulic lime mortar	191.36–294.40	1319.43–2029.89
Moderately hydraulic lime mortar	294.40–883.20	2029.89–6089.67
Internal walls, non-load-bearing	220.80	1522.42
Walls for 1 and 2 storey buildings, load-bearing	404.80	2791.10

V for all three soils, were used in phase 2. In the second phase, the 13 materials were used in a preferences study. Respondents from a low-income population in Kibera, a large slum in Nairobi, Kenya, were asked to rate the materials on the basis of personal preference. Kibera is arguably the largest slum in sub-Saharan Africa, with a population of over 1 million people. The respondents used a 5-point Likert scale to rate each of the materials, and were advised to use their own criteria for the rating. This was essentially an experimental design with 13 stimuli, and the clarity of its design permitted accurate analysis [16].

There were two main research instruments used in the second phase, a short biographic survey and a materials' rating instrument. The survey was intended to obtain information, such as the respondent's age, education and marital status. As described above, the materials' rating instrument was a 5-point rating of the 13 material samples (the 2-in. cubes) that were presented to the study participants. A total of 62 people filled out the biographic survey while 53 did the materials' rating [16].

GEE ordinal regression models were used to analyze the data from the ratings instrument. The results showed that both the 'mix' and 'soil' main effects were extremely significant in determining user preference, while the interaction effect was non-significant. Interestingly, the preference of a material rose as the clay content increased.

Two full models were run, one with the 'mix–soil' interaction effect and one without the effect. Tables 7 and 8 show the summary statistics for these two full models (not shown). The results show that while the interaction effect was non-significant, the 'mix' and 'soil' main effects were extremely significant.

Table 7
GEE Regression results (source: Ref. [16])

Score statistics for type 3 GEE analysis			
Source	*df*	χ^2	$Pr>\chi^2$
Mix	3	30.20	<.0001
Soil	2	21.31	<.0001
Mix * Soil	6	9.65	0.1402

Table 8
GEE regression results (source: Ref. [16])

Score statistics for type 3 GEE analysis			
Source	*df*	χ^2	$Pr>\chi^2$
Mix	3	30.43	<.0001
Soil	2	20.97	<.0001

5.2.2. Discussion of consumer preferences research results

The results indicate that there is great potential for materials research using soil as a substitute for cement. It is inconceivable that there is one type of soil or one type of mix that would achieve a uniformly high rating across different cultural contexts. While this may create technical challenges for materials researchers, it also creates numerous opportunities for experimenting with different combinations of mixes and soils with the main object being to satisfy the aesthetic and perceptual preferences of any given population of intended users. For example, the 13 different materials used in the second phase of the study varied in terms of color and texture. Materials producers and designers can use this wealth of aesthetic variety and market different materials to different groups of consumers depending on their aesthetic preferences.

The full-model level-wise results (not shown) suggest that the soil with the highest clay content ('Cleveland') had an extremely significant probability of having higher ratings than 'Ann Arbor' (and 'Grand Rapids' in one of the regression models not reported). These findings are significant for those cities in developing countries which have vast areas of highly clayey soils. These soils are normally considered a nuisance during construction, and require wasteful expenditure of resources in their disposal. This research proved that this disposal problem could easily be a non-issue given that the soil could be used to produce building materials on site.

Level-wise analysis by mix showed that the lower the cement content, the higher the probability that the mix would have a lower rating. While mix II and mix V were at the extremes of the ranking order (lowest and highest respectively), mix III and mix IV were in the middle, and the difference between them was non-significant. A possible reason why mix II materials received the low ratings might be that the samples used in the study showed more effects of rough handling and transportation as the study progressed. Mortars are generally not able to withstand weathering and rough handling as well as structural blocks are, and it seems like that effect was exacerbated by the lower levels of cement in mix II relative to the other mixes [16].

Mixes mix III to mix V had mean ratings above 3.0 on the 5-point Likert scale, suggesting their likeability to most participants. This, in turn, means that up to 50% of the normal cement content in a typical concrete mixture could be substituted with soil, and the materials produced would be perceived very favorably. This finding is especially significant for countries such as Kenya, where materials can constitute 70% or more of total construction costs. Cement alone can account for 50% or more of the total building materials' costs for a typical small- to medium-scale construction project [16]. In total, it should be feasible to reduce the costs of building low-cost housing by 25% to 50%, making low-cost housing a reality for poor people in Kenya and other developing countries.

In Section 4, it was suggested that the producer can target foreign markets using materials as either physical entities or as intellectual entities. The framework in Fig. 2 addresses some barriers materials producers face when trying to access foreign markets. These barriers would include: political risk; exchange rate fluctuations; receptivity to innovations in the foreign market; and competitiveness in the targeted economy.

6. Framework's utility to producers' entry into foreign markets

Political risk can range from instability and civil war to capricious policies by the host country. For instance, Hennart [19] notes that many host countries have attempted "to 'unbundle' the FDI [foreign direct investment] package by purchasing all of its components through contracts" so as to lessen the influence of foreign firms investing in their economies. FDI packages typically include such assets as: capital, patented and unpatented know-how, managerial skills and access to markets [19]. In the instances where host countries place limitations on direct investment, a materials producer can get around these hurdles by licensing the production of the material to a firm in that economy. Licensing would work well when the firm in question possesses the technological capability to manufacture the material according to the U.S. producer's processes. The producer would be selling the material as intellectual entity. An advantage of material as intellectual entity in the aforementioned situation where investment is limited due to political reasons is that "licensing is likely to be more efficient for process than product innovations. Process licenses are easier to price: the technology has always at least one close substitute, the old technology, which provides a benchmark for establishing the value of the new process" [19].

U.S. exporters in any field keenly follow the exchange rate between the dollar and the currency for the market they are interested in. Generally, the commonly held view is that a depreciation of the dollar makes it cheaper for U.S. firms to export to a prospective market, while an appreciation of the dollar has an opposite effect [20]. A depreciation of the dollar also makes it more expensive for foreign firms to export to the U.S. market, while an appreciation of the dollar has an opposite effect. The building materials producer interested in foreign markets can hedge against the volatility of exchange rate fluctuations in the following ways.

When the dollar depreciates, making it cheaper for U.S. producers to export their products, producers can market materials both as physical entities and as intellectual entities. Producers can also expand domestic markets since the dollar's depreciation makes it more expensive for foreign producers to export their products to the U.S. The decision on whether to target a particular market with physical entities or intellectual entities would be determined by: the degree of political risk associated with a particular country; the state of a country's industrial infrastructure; the presence (absence) of barriers to physical materials (such as tariffs); and the costs of transporting physical materials to that country. When the dollar appreciates, making it more expensive for domestic producers to export their products, producers can concentrate less on physical entities and more on intellectual entities. Paradoxically, the emphasis on materials as intellectual entities may make U.S. producers more competitive with foreign producers in domestic and foreign markets by making it easier to shift production to other countries with lower production costs, especially developing countries. The fact that U.S. producers can shift production to both the targeted country and other countries with lower production costs – through intellectual entity transfer and licensing – means that U.S. producers can even overcome issues related to competitiveness in the target foreign market.

Lastly, there is a perception among many U.S. production firms that certain technologies are only appropriate for the developed Western world, given that less-developed countries may be decades or even centuries behind the development track of the West. Consequently, many U.S. firms deny themselves access to markets in developing countries merely by assuming that there is no market for their products in these countries. Contrary to this general perception, Strassman [21] noted that it would be misleading to assume that "builders in poor countries will be unreceptive to innovations. On the contrary. . ., cost-reducing innovations have a better chance. The man who chooses is the man who can profit" [21]. Whether a U.S. producer decides to market materials as physical entities or as intellectual entities to a developing country will largely depend on the exchange rate. As noted earlier, the depreciation or appreciation of the dollar makes one option more favorable than the other, or has a more or less neutral effect. Where the receptivity to innovation is poor, and all other factors constant, the U.S. producer can reduce the risks associated with entry into foreign markets by concentrating marketing efforts on materials as physical entities, rather than as intellectual entities. The fact that the material has been manufactured in the U.S. should serve as a signal to alley consumers' fears as to its quality and suitability. Later, as the product gains in acceptance, the U.S. producer can then bring materials as intellectual entities into the picture. In the case of good receptivity to innovations, the U.S. producer should have no difficulty either selling materials as physical entities or as intellectual entities in that market. The choice between the two would then be determined by some of the issues related to foreign market entry that have been previously discussed.

7. Conclusion

As performed by the researcher, the materials study incorporated steps E1, E2, F1, G1, and G2 from the framework in Fig. 2. There are several future steps the researcher could take to expand the study. For example, the test data of the materials could be used to compile guidelines for application of the materials in field construction. In order to develop these guidelines, performance standards would have to be created for the new materials, a step akin to paths D1 and D2. These tables could, in turn, lead to the development of new standards for construction using soil–cement concrete substitutes.

Once guidelines for the application of the materials are developed, the researcher could then negotiate an agreement with a materials producer following paths B1 and B2. Subsequently, the researcher and producer could agree on the appropriate technological processes for producing these materials. Only then can the producer introduce the new building material into the market, determine whether this market is a domestic or foreign market (corresponding to paths O1 and O2) and determine when to launch the material as a physical entity or as an intellectual entity. The new material constitutes a ‘physical entity’, while the patented and unpatented know-how surrounding the material’s creation and eventual production form an ‘intellectual entity’.

Should the producer decide to target a foreign market, the producer can choose from the following three options. In the first option, a firm in the foreign market could be directly licensed to produce the new material by being given access to the ‘intellectual entity’. This option would work best when the firm can sufficiently meet the demands and standards of manufacturing the new material. In the second option, a joint venture could be established between the foreign firm and the U.S. producer. The U.S. producer would provide not only the material as ‘intellectual entity’, but also managerial skills and even marketing services. Finally, in the third option, the U.S. producer would directly invest in the market by building a production plant; the U.S. firm would then either have full or majority ownership. The producer would be solely responsible for introducing the different aspects of materials into the target market, with materials as intellectual entities and as physical entities. The last option would work best in situations where there is a lower degree of political risk [22].

The framework outlined is not exclusive in the sense that one could conceivably add paths and feedback loops to it where appropriate. The relationships between the different actors and processes could also be adjusted to suit different regional and national contexts. It is most important that the process of production and innovation in the building materials sector be systematized, as the gap in the current state of the sector is in conceptual frameworks. Fig. 2 is an example of a systematic conceptual framework. It should be noted that this framework was constructed with non-metal and non-wood building materials in mind, specifically materials such as soil–cement concrete alternatives.

The lack of a clear frame of reference in the building materials sector has meant that efforts at innovation are usually uncoordinated and often unsuccessful. Moreover, it has resulted in the current state of the sector, where there is a disjuncture between producers and consumers or end-users, and where a majority of establishments in the sector face unstable futures given the seasonal variability in the demand for building materials in the domestic economy. Most establishments attempt to buffer themselves from this effect by making inroads into several regional economies within the U.S. There is, however, a limit to the degree to which a materials producer can hedge on uncertainty in the domestic economy by targeting regional or sub-national economies. For instance, severe economic recessions in the U.S. usually result in declines in construction activity, leading to lowered demands for building materials. At such times, materials producers would do well to expand their markets by looking to foreign markets. But to do that, the producer needs to have a firm grasp of the consumer preferences in that particular market so as to distinguish between viable and non-viable materials in that market. A good knowledge of consumer preferences would help the producer gain a better understanding of potential end-users in the domestic market. In fact, it is quite possible that there are many untapped markets in the domestic economy due to the aforementioned divide between potential consumers and producers.

Further research on the state of the domestic building materials sector might establish the size and number of untapped domestic markets that could be reached through better links and feedback loops between materials producers and end-users. In the interim, it would behoove building materials producers to address those paths and feedback loops in the framework which they have hitherto ignored. This would not only improve their future financial stability, but would also establish better relations between producers and consumers.

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