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# Investing in advanced materials: A market-driven methodology

Jin S. Kim

*Corning Incorporated, Sullivan Park FR-02-12, Corning, NY 14831, USA*

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ABSTRACT

This study proposes a market-driven methodology for investing in materials innovation. This methodology is the counterpart of a technology-driven methodology, the investment methodology for materials (IMM) proposed in 2005. The two methodologies complement each other in guiding materials investment in the early stages of innovation. This methodology consists of three modules (market, technology, and commercial) and 12 elements in the three modules. An overview of each element is provided, as are the associations between and among them. Furthermore, two unique challenges of materials makers in implementing a market-driven approach are highlighted: 1) materials makers are located upstream in the value chain, and 2) process innovation is a key constituent of materials innovation. A case study is provided to clarify the methodology for practitioners.



## 1. Introduction

Advanced materials enable innovation across many industries, and yet present distinct challenges in technology management that complicate investment decisions (Maine and Garnsey, 2006; Linton and Walsh, 2003). Maine et al. (2005) proposed the investment methodology for materials (IMM), which is a useful tool for materials ventures. The IMM helps technology managers determine the attractiveness of materials innovation by systematically assessing 1) technical and economic viability, 2) new or substituting markets, and 3) the potential to capture value. Maine and Ashby (2002a; 2002b) illustrated IMM by applying it to the case of metal foams. The core concepts of IMM have been adequately adopted by advanced materials makers, although matching technology to market remains a differentiating capability (Maine et al., 2012).

The IMM is a technology-driven methodology that begins with a novel material or material invention and then determines how to commercialize this invention. Advanced materials makers use both technology- and market-driven methodologies. In many cases, they do not have a material invention on hand, but instead initiate a material invention in response to innovations down the value chain (Fig. 1), to which this study refers as market innovations. In such cases, they start with a market innovation and then examine what materials need to be developed or invented. Note that market in this study encompasses the entire value chain or all the downstream customers, not just the general consumer or direct customer alone.

This study proposes a market-driven methodology for investing in advanced materials that complements a technology-driven methodology. As discussed by many researchers, the customer or market orientation is highly effective in product innovation (Griffin and Hauser, 1993; von Hippel, 1986; Lilien et al., 2002). A recent survey shows that VoC (voice of the customer) methods are more effective in product innovation than other methods, such as open innovation and strategic planning (Cooper and Dreher, 2010). The methodology proposed in this study is an elaboration of VoC methods in the specific context of materials innovation.

In addition to being market-driven, the methodology in this study considers two unique challenges of materials innovation. The first is the value chain, i.e., the market for a materials maker includes both direct and downstream customers (Hillebrand and Biemans, 2011). The second is process innovation, i.e., materials innovation involves both product innovation and process innovation (Maine et al., 2012; Linton and Walsh, 2008; Frishammar et al., 2013). These characteristics of materials innovation separate a market-driven approach by materials makers from that by consumer manufacturers.

Section 2 describes the three modules of this methodology, starting with the market module, which then feeds the technology and commercial modules. Sections 3 through 5 articulate the main elements in each of the three modules. The two characteristics of materials innovation are discussed with respect to each element, and the associations between the elements are highlighted. Section 6 illustrates the methodology using a case of cloud computing and advanced materials. Section 7 discusses the general use of this methodology and topics for future research.

*E-mail address:* jin.s.kim@aya.yale.edu

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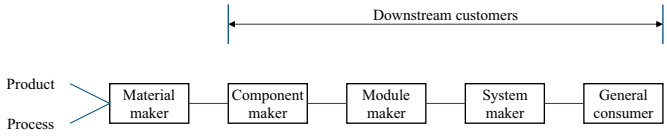


**Fig. 1.** Value chain.

## 2. Overview of the methodology

The methodology consists of three modules: market, technology, and commercial modules. The market module feeds the technology module, and they both feed the commercial module (Fig. 2). The market module is about understanding market requirements, the technology module is about specifying material concepts, and the commercial module is about determining commercial viability of the material concepts in the context of the market module.

The primary purpose of the market module is to understand market requirements. The market in this module comprises the entire value chain, as opposed to the general consumer only or the direct customer only. This module consists of four elements: Element 01 Industry Megatrends, Element 02 Target Markets, Element 03 Market Problems, and Element 04 Competitive Benchmark.

The market module starts with Element 01 Industry Megatrends. When a megatrend is emerging in an industry, the opportunity for technology innovation accompanies the emergence. Identifying such opportunities first and developing new technologies accordingly is the essence of market-driven methodologies. This concept is contrary to technology-driven approaches, in which a new technology is invented first and the right opportunities are sought accordingly. Element 02 Target Markets goes deeper into the megatrend to narrow the scope of work. The purpose of Element 02 is to segment the industry, size the segments, and determine the targets in preparation of moving forward to Element 03.

Element 03 Market Problems discovers, understands, and defines the market problems that customers in the target segments, either direct or downstream, have with their own technologies. Knowing a customer's problems includes understanding the relationships between the problems and prioritizing the problems. Without accurately identifying a customer's problems, scientists and engineers might develop technologies that are of no use in the markets. Accordingly, Element 03 Market Problems is the foundation of the technology module. Thus, moving from the market module to the technology module is a problem-solving process. The market module is about defining a problem, while the technology module is about solving the problem by means of materials invention.

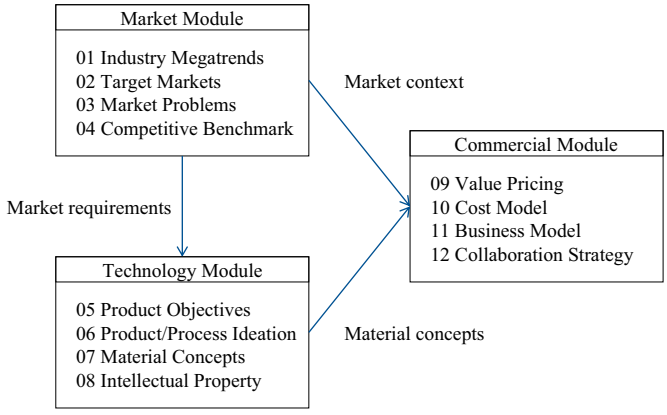


**Fig. 2.** MTC (market, technology, and commercial) modules.

Element 04 Competitive Benchmark is about understanding competitive approaches to market problems. Even if the firm can solve the customer's problem, the solution would not be commercially acceptable if it is lagging behind competitive solutions. Therefore, the product objectives should be set up in such a way that the firm's solutions address the customer's problems (Element 03) more effectively than the competitive alternatives (Element 04). Elements 04 and 03 are the two critical elements that define the market requirements, which feed Element 05 Product Objectives in the technology module.

The prime objective of the technology module is to design material concepts by interpreting market requirements into technical specifications (Fig. 2). Scientists and engineers eventually work to achieve the technical specifications. To achieve this objective, this module consists of four elements: Element 05 Product Objectives, Element 06 Product/Process Ideation, Element 07 Material Concepts, and Element 08 Intellectual Property. The ultimate outcome of this module is the material concepts (Element 07).

The technology module starts with Element 05 Product Objectives, in which a materials maker converts the market requirements from the market module into something conceivable by the scientists and engineers in the firm. The market module establishes the market requirements, and the technology module develops the requirements into something actionable by scientists and engineers. Once the product objectives are set, Element 06 Product/Process Ideation provides direction for the scientists and engineers as they develop and identify the technical ideas that meet the objectives. Element 06 is conducted for both product and process. Element 07 Material Concepts filters, prioritizes, modifies, and often combines the technical ideas from Element 06 in the design of material concepts. Element 08 Intellectual Property confirms whether these material concepts have patentable elements and meet the right-to-practice requirements with respect to IP laws (Ritchey, 2014).

The purpose of the commercial module is to establish the commercial viability of the material concepts designed in Element 07. While the material concepts may meet the market requirements, without commercialization, it constitutes only invention, not innovation. This module not only determines but also enhances the commercial viability of the material concepts. This module achieves this purpose by coupling the market module and technology module (Fig. 2), and consists of four elements: Element 09 Value Pricing, Element 10 Cost Model, Element 11 Business Model, and Element 12 Collaboration Strategy.

Element 09 Value Pricing and Element 10 Cost Model address commercial profitability. Element 09 supports estimating the price that the customers are willing to pay, whereas Element 10 supports estimating the cost for the firm to manufacture the materials. Element 09 requires the monetary interpretation of the value of the material concepts (Element 07) in the context of the market module. At the most elementary level, materials makers want to be certain that the estimated price (Element 09) exceeds the estimated cost (Element 10) and that the difference exceeds the firm's own margin threshold.

Element 11 Business Model and Element 12 Collaboration Strategy address the commercialization strategy. Element 11 explores the options for the firm in making and selling materials, and Element 12 examines how the firm collaborates with the direct and/or downstream customers. Note that the customer's willingness-to-pay (Element 09) is the maximum value, which is shared along the value chain. Developing a material with high value for the value chain is one matter but capturing a high share from that high value is another matter altogether. Element 11 addresses the latter and evaluates the feasible options for effectively capturing value. Element 12 Collaboration Strategy is another element in the commercialization strategy and involves