Knowledge from Research and Practice on the Barriers and Carriers to Successful Technology Transfer for Assistive Technology Devices

James A. Leahy & Joseph P. Lane
University at Buffalo, SUNY

Abstract

Historically, the assistive technology (AT) industry is made up of small to medium size companies serving relatively small markets with products characterized as 'niche' or 'orphan' products. Presenting opportunities to AT companies that are created by outside sources is difficult. Presenting such opportunities to companies serving larger markets is even more difficult. In both cases, transferring new or improved products is fraught with barriers.

This paper outlines the critical barriers to brokering efforts between major U.S. university technology transfer offices and U.S. corporations. This paper also identifies the corresponding carriers, or facilitators, and standard practices that are employed to overcome these barriers in both the AT and mainstream markets. The barriers identified in this paper will span the research, development, and commercialization continuum for technology transfer. Over the past 14 years, by using the carriers and standard practices delineated in this paper, the authors have successfully transferred new technologies and devices in the areas of AT and mainstream consumer products.

Key words: Barriers, Carriers, Facilitators, Technology Transfer, Assistive Technology, University-based Research, Technology Transfer Office

Background

Modeling the Technology Transfer Process

When an entity attempts to shift control and responsibility for a prototype invention to another entity, it engages in a process commonly referred to as technology transfer (TT). Definitions of TT vary widely. In order to provide common ground for dialogue, and for action within the field of AT, we created and published a generic model that characterized the key elements of the TT process (i.e., initiating transfer forces, critical events and stakeholder groups) and linked these elements within an overall process (Lane, 1999). This generic model (Figure 1 below) is intended for application within the context of any specific program.

In the context of this generic model, TT should be viewed and treated as a single broad process that encompasses multiple elements. The elements comprising TT are routinely viewed as disparate activities, but it is more constructive to treat them as stages of a continuous process from technology discovery through product consumption. Technologies enable a product's features and functions. For example, the manufacturer of a non-stick frying pan incorporates multiple technologies (e.g., metals, ceramics, plastics, and bonding agents), while the consumer only buys one product (e.g., a frying pan with the desired non-stick feature; Camp & Sexton, 1992).

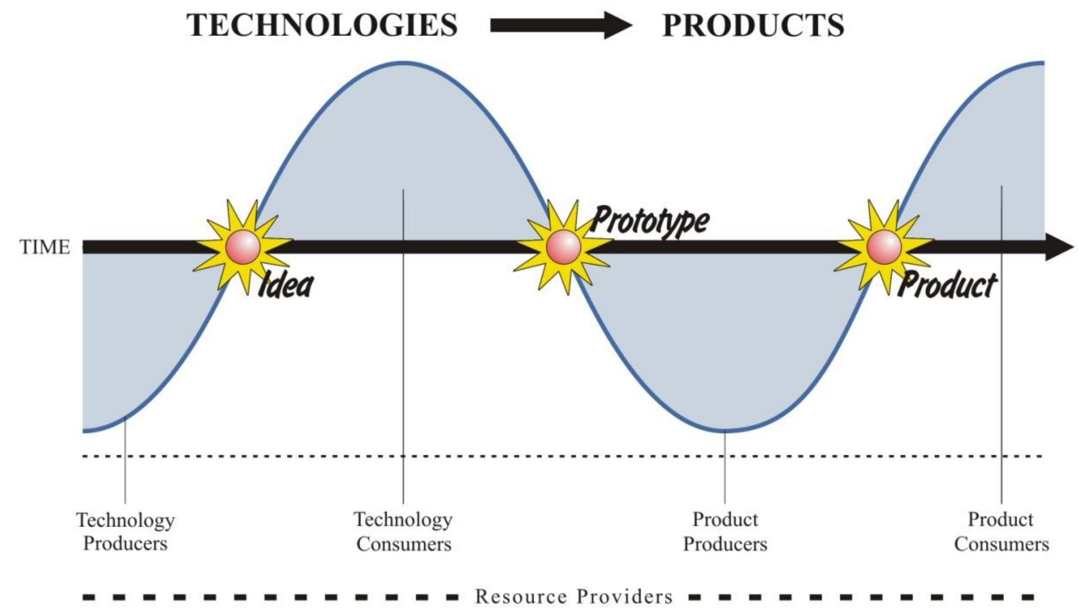

Figure 1. Generic model of the TT process.

TT commences by one of two initiating forces. Forces at either the technology discovery end or the product consumption end can initiate TT.

A *supply push* TT is initiated through an effort to apply a technology's utility within a new product. Otherwise put, the technology is *pushed* toward the marketplace to address an assumed, unsatisfied demand (Paul, 1987). For example, an elderly person may struggle to rise from a wheelchair because he or she struggles to engage the wheel locks. In an effort to solve this problem, a therapist prototyped a device that automatically engaged the wheel locks as the elderly person rose from the wheelchair. The device was effective, so the inventor sought a broader commercial market for the invention through license or sale. In this example, the inventor collaborated with the authors to improve and license this device to a corporation within the wheelchair industry. This is a classic case of supply push transfer in that an invention designed for limited application is assumed to be applicable to a larger population, without a validated expression of the market's need for the perceived solution. It is a gamble that may prove right or wrong.

Demand pull TTs, on the other hand, are initiated in response to a validated market demand for a product feature or function. Companies may seek a solution to a problem articulated by their customers (Von Hippel, 1986). The authors, for example, determined that power wheelchair manufacturers, and people with mobility impairments, considered the battery charging process to be inefficient. Once the market articulated demand for an improved battery charging process, we identified a device in the automobile industry that met the demand. Within six months the authors brokered a transfer agreement between the device and five wheelchair companies.

Another source of demand pull activity is evident in technology requests from manufacturers, or National Aeronautics and Space Administration (NASA) specifications, which circulate through the Small Business Innovation Research (SBIR) program because they are market problems seeking a technology solution.

In some cases, breakthrough technologies (e.g., telephone, integrated circuits) enter the market through supply push activities. Subsequently, demand pull forces expand those applications. Identifying the initiating force as either supply push or as demand pull helps validate the transfer opportunity, estimate market value, and assess the likelihood of future success.

Within the generic model, all technology transfer projects pass through three critical events. These critical events, which are listed and defined below, represent the transformation from core technology to commercial product (Rogers, 1995).

The *idea event* is the conceptual awareness that an existing technology might be applicable in a new field. The idea event involves no tangible development. Take, for example, an engineer who asserts that a transfer of composite materials used in aircrafts could improve consumer goods by reducing weight while increasing strength and flexibility.

The *prototype event* occurs when a working model demonstrates that the idea functions as expected in an actual application, where, in legal parlance, the idea is 'reduced to practice.' When bicycle and wheelchair frames that are formed from composite materials pass basic performance tests, a prototype event has occurred.

The transition from feasible prototype to market product is the crux of technology transfer. For the transition to take place, a manufacturer, or *product producer* (see Figure 1), must decide to invest in product development (Krishnan & Ulrich, 2001). They make this decision based on their assessments of the technology created by a *technology producer*. This decision is required whether the prototype is developed inside or outside a company. From a manufacturer's perspective, assessing the prototype's commercial viability includes internal manufacturing capabilities, sales and marketing expertise, and product planning horizons (Day & Shoemaker, 2000). Beyond that, the manufacturer's involvement requires successful negotiation of intellectual property, financial compensation, and agreement on due diligence terms between the manufacturer and prototype developer (Gutterman & Erlich, 1997). Problems in any area will likely result in project termination. Manufacturers maintain an especially low rejection threshold for external projects.

The *product event* takes place when the first production-quality unit leaves the assembly line for the marketplace. In our example, the proliferation of bicycle and wheelchair frames made from composite materials--along with limb braces, tennis rackets, and golf club shafts--demonstrates the range of *product events* that can result from an initial idea event. It also shows the power of one technology to enhance the lives of people with and without disabilities.

The product event represents the culmination of an arduous journey through the product development 'valley of death,' a series of gaps that must be bridged to achieve success (Rosenau, 1996). Specifically, the transition from prototype to product requires bridging three crucial gaps: the (a) *funding gap* between government and commercial support; (b) *value gap* between academic knowledge and market potential; and (c) *information gap* between technologists and marketers (Hartman & Lakatos, 1998). Successfully bridging all three gaps leads to the challenges of product introduction. Product introduction encompasses production, distribution, sales, marketing, and support activities (Jolly, 1997). Each of these must be considered in the developer's earliest transfer plans because manufacturers will consider the costs of these activities in their transfer decision.

As a TT broker, the authors focus on the portion of the TT process between the prototype event and the product event--the aforementioned valley of death. This focus makes the manufacturers (technology consumers/product producers) in Figure 1 the most critical stakeholder group and, therefore, our primary target population. Manufacturers are critical as they are uniquely positioned to turn a prototype into a commercial product. They are also pivotal to the roles of other stakeholders (Scadden, 1987). Manufacturers rely mostly on *product consumers*, including people with disabilities, to be customers for their products. To a lesser extent, manufacturers rely on *technology producers* for innovations in core technologies. For small markets like AT, manufacturers also need support from resource providers like federal agencies, which fund development projects, regulate new products, or set reimbursement levels. All of these stakeholders, therefore, are considered target populations, with manufacturers in a pivotal role.

However, in order to successfully transfer commercial products to the marketplace, the authors must also consider the implications of early work on the remaining elements of the technology transfer process. No matter how great the need, or whose need, not all prototypes culminate in products with value to the AT marketplace. Market failures can often be traced back to activity preceding the prototype event. Improper assumptions about ideas, incorrect information about markets, interpersonal conflicts, or the trajectory of parallel research that makes current work obsolete, can all lead to market failure. Early decisions, or actions, by any stakeholder group may have grave consequences later in the process.

In general, TT is clearly more business-oriented than academic-oriented. Intellectual criteria that make a project interesting in the context of an academic model are subordinate to economic criteria, which require a project to be sound and profitable in the framework of a business model. Even when a product is supported by a sound business plan, the champion of the product faces a major hurdle simply by virtue of coming from outside the targeted partner corporation.

External product submissions to companies must compete against internal product initiatives which are supported by internal corporate champions. These internal initiatives already have corporate time and money invested based on prior management decisions to proceed. The internal champions possess the experience necessary to: (a) navigate the corporate product development cycle, (b) overcome barriers, and (c) satisfactorily answer questions and address concerns from a company's internal managers. Few companies have slack resources available to support new projects. Instead, companies must weigh the merits of competing opportunities and then invest in the most compelling option.

Companies are generally risk-averse and, thus, conservative when investing internal resources on research and development. They tend to focus on refinements to existing products that are proven commodities with established market positions. It is safer and easier to invest in expanding market share for a profitable product than it is to justify the expense of fulfilling an unmet need in the marketplace with a new, unproven product. In the current environment, truly novel ideas are left to start-up companies. Established firms prefer to wait and will pay a premium to acquire a successful new product or company rather than make the risk investment themselves.

Eliminating or minimizing barriers to commercialization perceived by licensing companies is of the utmost importance to the successful transfer, licensing, and production of new inventions. It is much easier for a corporation to refuse an external invention than to accept it. A refusal requires neither licensing nor any expenditures of time or capital in research and development, marketing analysis, and consumer testing. The external inventor who hopes to initiate the product development cycle must overcome this corporate inertia.

Modeling the Product Development Process

For the purpose of this paper, discussion of barriers, carriers, and standard practices should be considered in the context of TT processes at federally funded (U.S.) programs at universities where prototype development is followed by TT to corporations for product development.

The Product Development Managers Association (PDMA) has published a series of textbooks on the product development process. We have extracted from this literature 20 steps--from the idea to product stages--which, when followed, ensure successful product development. Each step has input and output processes, which advance an idea from its conception to a successful product in the marketplace. There are 10 steps from the idea to prototype stage and 10 more steps from the *prototype* to *product* stage. PDMA's product development process is based on the assumption that one entity, a company, performs all 20 steps (see Figure 2).

However, in TT at universities, the initial product development process is performed by a university researcher. This process ceases when the prototype is developed. From there, a university's TT office (TTO) handles the invention's licensing and subsequent handoff to a company that completes the product development process.

The barriers, carriers, and standard practices discussed in this paper are the same, in some

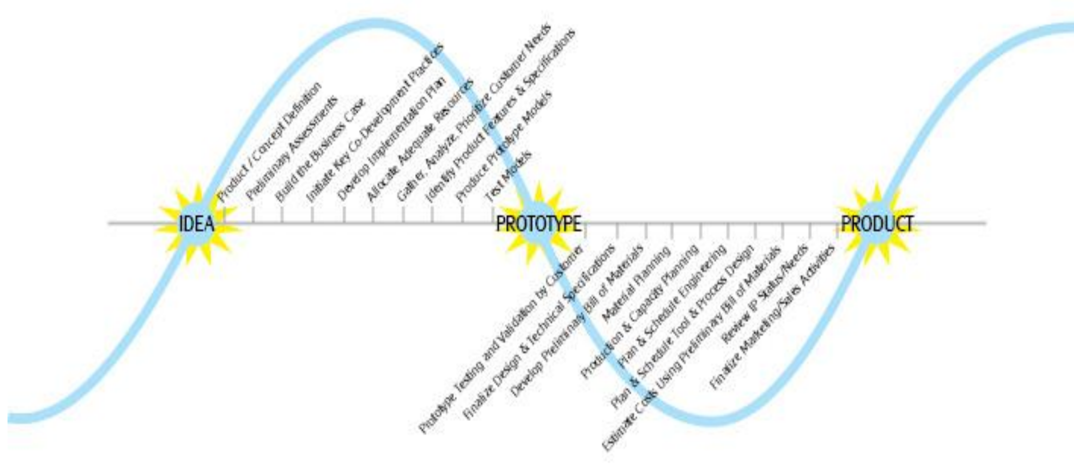

Figure 2. Development literature shows 20 steps from *idea* to *product*.

cases, as those encountered in standard new product development processes by corporations. However, because a university attempts to license a prototype invention to a company, the barriers, carriers, and standard practices are unique to university research communities and to universities attempting to license prototypes.

Figure 2 shows the three critical events of TT and the PDMA's 20 steps between the idea event for the application of an enabling technology to the product event resulting in a commercial product that is ready for production and market introduction. This paper describes and discusses barriers to progress in each of the critical events as well as carriers that will circumvent or dissolve those barriers.

Barriers and Carriers Prior to the Idea Critical Event

Our discussion begins with the 'valley' that precedes the idea critical event. Barriers to successful TT of an invention spring up at the earliest stages of research, even before a researcher develops an invention. If a researcher or inventor fails to meticulously consider and address these early barriers, the future product may fail downstream.

At this stage, the researcher knows of an unmet consumer need for a technology or a product. But at this point, the researcher is uncertain of exactly what to develop. He or she applies for a grant from a funding agency to do research to develop a technology that the researcher hopes will address the unmet need and become a usable product for consumers. Even at this stage, potential barriers that go unaddressed will lead to project failure.

Barriers to Achieving a Valid Idea Critical Event

Failure to allocate an adequate amount of researcher's time. Here, if a researcher allocates only minimal time to the research project, for example, 5%-10% full-time effort, practically speaking, the project won't receive enough attention to succeed (Lane, 2008).

Failure to allocate adequate resources. A researcher may allocate insufficient lab and financial resources to the project. If only one member of a research team works on a project, the future of the project is already in jeopardy. Similarly, if that individual leaves the team, it's possible that the team's remaining members would let the project fall by the wayside.

Carriers that Can Nullify Barriers Prior to the Idea Stage

Granting agencies or universities should see to it that federally funded investigators who perform research have allocated a substantial minimum amount of time to a research project. Generally, very low full-time effort allocation of a researcher's time (5%-10%) results in project failure (Lane, 2008).

Allocation of adequate resources includes staff, facility, and consumer involvement time. While researchers may understand their laboratory and staff needs, researchers who fail to allocate sufficient financial resources to a consumer component of research (i.e., focus groups, surveys, etc.) may remain unaware of the full range of consumers' needs, wants, and desires for a product solution. Researchers may incorrectly make assumptions about what is good for, necessary to, and desired by end consumers (Cooper, 1999).

Projects should be seeded with the efforts and interests of multiple researchers. Multiple investigators should contribute significant full-time effort. By this approach, a project can survive the departure of any single researcher (Lane, 2008).

Barriers and Carriers Between Idea and Prototype Critical Events

By now, a researcher has received federal funding and university backing. For research to result in invention, innovation, and, eventually, a viable commercial product, product development literature shows that certain carriers and standard practices should be performed by the research team at this early stage. Failure to navigate potential barriers here significantly inhibits the project's potential for success.

Barriers to Progressing to the Prototype Critical Event

Lack of preliminary assessment. Lack of due diligence by an inventor or research team could result in duplication of research and thus only minor or incremental improvements to technology and products that are already in the commercial marketplace. If the research team lacks awareness of the industry, of which technologies are being developed into commercial products, and of regulatory or business perspectives (i.e., device reimbursement issues, government accessibility regulations [such as those contained in Section 508 of the Rehabilitation Act], or the relocation of manufacturer production facilities overseas), their research will fail to lead to a development outcome of a product in the commercial marketplace.

Failure to build the business case. AT markets are historically small. Unless research generates technology that can be used across markets, the cost of the technology will stunt its early acceptance and use by consumers. If the overall goal of a research project is to impact the lives of consumers now, then awareness of the costs of technology is paramount. A decade ago the cost of the voice chips used in voice-interactive products was prohibitive, which delayed the arrival of many voice-operated products to the market. Today, as more product applications have appeared, and the technology to produce voice chips has become cheaper, the cost of voice-interactive products has decreased. These products are now viable commercially. Similarly, researchers may believe themselves to be experts in terms of both the technologies and products that are currently available as well as consumers' needs. Therefore they will not perform due diligence requirements on an industry. They will also fail to assess consumer needs in detail.

Carriers that Would Nullify Potential Barriers Between Idea and Prototype Stages

Perform preliminary assessments. Researchers should perform an extensive search of regulatory standards and competing technology and products to verify that their research will meet an existing need or solve a problem. Options include searching similar technologies, products, and patents. Researchers should contact industry associations in their areas of research to track current developments from manufacturing and regulatory standpoints.

Build the business case. Researchers should explore the technology costs and applications. Retailers and professionals may be visited to learn how individuals presently address the relevant function or need through products currently in the market. Inventors must also recognize that consumers sometimes prefer a technology-free option. Also, researchers need to constantly search for disruptive technologies as this may negatively affect the acceptance and adoption of their work.

Barriers and Carriers Between the Prototype and Product Critical Event

The remainder of this paper focuses on technology transfer at U.S. federally funded programs where prototype creation occurs at universities with subsequent technology transfer to corporations for product development. Universities operate technology transfer offices (TTO) to ensure compliance with all institutional and federal regulations concerning intellectual property, such as the Bayh-Dole, Patent and Trademark Act Amendments of 1980. Research performed by university employees, on or off premises, and specifically all research performed on university property, utilizing university facilities that leads to an invention by a university employee must be disclosed to the university's TTO. For inventions that result from federal funding, the TTO discloses the invention to the funding sponsor and determines if either the TTO or the sponsor elects to lay claim to the invention.

Potential Barriers Between Prototype and Product Stages

A university invention may meet a number of barriers on its path towards commercialization.

1. If researchers fail to communicate with the appropriate office at their university, the TTO may be unaware of a new federally funded grant being awarded to its university. The TTO, therefore, may be unaware of its duties and responsibilities under the new grant.
2. Unknowing or uninformed researchers may not make timely disclosures to the TTO, thus the TTO will not preliminarily search patent-related artwork. Thus the TTO may or may not proceed with intellectual property protection (patent) for the invention. Consequently, an inventor may not be the first to file for a patent on his or her invention. This may delay licensing or may result in failure to license the invention at all.
3. Inventors under pressure to publish research results, may, through their publications, publicly disclose their work, inadvertently activating a one-year time bar for filing patent application for the invention. For example, a researcher publicly disclosed his work on a thermostat with voice feedback. Unfortunately the researcher never filed for a patent on his work in the year following its public disclosure. Because his work had entered the public domain, no thermostat company could exclusively own the intellectual property rights to the concept. Thus, no company would invest in bringing the concept to fruition in the marketplace.
4. When universities retain claims to inventions, the institutions may include them among inventions that it passively solicits potential licensees for. In this case, the invention would not be shopped actively and may never be licensed.
5. Assuming the TTO finds a potential licensing company, the TTO may be unaware of the lower royalty rates (ranging from 3% to 8% for non-software items) associated with AT products (due to much lower sales volume) and may ask for too high of a return. This can mean the invention won't be licensed.
6. In some cases, inventors' main goal is to publish their work, not bring an invention to the marketplace. Due to the inventor's lack of interest and assistance, companies may forego licensing the invention.
7. The inventor may provide inadequate information to the TTO, thus hindering the intellectual property protection and licensing of the invention.
8. The eventual licensing of a prototype can be stalled by a university TTO's reluctance, skepticism, and

complacency in signing off on agreements, including a non-disclosure agreement.

9. An inventor may not actually have proof-of-concept for the prototype of his invention. In this case, licensing the invention will be most difficult.
10. If a university researcher proceeds without significant consumer input, the invention can be void of design functions and features that would enable its licensing and success in the marketplace.
11. In licensing negotiations, the inventor may delay sending the functioning prototype to the licensing company for evaluation. This delay may kill a potential licensing deal as companies cannot wait indefinitely this information. Companies interested in new product development may search for other opportunities. In the meantime, the invention may be rendered obsolete.
12. If an inventor's prototype does not function the way that potential licensing companies were led to believe by the TTO, it can negate a licensing company's interest.
13. In the eyes of consumers and licensing companies, a prototype may seem unfinished, thus negating the potential licensing to a company. This applies to companies that may lack the financial wherewithal to redesign a prototype into a product.
14. When inventors send prototypes to potential licensing companies, they may need to answer technical questions. Delays or non-responsiveness on the part of inventors may stifle licensing opportunities.
15. The TTO may fail to identify the correct corporate personnel to contact for licensing an invention, a possibility given that, in AT companies, that role may be filled by multiple people, though it's unclear who the true decision-maker is.
16. Due to triaging, both internal and external, of new inventions, corporate personnel may not respond to a university TTO's licensing inquiries.
17. Due to turnover of corporate personnel at a potential licensing company, the TTO representative may have to forge new working relationships with new personnel, or seek a different licensing partner.
18. Delays in agreements on terms between inventors and licensees can mean that timely inventions miss their windows of opportunity. During the delay, the licensing company may decide to focus on a different invention or technology.
19. Incorrect licensing terminology (e.g., the inaccurate use of 'Universal Design' [UD] instead of 'Transgenerational Design' [TD]) may inadvertently disinterest a company.
20. In presenting to potential licensing companies, TTOs may fail to provide enough information or may incorrectly format the information.

Carriers that Nullify Barriers Between Prototype and Product Events

The following are carriers and standard practices that can nullify the potential barriers noted above. The numbers listed with the carrier and standard practice correspond to the potential barriers above.

With the receipt of a new federal grant, a university's TTO office needs to be brought up to date as soon as the initial granting agency's site visit and prior to the actual financial award. The funded researcher and funding agency are responsible for ensuring that university TTO is aware of its commercialization duties and associated responsibilities under the new federal grant.

Time should be spent outlining both the researcher's development projects and the nature of the associated responsibilities a university's TTO should anticipate in terms of representing and licensing any resultant invention.

Having initiated a relationship between the researcher and his or her university TTO at the time of the grant award, the researcher should be made aware of the need for timely invention disclosures to the university TTO. This awareness and training should be continually reinforced by the university's TTO through faculty and researcher training programs.

TTO training programs for researchers and or inventors should clarify guidelines regarding the topics of intellectual property protection and public disclosure of the work.

Grant-generating entities, like the National Science Foundation, U.S. Department of Education, and National Institutes of Health, should make the university TTO aware of its expected role in commercializing any intellectual property (IP) resulting from the federally sponsored research. Due diligence clauses and expectations should be outlined for the university TTO in the final grant to ensure that the federally funded intellectual property generated is actively shopped to potential licensing companies.

Prior to the official award of the grant from the federal agency, negotiations with the university's TTO office should include how, and under what terms, resultant IP will be licensed by the university. Because the university's research is federally funded, there is an expectation that resultant IP will make its way to the commercial marketplace for the benefit of taxpayers who have funded that research. General guidelines for royalty rates and licensing expectations should be covered prior to the financial award of the grant to the university.

Researchers and or inventors should understand that the grant award has key deliverables that need to be accomplished. The granting agency should make the researcher aware that his or her deliverables for the grant are not finished when they have completed their publications and prototype. It remains incumbent upon researchers to assist in licensing any resultant IP from their research, which means being available for consultation, providing adequate information to their TTO, and continuing to work on the prototype so that it is presented in the best light to potential licensing companies.

Researchers should interject consumer input early in the design process and when finalizing the pre-production prototype. Even large manufacturers of mainstream consumer products make product design decisions without factoring in the needs, wants and expectations of the full range of end consumers. This process leads to ineffective products in the marketplace, new product failures and product abandonment. Failure rates for new product introductions vary by industry, but they generally range from 30% to 90%. Many of these failures can be traced to a point early in the product design process where significant consumer or device-user information was not collected and or not analyzed.

The AT industry has faced the same complaints for decades. The medical model of rehabilitation service provision readily substituted clinical requirements for user requirements. Failing to involve consumers with disabilities in every aspect of product design and development results in products that fail to meet consumer expectations and fail to deliver the required functional capabilities.

When a TTO contacts prospective licensing companies, it should be familiar in advance with the (a) companies they contact, (b) industry or industries those companies operate in, and (c) major players in those industries. Examples of questions to guide research in this area are: Which innovators seek to compete with industry leaders? What and when are the industry trade shows? How do companies in this industry introduce new products? And What are these companies' product development cycles?

Once a TTO makes contact with a licensing company, TTO personnel should attempt to meet multiple people within that organization. This not only builds relationships. It helps mitigate the negative effects of corporate personnel turnover in that multiple people at the licensing company will be familiar with the TTO and the invention under discussion.

The TTO must know enough about the industry to present an invention at the most opportune time. Missing a corporate product development window can stall a project within a corporation for up to a year. Prior to a TTO's contact with a potential licensing company, a TTO should outline the terms and conditions it will seek from the company in order to alleviate any possible negotiation delays. For example, in the wheeled mobility industry, new product introductions revolve around a trade show called Medtrade. A TTO must know when companies seek new products and when they will invest in developing the product or technology that needs licensing.

Timing and correct terminology are extremely important in licensing an invention. Certain terms and methods, in our experience, increase the likelihood of successfully licensing prototype devices. It's important to keep in mind that corporations are motivated by lower product cost, increased profit, and increased market share. Given that, our work has revealed four guidelines for approaching and engaging companies in negotiations to persuade mainstream consumer product manufacturers to add usability and accessibility features to the next generation of their products now: (a) what to say and what not to say; (b) which buzz terms turn off your corporate audience and which pique interest; (c) how to say it, and know how to address the corporate audience; and (d) when to say it.

For example, corporations know millions of Baby Boomers are rapidly approaching their senior years, and they wish to increase market share among this population. Aging, affluent Baby Boomers, who are tech savvy and receptive to product advancements, are changing the traditional consumer market for the elderly. For example, knowing the corporate attitude towards UD, the authors have found it beneficial to speak of TD rather than UD when making presentations to company executives. TD, a term coined by Dr. James Pirkl, is a knowledge-based design strategy that produces products, packages, graphics, and environments that accommodate physical and sensory impairments associated with human aging and which limit independence. TD products are designed to be used by people of all ages and ability levels. TD piques the interest of corporations trying to tap into the aging Baby Boomer market.

A licensing company should use detailed invention information packages or commercialization packages to evaluate the potential invention opportunity. Commercialization package elements include: (a) a listing of relevant product manufacturers; (b) in-depth literature on competing products; (c) literature for technical references; (d) standards and regulations; (e) consumer input through focus groups to determine possible product enhancements and priority ranking of characteristics; (f) technical analysis detailing device characteristics, technical feasibility, and product enhancements; (g) market analysis with a competing product matrix, benchmarking competing products versus the submitted device's characteristics; (h) identification of the target market and distribution channels; (i) supporting documentation in the way of CAD drawings, pictures, or graphics; and (j) virtual product matrix.

Product Life Cycle

The life cycle of a product has various stages. For the purpose of this paper we will focus on the initial product launch. At this stage, the researcher has little control over the end product unless the licensing company allows the TTO to place due diligence milestones for the company into the license agreement. The product has gone into production and has been launched into the marketplace by the licensing company and the onus is now on the company to make the product introduction successful.

Barriers Encountered After the Product Critical Event

1. Even upon licensing an invention, AT companies may lack sufficient corporate resources to bring many new products to market. Once the invention is licensed, the licensee may encounter unforeseen cost barriers.
2. Once an agreement to license exists, delays inside the licensing organization (related to engineering, product design or financing) can postpone the new product introduction.
3. Inadequate quality control on production of the final product can result in a high failure rate of the product or low consumer acceptance of the product.
4. If a company fails to adequately advertise and promote a new product, the product's life cycle may be short.
5. Pricing is extremely important. If the company overprices the initial offering of the product in an attempt to recoup molding costs quickly, the product may not sell; it may be overpriced compared to its competition.
6. Too many features and functions can increase manufacturing costs and subsequent retail price, thereby placing it at a competitive disadvantage.
7. If the manufacturer bundles two products into one, it may negatively affect sales.

Carriers to Nullify the Barriers Following the Product Critical Event

1. The only carrier and standard practice that can nullify the barriers listed above are applied at the time of licensing. The university TTO should strive to select a licensing company that has a history of successful AT product launches and one that agrees to include certain due diligence clauses in the license agreement.

Summary

Many early steps in the product development process are the same whether they are performed by a corporation or by a university researcher. Significant permutations in the process occur after the prototype event. Once the prototype step is reached, there are many possible branches to follow for commercialization. In this paper, the path we chose was that of a federally funded university researcher attempting to commercialize an invention through his or her university's TT office.

When a barrier is identified, the researcher or TTO must seek a carrier, or standard practice, to overcome the barrier. If the barrier is an internal policy or procedure, the researcher and his or her institution must enact corrective measures or rewrite policy. A researcher, and his or her institution, can seek answers or carriers from technology transfer literature or the PDMA.

Conclusions

The authors have served as TT brokers for the last 14 years. In the process we have established a high level of credibility with all stakeholders from researchers to manufacturers to consumers. This allows us to build upon our collaborations with AT and mainstream product manufacturers and to successfully navigate potential barriers to the successful TT of inventions. Knowledge gained from research and practice has helped us to identify barriers to successful TT and to craft carriers and standard practices that would ensure our relative success. University-based technology brokers can apply these same lessons to establish relationships in industries where their faculty members generate inventions.

In this paper we have identified significant barriers to TT and the subsequent carriers to overcome those barriers. However, a key carrier we didn't elaborate on is due diligence. If a researcher or TTO performs the tasks needed to initiate a carrier well, the barrier will be overcome. If the researcher and TTO do not perform well, or at all, the barrier will impede commercialization.

In many cases, successful implementation of a carrier requires significant patience and persistence. For example, if a market doesn't yet exist for a product, a researcher may cultivate a market. Or, if a sales track record for a product doesn't exist, but is needed to license the product, the researcher can make a short production run, sell the product on the internet, and gather data to present the business case to a licensing entity.

Having described a range of carriers to barriers, the authors realize that some barriers exist that researchers, or their organizations, can't overcome. Undeveloped technology and technology that is currently too costly present formidable barriers that may only be resolved with the passage of time. However, technology costs have a way of decreasing, and new opportunities or applications reveal themselves, creating new options for bringing inventions to market.

In the end, for successful technology transfer to take place, researchers and their organizations need not only due diligence, patience, and persistence, but also sufficient time and resources to execute the needed implementations of carriers. And, by the way, a little luck helps too!

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