# LEADING INNOVATION THROUGH DESIGN

Proceedings of the DMI
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AUGUST 8-9 2012 - BOSTON, MA. USA


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**Founded in 1975,** DMI is the world's leading professional organization dedicated to design management. Everything designed, be it a product, identity, interface, environment, or communication, has to be managed. Integrating the creative side (intuitive, visual thinking, designing) with the analytical side (deductive, measurable, business management) is not easy. Design management is the art and science of empowering design to enhance collaboration and synergy between "design" and "business" to improve design effectiveness.

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- Sponsor, conduct and promote research.
- Collect, organize and make accessible a design management body of knowledge.
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Peter Ford and James Woudhuysen (2012). *The fuzzy front end of product design projects: how universities can manage knowledge transfer and creation.*

# THE FUZZY FRONT END OF PRODUCT DESIGN PROJECTS: HOW UNIVERSITIES CAN MANAGE KNOWLEDGE TRANSFER AND CREATION

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De Montfort University

Over 20 years, the Design Unit at De Montfort University, Leicester, has undertaken research projects for both large firms and small or medium-sized enterprises. Many projects have been fully funded by private sector clients; but in those projects assisted by public funds, the Unit's research has brought together manufacturers, sub-contractors, design consultancies, market researchers, intellectual property specialists, funding bodies and other higher education institutions. Using these experiences, the paper focuses on the dynamics of knowledge acquisition during the 'fuzzy front end' of product design projects. We suggest that, through a novel management and integration of different players in new product development, higher education institutions can help small firms, in particular, get existing knowledge transferred to them, develop new knowledge, lower uncertainty through prototypes, and so make the most of design.

*Keywords: Innovation; uncertainty; prototypes*

## METHODOLOGY

The paper first reviews some of the literature that relates to knowledge transfer and the process of design in the early stages of new product development (NPD). It then considers the Design Unit's experience, since 1992, in design-based innovation in manufacturing in the UK's East Midlands region. The experience covers both commissions that were fully funded by private sector clients, and commissions that were partly or wholly funded by three schemes of state support for design. The paper analyses data from this work, and contrasts two projects funded by international companies with two state-supported projects for local firms. The paper concludes by proposing scenarios for the management and integration of knowledge around NPD.

## LITERATURE REVIEW

### KNOWLEDGE AND ITS TRANSFER

The impact of knowledge on general economic life first gained systematic recognition 50 years ago (Machlup, 1962). In the same era, too, there emerged an emphasis on the *communication* of ideas in society, rather than on their production (McLuhan, 1962; Fiore & McLuhan, 1967). In management literature, however, the subtleties of both the transfer of knowledge and its creation were captured in a much later landmark book, *The Knowledge-Creating Company* (Nonaka & Takeuchi, 1995). That book remains relevant today. One reason: more recent studies of product design in UK government-funded Knowledge Transfer Partnerships (KTPs), while useful about its

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commercial benefits, don't always clearly define the nature of the knowledge transfers (Ford & Davies, 2012).

For Nonaka and Takeuchi there are two kinds of knowledge: informal, subjective, intuitive and *tacit* knowledge held by individuals, and formal, *explicit* knowledge. For them, knowledge is primarily tacit, consisting of technical knowhow at the fingertips of professionals, as well as mental schemata, beliefs, ideals, values and emotions. However, when tacit knowledge is converted into the explicit sort, and vice versa, firms can, through such a 'knowledge spiral', acquire 'organizational' knowledge.

What circumstances prompt the kinds of knowledge conversion outlined by Nonaka and Takeuchi? Several authors contend that information from *sources outside the firm* is critical to innovation (Drucker, 1999; Van den Bosch, Volberda, & De Boer, 1999; Reid & de Brentani, 2004). Drucker (1999:114,115) maintained that such information comes not just from suppliers, rivals, and customers, but also from direct personal observation, volunteering for non-profit work, and continuing education. Indeed, what Drucker wrote about continuing education hinted at a useful role that higher education institutions (HEIs) could play with companies.

Others too have seen real possibilities in the tension between academic and corporate environments (Rynes, Bertunek, & Daft, 2001), and in the general interplay between these two milieux (Schaber & Thomas, 2008).

After Nonaka and Takeuchi published, the rise of the Internet gave new weight not so much to the creation of knowledge as to its communication. While the concept of the network society gained a mass audience (Castells, 1996), management literature veered toward the need for 'open' innovation, both in products and in services (Chesbrough, 2003, 2011). In this framework, large, vertically integrated firms manage information in a comforting 'landscape of abundant knowledge' (Chesbrough, 2003:XXV). Thus while Chesbrough concedes that innovation includes *knowledge generation*, he prefers to highlight *moving knowledge around* – getting it from customers, other companies, suppliers, universities, national laboratories, industrial consortia, consultants and start-up firms (Chesbrough, 2003:40, 52).

Clearly knowledge management is essential to product design, and designers need a 'know-what, know-who, know-why, and know-how' framework (Qiu, Chui, & Helander, 2006: 52). However, rather than just the diffusion of information, *intense interaction between both information sender and information receiver has to take place over time* if a true transfer of knowledge is to occur, (Thompson, Jensen & DeTienne, 2009:331,333). Also, true transfer can only take place if the knowledge acquired is *acted upon*, so that it creates *new* knowledge and is assimilated as experience. Open innovation, termed by its boosters as an 'established and mainstream engine of economic growth' (Harwood & Simoes-Brown, 2012:143), tends to downplay this creation of new knowledge and therefore, if anything, tends to impede growth (Woudhuysen, 2010).

## THE 'FUZZY FRONT END' OF NPD PROJECTS

The question of creating new knowledge, and even of acquiring knowledge that already exists, assumes particular force at the inception of an NPD exercise. Here, different participants encounter what has become known as the 'fuzzy front end' (FFE) of such exercises – circumstances that ensure that not all the knowledge necessary for any particular project is yet available to those working on it. Here, it's worth looking at the work done on the car industry by Kim Clark and Takahiro Fujimoto (Clark & Fujimoto, 1990, 1991).

In their original article, Clark and Fujimoto (1990) made names for themselves around the ideas of 'product integrity' and the 'heavyweight product manager'. 'Internal' product integrity in cars meant 'consistency between a product's function and its structure: the parts fit smoothly, the components match and work well together, the layout maximizes the available space' (Clark & Fujimoto, 1990:108). 'External' product integrity, by contrast, meant 'integrating a clear sense of customer expectations into the work of the product development organization as a whole' (Clark & Fujimoto, 1990:108). The work of leading both kinds of integrity fell to heavyweight product managers, automotive engineers who first were ‘deeply involved in creating a strong product concept’, and then, as the concept's ‘guardians’, were out to ‘keep the concept alive and infuse it into every aspect of the new product's design’ (Clark & Fujimoto, 1990:114). In this first excursion, it should be noted, Clark and Fujimoto made several references to the importance of *prototypes* in *early-stage* NPD. For example, they wrote:

> *Production people built high-quality prototypes that tested the design against the realities of commercial production early in the game and so eliminated expensive delays and rework later on.* (Clark & Fujimoto, 1990:119)

By contrast, Clark and Fujimoto made, at this moment, no reference to *uncertainty* in NPD.

By the time of their book, however, Clark and Fujimoto (1991) made several – though only several – mentions of uncertainty in early-stage NPD. Their emphasis remained on product integrity and skilled management. Interestingly, too, in both article and book, the authors emphasized how the heavyweight product manager had to ensure and personify effective communications, but laid much more stress on the person *pushing ideas forward*. The heavyweight had to go about ‘developing an integrated product concept’ (Clark & Fujimoto, 1990:110). Engaged in ‘integrated problem solving’, they were ‘responsible not only for internal coordination, but also for product planning and concept development’ (Clark & Fujimoto, 1991:128, 255).

In the same year that Clark and Fujimoto’s book was published, two other authors popularized the FFE (Smith & Reinertsen, 1991). Interestingly enough, their book argued that the FFE is ‘an area of extraordinary opportunity’ (Smith & Reinertsen, 1991:50). The period between recognition of an opportunity and the moment at which a full development team starts working on it can often be ‘roughly half the time to market’ (Smith & Reinertsen, 1991:50). In turn, buying time in that period is very much cheaper than doing the same later. Altogether, Smith and Reinertsen concluded,

> *The true cost of the Fuzzy Front End is much higher than managers suspect. The most important component of its cost is the cost of delay, not the cost of the people assigned to the project.* (Smith & Reinertsen, 1991:53)

However, reflecting the broader, cultural zeitgeist of uncertainty about the future that came into its own after the end of the Cold War, the literature of innovation and NPD soon lost Smith and Reinertsen’s ‘can-do’ attitude. Indeed, it went on to make a big issue of the unknown. In 1992, a group of four authors from northern Europe and the US wrote up a study of communication between R&D and marketing departments at the FFE: when published in full in 1995, it contained no fewer than 96 mentions of the string ‘uncertain’ (Moenaert, De Meyer, Souder & Deschoolmeester, 1995). Defining uncertainty as the *gap between required and possessed information about user needs, technology, competition, and the required resources*, the study proclaimed that ‘[I]nnovation patterns can be viewed as uncertainty reduction activities, as is shown by the vast majority of scholars in the field’ (Moenaert et al, 1995:244).

Again in 1995, Nathan Rosenberg, one of America’s leading experts on innovation, made a similar point. He wrote:

> *Uncertainty pervades not only basic research, where it is generally recognized, but also product design and new product development. This means that any early commitment to a specific large-scale project [in innovation] – as opposed to a more limited, exploratory approach, is likely to be risky.* (Rosenberg, 1995)

What Rosenberg wrote was not new, so much as a formal setting out of the idea that innovation – especially in large products – is an activity saturated with risk. Indeed, since 1986 and the first publication, in German, of Ulrich Beck's *Risk society* (Beck, 1992) the doctrine has grown that innovation itself is a source of risk.

If the open innovation framework is complacently satisfied with the world's existing knowledge, those who highlight uncertainty seem plagued by doubts. But there are ways out of this dilemma. First, uncertainty can be a positive thing in a sense broader than that specified by Smith and Reinertsen: it can be a *spur to the creation, through action, of new knowledge*. Second, it is possible that uncertainty at the FFE may be greatest for 'discontinuous' as opposed to 'incremental' innovations (Reid & Brentani, 2004:172). However, *prototypes* – early, and perhaps rapid, or virtual – can lower uncertainty in the FFE, across both incremental and discontinuous innovations. The evidence comes from Japanese manufacturers, making largely industrial products around which customer requirements were well understood, but for whom prototypes therefore lowered uncertainties of a technical nature (Verworn, Herstatt, & Nagahira, 2008:12,13). Nevertheless, it is suggestive.

## RESEARCH QUESTIONS

Is knowledge transfer bound up with the production of new knowledge, not just the communication of the existing sort?

Can a commercially experienced academic environment support innovation, in ways that design consultancies and government agencies cannot?

Is uncertainty at the FFE something to be relaxed about, particularly if prototypes are undertaken?

## CONTEXT – THE DESIGN UNIT

The Design Unit established itself in 1992 in response to demand from local industry for a style of design research and innovation that could probably only be met by a University with broad expertise and resources in NPD. For more than 10 years, the Unit designed products ranging from consumer goods, through transport equipment, to retail fixtures and fittings. It did this both for international companies, and for small and medium enterprises (SMEs): in each case, commissions were fully funded by the client. It should be noted here that in Britain, the 2006 Companies Act defines SMEs as firms that have two of three characteristics – an annual turnover of less than £25m (nearly $40m), gross assets of less than £12.5m (nearly $20m), or fewer than 250 employees.

As the Unit gained a name for its collaborative outlook and effective designs, so most projects came about through recommendation and repeat business. In all, more than two thirds of the concepts developed by the Unit reached production, with more than 22 products or product ranges being successfully launched to market over the period 1992-2001. In a significant majority of cases, the Design Unit engaged in a high level of collaboration with a number of players, and so assisted in the transfer of important knowledge. But there was something else, too: in a number of cases, *the level of innovation achieved depended on the creation of new knowledge – and was reflected both in patents, and in the winning of public awards.*

A few years after the election of a Labour government in 1997, the Design Unit's direct work for private sector clients began to be complemented by projects that, in whole or in part, enjoyed the support of the state. With the Regional Development Agencies Act of 1998, the government established Regional Development Agencies (RDAs) throughout the UK. Part of each RDA's job was to support (SMEs). In 2003, therefore, the Design Unit suggested to Leicestershire Economic Partnership, a body backed by money from the East Midlands RDA, that it fund a pilot scheme – Improving Business by Design – aimed at SMEs in the Leicestershire sub-region of the East Midlands (Ford and Marsden, 2005). Thereafter, the Design Unit suggested another initiative, known as the Design Pilot Scheme, to the government's Manufacturing Advisory Service. Today, while the Unit continues with work that is fully funded by private sector clients, it also gains assistance from the European Union, in the shape of the third venture it has put forward: a Regional SME Design Support Scheme, financed by the Union's European Regional Development Fund.

In fact, the Design Unit not only proposed but also managed and implemented each of these three schemes. That gave it the freedom to engage not just SMEs, but also manufacturers, sub-contractors, design consultancies, market researchers, intellectual property specialists, funding bodies and other higher education institutions (HEIs). From 2003 until today, these schemes have seen more than £750,000 (nearly $1.2m) invested in the local design community alone.

Below, we summarise the Design Unit's experience with commissions that were fully funded by private sector clients, and its experience with the three schemes that involved a degree of state support.

## COMMISSIONS FULLY FUNDED BY PRIVATE SECTOR CLIENTS, AND THE THREE SCHEMES USING STATE FUNDS

### COMMISSIONS FULLY FUNDED BY PRIVATE SECTOR CLIENTS, 1992-2002

The EU defines 'micro enterprises' as firms with a headcount of fewer than 10 employees, and a turnover of less than €2m (nearly $2.5m). Predictably, then, the vast majority of the Design Unit's commissions that were fully funded by private sector clients were for firms that were larger than micro enterprises. Often through project managers, clients supplied briefs and specification: in effect, they hired the Design Unit in the way they would a design consultancy, or consultants in design research and forecasting. Clients did bring other players into the work, but this happened only occasionally.

### THE IMPROVING BUSINESS BY DESIGN SCHEME, 2003-7

This scheme began with research into those Leicestershire SMEs that might benefit from support in NPD. The Design Unit identified 52 possible projects among capable manufacturers that also had definite routes to market. Eventually, the Unit selected 16 projects for further development and funding support, and went on to write project briefs and product specifications, hire local design consultancies to act on these, and retain a role guiding design research and implementation through to production. As described earlier, money for this work originated with the East Midlands Development Agency. However, UK central government's Higher Education Innovation Fund, which helps HEIs spin out their ideas into industry, also chipped in cash. Meanwhile, clients invested their time in the design research and implementation stage; they also invested their own cash – but only once manufacturing development began.

Overall, the scheme was highly successful. More than 62 per cent of the Design Unit's interventions went through to manufacture. In central government, industry minister Lord Sainsbury commended the Improving Business by Design scheme for showing 'a 14:1 return on public sector investment through the development of new markets for UK design and manufacturing companies' (Sainsbury, 2005).

### THE MANUFACTURING ADVISORY SERVICE'S DESIGN PILOT SCHEME, 2008-10

The Manufacturing Advisory Service operates across the UK, but has no specific mandate to support design. In 2008, central government was encouraging RDAs to adopt Designing Demand (Design Council), a state run scheme. However, the East Midlands RDA wanted to consider options, and invited the Design Unit to propose how it would support local SMEs through the MAS network.

Following a number of sub-regional events, the Design Unit selected 13 projects among capable manufacturers that also had definite routes to market. The Design Pilot Scheme that emerged around these projects followed Improving Business by Design, in that clients had to fund manufacturing development; but it differed from the earlier scheme in three respects. First, funding for the design stage of each project was here split 50:50 between the Advisory Service and the client companies second, the Unit not only hired design consultants, as before, but did design research and implementation alongside them, while retaining its role in supervising each project through to production. Third, the East Midlands RDA played a role on top of basic funding for design. To local food, drink, medical, transport and construction companies, the RDA's freshly established Innovation Networks made outlays to help in the analysis of markets, the protection of intellectual property and the assembly of prototypes. That, and the way in which the Networks referred clients to the Design Unit, proved an invaluable counterpoint to its Design Pilot Scheme.

Results were remarkable. In all, 11 of the 13 projects undertaken reached production.

### THE REGIONAL SME DESIGN SUPPORT SCHEME OF THE EUROPEAN REGIONAL DEVELOPMENT FUND, 2009-12

Since 2000, England has benefited from more than €5bn of monies from the EU's European Regional Development Fund. Here the Design Unit did not seek out client companies; rather, funds were available to any SME applying for innovation support – including manufacturers spun out from East Midlands universities other than De Montfort. In this case, all the cash for design work came from Brussels, as well as from the UK central government's Higher Education Innovation Fund. As with the Design Pilot Scheme, however, the Innovation Networks run by the East Midlands RDA assisted, and both design consultants and the Design Unit collaborated on the design work. Manufacturing development was, as in the previous two schemes, left for clients to fund.

The Design Support Scheme has turned out to be very popular. Under it, the Design Unit has taken on nearly 100 assignments to date. Strikingly, while about seven in every 10 companies employed just five or fewer staff, more than five in every 10 has so far neared or reached production.

## QUANTITATIVE ANALYSIS OF THE DESIGN UNIT'S WORK

The four figures below quantify the performance characteristics of the 181 design research and implementation projects so far undertaken by the Design Unit. Here, the category 'successful completions' refers to projects that have progressed or are progressing to manufacture, while 'unsuccessful completions' are projects that have not progressed or will not progress to manufacture. In our definition, small enterprises have fewer than 10 employees; medium enterprises form a rather broad category, having between 11 to 250 employees, and large enterprises are organisations with more than 250 employees.

Importantly, 'external Management & Integration' (M&I) refers to those projects in which the Design Unit coordinated the work of a number of players: manufacturers, sub-contractors, design consultancies, market researchers, intellectual property specialists, funding bodies and other higher education institutions.

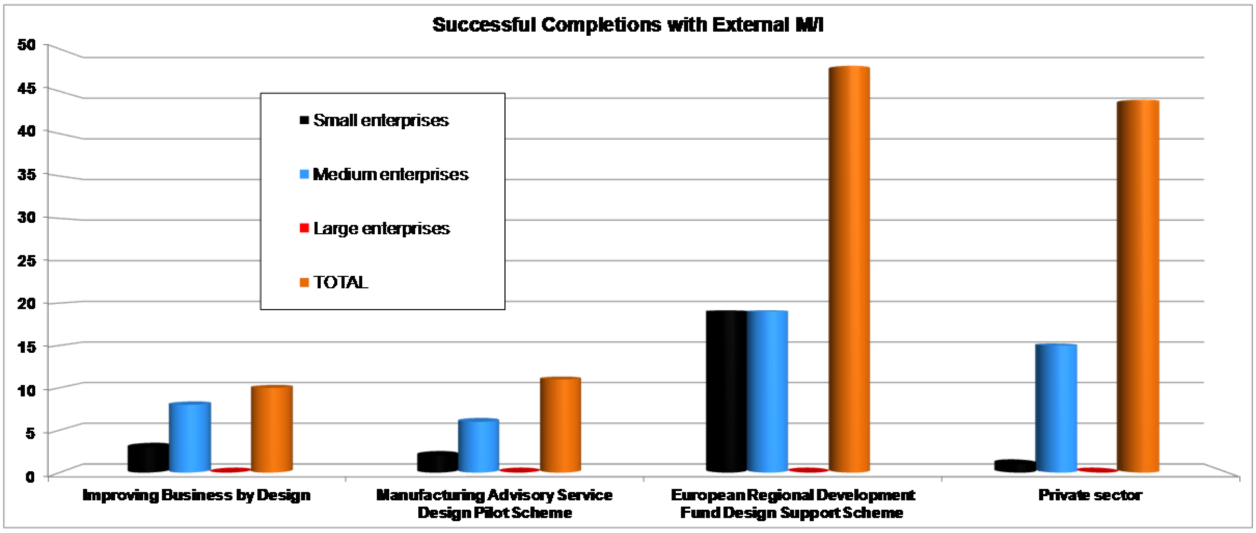


*Figure 1 Number of SUCCESSFUL completions conducted WITH external Management & Integration*

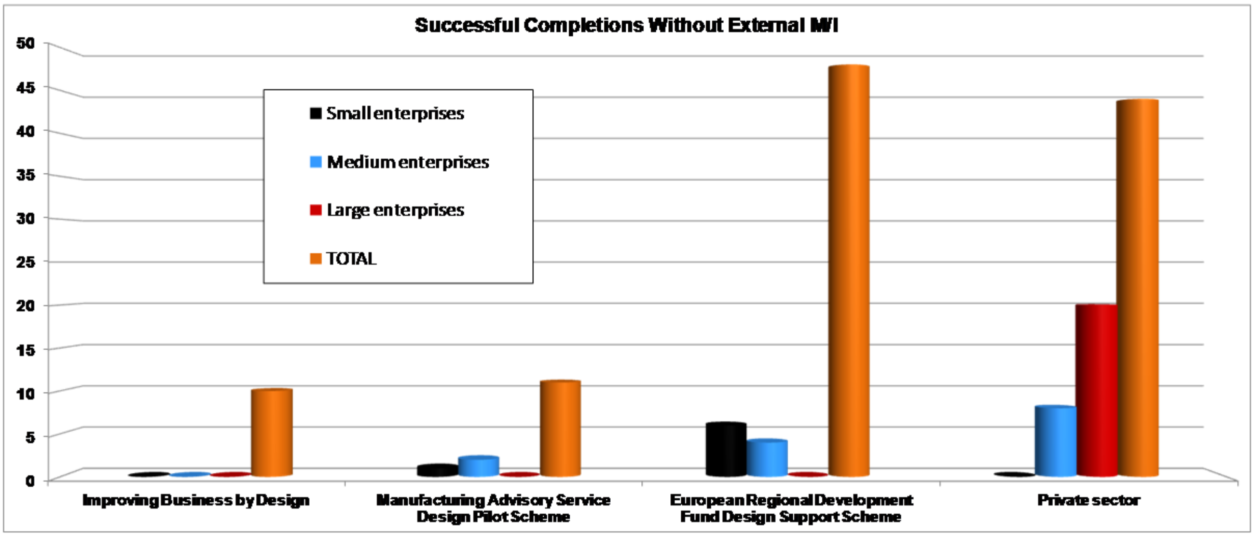


*Figure 2 Number of SUCCESSFUL completions conducted WITHOUT external Management & Integration*

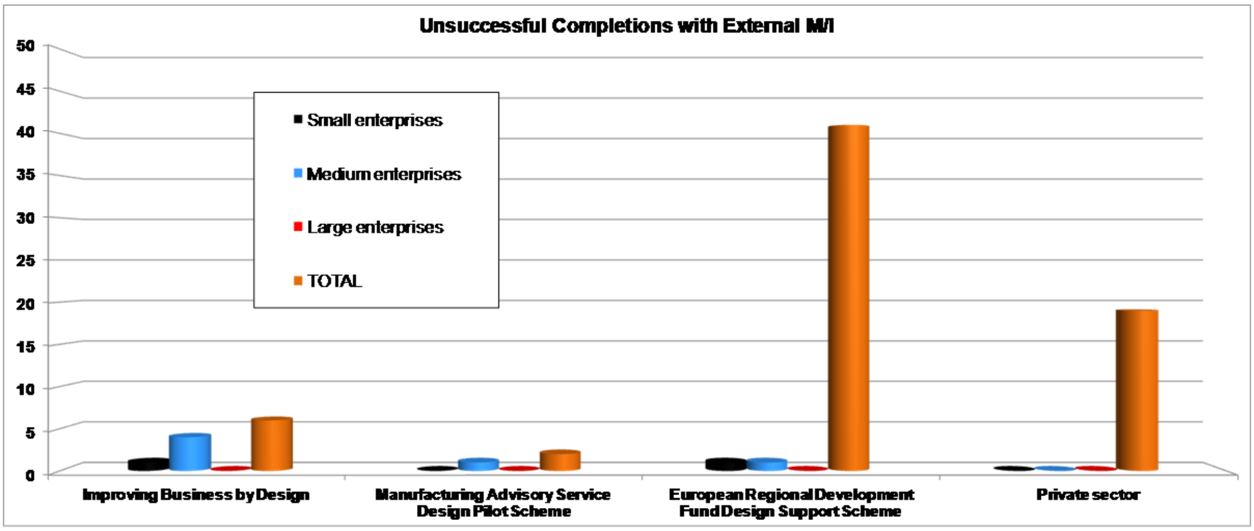


*Figure 3 Number of UNSUCCESSFUL completions conducted WITH external Management & Integration*

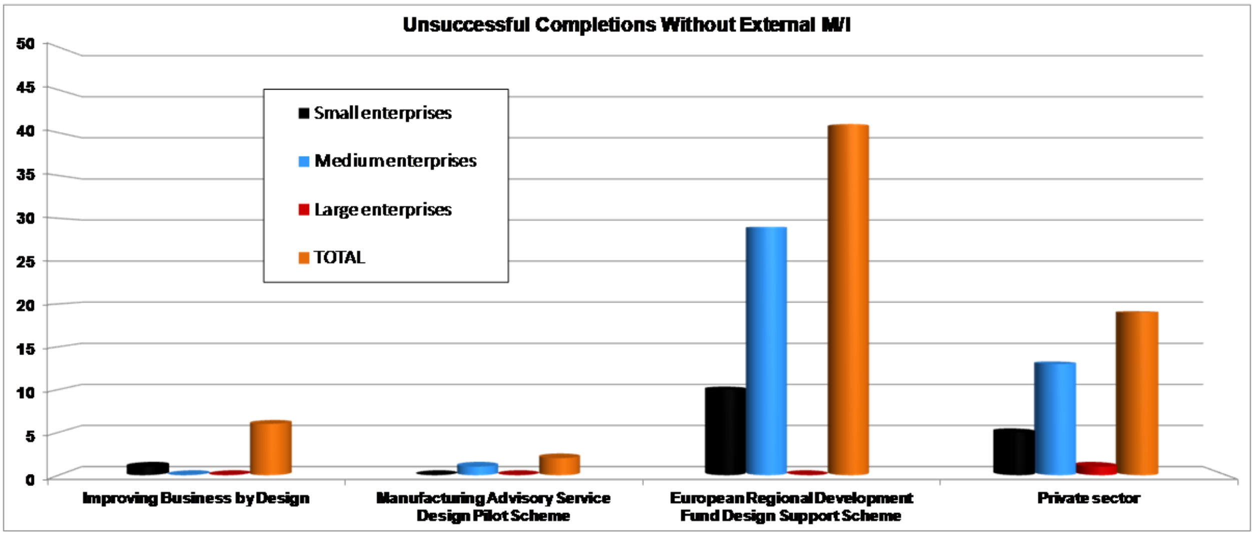


*Figure 4 Number of UNSUCCESSFUL completions conducted WITHOUT external Management & Integration*

Overall, the Design Unit successfully completed nearly two in every three projects. Among small and medium enterprises, there was a strong correlation between successful completions and external M&I: nearly four in every five of such projects met with success. Conversely, where small and medium enterprises enjoyed no external M&I, nearly nine out of 10 projects failed to complete successfully.

Large enterprises fared differently. With them, very few projects failed to complete – whether they were conducted with external M&I, or without it. Clearly, and not unexpectedly, it was small and medium enterprises that drew the most tangible benefits from external M&I.

We now examine four case studies of the Design Unit's work in the light of our quantitative analysis.

## FOUR CASE STUDIES OF THE DESIGN UNIT'S APPROACH

The case studies below span small, medium and large enterprises. Two were fully funded by private sector research contracts; two relate to the publicly funded schemes we have discussed. All four bring out the way in which, if information acquired is acted upon and worked up in the form of prototypes, new knowledge is created.

### CASE STUDY 1 – COMPANY SE, MAKERS OF HAND-HELD SCIENTIFIC EQUIPMENT

SE, a large producer of scientific equipment, runs manufacturing centres in the UK, the US and Scandinavia. Among other products, it makes hand-held devices that determine the composition of a variety of metals. In this product domain, SE's existing model had the reputation of being difficult and costly to manufacture, as well as unreliable to use: as a result, the product was losing market share. The Design Unit's job was to develop a replacement product that avoided these problems, boasted equivalent or higher functionality, and was more comfortable to use. The new product also had to display a whole number of warnings about use to those who handled it, in accordance with ever-tightening regulations. Above all, the new product had to be developed quickly to stem loss of market share. Indeed, the division of SE responsible for the new product knew that its future rested on the outcome of a development programme that, in all, cost £2m (more than $3m).

A key feature of the new design concerned how to manage the dissipation of heat from the product's internal components. The original device had two small heat dissipation panels which, although adequate from a thermal perspective, were very hard to assemble, and very hard, too, to seal inside the product. Eventually, a major innovation was made: a single large extruded aluminium panel was substituted for the two panels. In fact this component came to comprise the bulk of the upper part of the product: it proved to have structural and cosmetic merits, was comparatively easy to assemble, and avoided all the sealing issues of the previous design.

SE gave a dedicated manager responsibility for overall project management, and involved almost all the interested parties in initial concept development, so as to minimise uncertainties. At its conclusion, the project resulted in all the new product's commercial targets achieved and securing the future of the division in charge of it. However the product was late to market – something that inspires three observations.

OBSERVATION 1

While the old product was tricky to manufacture and seal, and had design details that were poorly resolved, it was at least in continuous manufacture. The new design was radically innovative in its configuration, but introducing it promised to disrupt production schedules quite dramatically. Nevertheless it was accepted, because it was 'not like the old model'. Given the disruption caused, there might have been wisdom in simply ironing out the worst features of the old model, and staying with the production routines that accompanied that. However, there was great prejudice against staying with the status quo in any way.

We find this turn of events absorbing. After all, irrational *management prejudice* never figures in the literature on the FFE in NPD.

OBSERVATION 2

A full two months after a first prototype of the new model was built, tests by SE found that the large new single panel within it didn't dissipate heat as well as the two smaller panels in the original model. In this respect, the product lacked what, as we have seen, Clark and Fujimoto (1990:108) termed 'internal' product integrity. Then it emerged that a member of SE's technical team, who had worked on the original design, had suspected all along that heat dissipation would be weak, but had elected to stay silent. Fortunately, *rapid prototyping techniques provided new knowledge*, relatively quickly, about how best to amend the new design.

The two months testing and subsequent design iterations caused delay – and that, combined with other delays (in further design development, the procurement of parts and the commissioning of production tools) had a significant impact on the project's end-date. Altogether, the remarks made by Smith and Reinertsen (1991) about delays at the FFE were strongly confirmed. Still, the use of rapid manufacturing techniques reduced the effect of these delays, and allowed 80 vacuum-cast pre-production models to be sold to and tested by impatient customers. Eventually, fully finished, injection-moulded products succeeded these models.

The lesson here is that *while powerful knowledge may already exist within a development team*, *corporate 'politics' may prevent such tacit knowledge from becoming explicit*. Again, one doesn't encounter such a turn of events in the literature on the FFE, even if the categories 'tacit' and 'explicit', pioneered by Nonaka and Takeuchi (1995), are all too relevant here.

OBSERVATION 3

In their book, Clark and Fujimoto (1991:255) write that heavyweight product managers have broad 'responsibility and clout', that they are 'usually senior within the organization, often at the same or higher rank' as the heads of its functional units, that they 'exercise strong direct and indirect influence across all functions and activities in the project'. The SE person in charge had no authority like this. Indeed throughout the project, all SE employees involved, and especially the person in charge of it, proved excessively cautious. Covering their backs, they unnecessarily prolonged their evaluation of design details (the heat dissipation feature, for example), and so cramped the ability of the Design Unit to assist SE.

Overall, *company habits and a lightweight product manager impeded swift decision-making*. Thankfully, however, the sheer size and financial resources of SE ensured market success. Still, there can be no doubt that SE staff suffered from a *blame culture*, which in turn led to an exaggerated and somewhat congenital *aversion to taking risks*. *Here uncertainty in the FFE was not a gap in information that needed to be closed, but a way of life.*

These facts, which are only too familiar, once again seem to elude the literature on the FFE.

### CASE STUDY 2 – COMPANY SF, MAKERS OF LIGHTWEIGHT SPORTS FOOTWEAR

SF forms a part of a large multinational brand-orientated group, which is highly regarded for its design and manufacture of quality outdoor leisure products. At the time of the Design Unit's involvement with SF, it was encountering rivals who were growing in confidence – while its own product range was in danger of becoming dated. Following an aggressive recruitment campaign, new product managers in both footwear and apparel began to inject a new dynamic into the company.

The Design Unit was commissioned to work alongside the new manager for footwear on a brand new range of high performance, off-road running shoes. The shoes had to be light, provide good support to the wearer, grip the ground very well, and repel all water. Above all, they had to be put on the market within nine months, ready for the start of the winter season.

The new manager was highly experienced and motivated, and integrated the Design Unit very well into the team at SF. Entirely confirming the thesis of Smith and Reinertsen (1991) about *avoiding delays* at the FFE, members of both SF and the Design Unit visited manufacturers in China *before* beginning significant concept work – and when they eventually found one with the skills to handle the project within the required timescales, the tight deadline for the project no longer looked insurmountable.

Innovation here centered on the development of the shoes' upper construction, which was based on volume mesh fabrics on to which polyurethane was flow moulded to provide impact resistance in critical areas. Until this moment, flow moulding at this level of precision had not been achieved on footwear, but the need to cut down weight and use materials that did not absorb water made the innovation essential. Significantly, the approach adopted eschewed all use of leather, since regulations enacted by Brussels ensured that any and all import of this material from China to the European Union would be subject to tax.

A second innovation was the development of a triangular lug on the sole of the shoe; this provides a wedge-shaped grip, with the two triangular arms of each lug giving a buttress-like support for each lug. Again, this was an unprecedented feature for footwear of this type. The final result was the lightest footwear on the market for off-road running, with highly effective grip and protection for the foot, and with a system that would repel water.

SF and the Design Unit undertook a considerable amount of both concept and detail development at the factory in China. The project required a large investment in tooling for sole units, and in particular the development of this unique grip system; but timescales did not allow for much in the way of theoretical analysis or even prototype development in the UK. Ironically, much of the progress achieved was based on the development of 2D data, which the Chinese manufacturer interpreted – at incredible speed – into 3D. Nevertheless, a number of rapid prototypes of the triangular lug system and the sole unit were produced in the UK, while the Chinese manufacturer was able to make prototypes of the upper units by hand, at extraordinary speed. This intimate, close relationship between SF, the Design Unit and the manufacturer, along with iterative development in China, led straight into production development, and was a key factor in the success of the project.

#### OBSERVATION

In direct contrast to SE, at SF *the project leader had the skill, experience and gravitas to act as a heavyweight product manager*. He fully integrated the Design Unit into the NPD process, giving the freedom to operate fully on behalf of SF as an external consultant. This resulted in a unique and innovative range of footwear, one that bolstered SF's position as a leading innovator in sports footwear. In this case, Clark and Fujimoto's heavyweight product manager framework accurately describes what was a successful instance of NPD.

### CASE STUDY 3 – COMPANY WT, MAKERS OF WOUND TREATMENT DEVICES

With 150 staff, WT is a medium enterprise. The East Midlands biosciences Innovation Network introduced it to the Design Unit under the Design Support Scheme of the European Regional Development Fund. The project was to develop what is called a negative pressure wound treatment device – that is, a powered means of lowering air pressure on wounds – which could be worn discreetly by the individual receiving treatment.

The product's primary requirements were to accommodate a power source, and to manage the tubing to and from the wound area – tubing that allow fluids safely to be extracted from the wound. The Design Unit undertook research, while WT was to develop the electronics and associated software.

The project was initiated and managed by WT's managing director, who was a dominant presence within the firm. Because he was also busy, the project moved at a slow pace: those working for the MD on the electronics and software would not make decisions without his approval.

Prototypes were eventually produced for evaluation with target end-users. However, it was discovered not long after, that a very similar product to that envisaged had already been introduced on to the market. That blow to the project proved terminal.

#### OBSERVATION

Given WT's appreciable size, and the obvious potential of the new product, both the Innovation Network and the Design Unit had assumed – wrongly – that WT had done due diligence on the project before it took advantage of state support. Clearly the MD's management style was a negative influence here, too. The result was that, though knowledge was acquired on the project as far as it went, it was not possible to generate new knowledge, because the project had to be cut short.

What this project encountered was an *over-heavy but absentee product manager*. This is a kind of professional who is probably quite common – but rarely, if ever, treated in books or journal articles about the FFE. The case study confirms the critical remarks made by Thompson et al (2009), for while information was in some ways *diffused* between the MD and other parties, *an intense interaction over time* was lacking.

### CASE STUDY 4 – COMPANY KD, MAKERS OF A DEVICE FOR ALLOWING HEALTHCARE PROFESSIONALS TO KNEEL PROPERLY WHILE TREATING PATIENTS

KD, a small enterprise with fewer than 10 employees, specialises in equipment for evacuating hospitals and schools and moving people around them. It identified a need to develop a kneeling system that would allow healthcare professionals – typically, midwives and podiatrists – to undertake a range of near-to-floor tasks in comfort, with proper support, and with full ease of movement. Owing to poor posture while kneeling, many such professionals suffer damage to knees, backs and hips. As with case study 3, the East Midlands biosciences Innovation Network introduced KD to the Design Unit under the Design Support Scheme of the European Regional Development Fund.

The device had both to provide comfort for knees and ankles, and to support the professional's buttocks in such a way as minimise pressure on and fatigue in the lower back and hips. The product also had to be durable, given the way it would likely be handled; adjustable, to accommodate different sizes of user; affordable, and as light as possible. Naturally, too, it had to conform to a number of medical regulations and furniture standards.

To put users in exactly the right position was something that had never been achieved on a product of this type before, and involved iterative theoretical and practical investigations. The iterative use of a range of prototypes, from the basic to those produced with 3D rapid prototyping techniques, eventually led to a unique product – one that supports the knees and the front aspect of ankles in a manner that prevents the blood flowing through joints from being constricted. Buttocks are supported on a saddle that can be moved backward and forward to accommodate different leg lengths. The height of this saddle is critical, for in kneeling it dictates the position of the back and hips, and therefore determines the level of comfort achieved.

Though it had limited experience in NPD, KD had fielded products that had enjoyed consistent sales in the healthcare market. The East Midlands biosciences Innovation Network was able to commission initial research into intellectual property around the new product, perform due diligence exercises on it, and later introduce KD to organisations that could validate its conformance to relevant medical regulations. As for the Design Unit, its usual tasks of research, design development, prototyping and human factors evaluation were supplemented by locating institutions qualified to assess whether the product met relevant furniture standards. Around NPD in this arena, regulation has a special salience.

The Design Unit also found an appropriate manufacturer – a vital task, given the originality of the product and the unknown size of its market. The balance of capital investment to product cost, and the ability to meet a range of potential production volumes was enough of a challenge for it to be required that the manufacturer become part of the development team, rather than act just as a contractor.

Given KD's relative inexperience in NPD, the Design Unit initially took responsibility for establishing the configuration of the product concept and, from then on, for its development; the Unit also managed and integrated of the various players in the project through to the production of initial prototypes. Following this, KD started to develop a stronger role in project management through to the device's final production, all the while continuing to enjoy support from both the Design Unit and the Innovation Network.

Given the innovative nature of the product, as well as uncertainty about the size of its market, the date for its launch was not fixed until pre-production prototypes had been built. That way of doing things proved invaluable, in that it allowed adequate time for the various tasks to be undertaken. Following the evaluation of these prototypes, a launch date was agreed and, later, met. Today, sales of the product have far exceeded expectations.

#### OBSERVATION

Much of the success of this project came down to innovating a unique solution to a clearly identified market need. The process took more than two years, but the willingness of KD to let the Design Unit manage and integrate all the relevant players from concept through to production allowed the Unit to *go beyond design research and implementation by acting as a heavyweight product manager*. On top of this, KD benefited from witnessing M&I in action, so that, in the later stages of the project, it could take on M&I itself. Thus *effective knowledge transfer occurred both in the immediate process of NPD, and in KD's acquisition of skills in M&I*. Also, *the centre of gravity for heavyweight product management shifted from external consultant to client.*

#### THE FOUR CASE STUDIES SUMMED UP

The four case studies above correlate reasonably well with our earlier quantitative analysis. It appears that *large companies can have enough resources to perform successful NPD even when a project manager is weak* (SE), *and certainly when the relevant individual is strong* (SF). Things are not so straightforward, though, for medium and small enterprises. *If they try to manage NPD projects themselves, but lack proper capabilities in M&I, SMEs can get into trouble* (WT). On the other hand, *if SMEs let an external heavyweight project manager take charge of M&I, they can move ahead, and even pick up the talent to perform M&I themselves* (KD).

## FOUR ARRANGEMENTS FOR MANAGING NPD PROJECTS AND TRANSFERRING KNOWLEDGE AROUND THEM

While Clark and Fujimoto (1990, 1991) focused on project management, Thompson et al. (2009) explain that, for true knowledge transfer to take place, it is vital to understand the identity of the senders and receivers, and where new knowledge may reside. Below, we present four heuristics through which both project and knowledge management can be better understood.

In figure 5, a large enterprise performs project management, and the main transfer of knowledge occurs between it and the other players. During the NPD process, the new knowledge created will reside largely within the design firm, though some may flow back to the client.

In figure 6, a small enterprise takes the place of the large one. Because the design firm plays a more dominant M&I role, much of the knowledge that is created and transferred ends up with it.

In figure 7 a business broker intervenes, introducing the client to the design firm, transferring knowledge about public funding possibilities to the client, as well accepting the transfer of knowledge from the client about its funding requirements.

In figure 8, finally, a body with responsibility for M&I handles transfers of knowledge for all players – sub-contractors, design firms and funders.

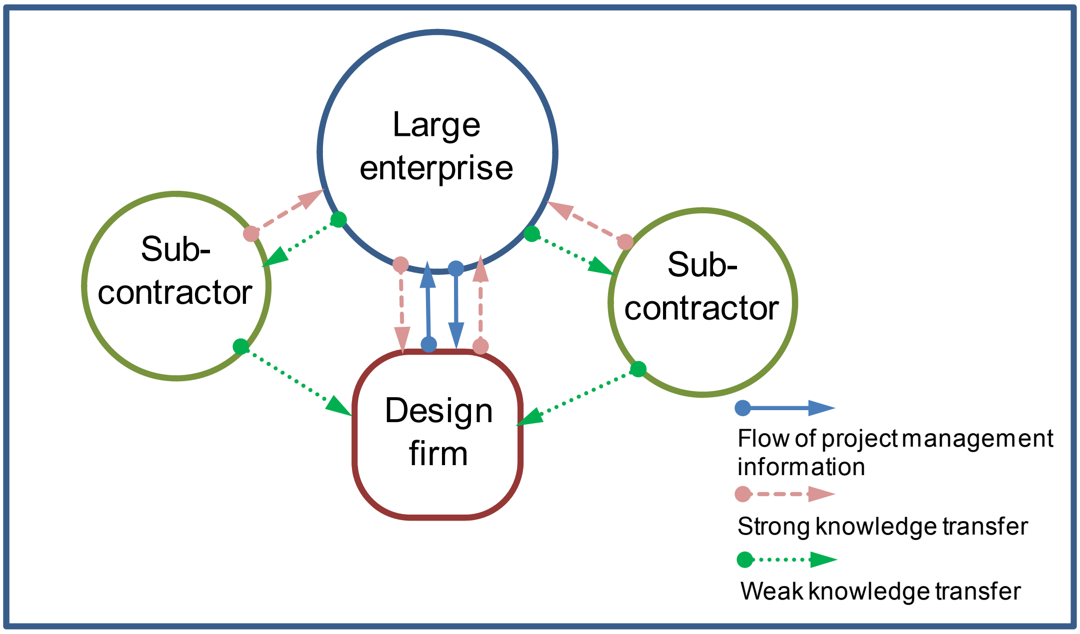


*Figure 5 A large enterprise plays the dominant role in project management and knowledge transfer*

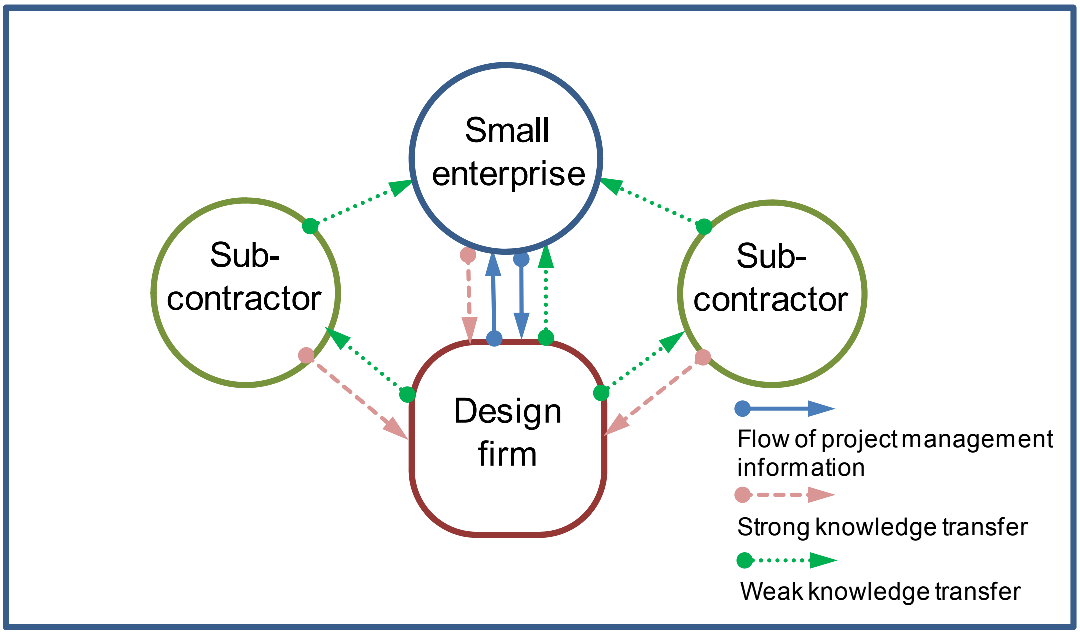


*Figure 6 With a small enterprise, the design firm dominates project management and knowledge transfer*

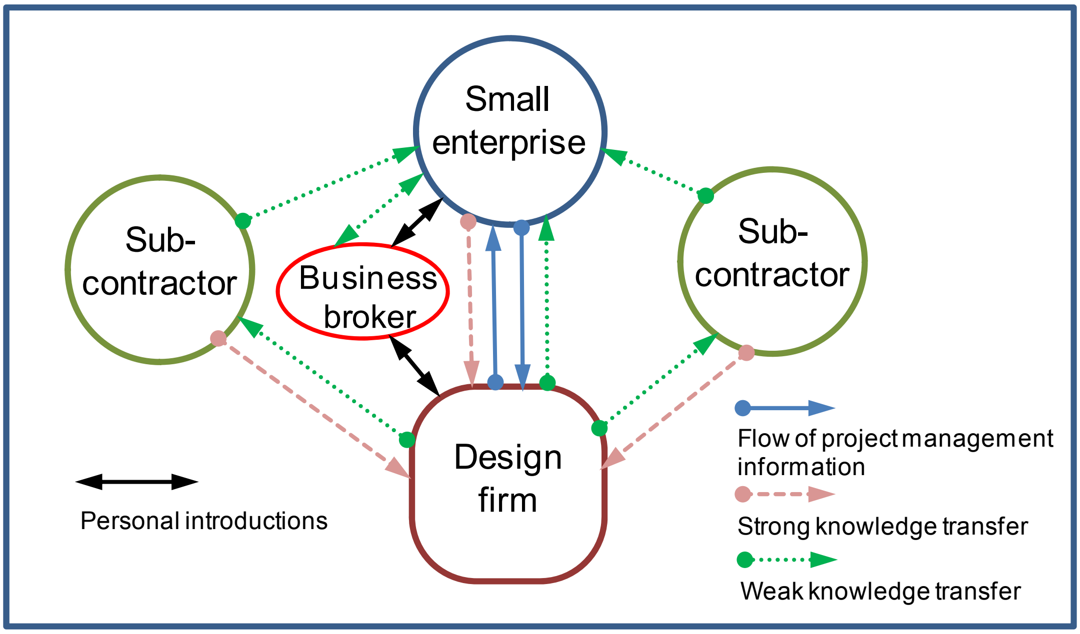


*Figure 7 A business broker links the design firm to a small enterprise, and has a dialogue with the latter about funding*

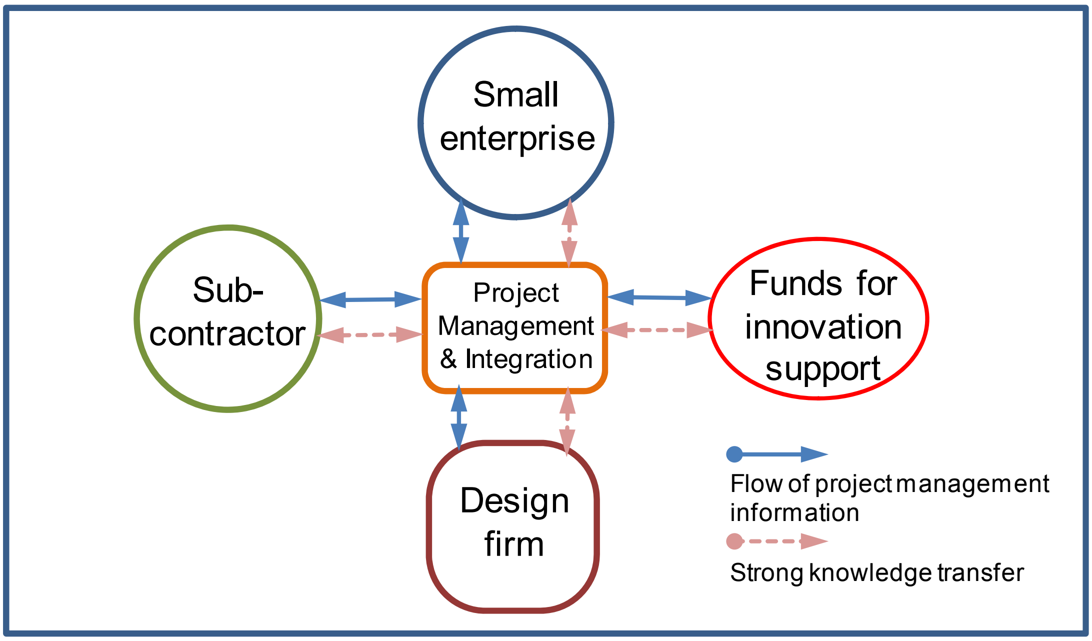


*Figure 8 A body with responsibility for M&I dominates project and knowledge management*

## CONCLUSIONS

The paper brings out a number of points about the fuzzy front end of new product development.

First, *the management of knowledge in NPD is not just about knowledge being relayed from point to point, but also about it being originated*. This ought to be obvious, given that a genuinely new product design or 'discontinuous' innovation might well be thought to embody new thinking; but the doctrine that innovation is largely and simply a clever combination of previous developments is all too fashionable nowadays (Woudhuysen, 2010:27). The significance of prototypes here also ought to be obvious. By its nature, a prototype is meant to test out new ideas, not just embody existing ones or lash them up together.

Second, *a commercially experienced higher education institution can play the role of heavyweight product manager*. It can manage and integrate the work of varied players and, in this work, can ensure not just that lines of communication are clear, but that whole new product concepts are developed and adhered to in the face of setbacks that are inevitable. A commercially experienced HEI can have the kind of clout, objectivity and balanced, comprehensive vision that can save time and money in NPD, and that a project manager internal to a client may not be able to muster. At the same time, HEIs have goals that go beyond time and money, a fact that can work to the advantage of clients.

Third, *uncertainty at the FFE is something to be embraced, not feared*. Again it should not need saying, but *if there were no uncertainty, there would be no novelty*. With company SE (handheld scientific equipment), a simple design facelift would have involved much less uncertainty – but would have led to much lower profits.

Fourth, uncertainty may surround not just user needs, technology, competition or the required resources, but also *state regulation*. The impact of regulation on NPD has almost certainly grown a great deal over the past 20 years, and closing information gaps about it was a key part of the Design Unit's work with company SF (sports footwear with imported components that could have been subject to EU taxes), and with company KD (kneeling devices for healthcare professionals). Indeed, had company WT's product gone forward, medical regulation would have been pivotal there as well.

Last, despite its relative absence from the literature on the FFE, *the size of client companies matters*. In the realm of construction, the category of the novice or inexperienced client has been shown to be relevant to the FFE (Tzortzopoulos, Cooper, Chan & Kagioglou, 2006: 658). That category pretty much describes how many small firms and not a few medium ones would see themselves.

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