THE ESTABLISHMENT AND GROWTH OF A HIGH TECHNOLOGY FIRM: INTERIM RESULTS FROM AN EXPLORATORY LONGITUDINAL CASE STUDY

Shuling Lu[1] and Martin G. Sexton[2]
1 School of the Built Environment, University of Salford, Salford, M5 4WT, UK
2 School of Construction Management and Engineering, University of Reading, RG6 6AW, UK

Entrepreneurs create companies, employment and are often in the vanguard of new technology developments and applications – they are the Schumpeterian agents of 'creative destruction.' This is a widely recognised reality which underpins national and regional policies to create the conditions necessary to encourage and sustain entrepreneurial start-up companies. It is therefore surprising that there is a dearth of research into entrepreneurship within a construction industry context – given the high company formation rate in most national construction sectors. This deficiency is further accentuated by the lack of understanding of entrepreneurship in high technology domains in an era when we seek new technologies to improve the environmental and whole lifecycle performance of buildings. This paper reports on an ongoing Construction Knowledge Exchange funded project which is tracking, real time, the start-up and growth of a company which is developing and introducing a range of leading edge light emitting diode technologies. Interim results will be presented on the interplay between business environment conditions and the complex emergence of the company: from the original motivation of the founders of the firm, to its growth strategy and organisational design and its business development and marketing strategy.

Keywords: entrepreneurship, high technology, light emitting diode.

INTRODUCTION

Small high technology firms play a pivotal role in being in the vanguard of disruptive innovation (for example, see Monck *et al.*, 1988), the development and exploitation of niche market opportunities (for example, see Makri *et al.*, 2006) and employment creation (for example, see Oakey, 1991). The contribution of small companies to the construction industry is beginning to be better understood and appreciated in terms of, for example, innovation (Sexton and Barrett, 2003), specialist subcontractor inputs (Dainty *et al.*, 2005) and professional practices (Lu and Sexton, 2009). However, there is a dearth of research into high technology small firms within a construction context. This deficiency needs to be urgently addressed for two key reasons. First, there is a growing recognition of the systems integration role of the construction industry in absorbing and embedding high technology from other industries (for example, see NESTA, 2007). Second, there is a raft of market and policy induced pressures for the construction industry to deliver more economically, socially and environmentally sustainable built environments which are requiring the adoption and

[1] S.L.Lu@salford.ac.uk
[2] M.G.Sexton@reading.ac.uk

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diffusion of a corresponding raft of new technologies. In unison, these pressures are creating the Schumpeterian Type 1 conditions for entrepreneurial start-up companies to lead the next wave of 'creative destruction.' There is, therefore, an urgent need for research to understand the establishment and growth of such high technology firms if their contributions to the construction industry are to be calibrated and maximised.

This paper begins to contribute to this agenda by offering early results of a longitudinal case study of the start-up of a high technology light emitting diodes (LEDs) company. The results highlight the core market, entrepreneurial, organisational and technological resources which have been developed in its early stages. The case study is appropriate, as LEDs technologies are very much disruptive in nature in that they offer potentially radically enhanced benefits over existing dominant technologies. In addition, the catalyst for the rapid advancement of the LEDs technology and its markets are small high technology firms – rather than the incumbent large lighting companies. The structure is as follows. First, a brief review of the company emergence literature will be given, which will culminate in an initial framework being adopted to structure the case study interim findings. Second, the unique features of high technology and high technology firms will be described. Third, the research methodology being employed will be summarised. Next, the interim results will be presented. Finally, conclusions will be draw and future intentions for the ongoing longitudinal case study articulated.

ORGANISATIONAL EMERGENCE

The research into the emergence of firms is generally an under researched field (for example, see Reynolds and White, 1997: 39). This research gap is certainly evident in a construction context where the authors could find very little theoretical or empirical research on construction firm emergence. What research there is has tended to focus on the growth of firms already established. Neves and Bugalho (2008), for instance, provide insights into the emerging multinational construction corporations; Huo *et al.* (2006) offer a range of factors for successful entrepreneurship with the construction and property sectors in Hong Kong; while Sexton and Barrett (2003) propose a hierarchy of growth stages for small construction firms from survival, through to stability and growth. But, to reiterate, in such research the focus is on firms that already exist. There are, however, a number of frameworks which have been developed in other sector contexts which may be of use. The common theme of these frameworks is the idea that there are core elements which need to be in place and that these elements are systemic in their interaction. Katz and Gartner (1988), for example, offered a framework that accounts for company formation by detailing the properties of emerging organisations. Beginning with the assumption that companies emerge from the interaction between individuals and the environment, Katz and Gartner posit that four core properties are central to organisational emergence. These properties are: intentionality – the purposeful vision and effort involved in organisation emergence; resources – the tangible and intangible building blocks of an organisation; boundary – the creation of protected or formalised areas in which emergence occurs (e.g. the creation of a legal company entity); and, exchange – the crossing of boundaries to either secure inputs (e.g. resources) or outputs of the organisation (e.g. sales). This process view of organisational emergence is evident in other work. Van de Ven *et al.* (1989) argued, for instance, that researchers exploring the business creation process should focus their attention on "(1) how a business idea (or strategy) emerges over time, (2) when and how different functional competencies are created to develop and market the first proprietary product, (3) when and how

these functional competencies are redeployed to develop subsequent new products in a family or products believed to result in a sustainable business, and (4) how these business development efforts both influence and are constrained by organisation and industry contexts" (pp. 224-225). The systemic nature of such process conceptualisations is captured by the argument made by Gartner (1985) that the process of new firm creation can only be fully understood by studying the interaction of the various components: "the creation of a new venture is a multi dimensional phenomenon; each variable describes only a single dimension of the phenomenon and cannot be taken alone" (p.697).

For the interim results reported in this paper, we have adopted the more snap-shot, analytical structure of emergence outlined by Vesper (1990) who argues that a new company consists of five principal components: (1) technical know-how, (2) a product or service idea, (3) personal contacts, (4) physical resources, and (5) customer orders. This framework has many limitations – for example it does not properly consider the capabilities and motivations of the founding entrepreneur(s) or the environmental context within which the organisation emerges (for example, see Sexton and Barrett, 2003). As the longitudinal case study progresses (see Research Methodology) this emergent perspective will become visible and, in a grounded theory sense, be articulated. At this early, exploratory stage the Vesper framework provides an initial starting point from which the researchers intend to develop more appropriate and sophisticated methodologies and grounded theories. Taking each of these components in turn, we understand them to be as follows:

6. Technical know-how - the necessary knowledge, experience and skills to establish the firm and develop new products or services.
7. Product or service idea - a product or service offering which creates or responds to a commercial viable market demand.
8. Personal contacts - the necessary market knowledge and relationship capital to exploit existing and develop new industry and market networks and contacts.
9. Physical resources - the necessary financial and tangible resources to initiate, direct and sustain activity.
10. Customer orders - the necessary orders to create and maintain viable revenue streams for company sustenance and growth.

HIGH TECHNOLOGY AND HIGH TECHNOLOGY FIRMS

There is considerable definitional ambiguity regarding high technology and high technology firms (for example, see Goss and Vozikis, 1994). Technology, in its broadest sense, is the stock of knowledge that allows new techniques to be developed and includes both product and process know-what and know-how. The dominant criterion which has been used to distinguish between high technology and low technology firms has been considered in terms of expenditure of R&D as a percentage of sales. There has been significant criticism of the validity of this measure. Mowery and Rosenberg (1986), for instance, has brought our attention to the reality that input R&D is a poor metric of innovation in that it ignores the pivotal role that the diffusion process has in significantly shaping the substance and application of new products. Taking note of this, and other, criticisms, the intentionality higher level definition given by the Office of Technology Assessment (1982: 9) is taken as a starting point for this research: "[those firms] engaged in the design, development, and introduction of new products and/or innovative manufacturing processes through the systematic application of scientific and technical knowledge."

Intrinsic to this conceptualisation of high technology is that for the high technology firm it has to respond to the following heightened uncertainties experienced by its actual and potential customers (compared to low technology products): market uncertainty, technological uncertainty and competitive volatility (Mohr *et al.*, 2005). Market uncertainty is the high degree of ambiguity about the type and extent of customer needs that can be satisfied by the new technology. Technological uncertainty refers to whether or not the new technology (and/or the firm providing it) can deliver on its promises to meet those specific needs. Finally, competitive volatility portrays the rapid changes in the determinants of competition, the entrance and exit of firms, and the basic and applied technologies being used. These characteristics are intensified in 'disruptive technologies.' A disruptive technology results in significant changes in the price-performance boundary (Christensen, 1997; Anderson and Tushman, 1990). Its appeal over existing products rests on superior functional performance rather than cost (Abernathy and Utterback, 1988). It has been found that when a disruptive technology is first brought to market, it is frequently not fully developed and the commercialising firm must, therefore, often introduce it in a smaller, peripheral market (Adner, 2002). As performance improves, the product comes closer to meeting the performance demands of the large, mainstream market. It enters the low-end part of this market, moving steadily upmarket as performance continues to improve (Adner, 2002; Christensen, 1997). The carriers of disruptive technologies are often start-up high technology firms which can challenge, and sometimes displace significantly larger and more powerful, experienced incumbents (Christensen, 1997).

High technology start-up firms, drawing upon the Vesper (1990) framework outlined above, need the necessary resources and capabilities to sense and manage these acute uncertainties during its emergence and growth. It is this development of a better understanding of this sensing making and emergent organisation of a high technology start-up company within a construction context which is central to this longitudinal case study described in the next section.

RESEARCH METHODOLOGY

The research, part funded by the Construction Knowledge Exchange, is at the early stages of what will be a longitudinal case study over a number of years which will track the emergence and growth (or decline) of STARTUP, a start-up LEDs lamp manufacturer. (STARTUP is a fictitious name for reasons of anonymity.) A longitudinal case study methodology has been adopted to capture and map the unfolding journey in real time (Van de Ven, *et al.*, 1999). This approach is consistent with Gartner (1998) who stressed the limitations of historical investigation of the start-up and growth of firms and extolled the need for new venture creation processes to be best studies ‘in the raw’ in order to develop and maintain a true and unbiased perspective of the phenomenon.

The data collection process began in August 2008 has taken the form of periodically sitting in on STARTUP meetings when important issues are being discussed (in particular, new product development issues), conducting semi-structured interviews with the founding entrepreneurs and with key clients, and analysing relevant company and client documentation. The meetings and interviews are recorded and transcripts produced. The data has been analysed using content analysis and cognitive mapping techniques.

At present, the research is very much in the sense-making stage from which theoretical constructs are emerging through which the ongoing case study is being chronicled and coded. Further, the longitudinal research methodology and methods are being developed and honed through the process in response to a maturing relationship between the 'researched' and the 'researchers' and to the events and decisions as they unfold. This emergent, iterative method resonates with Scott Poole *et al.*, (2000: 129) approach to longitudinal observation that "when [the] study of organisational development processes is at an embryonic stage …. initial categories emerge as "sensitising constructs" for conducting exploratory research [with the] categories becoming clearer as they are put to use, and eventually they can be codified into a formal scheme."

The principal research methodology challenge to date has been the risk of information overload. The researchers are aware that there is a mindset to try and capture everything that is happening as the firm emerges as they do not want to risk, in grounded theory terms, 'path dependency' on extant literature to distinguish between what is relevant primary data and what is not. From the case study firm's perspective, they value the collaboration, but want 'light touch' data collection methods (such as participation of the researchers in its business meetings) to reduce its time commitments. At present, therefore, we are seeking 'grounded' loci from the data to direct the research as well as 'low impact' data collection techniques to reduce the transaction costs of the case study to STARTUP staff.

INTERIM RESULTS

LEDs technology and market

A light emitting diode (LED) is a semiconductor diode which is electroluminescent. LED technology has marked functional benefits over incumbent incandescent and halogen technologies. White LEDs, for example, have a practical operational life of 50,000 hours compared with 1000 hours for incandescent lamps and 2-4000 hours for halogen lamps (e.g. FGL, 2006: 7). In addition, white LEDs are over 400% more efficient than incandescent lamps and 300% more than halogen (TSB / DIUS, 2007). LEDs are being seen as a disruptive technology. First, the significantly enhanced functional performance of the technology is responding to a long standing need in a way which is totally different from traditional lighting technologies. The IEA (2006, p. 42), for example, argue that "LEDs appear to have the greatest scope for improvement and may yet transform the global lighting market." Second, the LEDs market is attracting the entrance of many new start-up firms which is threatening the dominance of the 'big three' incumbent firms - Philips, OSRAM and General Electric (e.g. Strategies Unlimited, 2008).

The LEDS market is rapidly growing from a low starting point as the technology advances and application areas proliferate. According to Strategies Unlimited (2008), the market for LEDs in lighting amounted to $325 million in 2007 and is forecast to over $1.5 billion by 2012.

STARTUP - Five principal components of the firm

1. Technical know-how

The initial knowledge came from the three founders of the firm who set the firm up in July 2007 - all of which had significant experience of the LEDs industry. The Chief Executive Officer had ten years experience and expertise in setting up and managing manufacturing plant and integrated supply chains. This experience had an

international dimension with periods spent in Belgium, China, California and Malaysia. The second founder and President of the firm has extensive technical knowledge and experience of LEDs and has been involved in the development of international technical standards. The final founder is the Chief Technology Officer and he is the technical authority within the firm and has principal responsibility for the development of the patent portfolio. All three of the founders met whilst working in one of the global lighting firms and, prior to setting up STARTUP, were equity partners in a LEDs spin-off firm from that global company. The founding group, therefore, had a long history of working with each other. The founders were aware that they had comprehensive technical LEDs knowledge but lacked complementary in-depth market knowledge. At an early stage they headhunted a person from the global firm they had all worked for and made him an equity partner in February 2008. The new Vice President of R&D and Marketing had twenty years experience of new business development and marketing in the solid state lighting sector with a global network of contacts in client organisations and original equipment manufacturers (OEMs). The complementary knowledge and experience bases of the four equity partners of STARTUP are described as follows:

"So four very complementary sets of expertise so we building up the story. There are all of us saying the how we going to survive with [a] defensive strategy in the global lighting market. Secondly, with knowledge in our hands, it is making break through products [to] start up in lighting industry."

The firm recruited six additional members of staff in February 2008 and has recruited more people in 2009 so that by March it STARTUP has sixteen staff.

2. Product idea

The core product idea is the novel use of phosphorous coatings (which STARTUP has patented) in a suite of LED modules. STARTUP has a range of patents in this technology. No particular feature of the module is market leading in itself, but its overall technical performance in terms of colour point consistency and photometric performance and so on makes it, STARTUP claim, a unique product offering in the market:

"... our technology is probably not unique. Nor is unique neither in colour point, nor in unique in size. However, put this together it becomes unique. No product is the same in the market."

The initial product development was very much 'technology push' in nature, with the technical people in the R&D laboratory coming up with technical sophisticated module ideas but without any idea whether or not there was market demand for them. One of the first tasks the new marketing vice-president did was to have a two day workshop to filter out unviable ideas and then, with specifiers in his personal network, develop specifications:

"…first of all, few months before I join they played around with different technologies that are two or three or four ideas …with some basic ideas then I came. I have viable ideas much more than the others. I said that lets start one product not three and get in the market first. Let's make super product that has colour change and something more complex. Then I talk to specifiers and firm up a specification which is viable. Talking to specifiers was the first thing. We then redeveloped specification."

This co-production of product specifications between STARTUP and specifiers is at the core of both developing market knowledge and creating routes to market. The

main market demand is for increased lumen output which is driving the flow of new modules. STARTUP is experiencing a technology bottleneck, in that the required lumen output is predicated on more basic innovation in the LED semiconductors.

3. Personal contacts
The networks of the founding members are seen as key to whether or not STARTUP is a success: "relationship is the key in this [the lighting] industry." The networks are both sources of knowledge and sources of legitimacy for the firm. At this stage, new product development and market entry is being rotated around a number of small, progressive OEMs in Europe. The relationships with these OEMs are being nurtured for two reasons. First, STARTUP believes that these OEMs are more likely to adopt the new technologies as they operate in niche markets and are motivated to secure first mover advantage. Second, because of the OEMs want to bring the new technology to market fast, there is a greater commitment to sharing their knowledge and working closely with STARTUP in specifying the new modules. This user input and co-production is indicated in the following:

"We need to make [the module] right. Indeed there have been some small changes by working and listening with them. Very firstly, the demonstrators [or prototypes] they had are not the same as now. They [the OEMs] need to listen to the market change before they say O.K. … so it is a nice position to talk with OEMs."

Further, personal contacts are being extensively used to recruit staff. To date, all staff have been headhunted to secure valuable and unique knowledge and network capitals which STARTUP need.

4. Physical resources
The upfront investment for STARTUP is being provided mainly by the three founders from the proceeds from the selling off of the spin-off company that they had equity shares in (see 'technical know-how' section above). The business plan is based on a return on the initial investment after three years. The firm has a head office and a R&D laboratory in California and has outsourced the manufacturing to Malaysia in 2009. The setting up and ramping up of the manufacturing plant has been a major priority for the firm to ensure exalting quality control:

"…we need two or three month for testing and tuning. Now they are ready this week. This time we made a completely new module this week. We want 100 percent check. We quality checked the first twenty modules …so they did good job."

5. Customer orders
The STARTUP business plan has modest revenue targets for the first time for 2009 with breakeven on the initial investment planned for 2010. The pricing strategy has been a major problem because of the significant weakening of the pound against the US dollar (which the modules are priced in). The first orders have now been placed by two OEMs, with the OEMs absorbing all of the currency exchange risk. The 700 lumen module will be joined by the new 1000 lumen module in August 2009. STARTUP sees it as critical to launch this as orders are being delayed in anticipated of this upgraded module.

CONCLUSIONS

This paper has reported early results from what is anticipated to be a longitudinal case study over a number of years which will map the start-up and growth journey of a high technology firm. The priorities of the firm for the first eighteen months of its life has been to secure knowledge capital through careful recruitment of staff; the

harnessing of a limited number of OEM relationships to establish legitimacy for STARTUP and to co-produce the specifications for the new module products; and, the setting up of manufacturing capacity in Malaysia. The firm has not generated any revenue to date - this will now be the priority over the coming 12 months. This is going to be hampered by the current severe global recession. If the revenue is insufficient, the founders of the firm are sensitised to the reality that they may need to seek venture capital. This is not something that they want to do - as they want to keep the autonomy of the management of the firm intact.

The case study is also yielding results on the critical role of the original equipment manufacturers as intermediate users in shaping the new product design and application of LEDs. The ongoing capture and understanding of this phenomenon in the longitudinal case study will be informed by (and hopefully be of interest to) the socio-technical innovation systems research community which is expanding our understanding of the role of users in shaping and interpreting technology within a construction context (for example, see Harty, 2008).

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