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Diffusing Digital Ink-Jet Printing as a Production Innovation in the Printed Textiles Industry

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Abstract

We report on research into factors hindering and facilitating diffusion of digital ink-jet printing (DIP) as a full-scale production innovation in the printed textiles industry. DIP has gained substantial acceptance as a method for speedily producing small numbers of printed textiles as samples in the design and development phase. However, as a full-scale production method where high volumes are required at low cost then the technology has still to gain acceptance. To examine factors constraining and facilitating acceptance, a qualitative approach is undertaken using semi-structured interviews with senior managers located in organisations comprising major stakeholders in the supply chain for printed textiles. The interviews concentrate on key themes of knowledge of the innovation, supply chain relationships, and potential interaction between the innovation, and existing products and processes.

Keywords: Innovation, Textiles, Supply Chain, Digital Printing

1. Introduction

Technological innovation in manufacturing firms is widely acknowledged as one of the main engines for industrial competitiveness and national development (Freeman, 1982; Porter, 1985; Trott, 2002). In essence, innovation is seen as the essential step to the competitive success of individual companies and industrial sectors as a whole (Sadowski and Roth, 1999; Zahra et al, 1994). However, while much research has focused on the organisation as the unit of analysis, the need to recognise the influence of networks has grown. In this paper we investigate the barriers to the diffusion of a specific innovation, digital ink-jet printing (DIP), within the supply network of the textiles industry. Inkjet technology is widely used in the home, office, and
graphic arts environments, and is now extending into other areas such as the textile industry. Although DIP technology is increasingly adopted within the textile industry as a means of creating samples, where the key process capabilities include speed and low volume, it has yet to be embraced as a full-scale production method by textile manufacturers. Therefore, detailed research in identifying the barriers to the diffusion of DIP as a full-scale printing method and how these can be surmounted is useful. In this research a holistic approach to understanding the issues determining adoption by textile manufacturers is undertaken, an approach that acknowledges the influences in the supply network structure that the textile manufacturer is embedded within. The approach recognises that diffusion of DIP to the focal manufacturing firms is influenced by, and influences, the other actors in the supply network. One facet of this approach is to study the interaction of different innovation types: product, process and administrative. Another facet is to examine how supply chain relationships might influence innovation diffusion. First the paper outlines some theoretical background before examining the textile industry and its existing production technology. Next, DIP is introduced and its use in textile production discussed. The methodology is then detailed and some preliminary findings presented.

2. Theoretical Framework

Rogers (1995 p. 11), when focusing on the outcome rather than the process, defines innovation as “an idea, practice, or object that is perceived as new by an individual or some other unit of adoption”. Technology, a major innovation outcome, can be defined as “any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended”. This definition is a broad one that allows, when focusing on
manufacturing organisations, discussion of product, process and administrative technology just as the innovation process can be divided into the following three types. First, product innovation refers to development and introduction of a new or improved goods and services bundle that is successful in the market. Second, process innovation is associated with changes in the production process, i.e. new or improved methods of manufacture, distribution or delivery of service. Third, administrative, or organisational, innovation involves changes in management or work organisation. Although three innovation types can be identified, in practice such innovation types occur together and interact. For example, a particular process innovation may well be associated with the need to innovate in the product design (Abernathy and Utterback, 1978). Similarly individual innovations of a specific type may well occur and evolve together with one or more innovations of the same type.

When studying innovations a simplifying distinction can be drawn in the innovation process between the generation of the innovation and the adoption (Gopalakrishnan and Damanpour, 1997). Simplifying in the sense that such an approach ignores the evolution of an innovation that often takes place during its organisational assimilation.

While earlier research focused on individual organisations as units of analysis, increasing attention has been paid to the topic of networks. Networks can enter into innovation study in a number of ways. In one sense networks have been at the centre of innovation research since its inception in that conventional theory often deals with a network comprised of adopters or potential adopters. For example, according to Rogers (1995 p.304) “we must understand the nature of networks if we are to understand fully the diffusion of innovations”. Network in this
sense is used simply to mean groups of adopters or potential adopters that are able to communicate about a specific innovation under study. Teubal et al. (1987) argue that a network is a required form to ensure the success of an innovation. Successful innovation requires communicating via networks, forming and establishing relationships (Chesnais, 1988) and generating collective knowledge through these channels (Håkanssan, 1989). In a similar vein the focus can be on networks of individuals or organisations involved with the generation phase, i.e. networks of innovators.

However, more complex networks where network nodes occupy a wider variety of roles than simply adopter, or generator, of a specific innovation present a more challenging research problem. The supply chain is such a network, a value chain that forms an ecosystem of organisations where individual organisations interconnect and interact with one another in order to add value to the ultimate product (technology) (Tatikonda and Stock, 2003). In a simple supply chain one might envisage the situation where a manufacturer might adopt an innovative machine tool that had been generated by the equipment supplier. In this situation the manufacturer adopts a process innovation that embodies the product innovation of the equipment supplier. In turn the new process might require the material supplier to innovate in the material that they supply, i.e. a product innovation for the material supplier. Towards the other end of the supply chain the manufacturer’s process innovation may enable innovation in the product that they offer to their customer. These examples illustrate the interaction between different innovation types in the different nodes of the network. Afuah and Bahram (1995) concentrate on a similar theme when exploring the “hypercube of innovation”.

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One view of innovation diffusion focuses on information as a key determinant of the adopter’s decision to adopt (Lissoni and Metcalfe, 1994) therefore information or knowledge flows are important in supply chains. However, other factors loom important when considering supply networks. The relationships that exist “can be described in terms of the power–dependence relationship which exists between the companies, the state of conflict or cooperation and overall closeness or distance of the relationship as well as by the companies’ mutual expectations” (Håkansson, 1982).

Therefore a basic element of the theoretical framework adopted here is that the diffusion of a specific technological innovation (DIP) within a supply network (textile manufacturing) depends on the interactions of product, process, and administrative innovations within and between the individual organisations comprising the network. Knowledge flows and the relationships between actors in the network are seen as important aspects that affect the interaction.

3. The Textiles Industry and Existing Production Methods of Printing

The textile industry comprises a mature industry based on a complex supply network where stakeholders interact through multidimensional business and social relationships. Textile printing is usually a mainstream activity carried out by the textile producer positioned at the hub of the supply network (see Figure 1).
Figure 1: Key Stakeholders in the Textile Printing Supply Chain and their Major Interactions.

The black arrows show the physical interactions with the printing company/ commission printers (full-scale production) whereas the red arrows show the physical interactions with the designers/ converters/ garment makers (short or medium run production).

The green arrow indicates the physical interactions between the equipment/ inks and dyes/ software/ materials manufacturers and suppliers and the design schools/ colleges and universities.
Within the changing world of textile finishing and printing, there have been various methods of applying multi-colour designs to textile webs developed over the years. Almost 70% of fabrics are dyed, 20% are printed, 5% are made from dyed yarn, and 5% are produced white. A number of technologies have been, and in some cases continue to be, used in the textile industry. Rotary screen-printing is the most popular production technology and is likely to remain so for several years to come (see Figure 2).

![Figure 2: Production technology trends](image)

Roller printing is one of the oldest techniques whose high usage has diminished over the years from its dominant position in the 1970’s when it was considered the technique for mass production. It was supplanted by rotary screen-printing which during the 90’s reached 60% share of production. Rotary has proved to be an ideal sophisticated method of printing textiles. It has seemingly infinite capacity for adaptability to different media such as textile webs, wallpaper, carpets, and vinyl floor coverings. The technology is able to print intricate fine details, tonal effects, and textural effects that were previously only achievable by engraved rollers and hand screens. Therefore the technique can be used for all categories of printing work from smaller
quantities of sophisticated fabrics to mass production. Decreased production in the West but strong growth in the Far East, where flatbed production is predominantly used, has meant that the flatbed share has increased. This reflects the cheaper labour costs that render this (relatively) labour intensive method economical to use. A further reason for the increase in flatbed printing is the reduction in average production run length.

4. Digital Ink-Jet Printing

Ink-jet is a non-impact dot-matrix printing technology in which droplets of ink are jetted from a small aperture directly to a specified position on a media to create an image (Le, 1998). The widespread embodiment of ink-jet technology in computer printers means that the technology is reasonably familiar to many in the population. The technology can be grouped into three different types:

- Drop-on-demand (DOD)
- Continuous-spray
- Airbrush/valve spray

Of the three groups, the DOD and the continuous-spray methods are preferred methods used in printing onto textiles. In DOD printing, when the control mechanism wants to fire a droplet of ink onto the media, a signal is sent to the ink-jet head which does the job, i.e. one signal = one droplet (Pond, 2000). Although various types of DOD methods of printing have been developed over the past, the market is dominated by two methods specifically, the thermal bubble-jet and the piezoelectric types (Dawson, 2003). On the other hand, continuous-spray method of printing, works on the basis where each ink orifice sprays ink drops toward the printing surface continuously. When an ink drop leaves the orifice its trajectory is modified by electric charges,
which vary in strength based on digitised computer information (Adams, Faux, and Rieber, 1996). In moving from the computer-printer application area to that of printing on textiles then ink-jet technology confronts challenges. These include the need to print with different inks on a variety of substrates that are typically presented in continuous webs having widths measured in metres and required speeds that are substantially faster than those encountered in computer printing.

5. Digital Ink-Jet Printing and Textiles

The textile market can be divided roughly into three segments: apparel (63% by value), home furnishing (31%) and technical textiles (6%). Ink-jet printing has already been implemented in a wide range of applications: carpets, sampling and proofing, scarves and ties, garments, short-run apparel printing, theatre back drop, banners and flags, and automotive fabric. Common aspects of these application areas are low volume and/or speedy production of first one-off. DIP has already made substantial inroads into the area of sample production where very short runs are required speedily. However, a set of unresolved issues relate to the developing capability of the technology and its potential evolution into a full-scale production method that could supplant the existing dominant technology set. Designers and manufacturers of digital ink-jet printers for textiles have focused on the improvement of various technical aspects such as speed, reliability, and quality that act as barriers to the wider diffusion of digital inkjet printing as a full-scale production tool (Dawson, 2001). However, improvement of technical capabilities is only part of the picture if ink-jet technology is to become a full-scale production method for printing in the textile industry. It is well known that technical superiority is not of itself a sufficient ingredient for a particular technology to gain dominance, e.g. VHS vs. Betamax. Therefore in this study we
seek to investigate the barriers to diffusion of digital ink-jet printing as a full-scale production method in the textiles industry using a holistic perspective that we bring to bear on the industry supply network.

6. Methodology

The research described here is one component of a major three-year research programme funded by industry and the UK Engineering and Physical Science Research Council (EPSRC). This part of the programme focuses on determining the barriers to adopting DIP technology as a full-scale production method within the textile printing industry. A qualitative methodology was selected comprising semi-structured interviews with managers drawn from key stakeholders forming the supply network (see Figure 1). Purposive sampling was used to identify individual organisations representative of the different stakeholder groups. The questions for the interview schedule were designed using a framework that focused on four key issues: knowledge, relationships, products, and processes of the stakeholders. The questions investigate the extent of the organisation’s knowledge of both sample and full-scale production using DIP technology. Questions explore the relationships within the supply network that are key influences on the organisation. The innovation required within the organisation to facilitate adoption of DIP technology within the supply network is investigated on the three dimensions of product, process, and administration.

7. Preliminary Results and Discussion

The data collection phase has been recently completed and analysis started. However, some tentative findings can be presented here that will be extended in the conference presentation. First, it is apparent that there is a lack of knowledge of DIP technology amongst various
stakeholder groups and one reason for this is the fragile relationships between them that hampers the interchange of data and knowledge. Fragility refers here to the tendency for transactional decisions to be made on cost bases reflecting market-based or adversarial relationships to predominate and for collaboration to be on an opportunistic rather than on an established basis. Second, the new technology poses challenges to organisations’ existing products but companies are being cautious rather than actively looking to redesign existing products to capitalise on using the new technology. Third, firms that have been established for many years are reluctant to change their process technology at this point to accommodate a technology that seems to them relatively new and unreliable – again that are adopting a cautious “wait and see” approach. However, some instances of organisations blending together the new and existing technology are evident particularly where volumes are low, e.g. flag manufacturing. Finally, penetration of the technology as a full-scale printing method is hampered by the industry characteristics of diverse markets each with different configurations of customer requirements.

**8. Conclusion**

This research uses an innovative framework to integrate business and technical aspects to investigate diffusion of a technological innovation in a manufacturing supply chain. The research depends on the view that knowledge, relationships, products and processes of the stakeholders in the supply network are major factors influencing the diffusion of digital inkjet printing as a full-scale printing method in the textile industry.
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