The 2nd International Conference on Design Creativity (ICDC2012)

Glasgow, UK, 18th-20th September 2012

CULTURAL DRIVERS IN PRODUCT DEVELOPMENT: AN HISTORICAL CASE STUDY

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Abstract: This paper explores the role of cultural factors in product development. While a significant amount of research has outlined the economic and business conditions that make for appropriate innovation strategies, the effects of cultural factors such as institutional arrangements, resource endowments, proprietary functions and social values are less well understood and harder to quantify. A historical example is used to identify types of cultural factors and illustrate how they can interact and affect product development. In this case, the research reviews the steam plough and its use by the Duke of Sutherland for land reclamation in the late 19th century. Despite being vastly expensive and in this case of limited effectiveness, a unique set of cultural factors meant that huge sums of money were invested in the design, development and implementation of these devices. It was ultimately unsuccessful, with many crofters returning to more primitive methods with better results.

Keywords: *product development, cultural factors, steam plough, case study.*

1. Introduction

Since the Cox Report was published in 2005 (Cox, 2005), there has been an increasing demand for industry to be more innovative in the development of new products and services, with James Dyson's vision for an Ingenious Britain (Dyson, 2010) and the Technology Strategy Board's vision for accelerated economic growth by 'stimulating and supporting business-led innovation' (Technology Strategy Board, 2011) among the latest high-profile examples. These concepts remain focussed on business and economic measures as indicators of conditions and performance of innovation. While they can provide an understanding of financial issues driving product development, they do not reveal many of the other cultural factors that can play a part in taking a new product to the market. These are harder to quantify, encompass a wide range of issues and interact in complex ways.

A number of frameworks for cultural analysis have been proposed, including sociological approaches that identify nationalist dimensions such as individualism, masculinity, power and uncertainty (Hofstede & Hofstede, 2004; House, Hanges, Javidan, Dorfman, & Gupta, 2004), and anthropological approaches based on observations of context, space and time (Hall & Gay, 1996). On the effect of

culture on design and innovation, there are a range of factors that have been identified as important, ranging from labour costs to religion to values (Diamond, 1999; Mokyr, 1990). This research uses a particularly rich historical example – the use of steam ploughing in the reclamation in the Scottish Highlands 1869-1884 – to review how these factors work in a practical sense, and how they should be considered as key drivers in any product development process.

2. Culture in product design

New Product Development (NPD) has evolved into a prescriptive set of steps such as marketing, specification, concept design, detail design, manufacture and retail (Pugh, 1991). The evolution of ideas and products, however, is not an exact science, and despite the increasing clamour for 'innovation' across industry there is still disagreement over how ideas emerge and succeed in the development process. The Schumpeterian model (Akrich et al., 2002a) of the hero inventor who is single-handedly responsible for the success of new products has been widely refuted (Diamond, 1999; Mokyr, 1990; Williams, 1987). Major scientific and technological breakthroughs such as the development nuclear power and space travel are inevitably the result of large scale collaborations. These require a multitude collective agreements, or 'socio-technical negotiations' across a individuals and groups to achieve realisation of the goal (Akrich et al., 2002b). Indeed, the past has a tendency to highlight the importance of individuals when there were many other factors at play, and on closer examination many cases '...demonstrate that new technologies are seldom, if ever, developed by a single firm alone in the vacuum of an institutionalized environment' (Andrew H. Van de Ven, 1993). For example, in the development of the telephone Edison was working in light of 20 years of development, beginning with Meucci's communication devices of the early 1850s. He had a team of assistants and engineers as part of his development team, and even when he was awarded the relevant patents for the telephone in 1876, he was for several years in dispute with Gray, who has been undertaking parallel research. This is not to detract from the undoubted talent and leadership of Edison and others – only to illustrate that no development is without a range of contextual factors and that all but the most basic products involve some level of collaboration. Development therefore has a cultural dimension which can play an important role in motivation and acceptance through the process.

3. Origins of culture

The word culture originally – in the 15th century – meant 'a tilling of the land', and was derived from Latin cultura 'a cultivating, agriculture'. This is appropriate given that it was when humans moved from a hunter-gather to agricultural mode of living that permanent, continuous communities were formed. It was at this point that harmonious co-habitation, laws and traditions were established to allow larger numbers of people to live and work together. From early 19th century, culture was used to describe 'artistic and social pursuits, expression, and tastes valued by a society or class'. While support of creative arts and an appreciation of their enriching qualities are important in a civilised society, it can have negative connotations for those who feel alienated from the abstract or stylised presentation of certain forms, such as conceptual art or opera. Furthermore, during the colonising period of various Western empires, confidence in the superiority of these aspects of culture was used as justification for the destruction or assimilation of many indigenous communities. Later in the 19th century, however, the definition of culture was widened to include the 'activities, ideas and traditions of a group of people'. This more accurately reflects the wide range of behaviours that are developed, valued, and reinforced by different cultural groups. There are certain qualities of the human psyche that are universal in nature. These are the fundamental ability to feel love, anger, fear, joy, sadness etc. as well as a need to socialise, exercise, play etc. What a group does with these basic drives is

partly determined by their shared cultural values and reinforced over time. Finally, personality is a unique set of characteristics not shared with any other human being (Hofstede & Hofstede, 2004). This work illustrates the effects of cultural context while considering the role of individuals in the face of these.

3.1. The case of the steam plough

An historical example has been used to better understand the role that cultural factors can play on the development and introduction of new products. Agriculture has been a primary concern of human development and an area where much early design and innovation has taken place (Haining & Tyler, 1985). Beginning with the use of an appropriately shaped piece of wood to groove the soil as early as 5000BC, the plough has been a key product in productive working of the land. By 3500BC, an ancient Egyptian seal documents the use of a plough with handles added and men pulling the implement. Innovations such as the use of coulter, mould boards, and wheels subsequently emerged. It is interesting to note the vast range of configurations developed based on local conditions – the Museum of English Rural Life at the University of Reading holds hundreds of examples of plough design, each adapted for the particular characteristics of the land on which it was to be used. As ploughs became larger and heavier, animals were utilised to provide the independent, portable source of power required for the ploughing of fields. Oxes were bred specifically for this purpose, although they were generally harshly treated, with the ploughing rope commonly attached to their horns and even their tails. The distinctive factor affecting the plough was that it required an independent, portable form of power. The ox was bred to pull the plough, later to be supplanted by the heavy draught horse. These animals were harshly treated, with the ploughing rope attached to the beast's horn and even its tail. Their role was pivotal in the development of agriculture, and definition of land area in acres is indeed derived from the work that an ox could do in a day.

The introduction of steam ploughing in the 19th century was a radical departure from what had gone before. The development of steam power was initially motivated by the need to pump water from mines. Laterally, its transport, marine and industrial applications were critical to its development – its use in ploughing is somewhat nominal and it was not until the emergence of the internal combustion engine that the use of animals ceased. The steam engine was the key invention industrial revolution and steam ploughing an instructive example of Victorian optimism. It was used increasingly from 1855 onwards, and in 1869, the 3rd Duke of Sutherland began the largest land reclamation works in British history on his estates in the north of Scotland (Tindley, 2009); part of this project was fuelled by the Duke's enthusiasm for the latest steam technology, in particular the steam plough, being developed at this time by John Fowler's and Co. of Leeds (Lane, 1980). In partnership with Fowler's, itself a personal business based on improvements in steam machinery, the Duke adapted the eight steam plough sets he purchased from them to the specific difficulties of the Sutherland terrain and landscape.

The use of steam ploughing was never viable in these harsh geographic conditions. The stony ground required a huge amount of preparatory work before ploughing could even begin, and the engines were too cumbersome and heavy for the hilly, boggy terrain. A huge number of workers, mainly local workers, were employed to assist in the work. Problems with engaging them can be attributed to their pragmatic and skeptical view of the work – many continued to use more primitive methods independently with better results. Despite vast expense and limited effectiveness, huge sums of money were invested over a considerable period in the design, development and implementation of the Sutherland plough (Roberts, 1880). While the results were impressive, in hindsight it was always doomed to failure. The application of a rapidly emerging technology, the political and economic tumult of the Industrial Revolution, the range of stakeholders involved, and the Duke's singular

personality make this a rich example to unpick the many social, personal and environmental issues that form part of a cultural landscape, and can impinge on motivation for product innovation.

Figure 1. Steam ploughing by Loch Shin, copied from a painting by Rev. J M Joass in the 1870s

3.2. Steam ploughing in Sutherland

Steam ploughing typically consists of two traction engines located on either side of the field, and connected with a steel cable. A ploughing implement is dragged between the engines, with each pulling in turn. The plough can typically pivot around a central axis to allow it to work in two directions. Rocks and stones are then removed and often used to help form drains, boundary dykes and roads as appropriate. The ground would then be broken up, with lime spread prior to crops being sown.

In the case of the Sutherland reclamations there were significant environmental challenges: the interior consisted mostly of mountains, moors and bogs. In addition to this, the land was extremely rocky. Several adaptations were made to the standard plough design to meet these challenges (Lane, 1980). An extremely robust plough was required, so a single, large turn-furrow was used to cut through the soil rather than the four or five normally employed. In addition, very broad rollers were used to prevent the plough burying itself in soft ground. This configuration was found to perform well in ground where there were no obstructions, but the majority of land was riddled with rocks and boulders of varying sizes. These caused considerable damage to the share (the cutting head of the plough) on impact. To address this, a revolving coulter was developed. This was a steel disc placed in front of the share, cutting the soil to a depth of two inches below. When meeting a large stone, it would lift the plough over it. A further improvement was 'the Duke's Toothpick'. This was a large iron hook that trailed behind the rear of the plough and lifted any rocks the coulter was unable to move. Extremely large boulders would cause the engine to be backed up and the Toothpick lifted over, with dynamite or manpower used for removal. The ploughs were drawn at a slow speed, with engines operating at double their nominal power to deal with these considerable challenges. There was a trade-off to be made with power and weight, however, as larger, more powerful engines had a tendency to sink in bogs and cause delay.

There were also a number of ancillary developments around the reclamations. A sledge for stones allowed up to five tons to be drawn using the steam engines. This was designed to tip the stones out at the end of its run, and in addition to its convenience the dragging across the surface proved beneficial to the broken land, the rubbing action disintegrating it. With sheep grazing on the surrounding land, it was desirable to fence each field off entirely as the ploughing was taking place. To address this, a folding fence was developed that used steel wire with adjustable stays that could be quickly assembled. To make these sufficient for cattle and horses, coils of wires with 'spikes... twisted at intervals into them' were developed – now familiar as barbed wire. Finally, in order to break down the peat after ploughing, a 'Discer' was invented. While all previous machines tended to get choked by

the fibres of peat or turf after it had been loosened, the Discer was able to disintegrate enough of the ploughed field to allow seeding without disturbing the inverted turf. It consisted of a frame with series of discs mounted at an angle to the line of draft, cutting to a depth of two to five inches.

Steam ploughing in Sutherland, although ultimately doomed to failure, therefore consisted of a series of innovations. There were a range of people who were involved in the process including: the Duke of Sutherland, financier of the scheme and owner of the land; Fowler's and Co., steam plough manufacturer; John Greig, employee of Fowler's and based in Sutherland; John McLellan, a Sutherland farm manager who became deeply involved in the works; and the crofters and small tenants who worked on a temporary basis. Each of the parties involved had their own motivations, values and skill sets. As well as being distinct groups, the cultural dynamic of these groups is critical in understanding the motivation for the steam plough's on-going development.

4. Framework for analysis

A number of texts have reviewed human evolution and the range of factors involved in innovation in broad terms (Diamond, 1999; Mokyr, 1990). In a more modern context, tools such as PEST (Political, Economic, Social and Technical) analysis have been used to frame the macro-environment that forms operate in. These can be used when developing strategy or undertaking market research. Social constructivists have developed a number of approaches to understanding technological development. Social Construction of Technology (SCOT) is a theory that argues humans shape the development of technology (Pinch & Bijker, 1984). Actor-Network Theory is a subset of SCOT, and places material things and concepts in a single network map that captures all factors in the development process. In a more empirical approach, Van de Ven (Andrew H. Van de Ven, 1993; Andrew H. Van de Ven & Garud, 1993) has undertaken longitudinal studies that evaluated documents generated in the product development process to understand some of the social aspects that impact directly on innovation.

While Van de Ven's work is primarily focussed on the structures and formations of communities, it has provided a basis for a set of criteria that also take account of the cultural values and beliefs of the different groups involved. This consists of four main cultural factors: *institutional arrangements* are concerned with the rules and norms of the society in which individuals and organisations function; *resource endowments* relate to the financial and economic resources pertinent to development; *social values* pertain to the character, beliefs and morals of the parties involved; and *proprietary functions* incorporate the particular industrial, educational and geographic context of the work. These criteria are set out in Table 1, along with the examples relevant to the Sutherland study. These are reviewed in more detail below.

Table 1. Cultural factors relating to the use of the steam plough, after Van de Ven (1993)

Cultural factor	Institutional arrangements	Resource endowments	Proprietary functions	Social values
Criteria	• Political structures • Governance and regulations • Technology standards	• Financing and insurance arrangements • Market creation and consumer demand • Labour pool	• Scientific/ technological research • Educational systems	• Openness to technological change • Religion and belief systems • Social groupings and moral codes

Examples	• The British Establishment and the Duke's rejection of political office/ traditional roles • The perceived role of landowners and how investment in technology and land supported this • Patents developed by Fowler, the Duke, Greig and their worth	• The Agricultural and Industrial Revolutions, High Farming, 1850s, 1860s and its effect on agricultural product innovation • The Great Depression, 1879 – 1905 and subsequent challenges faced by Fowler's • The Duke's financial position and eventual abandonment of the reclamations given the poor returns	• Evolution of steam power and its application to different industrial contexts • Technical expertise and the limitations of the apprentice/ entrepreneurial model of Great Britain	• Victorian passion for technology and mechanical development • Role of the individual in Judeo-Christian religion and variations in faith across the collective • The perceived resistance of the Sutherland tenants to the work required in steam ploughing

4.1. Institutional arrangements

Motivation for the reclamation of Sutherland is rooted in political factors. The title of Duke of Sutherland was bestowed upon the 2nd Marquess of Stafford in 1833 by William IV. The Dukes of Sutherland were one of the richest landowning families in the United Kingdom and as bastions of the aristocracy were expected to take an active role in political life. The 3rd Duke, George Granville William Sutherland Leveson-Gower (1828 –1892) was, however a rather idiosyncratic character. He had no interest in public speaking or in politics, instead growing up fascinated by fire engines, railways and industrial enterprises of all kinds. The steam plough first came to his attention through demonstrations on the banks of the Nile in Egypt, where Britain's Imperial interests were still active. It occurred to him that this emerging technology could be harnessed for the challenges of his own land.

As the reclamation work continued, a series of patents were awarded to those involved. Intellectual property rights in Britain were the most sophisticated in the world, and provided a significant financial incentive to those named on them. The emphasis on the generation of intellectual property in the UK has been attributed as a key factor in its ascent during the Industrial Revolution. The development of the steam plough and solving of technical challenges by people across the collective is instructive. Fowler's had little hesitation in committing significant resource to the development of a new plough suitable for the demands of the Sutherland reclamations. The fact that a range of people involved in the project that did not have an engineering background, such as the Duke, his secretary and estate manager, suggests a 'can do' attitude towards the work and machinery required.

4.2. Resource endowments

Critical to the instigation and persistence of the Sutherland reclamations was the Duke's vast wealth. He had an annual income of £120k, the equivalent of £20m today. Despite being one of the richest men in the UK, the money he invested in the Sutherland reclamations was enormous, totalling £254k from 1871 to his death in 1892 (Spence, 1960). In the face of continuing technical and environmental challenges, he continued to pour money into a project that was vastly over budget. By 1880 it was

apparent that the scheme was likely to make a significant loss. Despite this, the Duke continued to invest for a further four years before work came to a halt. Without this massive capital investment, the Sutherland reclamations would never have been possible. While this had serious implications for the Duke's successors, the freedom afforded by this generous budget allowed Fowler's and Greig to explore technical options and overcome problems that may have been otherwise insurmountable.

The Sutherland reclamations took place at the height of the Industrial Revolution. During this period, new technologies were constantly emerging, mechanising and automating industries which had changed little over hundreds of years. The 'High Farming' movement of the second half of the 19thC was typical of this - innovations in fertilisers, foodstuffs, drainage and machinery revolutionised the production of food. This provided rich harvests and made it a prosperous period for the agriculture industry. The inducement then, to reclaim large tracts of previously wild land for productive agricultural use was attractive to the Duke and the financial rewards substantial. Despite the obvious geological challenges, the moderate success of such enterprises elsewhere in the country and the continuing evolution of technology would have made the proposition all the more attractive. Although the Duke was incredibly wealthy, he could not escape the economic climate. A factor in the eventual cessation of work may have been the Great Depression (1879-1905), when the sums being invested were no longer viable no matter how enthusiastic the Duke remained for the scheme.

4.3. Proprietary functions

The technical expertise of those involved in the project was a product of Great Britain's entrepreneurial industrial economy. Fowler's was a company experienced in iterative improvement of proven technologies. The Duke was a headstrong enthusiast with significant financial resources. In terms of taking a technology and making it work, the attitude and skills of this profile is ideal. As machinery and technology became more and more sophisticated, and the application of scientific principles necessary to understand and evolve complex designs, the more formal education system of countries like Germany began to prevail. Longer years of structured technical training allowed their engineers to plan long-term development projects that would in the coming years deliver economic success in areas such as the automotive and aeronautical industry. The Sutherland plough was an example of reactive designing, where changes were made as necessary based on the problems of undertaking the work. This iterative process relied on the resilience and ingenuity of Fowler's to ensure the work continued, but did not serve to identify and address broader strategic issues such as the development of the internal combustion engine and its implications for steam power.

4.4. Social values

There were three principle social groups in the collective involved in the Sutherland reclamations: the Duke, financier of the project and representative of the landed gentry; Fowler's and Co., who worked closely with the Duke in design and development of the Sutherland plough and seconded employees to aid with development; and the Sutherland tenants who were a traditional crofting community forced to undertake the labour associated with the work. Each of these groups had distinct vested interests and values that affected their approach to the work and to collaboration.

Victorian 'values' are often characterised as puritanical, with a strict moral and ethical code applied to all aspects of life. This does not seem to have been the case with the Duke, who was known to be of a 'carefree, independent nature' (Sutherland, 1957). Indeed, after the death of his first wife, there was considerable scandal when he remarried within three months – the 'proper' mourning period was considered to be a year. It was also said that he popularised the use of cigarettes in Great Britain rather than the customary cigars after walking down Bond Street in London smoking one (Sutherland, 1957). He did, however, have a deep passion of technology which is another characteristic of the

Victorian Era. If the history of human invention is considered, the explosion of new machines and devices through the Industrial Revolution is startling. It is little wonder that faith in new technologies and developments was so strong. When the Duke's seeming lack of inhibition is coupled with the passion for technology of the time, it provides a strong motive force for the work.

The crofting community were perceived as being particularly resistant to the reclamation works. There could be as many as 100 working in a field at a time, a surprisingly large number to operate two engines and a plough. They were regarded as surly, uncooperative and obtuse in their attitude and engagement with the work. From the perspective of the Duke and the establishment, the tenants were being provided with respectable jobs that would improve their lot. As a group who had tended the land with structures, tools and techniques developed over hundreds of years, the sudden changes imposed through the operation of unfamiliar technologies must have been disconcerting. This tension was evident all through the years of reclamation work, despite all the technical and environmental problems that made the reclamations so difficult, it was reported at the time that 'the chief mistake has been that sufficient supervision was not provided' (Roberts, 1880).

5. Conclusions

While the Sutherland steam plough included a range of innovative design features and the reclamation process was doggedly persistent over a number of years, it was ultimately unsuccessful. Even though the design improvements allowed the ploughing at times to operate impressively, huge numbers of men and crippling on-going investments were necessary to support the work. When it became apparent that the fields which had been ploughed were only moderately fertile and in some cases rapidly returned to their natural state, the work was eventually stopped. That is not to say that the Sutherland plough itself is not without merit: it is an imposing product, full of unique and highly specialised design features that make it distinctive in the era of steam ploughing.

In hindsight, it seems obvious that the cost, effort, geographical and technological challenges made the steam plough impractical. By reviewing and understanding the cultural motivations of those involved, we can better understand the direction and persistence of a line of development. The institutional, resource, proprietary and social factors all played a role in facilitating work undertaken in the face of such trying circumstances. It is, however, perhaps the social values that are most revealing. At a broad level, the strength of Victorian optimism and the faith in the deployment of steam power meant that the enterprise was undertaken with a good deal of enthusiasm. At an individual level, the Duke's idiosyncratic approach to his aristocratic role as well as his vast financial resources were also critical in facilitating the work. And while there was a great deal of good faith in the relationship between the Duke and Fowler's, with a series of innovations made during their collaboration, there remained a continuing unwillingness of the crofting community to embrace the use of the machinery.

This example illustrates the interplays between the cultural values of different parties in a product development process. These factors remain just as pertinent in modern product development, whether it be large-scale projects such as space exploration or specific products tailored for smaller societies or groups. It is the intention of the researchers to further explore the role of cultural drivers in product development through development of an analytical framework, considering techniques such as actor-network analysis to help quantify the cultural motivators at play, their interrelations, and what their influence may be on a particular development process. This will be developed through the interrogation of further historical case studies with the intention of eventually using it to review contemporary product development processes.

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